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Seventh International Symposium on

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BEST PAPERS SELECTION

The authors of around fifteen selected papers presented at BMSD 2017 will be invited by Springer-Verlag to submit revised and extended versions of their papers for publication in a Springer LNBIP Series book.

FOREWORD

Businesses changed when computers first appeared on the scene and enterprises had to accommodate (partial) automation of their business processes. Businesses changed again when web services and cloud infrastructures appeared, and enterprises faced the challenge of making (some) internal business processes external. All those changes have been justifying more and more the necessity of bringing together *enterprise modeling* and *software specification* – an enterprise engineer alone is insufficiently capable of grasping the technical complexity of an enterprise's IT system and its reach outside through software services, while a software engineer would have only superficial enterprise-specific domain knowledge. However, *enterprise engineering* and *software engineering* have developed separately, and hence the alignment between enterprise modeling and software specification is still uncertain. Bridging that gap is thus considered important with regard to *Enterprise Information Systems - EIS*. For this reason, the development of EIS should assume conceptual foundations that represent a common ground for creating models, no matter if they are enterprise-driven or software-driven. This would facilitate a modeling co-creation featuring: (a) *technology-independent enterprise models rooted in social theories*; (b) *technology-specific software specifications rooted in computing paradigms*, such that an integrated enterprise-software modeling is possible.

Among the challenges that are to be taken into account in this regard are: (i) the modeling generations and transformations (starting from unstructured business information, coming through enterprise models, and reaching as far as the specification and implementation of software); (ii) the alignment of the final software product with corresponding business goals, business semantics and business processes; (iii) the optimization of processes not only at enterprise level but also at software level; (iv) the enabling of agile business processes and the partitioning in turn of business logic into fine grained software services; (v) the (real-time) inter-enterprise coordination covering both business processes and software services; (vi) the adaptation of business processes to new IT-driven demands; (vii) the handling of product variability on the enterprise level as well as on the technical level; (viii) the reflection of context-awareness in engineered enterprise / software systems; (ix) the weaving of values, such as privacy and transparency, in the design, both on the enterprise level and also on the technical level as well as the establishment of information security; (x) the integration between business, IT and the operations technology; (xi) the achievement of loose coupling with regard to the integration of different software services; (xii) the enabling of human-centricity in the development of EIS; (xiii) the translation of (enterprise-level) strategy into (technology-enabled) execution; (xiv) the enrichment of enterprise / software models in terms of data, by considering knowledge representation, ontologies, and big data; (xv) the use of proper enterprise / software modeling notations. Those are only some discussion points relevant to the enterprise engineering area and its relation to software specification, being dominant for the researchers and practitioners brought together by *BMSD 2017* - the *Seventh International Symposium on Business Modeling and Software Design*. BMSD demonstrates for a seventh consecutive year a high quality of papers and presentations as well as a stimulating discussion environment. Those papers and also the above-mentioned challenges inspire the BMSD Community, and are in line with the main BMSD Areas:

- Business Processes and Enterprise Engineering
- Business Models and Requirements
- Business Models and Services
- Business Models and Software
- Information Systems Architectures and Paradigms
- Data Aspects in Business Modeling and Software Development

Further, each year, a special theme is chosen, for making presentations and discussions more focused. The theme of BMSD'17 is:

MODELING VIEWPOINTS AND OVERALL CONSISTENCY

This book contains the proceedings of BMSD 2017, held in Barcelona, Spain, on 3-5 July 2017. The proceedings consists of 28 high-quality research and experience papers that have not been published previously. Those papers have undergone a detailed peer-review process and were selected based on rigorous quality standards.

BMSD 2017 was organized and sponsored by the *Interdisciplinary Institute for Collaboration and Research on Enterprise Systems and Technology* (IICREST), being technically co-sponsored by *BPM-D*. Cooperating organizations were *Aristotle University of Thessaloniki* (AUTH), *Delft University of Technology* (TU Delft), the UTwente *Center for Telematics and Information Technology* (CTIT), the BAS *Institute of Mathematics and Informatics* (IMI), the Dutch Research *School for Information and Knowledge Systems* (SIKS), and *AMAKOTA Ltd.*

Since 2011, we have enjoyed six successful BMSD editions, namely: *Sofia 2011*, *Geneva 2012*, *Noordwijkerhout 2013*, *Luxembourg 2014*, *Milan 2015*, and *Rhodes 2016*. The Barcelona 2017 edition is the seventh one and we are proud to have succeeded in establishing and maintaining high scientific quality and stimulating collaborative atmosphere. Our community is of high competence and also inspired to share ideas and experience. In addressing the above-mentioned challenges and in line with the BMSD areas, BMSD 2017 is addressing a large number of research topics: from more conceptual ones, such as *conceptual enterprise modeling* and *meta-modeling*, *goal modeling*, *modeling abstractions* and *model transformations*, *modeling notations*, *inter-model consistency*, *knowledge modeling*, *context-aware systems*, and *privacy-by-design*, to more technical ones, such as *requirements engineering* and *software specification*, (*model-driven*) *software development*, *software product line engineering*, *software re-use* and *design patterns detection, information security*, *e-Business* and *service e-Marketplaces*, and *socio-technical information systems*, from topics exclusively focusing on Business Processes (BP), such as *BP modeling*, *BP modeling formalisms* and *BP modeling tools*, *BP management*, *sensitive BPs*, to topics related to architectures, such as *enterprise architectures* (and *inter-enterprise coordination*), *service-oriented architectures* and *service orchestration* addressing also *microservices*, with all those topics reflected in a number of application domains - among those domains are: *border security*, *food processing*, *holiday management*, and *manufacturing*.

BMSD 2017 received 57 paper submissions from which 28 papers were selected (including several invited papers) for publication in the current proceedings. 15 of those papers were selected for a 30-minute oral presentation (full papers), leading to a full-paper acceptance ratio of 26% (compared to 29% in 2016). In addition: 8 papers were selected for a 20-minute oral presentation (short papers) and 5 papers were selected for a poster presentation. The above-mentioned full-paper acceptance ratio shows a high BMSD quality which we intend to maintain and reinforce in the following editions of the symposium. Further, the BMSD'17 keynote lecturers and authors are from: Algeria, Austria, *Bulgaria*, Colombia, Greece, *Germany*, Japan, Kazakhstan, Luxembourg, Morocco, *The Netherlands*, Poland, Portugal, Spain, Sweden, Taiwan, Tunisia, Turkey, *UK*, and USA (listed alphabetically); that makes a total of 20 countries (compared to 16 in 2016, 21 in 2015, 21 in 2014, 14 in 2013, 11 in 2012, and 10 in 2011) to justify a strong international presence. Finally, 4 countries have been represented at all 7 BMSD editions so far – those are: Bulgaria, Germany, The Netherlands, and UK, to indicate a strong European influence.

Publisher of the current proceedings is *SCITEPRESS*. Besides printed proceedings we also deliver an electronic version – all presented papers will be made available on the SCITEPRESS Digital Library by September, 2017. Furthermore, all BMSD proceedings are *SCOPUS*-indexed and the BMSD'17 proceedings will be submitted to *DBLP* (Computer Science Bibliography) for indexation. Finally, the authors of around fifteen selected papers presented at BMSD 2017 will be invited by *Springer-Verlag* to submit revised and extended versions of their papers for publication in a Springer LNBIP (Lecture Notes in Business Information Processing) Series book.

The high quality of the BMSD 2017 program is enhanced by three keynote lectures, delivered by distinguished guests who are renowned experts in their fields: *Norbert Gronau* (University of Potsdam), *Oscar Pastor* (Polytechnic University of Valencia) and *Alexander Verbraeck* (Delft University of Technology). The keynote speakers and some other BMSD'17 participants will take part in a panel discussion and also in other discussions stimulating community building and facilitating possible R&D project acquisition initiatives. Those special activities will definitely contribute to maintaining the event's high quality and inspiring our steady and motivated community.

Organizing this interesting and successful symposium required the dedicated efforts of many people. Firstly, we must thank the authors, whose research and development achievements are recorded here. Next, the program committee members each deserve credit for the diligent and rigorous peer-reviewing. Further, we would like to mention the excellent organization provided by the IICREST team (supported by its logistics partner, AMAKOTA Ltd.) – the team did all the necessary work for delivering a stimulating and productive event. We are grateful to SCITEPRESS for their willingness to publish the current proceedings and we bring forward special compliments to *Vitor Pedrosa* for his professionalism, patience, and excellent collaboration with regard to the proceedings preparation. Last but not least, we thank the keynote speakers for their invaluable contribution and for taking the time to synthesize and deliver their talks.

We wish you all an inspiring symposium and an enjoyable stay in the beautiful city of Barcelona. We look forward to meeting you next year in Vienna, Austria, for the Eighth International Symposium on Business Modeling and Software Design (BMSD 2018), details of which will be made available on *http://www.is-bmsd.org*.

Boris Shishkov
Bulgarian Academy of Sciences / IICREST, Bulgaria

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KEYNOTE SPEAKERS

A Visionary Way to Novel Process Optimization Techniques

Norbert Gronau
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Abstract: Modern process optimization approaches do build on various qualitative and quantitative tools, but are mainly limited to simple relations in different process perspectives like cost, time or stock. In this keynote a new approach is presented, which focuses on techniques of the area of Artificial Intelligence to capture complex relations within processes. Hence, a fundamental value increase is intended to be gained. Existing modeling techniques and languages serve as basic concepts and try to realize the junction of apparently contradictory approaches. This keynote therefore draws a vision of promising future process optimization techniques and presents an innovative contribution.

BRIEF BIOGRAPHY

Univ.-Prof. Dr.-Ing. Norbert Gronau (born 1964) studied engineering and business administration at Berlin University of Technology. He got his Ph.D. in 1994 and finished then his habilitation thesis in industrial information systems. Since more than ten years he holds the Chair of Business Informatics, esp. Processes and Systems at the University of Potsdam, Germany. His main research activities concentrate on the areas of knowledge management and process management, in private and public organizations. Together with the Potsdam Consulting Group, Prof. Gronau has supported a variety of small and large companies, by advising them. Prof. Gronau is editor of the scientific journals *Industrie 4.0 Management*, *ERP Management*, and *Productivity Management*. He is author of books on enterprise systems, knowledge management, and business process management, and also author of many research papers in those areas.

From Goal Models to Software Products
A Conceptual Modeling-Based Approach

Oscar Pastor
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Abstract: A crucial success factor in information systems development is the alignment of the final software product with business goals, business semantics and business processes. Developers should be freed from programming concerns and be able to concentrate on these alignment problems. To assess that the right capabilities are used, sound Conceptual Modeling (CM) techniques within a Model-Driven system Development (MDD) must be applied in order to provide a structured and systematic approach to systems development, where developers can successfully use model transformation technologies to derive models of a lower abstraction level that can be further refined, even generating software code automatically. From the experience got with the use of advanced CM-based MDD platforms, this keynote will show how to start from an organizational goal-oriented (i*-based) model strategy in order to integrate Business Process Modeling (BPM), requirements engineering, and object-oriented CM with the objective of designing a software product that is conceptually aligned with the different types of conceptual models that have to be used in a conventional software production process. Concrete principles, concepts and common MDD-based practices will be presented with a special focus on model-driven requirements engineering, meaning by it how organizational and BPM models can be embedded in a complete CM-based software production process.

BRIEF BIOGRAPHY

Oscar Pastor is Full Professor and Director of the "Centro de Investigacion en Metodos de Produccion de Software (PROS)" at the Polytechnic University of Valencia, Spain. He received his Ph.D. in 1992. He was a researcher at HP Labs, Bristol, UK. He has published more than two hundred research papers in conference proceedings, journals and books, received numerous research grants from public institutions and private industry, and been keynote speaker at several conferences and workshops. Chair of the ER Steering Committee and member of the SC of conferences as CAiSE, ICWE, CIbSE or RCIS, his research activities focus on conceptual modeling, web engineering, requirements engineering, information systems, and model-based software production. He created the object-oriented formal specification language OASIS and the corresponding software production method OO-METHOD. He led the research and development underlying CARE Technologies that was formed in 1996. CARE Technologies has created an advanced MDA-based Conceptual Model Compiler called OlivaNova, a tool that produces a final software product starting from a conceptual schema that represents system requirements. He is currently leading a multidisciplinary project linking Information Systems and Bioinformatics notions, oriented to designing and implementing tools for Conceptual Modeling-based interpretation of the Human Genome information.

Real-Time Inter-Enterprise Coordination in a Highly Dynamic World

Alexander Verbraeck
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Abstract: Because of the relatively low cost of intercontinental transportation, activities take place in those parts of the world that either have cheap labor, or specialize in certain types of value adding activities. This causes supply chains and transport networks to grow in complexity, and makes them more and more vulnerable to dynamics and disruptions. Disasters like the flooding in Thailand a few years ago or the Fukushima tsunami, caused critical component stock-outs for the world market, disrupting thousands of supply chains across the planet. Coordination principles and information exchange have not adapted to the high volatility of today's enterprise networks, and risk assessment is not a standard tool in supply chain setup and inter-organizational information systems design. Yet, we all expect that sensor data and real-time coordination and control would be present to immediately address the problems that occur, and steer the complex systems to a stable state again. Unfortunately, current systems practices are often unable to utilize the real-time information and deal with the dynamics inherent to the overall system. The presentation will focus on these issues and will provide potential solutions using a modeling perspective.

BRIEF BIOGRAPHY

Alexander Verbraeck (MSc in applied mathematics 1987 (cum laude); PhD in logistics 1991), is a full professor at Delft University of Technology, Faculty of Technology, Policy and Management, Policy Analysis Department. His research focuses on modeling and simulation, especially in heavily distributed environments and using real-time data. Examples of research on these types of simulations are real-time decision making, interactive gaming using simulations, and the use of 3D virtual and augmented reality environments in simulations for training. The major application domains for research are logistics and transportation, and safety and security. He is a member of ACM, IEEE, SCS, and INFORMS, and a Fellow in the Research School TRAIL for Transport, Infrastructure and Logistics. In addition Alexander has a position as adjunct professor at the R.H. Smith School of Business at the University of Maryland, USA. Here, he applies the modeling and simulation research for studying real-time supply chains.

FULL PAPERS

A Visionary Way to Novel Process Optimization Techniques
The Transfer of a Process Modeling Language to the Neuronal Level

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Keywords: Process Modeling, Artificial Intelligence, Machine Learning, Neuronal Networks, Knowledge Modeling Description Language (KMDL), Process Simulation, Simulation Process Building, Process Optimization.

Abstract: Modern process optimization approaches do build on various qualitative and quantitative tools, but are mainly limited to simple relations in different process perspectives like cost, time or stock. In this paper, a new approach is presented, which focuses on techniques of the area of Artificial Intelligence to capture complex relations within processes. Hence, a fundamental value increase is intended to be gained. Existing modeling techniques and languages serve as basic concepts and try to realize the junction of apparently contradictory approaches. This paper therefore draws a vision of promising future process optimization techniques and presents an innovative contribution.

1 INTRODUCTION

A great potential of Artificial Neural Networks (short: ANN) is well known since nearly four decades. In general, those techniques copy the capabilities and working behavior of the brain in simulating a network of simple nerve cells. Early ANN architectures go back to the 1940s and numerous improvements can be found in late 1980 - 2000 (Schmidhuber, 2015). Because of their ability to learn non-linear relations, to generalize correctly and to built biologically motivated efficiently working structures, ANN have been applied successfully in various contexts such as music composition, banking issues, medicine, etc. Even simple processes have been modeled on behalf of ANN (Chambers and Mount-Campbell, 2000).

Nowadays, in times of big data, enormous amounts of data are available and the computing power has increased immensely and with this, the possibility to create bigger and more complex networks. Although, the collection of processing data has become easy, the neuronal modeling and decoding of complex processes has not been realized, yet.

Hence, the following research will focus on deep learning with ANN with the intention to answer the following research question: "How can the capability to create efficiently working structures of ANN be used for process optimizations?" This paper intends not to draw an all-embracing description of concrete technical realizations of those novel process optimization techniques. It intends to set a first step to realize the conjunction of the process modeling and optimization world on the one hand and the ANN world on the other hand, such that a sub research question is: "How can a process modeling language be transported on a neuronal level?"

In the following, a *Neuronal Process Modeling* is referred to as the modeling of processes on a neuronal level with a common process modeling language, the reinterpretation of the common process modeling based on that understanding as well as their difference quantity. The *Neuronal Process Simulation* is referred to as the process simulation of common process models considering ANN as knowledge model of process participants (persons and machines), the simulation of common process models reinterpreted as deep neuronal network and their difference quantity. The *Neuronal Process Optimization* is referred to as common process optimization techniques that are realized on a neuronal level (e.g. double-loop learning on a neuronal level), process optimizations that can be realized because of the learning capabilities of ANN in the domain of common process models as well as their difference quantity. Within this paper, a focus lays on the Neuronal Process Modeling.

The research approach is intended to be design-oriented as Peffers proposes (Peffers et al., 2006; Peffers et al., 2007), such that the paper is structured as follows: Section 2 presents underlying concepts; Section 3 derives objectives for a Neuronal Process Modeling; Section 4 provides the design, followed by its demonstration (Section 5) and evaluation (Section 6); Finally, Section 7 concludes the paper.

2 UNDERLYING CONCEPTS

Starting with the selection of a modeling approach and the question, how processes can be optimized in the first subsection, the second subsection refers to underlying knowledge generation concepts. A further subsection introduces ANN.

2.1 Process Optimization

Following the fundamental procedure model for simulation studies of Gronau (2017), a model creation is realized after the modeling purpose has been defined, analyzed and corresponding data has been collected. Hence, the following starts with modeling issues. Afterwards, as the model is valid, simulation studies are realized and results collected, analyzed and interpreted. As changes or optimizations are required, adjustments are defined and simulations tested as long as a sufficient solution has been identified. This will be realized.

The following starts with the understanding of process models to be a homomorphous mapping of a system that reduces the complexity of the real world with respect to the modeling objectives (Gronau, 2016). According to Krallmann et al. (2001), a *system* to be modeled consists of an amount of *system elements*, that are connected with an amount of *system relations*. As it is limited by a *system border*, the *system environment* and the system are connected with an interface to exchange *system input* and *system output*.

For the modeling of systems, several process modeling languages can be used. Considering organizational, behavior-oriented, informational and knowledge-oriented perspectives, Sultanow et al. (2012) identify the Knowledge Modeling Description Language (short: KMDL) to be superior in the comparison of twelve common modeling approaches.

Because of the analogy with a human brain as knowledge processing unit, especially a knowledge process modeling is focused. Here, Remus gives an overview of existing modeling methods and a comparison of their ability to represent knowledge (Remus, 2002). ARIS, EULE2, FORWISS, INCOME, PROMOTE and WORKWARE are only some representatives. Again, the KMDL can be identified to be superior because of its ability to overcome lacks in visualizations and analyses through the combination of several views such as the process view, activity view and communication view (Gronau and Maasdorp, 2016).

This language has been developed over more than ten years iteratively. Having collected experiences in numerous projects of numerous application areas such as software engineering, product development, quality assurance and investment good sales, the evolution of the KMDL can be found in (Gronau, 2012). Currently, the development of a third version is in progress (Gronau et al., 2016b). In addition to the modeling language, the KMDL reaches a fully developed research method which is described by (Gronau, 2009) in detail.

With its strengths in visualization and the focus of knowledge generation, the KMDL seems attractive for a transfer to the neuronal level. To the best of our knowledge, such a transfer has not been realized yet in any other process modeling language. With its intention to focus on the generation of knowledge following (Nonaka and Takeuchi, 1995) and to transfer the learning potential of ANN, the KMDL enables the modeling of tacit knowledge bases and single or numerous knowledge transfers beside common processing issues. Hence, the KMDL is selected as modeling language for the demonstration in section 5. The current paper builds on the wide spread KMDL version 2.2 (Gronau and Maasdorp, 2016).

Once, a valid process model has been created, a dynamic process can be simulated. Aiming to gain insights within a closed simulation system, the intention is to transfer them to reality. For this, the following pre-conditions have to be fulfilled: process models have to provide *completeness*. This includes the registration of input data such as time, costs, participants, etc. Further, process models have to provide *interpretability of decisions*. Here, values of variables, state change conditions and transfer probabilities are included. Further, *meta information* have to be considered, as for example the number of process realizations within a simulation. Beneath further objectives, the following can be evaluated quickly and at low costs: current sequences of operations, as well as plans and process alternatives. Those evaluations can be realized before expensive adjustments within current process models are carried out (Gronau, 2017).

2.2 Knowledge Representation

Nonaka and Takeuchi distinguish between explicit knowledge and tacit knowledge (Nonaka and Takeuchi, 1995). While the first can be verbalized and externalized easily, the second is hard to detect. On-building, the following four knowledge conversion types can be distinguished:

- An *internalization* is the process of integration of explicit knowledge in tacit knowledge. Here, experiences and aptitudes are integrated in existing mental models.
- A *socialization* is the process of experience exchange. Here, new tacit knowledge such as common mental models or technical ability are created.
- An *externalization* is the process of articulation of tacit knowledge in explicit concepts. Here, metaphors, analogies or models can serve to verbalize tacit knowledge.
- A *combination* is the process of connection of available explicit knowledge, such that a new explicit knowledge is created. Here, a reorganization, reconfiguration or restructuring can result in new explicit knowledge.

With the intention to focus on the potentials of human brains and its generation of knowledge, the knowledge generation concepts of (Nonaka and Takeuchi, 1995) seem attractive for the modeling on a neuronal level. Further, the KMDL builds on them, which is selected for demonstration purposes.

2.3 Neuronal Networks

Originally, neural networks were designed as mathematical models to copy the functionality of biological brains. First researches were done by (Rosenblatt, 1963), (Rumelhart et al., 1986) and (McCulloch and Pitts, 1988). As the brain connects several nerve cells, so called *neurons*, by synapses, those mathematical networks are composed of several nodes, which are related by weighted connections. As the real brain sends electrical activity typically as a series of sharp spikes, the mathematical activation of a node represents the average firing rate of these spikes.

As human brains show very complex structures and are confronted with different types of learning tasks (unsupervised, supervised and reinforcement learning) various kinds of networking structures have established, which all have advantages for a certain learning task. There are for example Perceptrons (Rosenblatt, 1958), Hopfield Nets (Hopfield, 1982), Multilayer Perceptrons (Rumelhart et al., 1986), (Werbos, 1988), (Bishop, 1995), Radial Basis Function Networks (Broomhead and Lowe, 1988) and Kohonen maps (Kohonen, 1989). Networks containing cyclic connections are called *feedbackward* or *recurrent networks*.

The following focuses on Multilayer Perceptrons and recurrent networks being confronted with supervised learning tasks. Here, input and output values are given and a learning can be carried out in minimizing a differentiable error function by adjusting the ANN's weighted connections. For this, numerous gradient descent methods can be used, such as Backpropagation (Plaut et al., 1986) and (Bishop, 1995), PROP (Riedmiller and Braun, 1993), quickprop (Fahlman, 1989), conjugate gradients (Hestenes and Stiefel, 1952), (Shewchuk, 1994), L-BFGS (Byrd et al., 1995), RTRL (Robinson and Fallside, 1987) and BPTT (Williams and Zipser, 1995). As the weight adjustment can be interpreted as a small step in an optimization direction, the fix step size can be varied to reduce great errors quickly. The learning rate decay can be used to reduce small errors efficiently and a momentum can be introduced to avoid local optima. In this stepwise optimization, analogies to continuous process optimizations can be found (see section 2.1).

Since neuronal networks model human brains and model the knowledge of a certain learning task, the following refers to neuronal networks as *neuronal knowledge models*.

3 OBJECTIVES OF A NEURONAL PROCESS MODELING

As one assumes to have a given process model and one aims to consider a neuronal network as a process participant's knowledge model within the simulation of that process model, the following objectives have to be considered coming from a modeling side:

1. Neuronal knowledge models have to be integrated within existing process models.
2. The same neuronal knowledge models have to be able to be integrated several times within a process model.
3. Neuronal knowledge models have to be integrated within process simulations.
4. Modeled environmental factors (material such as non-material objects) have to be integrated with considered knowledge models.
5. Outcomes (materialized such as non-materialized) of considered knowledge models have to be considered within the process model.

Further, objectives have to be considered coming from a neuronal techniques side:

6. Neuronal tasks have to be considered following its neurons biological models.

7. Parallel neuronal task realizations have to be considered within neuronal networks.
8. Time-dependent neuronal behaviors have to be considered within neuronal networks.
9. Sequential neuronal task realization have to be considered within neuronal networks.
10. Different levels of neuronal task abstractions have to be considered in the neuronal process modeling and simulation.
11. Sensory information and knowledge flows have to be considered within the modeled neuronal network.
12. Actuator information and knowledge have to be considered as outcomes of neuronal networks.

Each identified objective of those domains is relevant for the transfer of a process modeling language and serves as input for the following sections.

4 DESIGN OF A NEURONAL PROCESS MODELING

The following gives definitions of the concept of neuronal modeling. For this, basic definitions are given firstly and on-building definitions are given afterwards.

Neuronal knowledge objects are defined to be neuronal patterns, that evolve as current over a certain period of time that causes a specific behavior of consecutive neurons. Those patterns can reach from single time steps to long periods of time.

Neuronal information objects are defined to be neuronal currents, that serve as interface from and to the environment such as incoming sensory information and outgoing actuator information. Here, stored information is included as well.

Considering those objects, a *neuronal conversion* is defined to be the transfer of neuronal input objects to neuronal output objects. In accordance to (Nonaka and Takeuchi, 1995), the following neuronal conversion types can be distinguished:

- A *neuronal internalization* is the process of integration of explicit knowledge (neuronal information objects) in tacit knowledge. Here, experiences and aptitudes are integrated in existing mental models.
- A *neuronal socialization* is the process of experience exchange between neurons within a closed ANN. Here, new tacit knowledge such as common mental models or technical abilities are created.
- A *neuronal externalization* is the process of articulation of tacit knowledge (neuronal knowledge objects) in explicit concepts (neuronal information objects). Here, patterns can serve to verbalize tacit knowledge.
- A *neuronal combination* is the process of connection of available explicit knowledge (neuronal information objects), such that a new explicit knowledge is created. Here, a reorganization, reconfiguration or restructuring can result in new explicit knowledge.

Neuronal input objects are defined to be sensory information objects and knowledge objects.

Neuronal output objects are defined to be actuator information objects and knowledge objects.

An *atomic neuronal conversion* is defined to be a neuronal conversion considering only one input object and only one output object.

Complex neuronal conversion are defined to be neuronal conversions considering at least three neuronal objects of one neuron. *Pure* complex neuronal conversions do consider only one neuronal conversion type, while *impure* complex neuronal conversion do consider several neuronal conversion types such that one is not able to distinguish them.

Abstract neuronal conversion are defined to be neuronal conversions considering neuronal objects of more than one transferring neuron such that one is not able to identify participating neurons.

All together, those definitions are the basis for the transfer of a process modeling languages to the neuronal level.

5 DEMONSTRATION OF THE NEURONAL PROCESS MODELING

The following subsections show the realization of the neuronal process modeling on behalf of the *KMDL*. For this, theoretic examples and corresponding process process models are given, that visualize basic definitions. Then, practical examples follow.

5.1 Theoretical Examples

Definitions as they were given in section 4 are visualized in the following three theoretical examples: First, atomic knowledge conversions on a neuronal level can be found in Figure 1.

In this Figure, one can see a neuronal socialization on the top left, a neuronal externalization on the top right, a neuronal combination on the bottom right

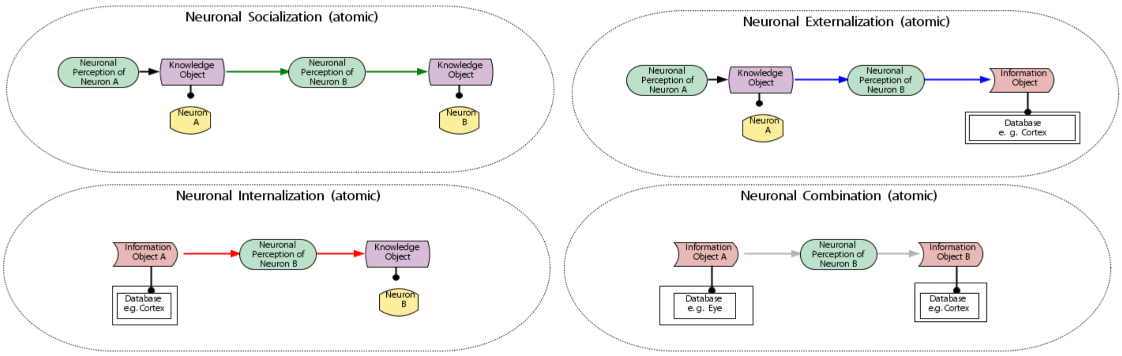

Figure 1: Atomic neuronal conversions.

and a neuronal internalization on the bottom left. All of them were visualized in the activity view of the KMDL.

The entity of *persons* as process participants (yellow) was mapped to *neurons* who interact on a neuronal level. In consequence, the entity of *tacit knowledge objects* (purple) are connected to neurons. The entity of the conversion (green) was mapped to the activity of a neuron that generates new knowledge based on the transfer of its input objects. The environment as well as interaction possibilities with the environment are modeled with the entity of a database (white rectangle). Further, neuronal information objects are stored within a database. In consequence, the shape of *information objects* (red) are connected to those databases.

Second, complex neuronal conversions are visualized in Figure 2.

Again, in this Figure, one can see a neuronal socialization on the top left, a neuronal externalization on the top right, a neuronal combination on the bottom right and a neuronal internalization on the bottom left. All of them were visualized in the activity view of the KMDL.

Following the KMDL, conversions of the activity view can be repeated without control flow. Hence, each neuron can develop several neuronal knowledge objects or neuronal information objects over time. Hence, modeled neuronal objects do represent the identified current knowledge of a certain neuron. Therefore, a strict sequence modeling therefore can be realized with help of the listener concept or the process view.

Third, an abstract neuronal conversion can be found in Figure 3.

In this Figure, one can see several impure complex conversions, which is the reason for the black color of the visualized arrows, as the KMDL asks for. Since more than one neuron (B1 and B2) are considered on that process model, an abstract level of neuronal conversions has been visualized.

5.2 Practical Examples

Using basic definitions of a neuronal process modeling, their transfer to practical examples coming from the industry is intended. The following gives four practical examples. All of them serve as a fruitful domain to visualize neuronal modelings, simulations and optimizations.

A first example focuses on the organization of goods depots. Those can follow various strategies. For example fix places can hold reservations for certain goods. Alternatively, goods can get an arbitrary place, which considers current free spaces. Here, the human brain can serve as biological inspiration for strategies to store memories and can optimize the depot organization of goods.

A second example focuses on production processes. Here, goods are not needed constantly. Meanwhile, they can be stored in goods depots or storage areas. Once, they are needed, they can be brought to the corresponding process step with help of transportation elements (Gronau et al., 2016a). As they are not required, a transportation element pauses and buffers currently not needed goods. Alternatively, materials can be considered as just-in-time inventory, such that they do not have to be stored in expensive goods depots. Here, the velocity of transportation elements is adjusted in dependence to the production order. Analogies can be found in the human brain. As the storage of goods, the storage of memories can be organized or vice versa. A short-term-memory (current currencies) deals with neuronal knowledge objects similarly to just-in-time inventory. Here, neuronal knowledge objects are used at consecutive neurons as they are needed. Buffered goods are stored within long-term-memories similar to goods depots. Here, currencies are unlocked as they are needed within the current process.

A third example focuses on specializations of production machines. As production processes can be considered as a single process network, machines are

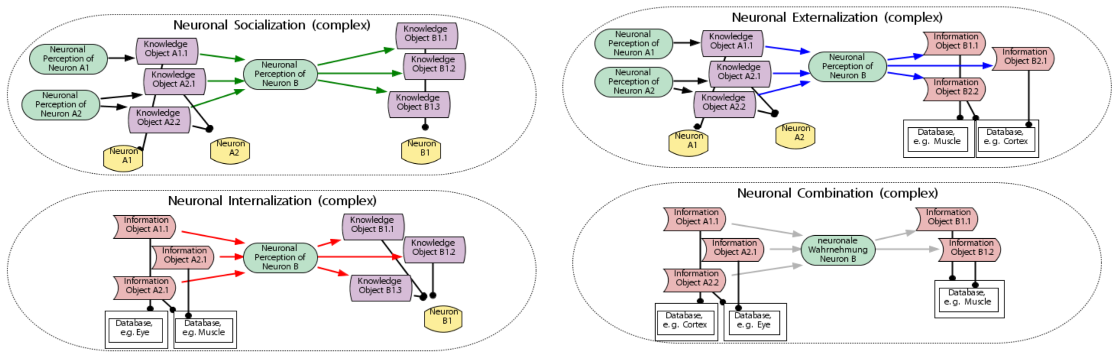

Figure 2: Complex neuronal conversions.

part of them. Since machines can show high specializations, the organization of production processes can be inspired by the organization of the human brain. Here, certain areas are responsible for a certain task and show high specializations as well. For example the auditory cortex deals mainly with acoustic information, the visual cortex mainly with optical information, etc.

The best choice to realize the entire process model is not always to realize all process parts in the own company. As parts can be outsourced to external parties, analogies can be found in the human brain as well. Here, speed relevant actions can be initiated by reflexes. This is efficient since the realization of a full cognitive task processing would be to slow. As an example, one can imagine the start of a sprinkler system. In case of a fire, it was not sense full to create action alternatives but start fighting a fire immediately like a reflex.

6 EVALUATION

Faced with the demonstration artifacts of the previous section, objectives of section 3 have been considered as follows.

Objective 1 can be fulfilled as neuronal knowledge models are modeled within the activity view characterizing a certain person. Here, a decomposition rises the process model granularity of the selected activity and connects all neuronal process models with common process models. Since the common activity view characterizes a corresponding process task of the process view, neuronal knowledge models are integrated within existing process models. Since a neuronal network characterizes entities of persons, a trained neuronal network can be reused in any activity (objective 2). As neuronal knowledge models can be activated and can evolve over time, they can be integrated within discrete process simulations easily (objective 3). From a common activity view modeled environmental factors (material such as non-material objects) serve as interface for the activity view on a neuronal level. Hence, objective 4 and objective 5 are considered as well.

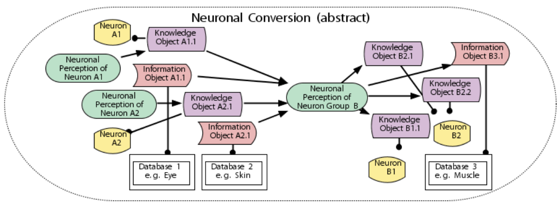

Figure 3: Abstract neuronal conversion.

Further, objectives have been considered coming from a neuronal techniques side as follows: As learning with neuronal networks is not affected by the here presented concepts, neuronal tasks can follow the neurons biological models (objective 6). A parallel neuronal task realization within neuronal networks has been considered (objective 7) as can be seen in Figure 2 (neuronal socialization and neuronal externalization) and Figure 3. Here, at least two neurons realize a parallel task processing. Objective 8 can be met as soon as recurrent connections are considered within the neuronal process models. Then, time-dependent neuronal behaviors are considered within neuronal networks. A sequential neuronal task realization within neuronal networks can be considered within the neuronal process modeling (objective 9), as presented activity views are characterizing corresponding tasks of the process view. Since logical control-flow operators can be used here, a sequential neuronal task processing can be modeled easily. Further, a time-dependent behavior of a network modeled within the activity view can result in a sequential task processing. Objective 10 has been met as can be seen in Figure 3. Here, the task "Neuronal Perception of Neuron Group B" models the activity of Neuron B1 and Neuron B2 on an abstract level. Further, knowledge objects, information objects, neurons and databases can be grouped and visualized on an abstract level. Sensory information and knowledge flows can be considered within the modeled neuronal network as can be seen in for example in Figure 1 and Figure 2. In both Figures, possible sensory information flows can be seen on the bottom (neuronal internalization and neuronal combination). Possible knowledge flows can be seen in both Figures on the top (neuronal socialization and neuronal externalization). Objective 12 can be met as follows: Actuator information and knowledge have been considered as outcomes of neuronal networks, as can be seen in Figure 1 and Figure 2. In both Figures, possible actuator information flows can be seen on the right (neuronal externalization and neuronal combination). Possible knowledge flows can be seen in both Figures on the left (neuronal socialization and neuronal internalization).

Considering the here presented evaluation of given objectives, it becomes clear that an idea for every objective has been identified. This supports the functioning of the transfer of the KMDL to the neuronal level, such that a neuronal process modeling, a neuronal process simulation and a neuronal process optimization can be built on base of that.

7 CONCLUSIONS

In this paper, a visionary way to novel process optimization techniques has been drawn and the base has been realized on behalf of the KMDL. Main contributions and scientific novelties are the following: Definitions of a neuronal process modeling, neuronal process simulation and a neuronal process optimization have been created. Objectives of a transfer of a common process modeling language have been identified. Further, definitions for those concepts have been created and a modeling language has been transferred to the neuronal world. This includes the reinterpretation of existing shapes of the KMDL. On that base, theoretical examples have been visualized on behalf of the KMDL. Further, analogies for the use of the here presented concepts in the industry context have been identified.

With this, the drawn transfer has been applied and proven. Hence, the sub research question was answered and the following potentials are suitable next steps:

The concretion of the functioning of previously presented concepts will be realized. Then, those will be realized as quantitative neuronal process modelings, simulations and optimizations. Further, the comparison of the here presented concepts with traditional results was attractive as well. Still promising is the rebuilding of common process model optimization on behalf of the here presented concepts.

The application of the here presented concepts are assumed to cause a fundamentally value increase. As simple and complex relations in different process perspectives like cost, time or stock can be considered, the prediction quality of process simulations is strongly improved. Further, common optimization potentials can be estimated efficiently. Additionally, new optimization approaches and optimization potentials can be identified.

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Microflows: Enabling Agile Business Process Modeling to Orchestrate Semantically-Annotated Microservices

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Keywords: Business Process Modeling, Workflow Management Systems, Microservices, Service Orchestration, Agent Systems, Semantic Technology, Declarative Programming.

Abstract: Businesses and software development processes alike are being challenged by the digital transformation trend. Business processes are increasingly being automated yet are expected to be agile. Current business process modeling is typically labor-intensive and results in rigid process models, with larger process models unable to cope with all possible process variations and enactment circumstances. In software development, microservices have become a popular software architectural style for partitioning business logic into fine-grained services that can be rapidly and individually developed and (re)deployed while accessed via lightweight protocols, resulting in many more services and a much more dynamic service landscape. Thus, a more dynamic form of modeling, integration, and orchestration of microservices with business processes is needed. This paper describes agile business process modeling with Microflows, an automatic lightweight declarative approach for the workflow-centric orchestration of semantically-annotated microservices using agent-based clients, graph-based methods, and the lightweight semantic vocabularies JSON-LD and Hydra. A case study shows how Microflow constraints can be automatically extracted from existing Business Process Modeling Notation (BPMN) files, how Microflow execution log file process mining can be used to extract BPMN models, and demonstrates an automated error recovery capability during enactment.

1 INTRODUCTION

The digital transformation sweeping through society affects businesses everywhere, resulting in an increased emphasis on business agility and automation. Business processes or workflows are one primary automation area, evidenced by $2.7 billion in spending on Business Process Management Systems (BPMS) (Gartner, 2015). The automation of a business process according to a set of procedural rules is known as a workflow (WfMC, 1999). A workflow management system (WfMS), defines, creates, and manages the execution of workflows (WfMC, 1999). BPMN (Business Process Model and Notation) (OMG, 2011), supports Business Process Modeling (BPM) with a common notation standard. However, with regard to agility, these workflows are often rigid, and while adaptive WfMS can handle certain adaptations, they usually involve manually intervention to determine the appropriate adaptation.

In software development, one observable agility trend is the widespread application of the microservice architecture style (Fowler and Lewis, 2014) for an agile and loosely-coupled partitioning of business capabilities into fine-grained services individually evolvable, deployable, and accessible with lightweight mechanisms. However, as the dynamicity of the service world increases, the need for more a automated and dynamic approach to service orchestration becomes evident.

Approaches have included service orchestration, where a single executable process uses a flow description (such as WS-BPEL) to coordinate service interaction orchestrated from a single endpoint. In contrast, service choreography involves a decentralized collaborative interaction of services (Bouguettaya et al., 2014), while service composition involves the static or dynamic aggregation and binding of services into some abstract composite process. While automated dynamic workflow planning could potentially remove the manual overhead involved in workflow modeling, a fully automated semantic integration process remains challenging, with one study indicating that it is achieved by only 11% of Semantic Web applications (Heitmann et al., 2012).

Thus, rather than pursue the heavyweight Service-Oriented Architecture (SOA) and semantic web, we chose a lightweight bottom-up approach. Analogous to the microservices principles, we use the term microflow to mean lightweight workflow planning and enactment of microservices, i.e. a lightweight service orchestration of microservices.

In our prior work, we described our declarative approach called Microflows for automatically planning and enacting lightweight dynamic workflows of semantically annotated microservices (Oberhauser, 2017) using cognitive agents and investigated its resource usage and viability (Oberhauser, 2016). This paper contributes enhanced support for business modeling with Microflows and microservices, providing bi-directional support for graphical modeling with BPMN via automated constraint extraction and BPMN generation from a Microflow execution log. Furthermore, automated error handing and replanning capabilities were extended to address the dynamic microservice landscape. Note that this approach is not intended to address all facets of BPMS support, but focused on a narrow area addressing the automatic orchestration of dynamic workflows given a multitude of microservices using a pragmatic lightweight approach rather than a theoretical treatise.

This paper is organized as follows: the next section discusses related work. Section 3 presents the solution approach, while Section 4 describes its realization. The solution is evaluated in Section 5, which is followed by a conclusion.

2 RELATED WORK

Microflow is used in IBM business process manager terminology to mean a transient non-interruptible BPEL (Web Services Business Process Execution Language) process (IBM, 2015), while in our terminology a microflow is independent of any BPMS, choreography, or orchestration language.

As to the combination of BPM with microservices, while (Alpers et al., 2015) mention business process modeling with microservices, their focus is on collaborative BPM tool support services, presenting an architecture that groups them according to editor, management, analysis functionality, and presentation. (Singer, 2016) proposes a compiler-based actor-centric approach to directly compile Subject-oriented Business Process Management (S-BPM) models into a set of executable processes called microservices that coordinate work through the exchange of messages. In contrast, we assume our microservices preexist.

With regard to orchestration of microservices, related work includes (Rajasekar et al., 2012), who describe the integrated Rule Oriented Data System (iRODS) for large-scale data management, which uses a distributed event-condition-action rule engine to orchestrate micro-services into conditional chain-oriented workflows, maintaining transactional properties through recovery micro-services. (Alpers et al., 2015) describe a microservice architecture for BPM tools, highlighting a Petri Net editor to support humans with BPM. (Sheng et al., 2014) surveys research prototypes and standards in the area of web service composition. Although the web service composition using the workflow technique (Rao & Su, 2004) can be viewed as similar, our approach does not explicitly create an abstract composite service; rather, it can be viewed as automated dynamic web service orchestration using the workflow technique. Declarative approaches for process modeling include DECLARE (Pesic, 2007). A DECLARE model is mapped onto a set of LTL formulas that are used to automatically generate automata that support enactment. Adaptations with verification during enactment are supported, typically via GUI interaction with a human, whereby the changed model is reinitiated and its entire history replayed. As to inputs, DECLARE facilitates the definition of different constraint languages such as ConDec and DecSerFlow.

For combining multi-agent systems (MAS) and microservices, (Florio, 2015) proposes a MAS for decentralized self-adaptation of autonomous distributed components (Docker-based microservices) to address scalability, fault tolerance, and resource consumption. These agents known as selfLets mediate service decisions using partial knowledge and exchanging messages. (Toffetti et al., 2015) provide a position paper focusing on microservice monitoring and proposing an architecture for scalable and resilient self-management of microservices by integrating management functions into the microservices, wherein service orchestration is cited to be an abstraction of deployment automation (Karagiannis et al., 2014), microservice composition or orchestration are not addressed.

Related standards include OWL-S (Semantic Markup for Web Services), an ontology of services for automatic web service discovery, invocation, and composition (Martin et al., 2004). Combining semantic technology with microservices, (Anderson et al., 2015) present an OWL-centric framework to create context-aware applications, integrating microservices to aggregate and process context information. For a more lightweight semantic description of microservices, JSON-LD (Lanthaler and Gütl, 2012) and Hydra (Lanthaler, 2013) (Lanthaler and Gütl, 2013) provide a lightweight vocabulary for hypermedia-driven Web APIs and enable the creation of generic API clients.

In contrast to the above work, our contribution specifically focuses on microservices with an automatic lightweight declarative approach for the workflow-centric orchestration of microservices using agent-based clients, graph-based methods, and lightweight semantic vocabularies like JSON-LD and Hydra. The extraction of goals and constraints from existing BPM is supported and error handling permits dynamic recovery and replanning.

3 SOLUTION APPROACH

The principles and process constituting the solution approach, based on (Oberhauser, 2016) and (Oberhauser, 2017), are elucidated below and reference the solution architecture of Figure 1. One primary difference of our solution approach compared to typical BPM is the reliance on goal- and constraint-based agents using automated planners to navigate semantically-described microservices, thus the workflow is dynamically constructed, reducing the overall labor involved in manual modeling of rigid workflows that cannot automatically adapt to changes in the microservice landscape, analogous to the benefits of declarative over imperative programming.

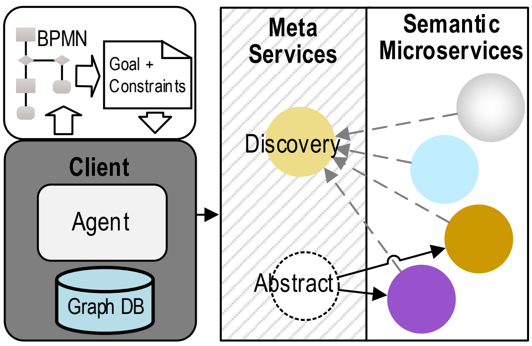

Figure 1: Solution concept.

3.1 Microflow Principles

The solution approach consists of the following principles:

Microservice semantic self-description principle: microservices provide sufficient semantic metadata to support autonomous client invocation, such that the client state at the point of invocation contains the semantic inputs required for the microservice invocation. Our realization uses JSON-LD/Hydra.

Client agent principle: for the client agent of Figure 1, intelligent agents exhibit reactivity, proactiveness, and social ability, managing a model of their environment and can plan their actions and undertake goal-oriented behavior (Wooldridge, 2009). Nominal WfMS are typically passive, executing a workflow according to a manually determined plan (workflow schema). Because of the expected scale in the number of possible microservices, the required goal-oriented choices in workflow modeling and planning, and the autonomous goal-directed action required during enactment, agent technology seems appropriate. Specifically, we chose Belief-Desire-Intention (BDI) agents (Bratman et al., 1988) for the client realization, providing belief (knowledge), desire via goals, and intention utilizing generated plans that are the workflow.

Graph of microservices principle: microservices are mapped to nodes in a graph and can be stored in a graph database (see Figure 1). Nodes in the graph are used to represent any workflow activity, such as a microservice. Nodes are annotated with properties. Directed edges depict the directed connections (flows) between activities annotated via properties. To reduce redundant resource usage via multiple database instances, the graph database could be shared by the clients as an additional microservice.

Microflow as graph path principle: a directed graph of nodes corresponds to a workflow, a sequence of operations on those microservices, and is determined by an algorithm applied to the graph, such as shortest path. The enactment of the workflow involves the invocation of microservices, with inputs and outputs retained in the client and corresponding to the client state.

Declarative principle: any workflow requirement specifications take the form of declarative goal and constraint modelling statements, such as the starting microservice type, end microservice type, and constraints such as sequencing or branch logic constraints. As shown under Models in Figure 1, these specifications may be (automatically) extracted from an existing BPM should one exist, or (partially) discovered via process execution log mining.

Microservice discovery service principle (optional): we assume a microservice landscape to be much more dynamic with microservices coming and going in contrast to more heavyweight services.

A microservice registry and discovery service (a type of Meta Service in Figure 1) can be utilized to manage this and could be deployed in various ways, including centralized, distributed, client-embedded, with voluntary microservice-triggered registration or multicast-triggered mechanisms. For security purposes, there may be a desire to avoid discovery (of undocumented microservices) and thus maintain a whitelist. Clients thus may or may not have a priori knowledge of a particular microservice.

Abstract microservices principle (optional): microservices with similar functionality (search, hotel booking, flight booking, etc.) can be grouped behind an abstract microservice (a type of Meta Service in Figure 1). This simplifies constraints, allowing them to be based on a group rather than having to be individually based. It also provides an optional level of hierarchy to allow concrete microservices to only provide a client with a link to the logical next abstract microservice(s) without having to know the actual concrete ones, since the actual concrete microservice followers can be numerous and rapidly change, while determining exactly which ones are appropriate can perhaps best be decided by the client in conjunction with the abstract microservice.

Path weighting principle (optional): any follower of a service, be it abstract or concrete, can be weighted with a potentially dynamic cost that helps in quantifying and comparing one path with another in the form of relative cost. This also permits the navigation from one to another to be dynamically adjusted should that path incur issues such as frequent errors or slow responses. The planning agent can determine a minimal cost path.

Logic principle (optional): if the path weighting is insufficient and more complex logic is desired for assessing branching or error conditions, these can be provided in the form of constraints referencing scripts that contain the logic needed to determine the branch choice.

Note that the Data Repository and Graph Database could readily be shared as a common service, and need not be confined to the Client.

3.2 Microflow Lifecycle

The Microflow lifecycle involves five stages as shown in Figure 2.

Figure 2: Microflow lifecycle.

For the *Microflow Modeling* stage, goal and constraint specifications are modeled (currently in JSON) or extracted via tools from existing business process models such as BPMN or process mining of process (or Microflow) execution logs.

The *Microservice Discovery* stage involves utilizing a microservice discovery service to build a graph of nodes containing the properties of the microservices and links (followers) to other microservices, analogous to mapping the landscape.

In the *Microflow Planning* stage, an agent takes the goal and other constraints and creates a plan known as a Microflow, finding an appropriate start and end node and using an algorithm such as shortest path to determine a directed path.

In our opinion, a completely dynamic enactment without any planning (no schema) could readily lead to dead-end or circular paths causing a waste of unnecessary invocations that do not lead to the desired goal and can potentially not be undone. This is analogous to following hyperlinks without a plan, which do not lead to the goal and require backtracking. Alternatively, replanning after each microservice invocation involves planning resource overhead (CPU, memory, network), and since this is unlikely to dynamically change between the start and end timepoints of this enactment lifecycle, we chose the pragmatic and hopefully more lightweight approach from the resource utilization perspective: plan once and then enact until an exception occurs, at which point a necessary replanning is triggered. Further advantages of our approach in contrast to a thoroughly adhoc approach is that the client is assured that there is at least one path to the goal before starting, and validation of various structural, semantic, and syntactic aspects can be readily performed.

In the *Microflow Enactment* stage, the Microflow is executed by invoking each microservice in the order of the plan, typically sequentially but it could involve parallel invocations. A replanning of the remaining Microflow can be performed if an exception occurs or if notified by the discovery service of changes to the set of microservices. A client should retain the Microflow model (plan) and be able to utilize the service interfaces and thus have sufficient semantic knowledge for enactment.

The *Microflow Analysis* stage involves the monitoring, analysis, and mining of execution logs in order to improve future planning. This could be local, in a trusted environment, or this could be distributed. Thus, if invocation of a microservice has often resulted in exceptions, future planning for this client or other clients could avoid this troublesome microservice. Furthermore, the actual latency incurred for usage of a microservice could be tracked and shared between agents and taken into account as a type of cost in the graph algorithm.

4 REALIZATION

Figure 3 shows our realization of the Microflow solution concept with a mapping of primary technology choices in our prototype. As various details of our Microflow realization and lifecycle were previously detailed in (Oberhauser, 2016) and (Oberhauser, 2017), a short summary is provided and the rest of this section details the new extensions.

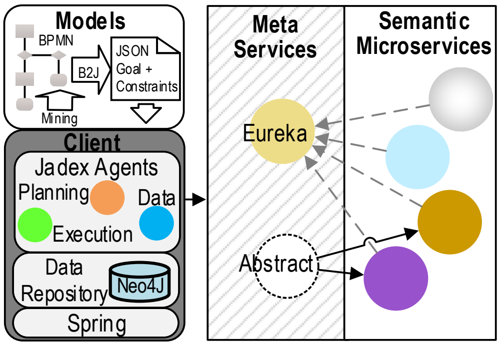

Figure 3: Microflow prototype realization.

Implementations of microservices are assumed to be REST compliant using JSON-LD and Hydra descriptions. For our prototype testing, REST (REpresentational State Transfer) and HATEOAS support (Fielding, 2000) was integrated with Spring-boot-starter-web v. 1.2.4, which includes Spring boot 1.2.4, Spring-core and Spring-web v. 4.1.6, Embedded Tomcat v. 8.0.23; Hydra-spring v. 0.2.0-beta3; and Spring-hateoas v. 0.16 are integrated. For JSON (de)serialization Gson v. 2.6.1 is used. Unirest v. 1.3.0 is used to send HTTP requests. As a REST-based discovery service, Netflix's open source Eureka (Eureka, 2016) v. 1.1.147 is used.

The microservice clients uses the BDI agent framework Jadex v. 3.0-SNAPSHOT (Pokahr et al., 2005). Jadex's BDI nomenclature consists of Goals (Desires), Plans (Intentions), and Beliefs. Beliefs can be represented by attributes like lists and maps. Three agents were created: the DataAgent is responsible for providing for and maintaining data repository, the PlanningAgent generates a path through the graph as a Microflow, while the ExecutionAgent communicates directly with microservices to invoke them according to the Microflow. Neo4j and Neo4j-Server v. 2.3.2 is used as a client Data Repository.

Microflow goals and constraints are referred to as PathParameters and consist of the startServiceType, endServiceType, and constraint tuples. Each constraint tuple consists of the target of the constraint (the service type affected), the constraint, and a constraint type (required, beforeNode, afterNode). For instance, target = "Book Hotel", constraint = "Search Hotel", and constraint type = "afterNode" would be read as: "BookHotel" is after node "Search Hotel", implying the microflow sequencing must ensure that "Search Hotel" precedes "Book Hotel" (but does not require that it must be directly before it).

During Microflow Planning, constraint tuples are analyzed, whereby any AfterNode is converted to a BeforeNode by swapping target and constraint, RequiredNode constraints are also converted to BeforeNode constraints, and redundant constraints are removed and the constraints are then ordered.

4.1 BPMN Transformation

A BPMN-Microflow transformation tool (B2J in Figure 3) was implemented in Java that parses BPMN 2.0 files, automatically extracting the start and end node (goal) and any constraints, generating a Microflow JSON file. The java libraries camunda-bpmn-model and camunda-xml-model version 7.6.0 were utilized for parsing.

It includes support for the following BPMN elements: activities, events, gateways, and connections. Currently unsupported in the implementation for automated extraction are swimlanes, artifacts, and event subprocesses (throwing, catching, and interrupting events).

4.2 Microflow Constraint Mining

A MicroflowLog-BPMN mining tool (represented by Mining in Figure 3) was implemented in Java that automatically parses our Microflow execution log file and generates a BPMN 2.0 file. Since it generates a direct sequence of the actual path taken, it results in a simple sequence of tasks. However, this can be helpful in providing a graphical depiction for human analysis and comparison, determining issues, debugging constraints, and as a reference or starting point for models having greater complexity.

4.3 Microflow Error Recovery

To support enactment error recovery, the Microflow client now supports data versioning of its state, integrating the javersion data versioning toolkit v. 0.14. The algorithm is shown in Figure 4 and referred to by line. At each abstract node, the current client state (JSON data outputs from microservices) is committed (Line 11). If the execution of a microservice is not successful, the transition is penalized by adding to its cost so that any replanning does not necessarily continue to include a microservice with constant issues (Line 22); the node index is set to the last node where a commit was performed (Line 24) (ultimately the start node if none) and its state at that node restored (analogous to a rollback); and a replanning is initiated (Line 25) from that node.

```
1  procedure ExecuteWorkflow(path, constraints, initialInput)
2   lastAbstractNode ← null
3   availableInput ← MapOfListOfStings()
4   availableInput.add("START", initialInput)
5   nodeIndex ← 0
6   while nodeIndex < length(path) do
7    description ← getNodeInfoForNodeInPath(nodeIndex, path)
8    inputs ← availableInput.getAllValidInputsFor(description)
9    if isAbstactNode(description) then
10    if lastAbstractNode != description then
11     revisionID ← commit(nodeIndex, availableInput)
12     enqueue(revisionID)
13     lastAbstractNode ← description
14    end if
15   else   // current node is a regular microservice
16    state ← NONE
17    for each input in inputs do
18     state, result ← executeMicroservice(description, input)
19     if state == SUCCESS then
20      availableInput.add(description, result)
21     else  // state == Exception
22      penalizeTransitionToCurrentNode(nodeIndex)
23      revisionID ← dequeue()
24      resetNodeIndex, availableInput ← checkout(revisionID)
25      newPath  ← getNewShortestPathAfterException(path, resetNodeIndex, constraints)
26      nodeIndex ← resetNodeIndex
27      path ← newPath
28      break
29     end if
30    end for
31    if state == SUCCESS then
32     if isBranchingNode(description,constraints) then
33      newNodeIndex ← runGroovyScriptFromConstraint(description,constraints)
34      newPath ← getNewShortestPathForAnotherBranch(path, nodeIndex, newNodeIndex)
35      nodeIndex ← newNodeIndex
36      path ← newPath
37     else   // current node is not a branching one
38      nodeIndex++
39     end if
40    end if
41   end if
42  end while
43  return availableInput
44 end procedure
```

Figure 4: Microflow execution algorithm.

Thus, Microflow clients support an automated recovery and replanning mechanism. This is in contrast to standard BPMS whereby an unhandled exception typically results in the process terminating. In contrast to basic HATEOAS client implementations, the client state can be rolled back to the last known good service and a replanning enables the client to seek an alternative to reach its goal. This error recovery technique can be used to support the Microflow equivalent of BPMN subprocess transactions.

5 EVALUATION

A case study is used to evaluate the solution, first considering the extraction of constraints from BPMN models, the mining of BPMN models from a Microflow execution log, and then error recovery.

5.1 BPMN Transformation

As an illustrative example, we created our own travel booking process shown in Figure 5, whereby both a hotel and flight should be found, whereafter a booking (reservation) of each is performed, and then payment is collected. Virtual microservices are used during enactment that differentiate themselves semantically but provide no real invocation functionality. The equivalent BPMN model (Figure 7) generated an XML file using Camunda Modeler consisting of 209 lines and 11372 characters. In contrast, the Microflow constraint JSON file generated from this model by our BPMN-Microflow transformation tool contains 14 lines and 460 characters (Figure 5).


```
{ "startServiceType":"Preferences",
  "endServiceType":"Payment",
  "constraints":[
   { "type":"RequiredNode",
     "target":"Flight Search"},
   { "type":"AfterNode",
     "target":"Payment",
     "constraint":"Book Hotel"},
   { "type":"BeforeNode",
     "target":"Hotel Search",
     "constraint":"Book Hotel"},
   { "type":"AfterNode",
     "target":"Payment",
     "constraint":"Book Flight" }]}
```


Figure 5: Travel booking example Microflow constraints.


```
{ "startServiceType":"StartProcess",
"endServiceType":"EndProcess",
"terminateServiceType":"TerminateProcess",
"constraints":[
 { "type":"BeforeNode",
   "target":"Shipping Handling",
   "constraint":"Review Order"},
 { "type":"BeforeNode",
   "target":"Order  Handling",
   "constraint":"Review Order"},
 { "type":"BranchAfterExecution",
   "target":"Approve Product",
   "constraint":"TerminateOrContinue.groovy"},
 { "type":"BeforeNode",
   "target":"Approve Customer",
   "constraint":"Approve Product"},
 { "type":"BeforeNode",
   "target":"Quotation Handling",
   "constraint":"Approve Customer"}]}
```


Figure 6: SubProcess BPMN extracted constraints.

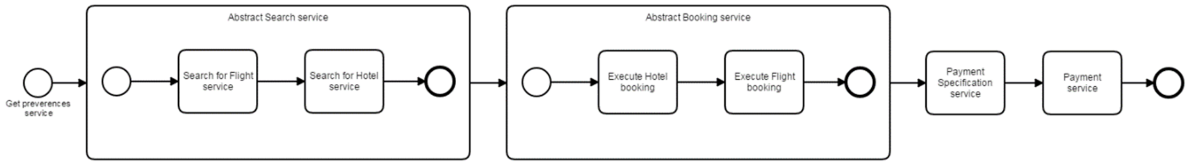

Figure 7: Travel booking example as BPMN.

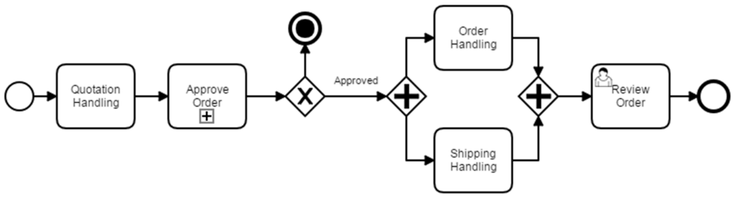

Figure 8: Collapsed SubProcess BPMN model.

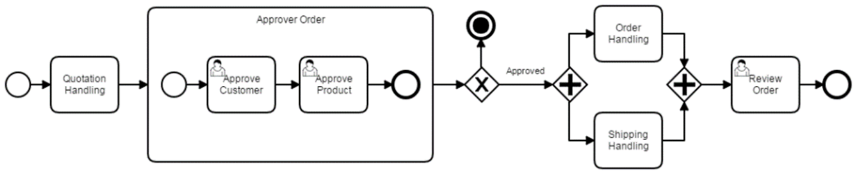

Figure 9: Expanded SubProcess BPMN model.

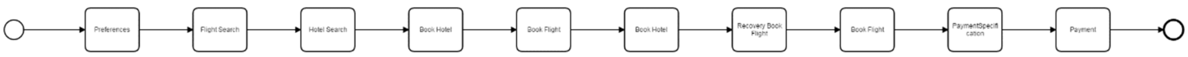

Figure 10: BPMN process mined from Microflow execution log containing a recovery case.

To determine to what extent the spectrum of BPMN 2.0 is supported and if any issues are a result of the approach or limitations of the implementation, the BPMN files from OMG BPMN Examples (OMG, 2010) were tested. Both the collapsed SubProcess as well as the Expanded SubProcess BPMN models shown in Figure 8 and 9 respectively consist of 222 lines and 13996 characters of BPMN XML and were automatically transformed to constraint files of 19 lines and 622 characters in Microflow JSON as shown in Figure 6. Both BPMN files contain the subprocess information which is hidden in the graphical representation in Figure 8.

Assessing the subset of BPMN transformations of the OMG BPMN examples that were unsuccessful, which included portions of Incident Management, Nobel Prize Process, Procurement Process With Error Handling, Travel Booking, Pizza Order Process, Hardware Retailer, Email Voting, we identified the following issues:

- Multiple start events: this implies multiple processes are enacted concurrently, resulting in issues with planning and merging state and potential race conditions. These issues, however, are due to limitations with our prototype implementation, not of the approach. Future work will consider concurrent enactment and synchronization.
- Multiple end or terminate events: in this case, the planner cannot identify the goal node for the Microflow. One current implementation workaround is to create an abstract final node or a final common end node, which can be inserted into our internal graph with the appropriate additional relations.
- Missing start and end events: these are optional in BPMN and result in no clear start and end goal for the planner. One workaround for our implementation is to assume these are implied based on activities having no predecessor or no successor.
- Event subprocess: the prototype does not automatically map exception areas, yet it would be feasible by adding a constraint to each contained node with a conditional before whereby a new path is then dynamically replanned from this relation on error.
- Swim lanes: currently only isolated swim lanes are supported, but future work will consider a mapping to abstract nodes and possible

communication and synchronization support.

- Artifacts: our implementation cannot map BPMN inputs since in these models they lack sufficient semantic detail. One workaround would be to provide a manually created map of BPMN types to JSON-LD types.

5.2 Microflow Constraint Mining

Our MicroflowLog-BPMN mining tool was used to extract a BPMN file from our execution log (Figure 11) based on the Figure 5 and Figure 7 example that included an automated error recovery condition. Figure 10 shows the graphical BPMN representation and Figure 13 an extract from its BPMN file. As explained in Section 4.2, this can assist human analysis or serve as a starting point for a model.

```
Plan: (7)--[CAN_CALL,6]-->(5)--[CAN_CALL,5]-->(6)--[CAN_CALL,11]-->(5)--[CAN_CALL,4]-->(4)--
[CAN_CALL,2]-->(5)--[CAN_CALL,3]-->(1)--[CAN_CALL,8]-->(8)--[CAN_CALL,10]-->(1)--[CAN_CALL,9]
-->(0)--[CAN_CALL,0]-->(1)--[CAN_CALL,7]-->(3)--[CAN_CALL,1]-->(2)
Executing: http://178.18.9.151:8333/ (Get preferences service) Received: ItemList
Skipping Abstract Node:http://178.18.9.151:8335/ (Abstract Search service)
Executing: http://178.18.9.151:8340/ (Search for Flight service) Received: Flight
Skipping Abstract Node:http://178.18.9.151:8335/ (Abstract Search service)
Executing: http://178.18.9.151:8339/ (Search for Hotels service) Received: Hotel
Skipping Abstract Node:http://178.18.9.151:8335/ (Abstract Search service)
Skipping Abstract Node:http://178.18.9.151:8334 (Abstract Booking service)
Executing: http://178.18.9.151:8336/ (Execute Hotel booking) Received: LodgingReservation
Skipping Abstract Node:http://178.18.9.151:8334 (Abstract Booking service)
Executing: http://178.18.9.151:8337/ (Execute Flight booking)
ERROR: Flight
Restart with new path at index 6
Plan: (7)--[CAN_CALL,6]-->(5)--[CAN_CALL,5]-->(6)--[CAN_CALL,11]-->(5)--[CAN_CALL,4]-->(4)--
[CAN_CALL,2]-->(5)--[CAN_CALL,3]-->(1)--[CAN_CALL,8]-->(8)--[CAN_CALL,10]-->(1)--[CAN_CALL,12]
-->(10)-->[CAN_CALL,13]-->(0)--[CAN_CALL,0]-->(1)--[CAN_CALL,7]-->(3)--[CAN_CALL,1]-->(2)
Restore availableInput for node index: 6
Skipping Abstract Node:http://178.18.9.151:8334 (Abstract Booking service)
Executing: http://178.18.9.151:8336/ (Execute Hotel booking) Received: LodgingReservation
Skipping Abstract Node:http://178.18.9.151:8334 (Abstract Booking service)
Executing: http://178.18.9.151:8357/ (Recovery for Flight booking) Received: FlightBookingRecoveryReport
Executing: http://178.18.9.151:8337/ (Execute Flight booking) Received: FlightReservation
Skipping Abstract Node:http://178.18.9.151:8334 (Abstract Booking service)
Executing: http://178.18.9.151:8341/ (Payment Specification service) Received: PaymentChargeSpecification
Executing: http://178.18.9.151:8338/ (Payment service) Received: PaymentStatusType
```

Figure 11: Log file output (highlighting recovery in bold).


```
{ "startServiceType":"StartProcess",
"endServiceType":"EndProcess",
"constraints":[
 { "type":"BeforeNode",
  "target":"PaymentSpecification",
  "constraint":"Payment"},
 { "type":"BeforeNode",
  "target":"Book Flight",
  "constraint":"PaymentSpecification"},
 { "type":"BeforeNode",
  "target":"Recovery Book Flight",
  "constraint":"Book Flight"},
 { "type":"BeforeNode",
  "target":"Book Hotel",
  "constraint":"Recovery Book Flight"},
 { "type":"BeforeNode",
  "target":"Book Flight",
  "constraint":"Book Hotel"},
 { "type":"BeforeNode",
  "target":"Book Hotel",
  "constraint":"Book Flight"},
 { "type":"BeforeNode",
  "target":"Hotel Search",
  "constraint":"Book Hotel"},
 { "type":"BeforeNode",
  "target":"Flight Search",
  "constraint":"Hotel Search"},
 { "type":"BeforeNode",
  "target":"Preferences",
  "constraint":"Flight Search"}]}
```


Figure 12: Constraints from Travel Booking BPMN.


```
<?xml version="1.0" encoding="UTF-8"?>
<bpmn:definitions id="Definition_1" targetNamespace="http://bpmn.io/schema/bpmn" xmlr
<bpmn:process isExecutable="false" id="_1-">
 <bpmn:startEvent name="" id="StartProcess">
  <bpmn:outgoing>_2-0</bpmn:outgoing>
 </bpmn:startEvent>
 ...
 <bpmn:task completionQuantity="1" isForCompensation="false" startQuantity="1" name=
  <bpmn:incoming>_2-1</bpmn:incoming>
  <bpmn:outgoing>_2-2</bpmn:outgoing>
 </bpmn:task>
 ...
 <bpmn:task completionQuantity="1" isForCompensation="false" startQuantity="1" name=
  <bpmn:incoming>_2-9</bpmn:incoming>
  <bpmn:outgoing>_2-10</bpmn:outgoing>
 </bpmn:task>
 <bpmn:endEvent name="" id="EndProcess">
  <bpmn:incoming>_2-10</bpmn:incoming>
 </bpmn:endEvent>
 <bpmn:sequenceFlow sourceRef="StartProcess" targetRef="_1-0" name="" id="_2-0"/>
 <bpmn:sequenceFlow sourceRef="_1-0" targetRef="_1-1" name="" id="_2-1"/>
 ...
 <bpmn:sequenceFlow sourceRef="_1-9" targetRef="EndProcess" name="" id="_2-10"/>
</bpmn:process>
<bpmndi:BPMNDiagram id="BPMNDiagram_1">
 <bpmndi:BPMNPlane id="BPMNPlane_1" bpmnElement="_1-">
  <bpmndi:BPMNShape id="StartEvent_StartProcess" bpmnElement="StartProcess">
   <dc:Bounds x="250" y="222" width="36" height="36"/>
  </bpmndi:BPMNShape>
  ...
  <bpmndi:BPMNShape id="Task__1-8" bpmnElement="_1-8">
   <dc:Bounds x="2000" y="200" width="100" height="80"/>
  </bpmndi:BPMNShape>
...
  <bpmndi:BPMNShape id="EndEvent_EndProcess" bpmnElement="EndProcess">
   <dc:Bounds x="2400" y="222" width="36" height="36"/>
  </bpmndi:BPMNShape>
  <bpmndi:BPMNEdge id="SequenceFlow_2-0" bpmnElement="_2-0">
   <di:waypoint xsi:type="dc:Point" x="286" y="240"/>
   <di:waypoint xsi:type="dc:Point" x="400" y="240"/>
  </bpmndi:BPMNEdge>
...
 </bpmndi:BPMNPlane>
</bpmndi:BPMNDiagram>
```


Figure 13: BPMN from Travel Booking log file with error.

Though not necessarily useful, this extracted BPMN was then converted to Microflow constraints as shown in Figure 12 to demonstrate that a full cycle back to a Microflow specification from an execution log is feasible. These constraints could, for example, then be reduced by a human to only those required and adjusted for requisite sequencing in order to utilize the dynamic planning capability.

5.3 Microflow Error Recovery

To demonstrate the automated error recovery capability, the Flight Booking service was modified to return an HTTP 500 status code and a Recovery for Flight Booking microservice (which could for example attempt to restart the failing service) was added as a microservice with a path cost higher than that of the normal Flight Booking just to demonstrate the ability for replanning to adjust and take a different path after receiving an error. It does not imply that recovery microservices are needed.

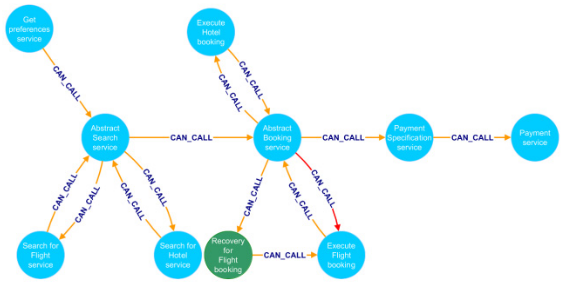

Figure 14: Travel Booking example as Neo4J graph (error recovery shown in green).


```
1   FlightReservation:
2   -
    {"reservationFor":{"departureTime":"","departureTerminal":"","departureAirport":{"iataC
    ode":"","icaoCode":"","@type":"Airport"},"departureGate":"","@type":"Flight","arrivalTi
    me":"","aircraft":"","arrivalAirport":{"iataCode":"","icaoCode":"","@type":"Airport"},"
    arrivalGate":"","arrivalTerminal":"","flightNumber":""},"bookingTime":"","boardingGroup
    ":"","reservationId":"","totalPrice":0,"@type":"FlightReservation","@context":{"@vocab"
    :"http://schema.org/"},"reservationStatus":"https://schema.org/ReservationConfirmed","u
    nderName":""}
3   LodgingReservation:
4   -
    {"reservationFor":{"address":"","@type":"Hotel","name":""},"bookingTime":"","checkinTim
    e":"","numAdults":0,"totalPrice":0,"@type":"LodgingReservation","@context":{"@vocab":"h
    ttp://schema.org/"},"reservationId":"","lodgingUnitDescription":"","numChildren":0,"che
    ckoutTime":"","reservationStatus":"https://schema.org/ReservationConfirmed","underName"
    :""}
5   Flight:
6   -
    {"departureTime":"","departureTerminal":"","departureAirport":{"iataCode":"","icaoCode"
    :"","@type":"Airport"},"departureGate":"","@type":"Flight","arrivalTime":"","aircraft":
    "","@context":{"@vocab":"http://schema.org/"},"arrivalAirport":{"iataCode":"","icaoCode
    ":"","@type":"Airport"},"arrivalGate":"","arrivalTerminal":"","flightNumber":""}
7   Hotel:
8   - {"address":"","@type":"Hotel","name":"","@context":{"@vocab":"http://schema.org/"}}
9   ItemList:
10  - {"@type":"ItemList","numberOfItems":0,"@context":{"@vocab":"http://schema.org/"}}
```


Figure 15: Output of client state in JSON.

Figure 14 includes a recovery microservice (green). In the execution log file of Figure 11, after receiving an error the execution returns to Abstract Booking Service. The client state (shown in Figure 15) is restored to that which it was at the last commit, leaving ItemList, Hotel, and Flight (Lines 5-10) and discarding LodgingReservation and FlightReservation (Lines 1-4). The relation between Abstract Booking and Flight Booking is penalized, resulting in a replanning from Abstract Booking that now includes Recovery for Flight Booking since it is the path with the least cost. This is seen in Figure 11 with the difference in the planning sequence from [CAN_CALL,9] to [CAN_CALL,12]-->(10)-->[CAN_CALL,13].

6 CONCLUSIONS

In this paper, we described business process modeling integration with Microflows, an automatic lightweight declarative approach for the workflow-centric orchestration of semantically-annotated microservices using agent-based clients, graph-based methods, and lightweight semantic vocabularies. The solution principles of the Microflow approach and its lifecycle were elucidated. The evaluation showed that Microflow constraints can be automatically extracted from existing BPMN files, that Microflow execution log file process mining can be used to extract BPMN models, and that certain types of client error recovery can be automated with client state rollback, path cost penalization, and dynamic replanning during enactment. The Microflow constraint specification files were found to be quite smaller than the equivalent BPMN files.

With the Microflow approach, only the essential rigidity is specified via constraints, permitting a greater degree of agility in the business process models since the remaining unspecified areas of the workflow are automatically determined and planned (and thus remain dynamically adaptable). This significantly reduces business process modeling labor and permits a higher degree of reuse in a dynamic microservice world, reducing the total cost of ownership. Since the workflow (or plan) is not completely adhoc and dynamic, validation and verification checks can be performed before execution begins, and one is assured that the workflow is executable as planned. However, enhanced support for verification and validation of the correctness of the microflow is still required for users to entrust the automatic planning.

Future work includes expanded support for BPMN 2.0 elements in our implementation, integrating advanced verification and validation techniques, integrating semantic support in the discovery service, supporting compensation and long-running processes, enhancing the declarative and semantic support and capabilities, and an empirical and industrial usage.

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Models in Business
Experiences from the Field

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Abstract: This paper reflects on the developments over the past decades in business modeling and software design in the context of a very specific niche market. It represents my personal views and supported by theories of the firm and semiotic theories. In the end, the paper argues against a reductionist approach to developing information systems for companies, and pleads for a dissociation between formalised views and formalised modeling on one side, and business views and business modeling on the other side.

1 INTRODUCTION

The continuing theme in our company for nearly four decades of building systems for the food processing industry has been an orientation on business value, on data quality and on the fit of our solutions to the practical circumstances. This orientation did not originate from marketing considerations, but from our companies' background in both designing production facilities and building control and registration systems. The founder of the company, Hans Kortenbach, had a strong drive to combine his technical acumen and business knowledge to design innovative solutions for production processes, and our IT solutions had to make true on his promises to the customer and his intentions at design time. In other words: the solutions just had to work under practical (and often tough) circumstances.

Of course, during that time a lot of things changed in our company. The rapid developments of IT technology (both in hardware and in software development tools) were accompanied by a more and more reductive approach to information and information systems. Our thinking about the nature of the firm, about the nature of information in business processes and about the nature of IT systems moved in the opposite direction: information system development should start from real world business and its processes with their information needs, accommodate heterogeneity of information carriers, accommodate irregularities and possibly inconsistencies, and use IT systems only where those systems have added value. Reductive thinking about information and meaning that comes with IT oriented projects should be avoided.

In the paper the history of our developments in doing software projects, our view of organisations and our approach to modeling processes will be discussed.

2 EARLY YEARS

In 1978 I built my first commercial-use software for a tulip grower / trader. This was an invoicing program which used a manually entered order header data, customer number and order line data (item number – quantity – unit price) to produce a paper invoice. Master data for the customers and items were retrieved from a mini-cassette tape. This invoicing program saved administrative work and reduced the risk of errors. The paper invoice was processed further in the traditional workflow in the paper-based accounting and records keeping. Invoices were not stored in the system: the two Philips P300 Office Computers used here had a working memory of respectively 2kB and 6kB and they had only the mini-cassette drive for external memory. Disk storage was not an affordable option for this kind of computer. This was the automation of one part of a process, one step on from the 'smart' electronic typewriters; it was not an information system.

Within RBK we built dedicated stand-alone systems from the early eighties, but by then external 'mass' storage was available on floppy disks (360kB storage capacity). Hard disks were available but still very pricey (and they had a capacity of 10 or 20 MB). Filleting systems were the most important software product: registration of the input and output of individual filleters in a production line, with a weekly payment based on the volume produced and the efficiency achieved. Later this was extended with quality registration (e.g. fish bones found), giving a penalty in pay when the number of quality errors exceeded a norm. These programmes operated in a fixed weekly cycle which finished on Friday afternoon with the payment calculation for each filleter. A connection to the further financial processes was realised by generating the weekly results with such a lay-out that the data could be checked quickly and easily and typed over quickly and reliably by accounting. In some individual cases an intermediate file was created that could be read in by accounting. After all procedures had been carried out at the end of the week, the floppy disks were erased and the system was prepared for the upcoming week. We did not keep history inside the system. These were our first information systems, although rather limited. The system would provide the users with information about yields and productivity both on screen and on paper.

From the early eighties we built control systems for cooling/freezing processes in production lines and for cold storage warehousing. For the former the most important goals were to minimise the product quality loss and to optimise the energy efficiency of the cooling/freezing process. For example, in belt freezers for fish the product is frozen to a product temperature of -18 degrees Celsius and each individual product is encapsulated in a thin layer of ice. Improving the control accuracy results in significant gains; an improvement by just 0.5 degrees can generate an extra annual revenue of EUR 50 000. The same principle applies to other cooling and freezing processes in production lines. Optimal product quality and reduced weight loss are the key parameters. A similar approach to the cooling of cold stores resulted in power consumption savings of up to 30%.

All these systems were based on fundamental and innovative thinking by Hans Kortenbach, the founder of our company. Taking into consideration (1) the physical temperature processes and their effects on the products, (2) the characteristics and possibilities of industrial refrigeration systems (both equipment and control), (3) issues of product value and business value in relation to the markets at that time, and (4) the interdependence between the three aspects, he designed the installations, and we (the software developers), built the control systems.

2.1 Business Value and Data Quality

For us as software developers, building and implementing our software solutions was rather straightforward at the time. The relation between the business and the software was not problematic: either our software "created" reality, as in the technical control systems for freezing and chilling products, or our software was "just" representing the quantity, quality and yields of one production line. Such was the naiveté of our world as programmers. From a broader point of view, however, the combination of the design of the physical system by Hans Kortenbach and our control systems represented a kind of business process reengineering without thinking in those terms. There was no business modeling, only technical designs that reflected new ways of thinking about business and that took all aspects of the business into account.

A fundamental issue in this early phase was the emphasis on data quality. We were imparted with the importance of getting reliable data into the system, as a prerequisite for the control quality and the quality of calculations and decisions based on information from our systems. In particular, we learned the hard way how much effort goes into creating reliable registration systems for the shop floor. In years since, we often have been astonished by the neglect of this subject and by the sloppiness in thinking about data quality.

3 COVERING PROCESSES

Starting in 1989 we developed new software for slaughterhouses and for control of industrial refrigeration systems. All shop floor production processes in slaughterhouses were covered by our systems, as well as the commercial processes of the invoicing of livestock and for the sales processes. The invoicing system for livestock was very specific and very advanced, reflecting the competitive market in the Netherlands at that time. The commercial systems were AS/400 based, the shop floor systems based on PC's in a Novell network, and the industrial control systems were based on the combination of industrial control hardware with a stand-alone PC for the user interface and data management. Exchange of information between systems was standard. We were specialising in a very specific niche market where we were acquainted with all key processes. A few years after the start of this development, products for meat processors and for producers of pre-packaged meat for retailers were added to our software solutions. Short lead times, perishable products, variability of qualities and quantities formed the main characteristics of our markets. In subsequent decades, quality control requirements generated by food safety concerns and market requirements by the big retailers could be added to the list of key requirements.

Technically our shop floor systems were event-driven, (semi-)real time with a response time of less than 0.5 sec, and provided with multi-tasking mechanisms within the application. Events were either generated by peripheral equipment (weighing systems, hardware contacts) or generated via the keyboard (input from users). We developed our software in Borland Pascal in a MS-DOS environment with text-based user interfaces. All data was stored in binary files. Each registration would open / modify / close the relevant files, risk for loss of operational data was very low.

In later years, our programming concepts prohibited an easy way to move to the Windows / SQL platform. We needed to have access to the physical world in our systems, and we needed our guaranteed response times for our real time tasks. The Windows environment would shield the hardware from our software. Apart from that issue we did not trust the response times of the databases in those years.

Concepts for individual identification of crates and containers with barcodes were developed in that time, partially as an instrument to facilitate registration processes and production management, and partially as a method for tracking and tracing. Each container would have a fixed identification number, and the tare of the container is kept in the master data, which improved the collection of weight data. We could capture a lot of information connected to the physical unit of handling, and the scan of a barcode is a reliable and fast way of registration. The origins of this concept dated back to 1988, and it paid off very well. We did our first experiments for identification with RF-tags in 1987, but this concept has one very important drawback: it provides information just for systems, not for people. And on the shop floor visual information is important. Information flows for the shop floor must be designed taking all kinds of information for the shop floor into account, and not only deal with information in computer systems.

3.1 Business Viewpoints

The development of our systems was based on very close cooperation with our users. The customer would express a problem or wish, we would look into it and together we would discuss and try solutions. Sometimes this resulted in a prolonged iterative process, finding out what was really the case and finding out about side effects, adapting the problem, and so on. In a few cases we would get the feeling that creating a satisfactory solution was a kind of a random walk through possible problems and possible solutions. Fortunately, more often than not it was a more linear exploration through different viewpoints and different contexts. As a specialist and supplier of standardised software in this specific market we would try to satisfy two objectives: (1) the separation and expression of the general problem abstracted from the concrete questions and the specific circumstances of the individual customer, and (2) the identification of the proper interests of the different stakeholders. The term ‘proper’ is important here: a lot of people will express many interests (and sometimes provide detailed directions for solutions), but only interests related to the constructive role of the person in the business process are to be considered proper interests. In a nutshell, the steps in finding and verifying solutions were: Identification of the business processes, identification of the roles of people and systems in the respective processes, identification of the specific questions, generalisation of the questions, finding solutions to the generalised questions, making the solutions available to the specific context, and finding out if every proper information need is met.

Explicit modeling of business was not an issue at the time, but for myself thinking about businesses and organisations was very much an issue in these years. During my education and in the first 10 years of my work I was strongly oriented on theories of the organisation as a means to analyse and understand the functioning of an organisation. Herbert Simon with his model of bounded rationality (Simon, 1976), Jay R. Galbraith with the concept of slack in processes (Galbraith, 1973), and Henry Mintzberg with his Structured Organisation (Mintzberg, 1979) were important sources. In studies of organisations the difference between the formal organisation and the informal organisation was of course a major theme. To me this was an easy and a-theoretical escape explanation. Organisational theory would provide explanations about and the rationale behind the formal structures of the organisations; any deviation could be explained away by referring to the irrationality of human behaviour and to the informal social structures in an organisation. This was an unsatisfying state of affairs for me.

A project for a producer of pre-packaged meat products changed my thinking about business and organisation. The company was led by a dominant owner/director and had a very flat organisation. In the management positions would be either trusted old hands with a fair amount of leeway to make decisions, or employees who had a more or less token position without discretionary powers. Old hands would be overruled occasionally, the others frequently. Operational decisions regarding production and distribution were more based on experience and organisational patterns than on organisational roles. Operationally, this was a sound company with a good reputation and with good financial results. It was a well running and responsive organisation that allowed the director / owner to realise his commercial vision.

The breakthrough was partly triggered by a question a colleague asked me during the project: why do you think that this company gives us all this money? What do you think that the company wants to achieve with our systems? I then started to think in a different way about how the functioning of an enterprise should be understood. Not the organisation of an enterprise should be the starting point, but its markets and products. The characteristics of the markets and products determine the behaviour and the business processes of an enterprise and the (formal) organisation is a means to stabilise the business processes. I started to think and analyse from the opposite direction, outside-in instead of inside out. And, as a consequence, I started to look for the foundations for information systems in the business processes, instead of in the organisational structures.

4 YEARS OF RENEWAL

The period started around 2001 with the conversion of our software environment from MS-DOS to Windows, which brought changes in programming language, data management, and user interface. It also meant the replacement or abolishment of most of our software patterns, established and fine-tuned over a decade. These patterns might be either ‘just habits’ or skilfully engineered fundamental solutions for basic problems. Patterns for dealing with the multi-tasking and real-time aspects of our systems belonged to the latter category. We had to think of new ways for coordination between our systems and the physical world, and the coordination between processes in our software.

Apart from dealing with the more technical software issues, we used this transition to rethink our fundamental concepts for representing business processes in our software. On the shop floor, we used two basic concepts: the production order and the individual container. Stock management was problematic in our software, a problem which we could neglect for a long time because (1) in production of fresh food, stocks are a minor issue in the business processes and (2) we had made some nice and creative work-arounds for representing fresh stock in production orders or in containers.

We also wanted to solve two conceptual problems in representing the physical flows in our new software. One conceptual problem is specific to our kind of industry, the other is generic. The specific problem is exemplified best by the curing process. The curing of products, whereby the products are biochemically changing over time, can take a few hours (tumbling), a few days (brining) or up to a few weeks (dry sausages). In the processing of herring, for example, the product is successively graded, filleted, cured, frozen, packed, and stored. In curing the herring is put in a sour bath for two or three days, while stirred every 12 hours. The curing process has characteristics of both a production order (semi-finished products are transformed into other semi-finished products) and stocks (products in a storage area for several days). This leads us to the generic problem of a real time representation of a production flow as a concatenation of stocks and production orders: the products are ‘lost’ between the input and output on a production order.

Due to our background and driven by our motivation to represent an uninterrupted flow of goods in our systems, we decided to replace our basic concept of production order by the basic concepts of stock, lot and location. Locations are either “storage” or “process”. An input on a production order is represented as a stock movement from storage stock to process stock, and an output as a stock movement from process stock to storage stock. At the end of the production process, the resulting stock balance on the process stock represents the loss of materials in the production process. These few very simple concepts allowed us to represent any flow of goods, and give us a lot of freedom to model the flow of goods in a concrete project.

4.1 Business Models

In this time we would start projects by a descriptive and informal model of the business processes at the customer, supported by a few generic business models for typical process patterns. It was more or less a model based approach along the lines of the concept of Max Weber of the ideal type. Ideal in his concept does not denote how the world should be, it does not mean perfection. “Ideal” in ideal type is a construct of the mind, it is logically coherent idea (model) about some part of reality. An ideal type, therefore, can be a useful instrument to look at specific business processes to compare the ideal type with the actual processes. Differences between them should be analysed to find the causes or reasons. Sometimes they are caused by unchangeable circumstances, sometimes they are there for a good reason, and sometimes they represent patterns evolved over time, either better left in place or detrimental to the process and to be erased. But the first step always is to try to find the possible rationale behind the specific practices.

My way of thinking about firms changed further in these years. Not the organisation, but the markets and products would now be my starting point in the analysis of a firm. An understanding of the markets and the products of the firm provides both background and norms for the analysis, understanding and evaluation of its business processes. The formal organisation was increasingly side-lined as a peripheral phenomenon. This approach was supported by the study of works about the theory of the firm (Coase, 1937; Kay, 1993; De Geus, 1997) and about knowledge in organisations (Weick e.a. 2001; Patriotta, 2004; Boisot, 1998). The study Thought and Choice in Chess (De Groot, 1978) about human problem solving and especially about the role of the perceptual processes of the expert was important for the importance of intangible patterns in business processes.

Another line of study was the theoretical semiotic analysis of signs, sign systems and interpretation processes (in theory), together with the practical analysis of how individuals work with information in business processes and how emerged patterns give stability in working practices. How do individuals deal with regularities (day-to-day patterns) and with irregularities (both recurring and truly incidental incidents)? A lot of relevant information in business processes is either background routine or background knowledge, both for regular situations and for unforeseen situations.

Increasingly I became aware of the limitations and drawbacks of rational-mechanistic approaches of business processes and information systems. Of course, rational models are necessary as a means for understanding and communicating. Models are important for analysis and can be useful instruments for change. Software systems incorporate models of reality. The danger lies in the inversion of the relation between model and reality. At the start of the project the model is a representation of reality, and at the end reality is considered to be an implementation of the model. Misfits between model and reality are at the end of the day regarded as problems of reality to be corrected, the model is rational and “true”. Incidentally, this kind of problem is of course very old. Many discussions between accounting departments (‘bean counters’) and operational departments can be traced back to this type of argument.

5 HETEROGENEITY

In what can be considered as the fourth phase of our information systems we moved into heterogeneous system landscapes (to borrow a term from German). A first example is the replacement of our systems for slaughtering and grading processes. Our first system in this field dated back as far as 1987, and from that starting point it grew out gradually to octopus-like structures. Two decades of meeting a variety of information demands in one monolithic system will result in a lot of add-ons. The old system was (and still is) very stable and dependable, but increasingly difficult to adapt and maintain. A further major drawback was the dependence on the one programmer who had originally developed the system and adapted it since, and who was the only one with the knowledge and experience to support the system.

The objectives for our new system were: (1) replacing the old monolithic and entangled system serving heterogeneous needs (physical input/outputs, real-time aspects, user interface, data management, decision rules) by a heterogeneous landscape with dedicated, single-function subsystems; (2) independence of support by individual persons with special knowledge; (3) a clear overarching model, understandable to business people without technical knowledge; and (4) full specification of all information flows, their effects in related processes and their origins in the production lines. The latter objective is not realistic in general, but in this case attainable because the business domain is highly specific. Further, it is important because the use of terms in this domain can be highly confusing and coloured by local habits.

This resulted in a model with four different subsystems. The first subsystem handles all physical aspects and tracks the movements of all individual pieces of meat in the conveyors, the second subsystem handles the user interfaces (touch screens) in the production lines, the third subsystem is responsible for data management and decouples the real time world from database actions (making response times independent of possible lateness of database transactions), and the fourth subsystem connects the other three and handles all business rules. The very knowledgeable employee who had developed the system from its origins some decades ago to the existing system would be the developer of the first subsystem with the real time and physical issues. He could share his knowledge in this field with his technically oriented colleagues. Informational aspects would be handled by other people, and this was made possible by the full specification of all information flows.

In another interesting recent project we developed a control system for individualised deboning processes. Each individual piece of meat produced on the new production lines would be traceable to the original animal. Depending on the demand of finished products and depending on the individual characteristics of the raw material the system will decide which finished products are to be produced out of which raw material and the system will show individualised instructions to the people in the production line.

At the start of this project the customer knew exactly what he wanted to achieve (full traceability to improve his market position and improvement of yields to earn his investments back) and had general ideas about how to achieve it. The translation of the general ideas into working solutions was up to the main contractors for all physical equipment and the IT system (us). In this kind of projects the customer is catapulted from a situation under direct control of foremen, with a lot of flexibility, a lot of room for making (and correcting) errors, and a lot of buffers and internal transport into a world that is computer controlled, very straightforward and rigid, and with a very efficient throughput. Preparing the customer for the change is a big challenge for several reasons. The customer is used to make snap decisions on the work floor, in the new situation this is not possible any more. Once the quality grade is assigned to a piece of meat (before processing), all decisions are computer-controlled. The only human decision during the processing and packaging of the meat is to reject meat and take it out of the line, which should rarely happen.

To design the system and to prepare its configuration asks for a lot of information from the customer about his current processes, which comes mostly in a highly unstructured way with a lot of exceptions, a lot of imprecise terms, and a lot of qualifiers as “normally”, “basically”, “mostly” or “at least, that should be the case”. Finding understandable and verifiable models in such a project asks for both creativity and background knowledge. The latter is not only important for asking the right questions and understanding the answers, but also for listening to what the customer is not saying.

5.1 Process Logic and Real Business

In the projects mentioned above the modeling phase was not only based on direct observation of visible processes or on interviewing the customer to inform the analyst about his processes. Rather, it was based on a two-step analysis where in the first step a generic model of the underlying and invariant processes was obtained by logical analysis and background knowledge, and in the second step the actual customer’s business processes were modeled. The invariances of the model in the first step are partially determined by the characteristics of products, partially by the characteristics of market conventions in dealing with customers, and partially by social and legal norms belonging to that kind of markets and products. The first kind of invariance is more stable over time than the second as markets, norms and regulations will change over time, but at any given time any company that serves a certain market (in a certain country) must obey the rules and conventions of that market.

The generic model is most stable in its ontology and static structures. In a market-oriented company, demand expectation will always be captured and be translated into quantities to be produced, and via production planning be translated into demand of raw materials and resources. Also belonging to the first business model, but possibly less stable over time, are the dynamic aspects of the model. The market for pre-packaged fresh food has typical lead times and a typical planning/production cycle that can be observed by every company in that market. Lead times may gradually shift a bit over time due to market expectations and due to new packaging methods that prolong shelf-time, but the general dynamics of the planning/production cycle will be unaffected and stable.

In the second modeling step the business processes of the specific company are analysed and modeled against the background of the first model. The first basic assumption is that the second model can be mapped on and abstracted to the first model (with a loss of information), and the second basic assumption is that this mapping is not trivial and certainly not one-on-one. Some elements of the first model may be completely implicit and “invisible” in the second model, some elements may be combined and some elements may be differentiated. Interaction between elements may be consecutive in one company, iterative in a second company and even seemingly reversed in a third company. In the latter case, the planning cycle might start at the raw material level (as a bottleneck), taking demand for finished products for granted. In this situation the demand for finished products will be implicitly translated and generalised by the planner into raw material demand, and checked later on in the planning process.

6 DEVELOPMENTS OVER TIME

The continuity in the business processes of our customers is found in the physical processing of fish and meat into products fit to be used for further processing or to be consumed. The anatomy of fish and meat has not changed over the last century, nor have the basic ways of deskinning, deboning, cutting, and portioning. What has changed much since 1990 are conservation and packaging techniques (prolonging shelf life), tracking and tracing requirements, branding of products (“Welfare” or “Good Farming” products) and market demands (shorter lead times, vendor managed inventory). The first change brought more flexibility to the business processes, all other changes brought additional information requirements and the necessity to separate and monitor more and more different physical product flows.

The two basic ways to respond to the changes in the environment are (1) to consider it as a burden and to try to meet the extra demands at minimal cost, doing just enough to satisfy the specific requirement of the specific stakeholders; or (2) to let the externally triggered change induce internal improvement of processes. In the second response the challenge is to use new requirements on information, induced by one stakeholder, to reflect on the essentials of the processes and the information and to generate the most value of the change for all stakeholders. In particular the extra information needs generated by tracking and tracing regulations can be used to improve production management and control. Business processes are rarely changed in fundamental ways, but rather adapted incrementally by fundamental analysis of the value of the information involved for all stakeholders.

For me, working with business models over time shifted from a latent background notion via heuristic models to ideal-types. Later on, I started to use business models in two different ways: (1) as models representing the process logic of the underlying business processes of a typical company in a certain market, and (2) as a description of an actual company with its idiosyncrasies. The first model supports software development, as it represents basic business functions and relations and as it is specified in formal terms. The second model supports information system development (configuration of the software being part of it), as it describes the real company in its specific environment.

In my view, business modeling for information system development too often tend to mix the two uses of business models. As a result, it is reductionist in two ways: (1) it reduces real process structures to formal schemes, (2) it reduces information to computerised data. This reductionist business model is then projected onto the real company with its real business as the model to be realised.

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Combined Variability Management of Business Processes and Software Architectures

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Abstract: Nowadays, organizations are faced with the challenge of surviving in a highly flexible and competitive market. Especially the domain of Internet of Things is affected by short product cycles and high pricing pressure. Business Process oriented organizations have proven to perform better regarding highly flexible markets and fast production cycles. However, especially industries focused on low cost IoT systems are facing big problems if the according business processes are not aligned with the business processes. Consequently, a lot of development effort is spent for features which are never addressed by any business goal. With this work, we propose to use a combined variability management in order to efficiently address product variability on the organizational level as well as on the technical level.

1 INTRODUCTION

We are living in an ever changing and interconnected world. The dawn of the Internet of Things (IoT) further increases the trend for organizations to deliver feature rich systems in high quantities and at low costs. Due to this pricing pressure, methods have to be investigated which allow modular and highly configurable systems such that the products can be adapted to the current requirements of the market.

Business Process (BP) oriented organizations are known to perform better regarding highly flexible demands of the market and fast production cycles (McCormack and Johnson (2000); Hammer and Champy (1993); Valena et al. (2013); Willaert et al. (2007)). This is achieved by introducing a management process during which business processes are modeled, analyzed and optimized in iterative improvement processes. During recent years, business process management is further coupled with a workflow management in order to monitor the correct execution of the process and to integrate responsibilities to the process models. In order to react to changing requirements, context aware business process modeling techniques were introduced by Saidani and Nurcan (2007): Flexibility is gained through the analysis of the context states of the environment which are mapped to the according business processes and their related software systems. The problem with such approaches is that the used software systems are often developed independently from each other, although they share a similar software architecture.

Software Product Lines (SPL) have proven to be essential for the development of flexible product architectures which can be adapted to the current requirements (Pohl et al. (2005)). Through the use of a common architecture and reusable product features, SPL promises to deliver high quality products while simultaneously maintaining low development costs. The most critical phase during the design and the implementation of a product line is the identification of the variable parts and the common parts of the product family (Pohl et al. (2005)). Consequently, a lot of effort is invested to identify the domain requirements of the final product portfolio. Equally important is the selection of the according features during the application engineering: It has to be guaranteed, that the customer requirements are fully met; further, all unnecessary features need to be excluded in order to ensure low productions costs of the final product. Since the identification of the domain requirements is usually carried out from developers, an integrated view of the organizational goals is often missing. Thus, the efficiency of the product line is reduced since additional effort needs to be invested to configure the product according to the current requirements.

This work focuses on the development of a framework which aims to enforce a link between the variability of the business processes and the variability of the product platform. As such, we propose a combined variability modeling in which the requirements for the organization as well as for the development of the product platform are identified together. After identifying the requirements, order processes are designed which reflect the possible product configurations that can be ordered by a customer. These variable order processes are further used to automatically trigger the product customization process in order to reduce the production costs of the final product. This work is based on our previous works in which we already defined systems for the modeling variability of business process models (Sinnhofer et al. (2015)) as well as a framework for generating software configurations based on order processes (Sinnhofer et al. (2016, 2017)).

This work is structured in the following way: Section 2 summarizes basic concepts about business process modeling as well as software product line engineering. Section 3 summarizes out approach to link variable order process models to variable software architectures in an automatic way. In Section 4 we describe how we applied the introduced concepts in an industrial use case and present a simplified example for illustration purposes. Since the identification of business drivers is essential for an organization to survive in a competitive market, we show in Section 5 how we were able to identify improvement opportunities, by analyzing the results of our framework. We conclude this work by presenting related work in Section 6 and a summary in Section 7.

2 BACKGROUND

The current section summarizes the basic concepts of Software Product Line Engineering and Business Process Modeling, which are applied in this work. Further, our previous publications – which are forming the foundation of this work – are briefly summarized.

2.1 Software Product Line Engineering

Software Product Line Engineering (SPLE) applies the concept of product lines to software products. As a consequence, SPLE promises to create diverse and high quality software products of a product family in short time and at low costs Pohl et al. (2005). Instead of writing software for every individual system, software products are automatically generated by combining the required domain artifacts. The principal concept can be split into two main phases: the Domain Engineering and the Application Engineering (Pohl et al. (2005); Weiss and Lai (1999)).

The Domain Engineering is the phase in which the variabilities and the commonalities of the according domain are identified and the reusable domain artifacts are implemented. Domain artifacts are development artifacts like the software architecture or the software components. One essential phase during the domain engineering is the requirements engineering process, in which a domain analysis has to be performed in order to identify the requirements of the final product. Based on the identified requirements, the domain is usually modeled by using a Feature Oriented Design Modeling (Kang et al. (1990)) approach. During this process, Feature Models are used to explicitly describe all features of a product, their relationships, dependencies and additional restrictions.

The Application Engineering is the phase during which the final products are created by combining the domain artifacts in a meaningful manner. This is enforced by the use of domain constraints which were modeled during the Domain Engineering phase. In difference to the Domain Engineering, the Application Engineering is mainly focused on reusing artifacts rather than the implementation of new artifacts. In the ideal case, this phase makes use of software generators to automatically derive product variants without the need of implementing any new logic. The amount of reused domain artifacts heavily depends on the application requirements and gives an estimate on the efficiency of the product line. Hence a major concern of the application engineering is the detection of deltas between the application requirements and the available capabilities of the product line.

2.2 Business Process Modeling

Business Processes (BP) are a specific sequence of activities or (sub-) processes which are executed in a certain order to create an amount of value to the customer Hammer and Champy (1993). In this work, we use the concept defined by Österle (1995) to model BPs: BPs are modeled in different layers, where the top level (macroscopic level) is a highly abstract description of the overall process and the lower-levels (microscopic levels) are more detailed descriptions of the sub-processes. A reasonable level of detail is reached, if the process description on the lowest levels can be used as work-instructions for the responsible employees. This leads to the fact that the higher levels of the process description are usually independent of the production facility and the supply chains; while the lower levels are highly dependent on the production facility and its capabilities. As a consequence, the macroscopic level is more stable with respect to changes and can be reused in different contexts and production environments. The microscopic levels need to be updated in order to reuse them in different contexts. Variability of such process structures can be modeled through a variable process structure (i.e. by adding/removing activities in a process) or by replacing process refinements with different sub-processes. In general, three main types of business processes can be distinguished (see Association of Business Process Management Professionals (2009)):

- **Primary Processes**: Each of the process activities adds a specific amount of value to the value chain. Consequently, such processes are also often referred to as Core Processes since the customer value is directly reflected in these processes.
- **Support Processes**: Are processes which are designed to support the Primary Processes like managing resources or infrastructure. Such processes do not directly add value to the customer but are essential to ensure the proper execution of the Primary Processes.
- **Management Processes**: Are designed to monitor and schedule business activities like the execution of Primary Processes or Support Processes. While Management Processes do not directly add value to the customer, they are designed to increase the efficiency of the business activities.

Domain specific modeling languages are usually used to model all the activities, resources and responsibilities within a Business Process. In the scope of this work, the Business Process Model and Notation (BPMN, Object Management Group (2011)) is used to model processes, but the general concept of this work is not limited to this notation. The key concepts which are used in this work, are summarized below (Object Management Group (2011); Sinnhofer et al. (2017)):

Events: Occurs during the execution of a process and may affect the flow of the process. For example, the start or the completion of an Activity are typical events that occur in every process. According to the BPMN specification Object Management Group (2011), events are used only for those types, which affect the sequence or timing of activities of a process.

Activities: An Activity is a specific amount of work that has to be performed by the company – or another organization – during the execution of a process. Two different types of activities can be distinguished: Atomic activities (i.e. a task) and non-atomic activities (e.g. sub-processes).

Gateways: Are used to control how the process flows through different sequences of activities. Each gateway can have multiple input and/or output paths. One example is a decision, where out of many possibilities, only one path is selected. The selection of the paths can be coupled to conditions or events which are triggered during the execution of the process.

Data: Data objects represent the information flow through the process. Two types of Data objects can be distinguished: Input Data that is required to start a specific activity and Output Data which is produced after the completion of an Activity.

Pool and **Lanes**: Are used to model responsibilities for specific activities in a process. Responsibilities can be usually assigned to an organization, to specific roles or even dedicated employees.

It is common practice for organizations to maintain multiple variants of business processes which are based on a common template (Rosa et al. (2017)). This leads to the situation that similar process variants are created through a copy and clone strategy. As a consequence, maintaining these process variants is a time consuming tasks since every single process variant has to be manually updated by the according process designer. Besides the additional maintenance effort, using copy and clone strategies also have a negative influence on the process documentation. To solve these issues, we proposed a Software Product Line approach for the derivation of process variants from business process models (see Sinnhofer et al. (2015, 2016, 2017)). The concept can be split into four different phases:

Process modeling: During the process modeling, process designers are responsible to design process templates. The process templates are designed using the BPMN notation and additional artifacts are integrated like documentation templates, responsible roles, resource allocations, etc. The process templates are designed in an appropriate BPM Tool to fully support the process designers during the design process. The process of designing the process templates and the process of creating the according domain model goes hand in hand to ensure that the created templates can be reused in many different contexts.

Domain modeling: During this process, the created templates are imported into a Software Product Line tool and translated into a so called feature model (see Sub-Section 2.1). During the creation of the feature model, it has to be decided which parts of the process are designed to be variable and which parts are static. For illustration purposes, the following example is given: A company creates car parts for two major car manufacturers. While the overall process for creating the car parts is identical for both customers, different production planning strategies are used to optimize the material usage (e.g. stock size, etc.). As a consequence, the production planning strategy has to be designed variable such that the overall process model can be reused for both customers. The definition of variable parts and static parts happens in close cooperation with the according process designers and may even lead to a re-iteration of the first phase if some process templates need to be adapted. Not every combination of variants may create meaningful process variants. As a result, a comprehensive list of restrictions and rules has to be designed as well to guarantee that only valid and meaningful process variants can be created by the product line. The list of rules and restrictions has to be defined flexible as well, since not every restriction may be identified when the process model is created. Consequently, re-iterations of the restriction model are common after collecting evaluation data from the execution of the process.

Feature selection: Based on the current requirement of the organization, process variants are created using the created feature model. This is done be selecting the required features from the model and by translating this feature selection to a valid business process structure. To ensure an automatic transformation, generators have to be developed which are able to translate between the business process model and the feature model. The defined rules and restrictions are enforced during this process to guide the domain expert in selecting a meaningful set of options. To continue the example from above, two process variants may be created for the two customers. The only difference between the processes is the production planning strategy.

Maintenance and Evolution: One of the most important phases is the maintenance and evolution phase: To be highly flexible and adaptive to the current requirements of the market, processes and their according models have to be continuously improved and adapted. As such, the derived processes are monitored by production experts during the time in use and evaluated against the requirements. Based on the collected data, feature selections can be improved or process improvement processes can be scheduled. During a process improvement process, process templates are updated or created from the process designers and integrated into the existing feature model. Through the capabilities of the Software Product Line tool, it is possible to automatically propagate the changes of the process templates to every instance. As a consequence, no time consuming and error prone manual maintenance process is necessary to adapt all the existing process variants. Since it may happen that some of the process variants shall not be updated in case of changes, version control can be used to explicitly state which version of a template shall be used.

Our today's business environment is focused on creating sustainable value by increasing the revenue of business drivers. The identification of such business drivers, or the identification of the drivers which are able to destroy value is an essential step for an organization Strnadl (2006). Otherwise, staying competitive or even survive on a flexible market is not possible. The combination of business variability and software variability is a promising way to improve the identification of such drivers. Further, having a combined view of the requirements helps to increase the overall efficiency of the product line.

3 COMBINED VARIABILITY MODELING

The goal of this work is an automatic generation of software products based on the product order. In order to achieve this goal, an integrated view is necessary in which the variability of the software product is reflected in a variable order process. Since only a few configuration options are usually exposed to the end-customer, also all internal processes need to be covered in the variability management process. The overall concept of the resulting process is highlighted in Figure 1. As illustrated, the Process Variability Framework – which was described in Sub-Section 2.2 – is used as a foundation to model variable order process models. Based on this order process models, order entry forms are automatically generated which need to be filled by internal or external customers. Based on the provided data, a product line is triggered which maps the provided order data to the customization options of the software product. Based on the generated feature mapping, the final product can be automatically derived without any manual step beside verification steps which may be required by certification requirements. In order to achieve a binding between the order process models and the generated order entry forms, the following type model was introduced (Sinnhofer et al. (2017)):

- **None**: No special data needs to be submitted. Thus, a process node marked with none will not appear as a setting in the order entry form.
- **Inputs**: This is the abstract concept for different input types which are described below. Each

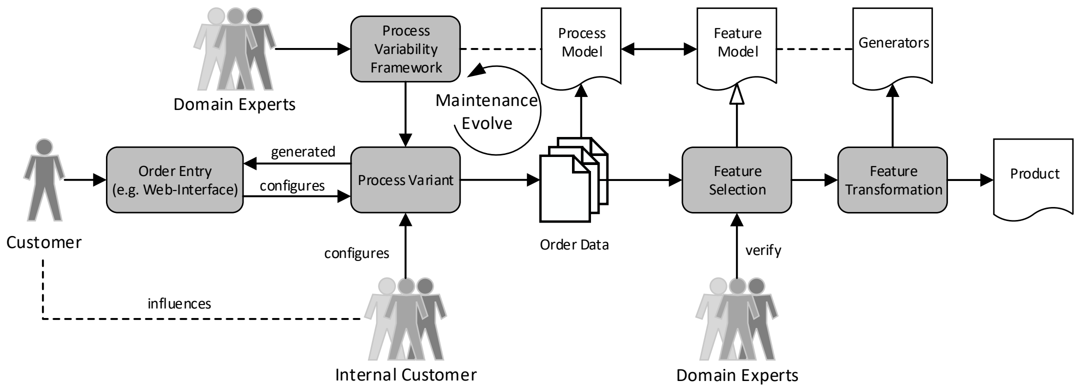

Figure 1: Overview of the concept for combining order process variability and software variability to automatically derive software products.

Input is mapped to a specific input type, defining the format of the input. For example, input data could be delivered in form of a file, or configuration settings could be delivered in form of strings or integer values. Depending on the applied domain, also non functional properties may need to be modeled in the Input type. For example, if a security critical product is developed, a customer may be asked to provide a cryptographic key which is used to authenticate the customer to the device. Besides providing this key, also some kind of specification is required in which format this data was provided (e.g. pgp encrypted, etc).

- **Customer Input**: Specific data that has to be added from an external customer. A process activity marked with this type will generate an entry in the order entry form of a specific type. For example, drop down list will appear if a customer can select between different options.
- **Internal Input**: Specific data needs to be added from an internal stakeholder. A process activity marked with this type will not generate an entry in the external customer order interface, but will create a separate order entry for the according internal stakeholder.
- **Input Group**: A set of inputs which are logically linked together. As a consequence, all of these inputs will be highlighted as a group in the generated order entry and all of them are required for a single customization feature of the final software product.

The information type has to be added to the process feature model of the SPLE tool. To support the domain experts in creating the according mappings, the following rules are automatically applied by the SPLE tool based on the BPMN types (Sinnhofer et al. (2017)):

- **Activities**: Non-atomic activities are used to group specific sets of input parameter to a single feature. For example, a process designed for customizing an application may require several input parameter (like user name, password, license files, etc.). As a consequence, non-atomic activities will appear as an Input Group for all inputs defined by the according sub-process(es). Any atomic activity will be automatically tagged as input type "None". The input type "None" is also automatically applied if a non-atomic activity does not contain any data. Consequently, "empty" non-atomic activities will also not appear in the generated order entry form.
- **Gateways**: Are used to define the structure of the generated form. For example, for a decision node, a drop down selection will appear such that the customer can choose between different customization paths. For decisions it is further enforced that the customer can only select and submit the data for one single path.
- **Data**: Data is to be provided by any entity involved in the process(es). With respect to our case study, "String" turned out to be a meaningful default value.
- **Pool** and **Lanes**: Are used to define the source of the input data. For example, a data node which is part of a company internal lane will automatically be tagged as an "Internal Input", while Data in an external lane will be marked as "External Input". "Internal Input" should be used as a default value to circumvent accidental exposure of internal configuration settings to the end-customer if Pool and Lanes are not used.

All default mapping rules can be manually overwritten by the Domain Expert during the creation of the process model. Changes to the process model

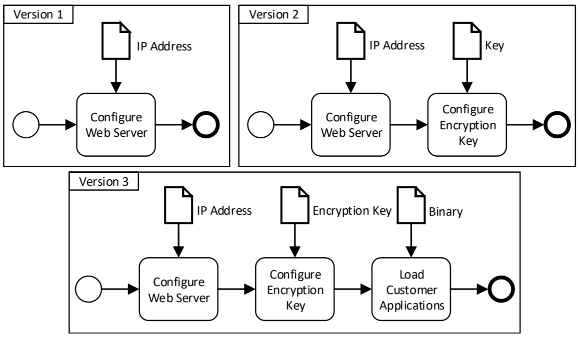

Figure 2: Exemplary order processes for the three different versions of the IoT device, based on (Sinnhofer et al. (2017)).

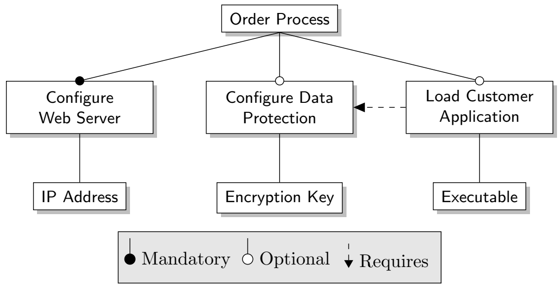

Figure 3: Exemplary feature model for the customization of the IoT device in three different flavors.

(e.g. adding/removing/changing activities) are traced via unique identifiers and illustrated as a diff-model such that changes can be reviewed by the Domain Experts. After the order process model was successfully tagged, the according order entry forms can be generated. With respect to this work, we have chosen web-based forms since they are commonly used in practice.

As illustrated in Figure 1, the provided customer data is used to create the feature selection of the final product. A manual verification step is advisable in order to ensure that no mistake was made during the development of the translation logic. Additionally, for certification purposes it may also need to be proven that a verification was done to ensure that no customer related data is confused with other products. In order to automatically select the features, the grouping information of the order entry is used to select the required features. After the selection was approved by the Domain Experts, it is automatically processed by the product specific code generators of the product line which utilizes the provided order data to actually generate the according product. The result of this process strongly depends on the use case: It could be a binary file that is loaded to the Integrated Circuits during the production, a configuration script which is executed on the final product, or any other approach. We will discuss a script based approach in Section 4 in more detail.

Especially for new types of products it is very likely that new knowledge is gained on how to increase the efficiency of the whole process(es). Only if changes to the generated order entry forms are necessary, a maintenance process for the product customization system is required. The maintenance costs for the product line can be kept as low as possible, since the code generators and model transformation logic only has to be updated once, but can be reused for the whole product line.

4 INDUSTRIAL CASE STUDY

For illustration purposes, we will discuss our industrial case study in more detail, showing how process models are translated and the final product is automatically derived. The implemented business processes of our industrial partner are controlled by an SAP infrastructure and are designed with the BPM-Tool Aeneis. Further, we are using the SPLE tool pure::variants to manage to variability of the business processes as well as the variability of the final product configurations. A more detailed description of the developed tools plugins can be found in our previous publications (see Sinnhofer et al. (2015, 2016)). For illustration purposes, we will consider the following – simplified – example: A company is developing small embedded systems which are used as sensing devices for the Internet of Things (IoT). The devices are sold to distributors (refered to as customer in the following) in high quantities which mean that the customization of the devices cannot be done by the customer in a feasible way. The device is offered in three different variants with the following features (based on Sinnhofer et al. (2017)):

Version 1: Senses the data in a given time interval and sends the recorded signal to a customer operated web-server which is used for post-processing the data. In the first version, the communication channel between the web-server and the device is unprotected. The customer is responsible for providing the connection string of the web-server to the company.

Version 2: Additionally to the basic features of the first version, this version allows encryption of the communication channel between the server and the node using symmetric encryption algorithms. For simplicity of this example, it can be assumed that the encryption key is provided by the customer, which has to be loaded to every single device. For simplicity, we assume that the key is sent in plain by the customer.

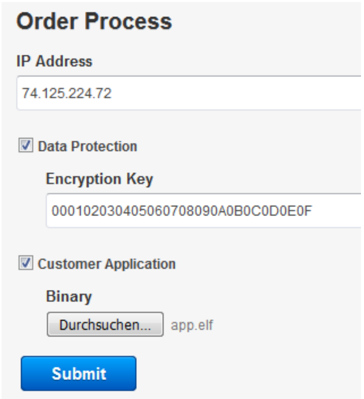

Figure 4: Exemplary order entry form that is automatically generated from the Feature Model highlighted in Figure 3.

Version 3: Additionally to the basic features of the first version, this version allows customer applications to be run on the system. This requires that the customer submits a binary file which is loaded to the device during the production.

Traditionally, this would result in three different order processes which are formed via a copy and clone strategy (see Figure 2): The order process of the first version is copied and extended for the second version, while the third version is an extended copy of the second version. This means that changes to the basic version would result in the maintenance of two other processes as well. Using our developed framework leads to the situation that all three process variants are derived from one common process model. As such, the same result is achieved like using a manual preparation, but the maintenance costs can be reduced essentially since all variants are automatically updated. The according Feature Model is illustrated in Figure 3. For illustration purposes, a ”requires” relationship between the web-server configuration and the data protection configuration is not highlighted since the ”Configure Web Server” feature is a mandatory feature. Consequently, the configuration is always part of the final product and does not need to be explicitly modeled.

To automatically generate the order entry form based on the feature model, the input data ”IP Address”, ”Encryption Key”, and ”Binary” has to be set to the according type. As such, rules can be defined to ensure that the given IP Address is formatted as a valid IPv4 or IPv6 IP Address, or that the encryption key has a meaningful length, etc. If no additional checks are implemented, the Domain Expert would only need to specify the input type of the ”Binary” to be a binary file. Doing so, the order entry form illustrated in Figure 4 can be generated, assuming that all input parameter are provided by the customer. After

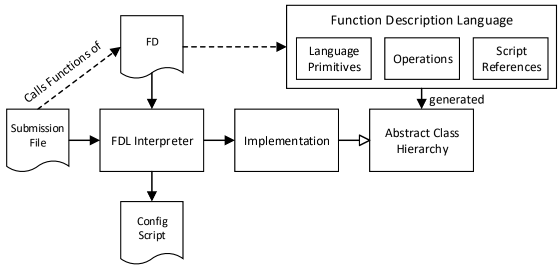

Figure 5: Framework for a flexible, runtime-configurable script generation system.

clicking the submit button on the order entry form, the provided data is converted into an XML file and zipped together with all the provided files to a zip archive. The XML file is necessary to ensure that the product configuration product line is able to automatically interpret the given zip file. Further, having an XML file has also the positive side effect that it is human readable which is essential for manual verification steps. Additional data can be included into the archive like identifiers and time-stamps to have a traceable link from placing an order to the actual manufacturing of the product.

Based on the provided data, the final product can be generated using dedicated code generators. To allow a flexible system without the need of re-releasing the product line if new products are supported, we decided to define run-time configurable generators. For this purpose we defined a Domain Specific Language (DSL) which is designed to be used by product experts. This DSL is called Function Description Language (FDL) and is used to create customization scripts for the final product. This means that during the production process, a script is loaded to each device which is triggered automatically to customize the according devices. For every supported product family, a Function Description (FD) is written which basically lists all the possible features of the platform (i.e. the customization options of the order process model) and how the provided order data is translated into the final script. The overall concept is illustrated in Figure 5. A script library is used which contains common scripts that can be referenced by the function description. For example, a ’loadApplication’ script may be developed for the product line in order to install the customer provided application to the devices.

5 EVALUATION

First results were already compiled in our previous works (Sinnhofer et al. (2016, 2017)) in which we compared the development efforts using ”traditional software development" techniques and compared it with the overhead of the developed framework. We use the term "traditional software development" techniques for a software development with ad-hoc (or near to ad-hoc) software architecture which means that multiple different systems are designed almost independent, but make use of copy and adapt strategies. Consequently, the maintenance efforts for such systems are rather high. We investigated, that the economical breakeven point of the developed framework is at around 3 to 4 systems. Further, the robustness of the customization process was increased since automatic methods were used for the feature selection and thus, configuration errors could be reduced significantly. Through the use of automatic methods, it was also possible to generate log-files for certification purposes which are used to ensure that the provided customer data was loaded and not confused or manipulated.

In this work, we will investigate other aspects of the developed framework, namely the identification of business drivers: We analyzed the development efforts of individual product features and contrasted them with the revenue that was earned by selling the according product configuration. The development efforts were extracted from the time-recordings of the responsible workers and should give a reasonable estimate about the real development efforts. In total, 106 different product orders were analyzed which provided 30 individual configuration settings. The results are illustrated in Figure 6. The first 10 product configuration options are internal system specific configuration settings which are mandatory for every product. A business decision was taken to reduce the costs for the base system to a minimum level to ensure a low cost base product. As a consequence, the revenue earned by the basic product configuration is rather low compared to other customization options. An interesting finding was that a lot of development effort was invested in complex features which were never used for any customer or are only rarely used. Due to this finding, it was decided that some of the features will be removed from the product in a future release, in order to reduce the overall costs. As illustrated in the Figure, feature 12 required a lot of development effort, but is also frequently ordered by customers. Consequently, an improvement process was triggered in order to reduce the costs of this feature.

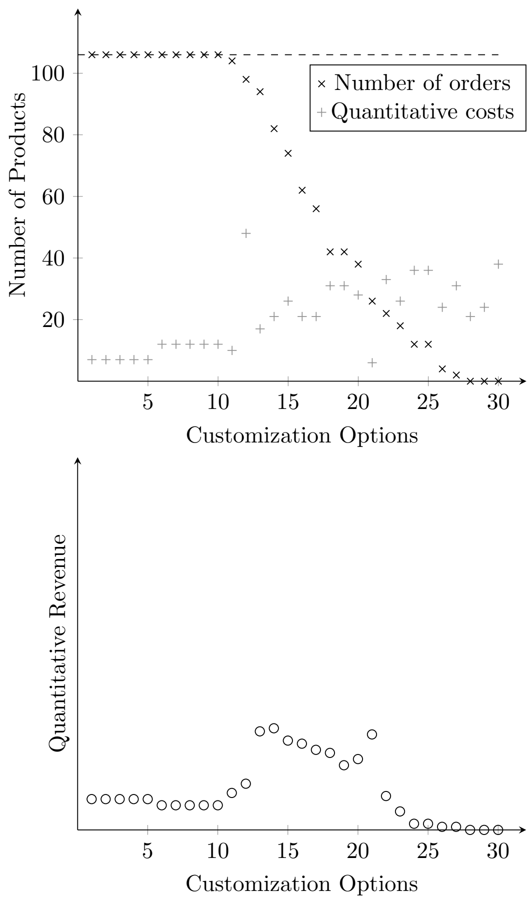

Figure 6: Analysis of the development efforts and revenue to identify business drivers. The revenue and the costs are illustrated in a quantitative manner.

After having discussed the positive aspects of the developed framework, we also want to address some limitations of the current implementation: While we were able to fully generate the required customization scripts for simple product configurations, we were able to only partially generate the scripts for complex product configurations due to the high number of inter-feature constraints of the product features. This is not a technical problem of the approach, but having a complete coverage of all inter-feature constraints is a time-consuming and iterative process. Further, modeling all the constraints in advance is usually not possible for complex systems. As a result, we decided to model only basic constraints in advance and to update the constraint model with every product order. Based on this semi-automatic generation, we managed to reduce the time to release a complex product by 50 percent.

6 RELATED WORK

Traditionally, business process modeling languages do not explicitely support the representation of families of process variants (Rosa et al. (2017)). As a consequence, a lot of work can be found which tries to extend traditional process modeling languages with notations to build adaptable process models. As such, adaptable process models can be customized according to domain requirements by adding or removing fragments to the model and by explicitly transforming this model to dedicated process variants which can be executed in the field. This promises to increase the flexibility of business process oriented organizations with respect to highly flexible requirements of the market. Having such a variability modeling for business process models builds the foundation of this work. Thus, related work which is utilizing similar modeling concepts are presented in the following:

Derguech (2010) presents a framework for the systematic reuse of process models. In contrast to this work, it captures the variability of the process model at the business goal level and describes how to integrate new goals/sub-goals into the existing data structure. The variability of the process is not addressed in his work.

Gimenes et al. (2008) presents a feature based approach to support e-contract negotiation based on web-services (WS). A meta-model for WS-contract representation is given and a way is shown how to integrate the variability of these contracts into the business processes to enable process automation. It does not address the variability of the process itself but enables the ability to reuse business processes for different e-contract negotiations.

While our used framework to model process variability reduces the overall process complexity by splitting up the process into layers with increasing details, the PROVOP project (Hallerbach et al. (2009a,b) and Reichert et al. (2014)) focuses on the concept, that variants are derived from a basic process definition through well-defined change operations (ranging from the deletion, addition, moving of model elements or the adaptation of an element attribute). In fact, the basic process expresses all possible variants at once, leading to a big process model. Their approach could be beneficial considering that cross functional requirements can be located in a single process description, but having one huge process is also contra productive (e.g. the exchange of parts of the process is difficult).

The work of Gottschalk et al. (2007) presents an approach for the automated configuration of workflow models within a workflow modelling language. The term workflow model is used for the specification of a business process which enables the execution in an enterprise and workflow management system. The approach focuses on the activation or deactivation of actions and thus is comparable to the PROVOP project for the workflow model domain.

Rosa et al. (2008) extend the configurable process modelling notation developed from Gottschalk et al. (2007) with notions of roles and objects providing a way to address not only the variability of the controlflow of a workflow model but also of the related resources and responsibilities.

The Common Variability Language (CVL Haugen et al. (2013)) is a language for specifying and resolving variability independent from the domain of the application. It facilitates the specification and resolution of variability over any instance of any language defined using a MOF-based meta-model. A CVL based variability modelling and a BPM model with an appropriate model transformation could lead to similar results as presented in this paper.

The work of Zhao and Zou (2011) shows a framework for the generation of software modules based on business processes. They use clustering algorithms to analyse dependencies among data and tasks, captured in business processes. Further, they group the strongly dependent tasks and data into a software component.

7 CONCLUSION

The reuse of business process models is an important step for process driven organizations to survive in a competitive market. Through an integrated view of the according IT, it is possible to raise the efficiency of the overall business. With this and our previous works, we proposed a way to use software product line engineering techniques for the modeling of business process models. Further, we developed a framework which enables to combine the variability models of order processes with the variability models of software customization product lines. This enables an automatic customization process which is triggered by the according order processes. As a result, the development costs and the required time to react to changes of the market can be reduced significantly. Moreover, using the proposed techniques supports Domain Experts to identify business drivers and thus, raise the overall efficiency of the organization.

In the current state, the presented framework is focused on covering the variability of order processes for similar type of products. Consequently, future work will address the extension of the developed framework to other processes. Further, we are currently investigating methods on how to bind nonfunctional requirements like security requirements to the variability models in order to enforce specific properties throughout the whole process in an automatic and systematic way.

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Towards Context-Aware and Privacy-Sensitive Systems

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Abstract: Current global trends push *enterprises* to be increasingly efficient and flexible, and at the same time compliant with legislation regarding privacy, security, and transparency. The latest *IoT* (Internet-of-Things) developments offer opportunities for enterprises but at the same time those developments lead to an increased complexity with regard to the underlying software, this in turn leading to new risks. Hence, more advanced modeling methods and techniques may be necessary, especially in the area of *enterprise information systems* (often featured currently by enterprise-aligned *IoT*-enabled software systems), such that both the enterprise needs are captured (and understood) and software features are specified accordingly. We need a common modeling ground for this, allowing us to properly align *enterprise modeling* and *software specification*. Such a common ground can be co-created by enterprise engineers and software engineers, featuring: (a) technology-independent enterprise models rooted in social theories; (b) technology-specific software models rooted in computing paradigms. An approach is needed on top of that because such an integrated enterprise-software modeling requires to be greased by modeling guidelines and notations, such that adequate modeling generations and transformations are possible. This means that taking as input unstructured business information, we should be able to usefully apply a modeling and design process, such that we come through enterprise models and reach as far as the specification and implementation of software. We argue that an existing approach has those capabilities, namely the approach *SDBC* (Software Derived from Business Components). Hence, we adopt *SDBC* in the current research. Further, we have opted for an explicit consideration of *context-awareness* and *privacy*, claiming their relevance with regard to some current *IoT*-related demands (mentioned above). Nevertheless, it has not yet been extensively studied how *SDBC* can be used for modeling software systems with requirements on those properties. For this reason, we aim at enriching the *SDBC*-rooted enterprise-modeling-driven software specification, by weaving in *context-awareness* and *privacy enforcement*. We partially demonstrate our proposed way of modeling, by means of a case example featuring *land border security*.

1 INTRODUCTION

Current global trends push *enterprises* to be increasingly efficient and flexible, and at the same time compliant with legislation regarding privacy, security, and transparency. The latest *IoT* (*Internet-of-Things*) developments offer opportunities for enterprises but at the same time those developments lead to an increased complexity with regard to the underlying software, this in turn leading to new risks (IoTDI, 2017). Hence, more advanced modeling methods and techniques may be necessary, especially in the area of *EIS* - *Enterprise Information Systems* (often featured currently by enterprise-aligned *IoT*-enabled software systems), such that both the enterprise needs are captured (and understood) and software features are specified accordingly; it is important to bring together enterprise modeling and software specification since an *enterprise engineer* alone is insufficiently capable of grasping the technical complexity of an *EIS* (and its reach outside through software services), while a *software engineer* would have only superficial enterprise-specific domain knowledge (Shishkov, 2005). We need a common modeling ground for this, allowing us to properly align *enterprise modeling* and *software specification*. Such a common ground can be co-created by enterprise engineers and software engineers, featuring: (a) *technology-independent enterprise models* rooted in social theories; (b) *technology-specific software models* rooted in computing paradigms. An approach is needed on top of that because such an integrated enterprise-software modeling requires to be greased by *modeling guidelines and notations*, such that adequate modeling *generations* and *transformations* are possible. This means that taking as input unstructured business information, we should be able to usefully apply a modeling and design process, such that we come through enterprise models and reach as far as the specification and implementation of software. We argue that an existing approach has those capabilities, namely the approach *SDBC* - Software Derived from Business Components (Shishkov, 2017). Hence, we adopt *SDBC* in the current research. SDBC is consistent with the *Model-Driven Architecture – MDA* (MDA, 2017) that features a life cycle starting with computation-independent modeling and ending up with code. Further, we have opted for an explicit consideration of *context-awareness* (Shishkov and Van Sinderen, 2008) and *privacy* (Hustinx, 2010), claiming their relevance with regard to some current *IoT*-related demands (mentioned at the beginning of this section). Nevertheless, it has not yet been extensively studied how *SDBC* can be used for modeling software systems with requirements on those properties. For this reason, we aim at enriching the *SDBC*-rooted enterprise-modeling-driven software specification, by *weaving in context-awareness and privacy enforcement*. We partially demonstrate our proposed way of modeling, by means of a *case example* featuring *land border security* (Shishkov and Mitrakos, 2016).

In this paper, for the sake of brevity, we are limiting our focus to the *CIM* generation (*Computation-Independent Models (CIM)* point to the highest level of abstraction in *MDA*), noting that:

- *SDBC* is capable of adequately reflecting a *CIM* input into lower-level software specifications;
- It is at this highest level of abstraction where context-awareness and privacy are to be weaved in, bringing together both an enterprise perspective and a software perspective.

The remaining of the current paper is organized as follows: In Section 2, we consider the *SDBC*-rooted enterprise-modeling-driven specification of software, by: (a) motivating the choice of *SDBC* over other approaches, inspired by relevant features and strengths of the *SDBC* approach; (b) coming through several important SDBC modeling constructs, limiting ourselves to those ones that are actually used in the case example; (c) addressing the SDBC design method. In Section 3, we address context-awareness and privacy, and also the challenge of weaving them in the software specification, and we address related work as well. In Section 4, we present a motivating application scenario in the public security domain (and particularly, in the area of land-border security), in which different situations are specified, such as the monitoring of the border, the detection of illegal crossings, and so on. In Section 5, we put forward our case-driven modeling where we further elaborate our ideas concerning the specification of context-aware and privacy-sensitive software systems. Finally, in Section 6, we present the conclusions.

2 BACKGROUND

In this section: we will firstly motivate the choice of SDBC; secondly, we will consider several important modeling constructs; thirdly, we will focus on the design process.

2.1 SDBC Modeling

SDBC is a software specification approach (consistent with *MDA*) that covers the early phases of the software development life cycle and is particularly focused on the derivation of *software specification models* on the basis of corresponding (re-usable) *enterprise models*. *SDBC* is based on three key ideas: (i) The software system under development is considered in its *enterprise* context, which not only means that the *software specification models* are to stem from corresponding *enterprise models* but means also that a deep understanding is needed on real-life (*enterprise*-level) processes, corresponding roles, behavior patterns, and so on. (ii) By bringing together two disciplines, namely *enterprise engineering* and *software engineering*, *SDBC* pushes for applying *social theories* in addressing *enterprise-engineering*-related tasks and for applying *computing paradigms* in addressing software-engineering-related tasks, and also for bringing the two together, by means of sound methodological guidelines. (iii) Acknowledging the essential value of re-use in current software development, *SDBC* pushes for the identification of re-usable (generic) *enterprise engineering building blocks* whose *models* could be reflected accordingly in corresponding *software specification models*. We refer to (Shishkov, 2017) for information on *SDBC* and we are reflecting the *SDBC* outline in Figure 1.

As the figure suggests, there are two *SDBC* modeling milestones, namely enterprise modeling (first milestone) and software specification (second milestone). The first milestone has as input a case briefing (the initial (textual) information based on which the software development is to start) and the so called domain-imposed requirements (those are the domain regulations to which the software system-to-be should conform).

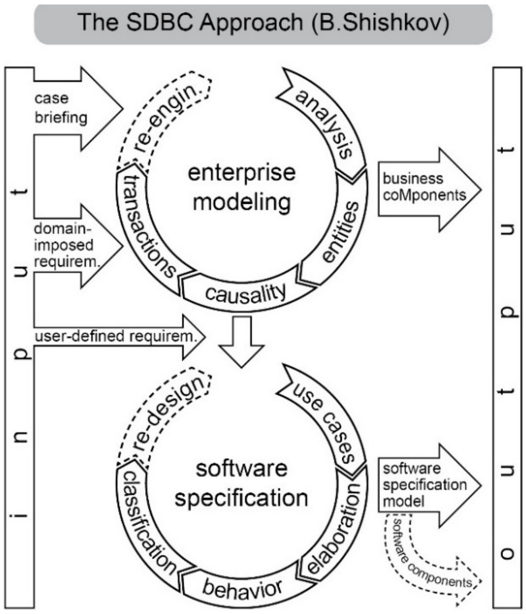

Figure 1: SDBC – outline.

Based on such an input, an analysis should follow, aiming at structuring the information, identifying missing information, and so on. This is to be followed by the identification (supported by corresponding social theories) of enterprise modeling entities and their inter-relations. Then, the causality concerning those inter-relations needs to be modeled, such that we know what is required in order for something else to happen (Shishkov et al., 2006). On that basis, the dynamics (the entities' behavior) is to be considered, featured by *transactions* (to be addressed in the following sub-section). This all leads to the creation of *enterprise models* that are elaborated in terms of *composition*, *structure*, and *dynamics* (all this pointing also to corresponding *data* aspects) – they could either feed further software specifications and/or be 'stored' for further use by enterprise engineers. Such enterprise models could possibly be reflected in corresponding *business coMponents* (see Sub-section 2.2). Next to that, re-visiting such models could possibly inspire enterprise re-engineering activities, as shown in Figure 1.

Furthermore, the second milestone uses as input the *enterprise model* (see above) and the so called user-defined requirements (those requirements reflect the demands of the (future) users of the software system-to-be towards its functioning).

That input feeds the derivation of a use case model featuring the software system-to-be. Such a software specification starting point is not only consistent with the *Rational Unified Process - RUP* (Kruchten, 2003) and the *Unified Modeling Language – UML* (UML, 2017) but is also considered to be broadly accepted beyond RUP-UML (Cockburn, 2000; Dietz, 2003; Shishkov, 2017). The *use cases* are then elaborated, inspired by studies of Cockburn (2000) and Shishkov (2005), such that software behavior models and classification can be derived accordingly. The output is a *software specification model* adequately elaborated in terms of *statics* and *dynamics*. Applying de-composition, such a model can be reflected in corresponding software components, as shown in the figure. Such an output could inspire software engineers to propose in a future moment software re-designs, possibly addressing new requirements.

As studied by Shishkov (2017), there are many other modeling approaches, some widespread and widely used. What justifies our considering particularly *SDBC* is the following:

- *SDBC* is neither addressing only enterprise modeling nor is it addressing only software specification; instead, the approach brings both together which is important if one needs to reflect sophisticated (legislative) requirements in complex software architectures.
- *SDBC* is not only limited to general guidelines and proposed modeling notations but it is also a method in the sense that different modeling activities are carried out in a specific order – this is to ensure that the software system being modeled is well-aligned with the business needs.
- *SDBC* is empowering re-usability and traceability which are considered essential with regard to software development in general.
- *SDBC* is aligned with the *UML* notations representing a *de facto* standard notation for specifying software (UML, 2017) and is consistent with *MDA*.
- In previous work, *SDBC* has been considered particularly in the border security application domain (Shishkov and Mitrakos, 2016).

For this reason, we have opted for adopting *SDBC* in the current work.

2.2 Concepts and Modeling Constructs

There are numerous concepts and modeling constructs underlying *SDBC*. For the sake of brevity however, we will only address some of them in the current sub-section, especially those ones that are considered relevant to the challenge of weaving context-awareness and privacy-enforcement in land-border-security-related software specifications. For more related information on *SDBC*, interested readers are referred to (Shishkov, 2017).

Taking this into account, we firstly present the *system* definition inspired by Bunge (1979) and having fundamental importance with regard to both *SDBC* milestones:

DEFINITION 1 Let *T* be a nonempty set. Then the ordered triple $\sigma = <C, E, S>$ is **system** over *T* if and only if *C* (standing for *Composition*) and *E* (standing for *Environment*) are mutually disjoint subsets of *T* (i.e. $C \cap E = \varnothing$), and *S* (standing for *Structure*) is a nonempty set of active relations on the union of *C* and *E*. The system is *conceptual* if *T* is a set of conceptual items, and *concrete* (or material) if $T \subseteq \Theta$ is a set of concrete entities, i.e. things.

Inspired by the *system* definition, we focus particularly on **enterprise systems** since a (border-security) software system would inevitably operate in an enterprise surrounding (comprising (organizational) entities, business processes, regulations, and so on) and we consider an *enterprise system* as being composed of *human entities* collaborating among each other through *actions*, driven by the *goal* of delivering *products/services* to entities belonging to the environment of the system. As for an **EIS**, it is also composed of *human entities* (they are often backed by *ICT* (Information and Communication Technology) applications as well as by technical and technological facilities) but the *EIS* goal is to support informationally a corresponding *enterprise system*. This is functionally reflected in the collection, storage, processing, and exchange (or distribution) of data among users within or between enterprises, or among people within wider society (Shishkov, 2017).

Further, it is important to present the *SDBC* units of modeling and in this regard, it is to be noted that essentially, *SDBC* is focusing on the ENTITIES to be considered and their INTER-RELATIONS. It is desired to be able to model entities and relations abstractly (no matter if enterprise entities or software entities are concerned), and also to be able to specialize such models accordingly, in an enterprise direction or in a software direction. For this:

- We consider actors (combination of the *actor-role* and the *entity* fulfilling the *role*) since often one *entity* type can fulfil many *role* types and one *role* type can be fulfilled by many *entity* types (Shishkov, 2017).
- We consider a generic interaction pattern (featuring the *transaction* concept – see Definition 2) that is claimed to be helpful in modeling any real-life interaction in an enterprise/software context:

DEFINITION 2 A **transaction** is a finite *sequence of coordination acts* between two actors, concerning the same *production fact*. The actor who starts the transaction is called the *initiator*. The general objective of the initiator of a transaction is to have something done by the other actor, who therefore is called the *executor* (Dietz, 2006).

Hence, *enterprise modeling* and *software specification* are both being approached by those two essential concepts: ACTOR and TRANSACTION. Thence, a **business process** is viewed as a *structure of* (*connected*) *transactions* that are executed in order to fulfil a starting transaction and a **business component** is viewed as an *enterprise sub-system* that *comprises exactly one business process*. Further, a complete (by this we mean elaborated in terms of structure, dynamics, and data) **model** of a *business component* is called a **business coMponent**. That is why Figure 1 is featuring the identification of *business coMponents* as an essential enterprise modeling task within *SDBC*. Said otherwise, **THE FIRST SDBC MILESTONE** is about the identification of *business coMponents* featured in terms of *actors* and *transactions*.

Further, in bringing together the first milestone of *SDBC* and the second one, we need to be aware of possible *granularity* mismatches. The *enterprise modeling* is featuring *business processes* and corresponding *business coMponents* but this is not necessarily the level of granularity concerning the *software components* of the system-to-be. With this in mind, AN ICT APPLICATION is considered as matching the granularity level of a *business component* – an **ICT application** is an *implemented software product* realizing a particular *functionality* for the benefit of entities that are part of the composition of an *enterprise system* and/or a (corresponding) *EIS*. Thus, the label 'software specification model' as presented in Figure 1, corresponds to a particular ICT application being specified. Hence, **software components** are viewed as *implemented pieces of software*, which represent *parts of an ICT application*, and which *collaborate among each other* driven by the *goal* of *realizing the functionality of the application* (functionally, a **software component** is a *part* *of an ICT application*, which is *self-contained*, *customizable*, and *composable*, possessing a *clearly defined function and interfaces* to the other parts of the application, and which can also *be deployed independently*). Hence, a ***software coMponent*** is a *conceptual specification model* of a *software component*. Said otherwise, **THE SECOND SDBC MILESTONE** is about the identification of *software coMponents* and corresponding *software components*.

In this paper, we will only address the *business-coMponent* identification and its reflection in a *use case model* featuring the specification of the *ICT application*-to-be, weaving in *context-awareness* and *privacy-enforcement* accordingly.

2.3 Design Method

SDBC assumes four modeling perspectives, namely: *Structural perspective* that reflects entities and their relationships; *Dynamic perspective* that reflects the overall business process and corresponding to this – the states of each entity, evolving accordingly; *Data perspective* that reflects the information flows across entities and within the business process; *Language-action perspective* (Dietz, 2006) that reflects real-life human communication and the expression of promises, commitments, etc. as also relevant to the challenge of soundly building an exhaustive enterprise model. In this, *SDBC* is grounded in line with: (a) *Enterprise engineering* and in particular, *enterprise ontology* and *organizational semiotics* (Dietz, 2006; Liu, 2000); (b) *Software engineering* and in particular, *model-driven engineering* and *component-based development* (Shishkov et al., 2007; Shishkov, 2017). Next to that, *software specification models* derived by applying *SDBC*, can be further updated to accommodate *service-orientation* (Shishkov et al., 2006).

Further, *SDBC* comes through several key modeling outputs (Shishkov, 2017):

1. Building a **business entity model** is the first major challenge requiring the fulfilment of many inter-related analysis/modeling tasks including: information structuring, gathering of additional information, reflection of the domain-imposed requirements, decision about the system boundary (determining the modeling focus), identification of actor-roles, capturing of their inter-relations, and so on, in concert with *Definition 1* and *Definition 2*. Hence, the resulting model shows the system boundary, the entities (actor-roles) that are inside the system and the relevant entities that remain outside the system boundary, the relations among those entities (featuring potential *transactions*), the related data aspects, and the *initiator-executor* positioning as according to *Definition 2* and Dietz (2006).
2. Deriving a corresponding **causality model** (Shishkov et al., 2006) abstracting from entities and only featuring the dependencies among corresponding transactions, such that it becomes clear how the realization of one transaction would possibly depend on the completion of another one(s).
3. Making an elaboration in terms of **transactions and underlying communicative acts** (Dietz, 2006; Shishkov, 2017), such that it becomes clear how the causalities (see above) are dynamically realized.
4. This all represents an adequate basis for **deriving use cases**, as studied by Shishkov and Dietz (2003).

For the sake of brevity, we limit ourselves to this partial outline of the *SDBC* design method and its underlying modeling / specification process – we only cover issues that are relevant to the current case-driven research and for the rest, interested readers are referred to (Shishkov, 2017).

In the following section, we will address *context-awareness* and *privacy*, and study the potentials for their incorporation in the *SDBC* driven specification of software.

3 CONTEXT-AWARENESS AND PRIVACY

In this section, we will firstly address *context awareness* and secondly, we will address *privacy*.

3.1 Context-awareness

Referring to *Definition 1*, **context-awareness** is about the system *environment*. The system user (using what the *system* is delivering) may comprise one or more entities belonging to the *environment* – each of them (or they all) could consume different *services* (or they could consume together one *service*). Further, not all entities belonging to the *environment* should necessarily be parts of the *user* since it might be that the *system* needs to collaborate with other entities from the *environment* (different from the *user*), such that the *system* is capable of delivering the requested products and/or services to the *user*.

Hence, a *user perspective* is needed in order to capture such a delivery of a product and/or a service (we call this <u>*service*</u>, for short). Further, it is often that the *service* delivered to the *user* is to be adapted to the situation of the *user*. For example, a person wearing a body-area network (AWARENESS, 2008) through which body vital signs are captured, may appear to be in 'normal state' and then, for example, vital signs are captured and recorded as archival information, or the person may appear to be in 'emergency state' and then help would need to be urgently arranged. Thus, one kind of *service* would be needed at *normal state* and another kind of *service* would be needed at *emergency state*. For this reason, the *system* (or a corresponding system-internal EIS or ICT *application*) should be able to: (i) *identify the situation of the user*; (ii) *deliver a service to the user, which is suited for the particular situation*. This is illustrated in Figure 2:

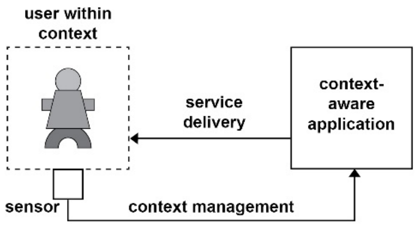

Figure 2: Schematic representation of a context-aware application (Shishkov and Van Sinderen, 2008).

As it is seen from the figure, a *service* is delivered to the *user* and the *user* is considered within his or her **context**, such that the *service* is adapted on the basis of the *context state* (or *situation*) the *user* finds himself/herself in. That state is to be somehow *sensed* and often technical devices, such as sensors, are used for this purpose. In the current paper, we do not go into discussing *sensor technology* in detail and for this reason, by **sensor** we broadly mean the technical or other facility that helps establishing the *user situation*. As mentioned before, it might be an *EIS* delivering the *service* to the *user* or it might be that just one ICT *application* (for example) as part of the *EIS* is delivering the *service* – no matter whether the former or the latter, we call it **context-aware application** in the current paper. Hence, a *context-aware application* adapts its behavior, in delivering *service*(*s*) to the *user*, based on the actual <u>*context state*</u> of the *user*, which *context state* is captured by *sensors* and corresponding information is sent to the *context-aware application* accordingly.

Nevertheless, the raw sensor data is of limited value unless it is reflected in higher-level context information that can be reasoned about.

It is also to be known how the application would 'move' from one behavior to another, when the user situation (*context state*) changes.

Summarizing the above, a *context-aware system* can be seen as concerning a sequence of *actions* that achieve: **S** (*sensing* and *capturing*), **I** (*interpretation* and *state derivation*), **w** (*switching*), and **P** (*provisioning*), as shown in Figure 3:

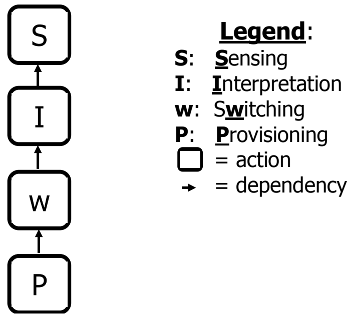

Figure 3: Simplified view on a context-aware system (Shishkov, 2017).

With regard to **S**: The system should be able to *sense context* and *capture this context as context information*. With regard to **I**: the system should be able to *interpret* the captured context information and *derive higher-level context information* that would be used to identify context state changes (those changes are to trigger in turn changes in the system behavior). With regard to **w**: the system should be able to *handle the switching between its alternative behaviors*. With regard to **P**: the system should be able to *provide services* covering different possible context states.

This is obviously a simplified model, since each of the actions represents a potentially complex process, and the dependencies between those normally involve multiple instances of information exchange and triggering.

Based on the above background, we propose the following way of weaving context-awareness in the SDBC-rooted enterprise-modeling-driven software specification: (i) particular user *context state types* are foreseen at *design time* and 'stored' in a reference bank; (ii) corresponding system *behavior types* are specified at *design time*; (iii) the *current user context state* is captured (see above) and matched to the bank of state types; (iv) if there is a match, then a *corresponding behavior type is instantiated* accordingly, otherwise, the system switches to '*auto-pilot*' in order to deliver a behavior in an exceptional situation. This is illustrated in Figure 4, using the notations of UML Activity Diagram (UML, 2017):

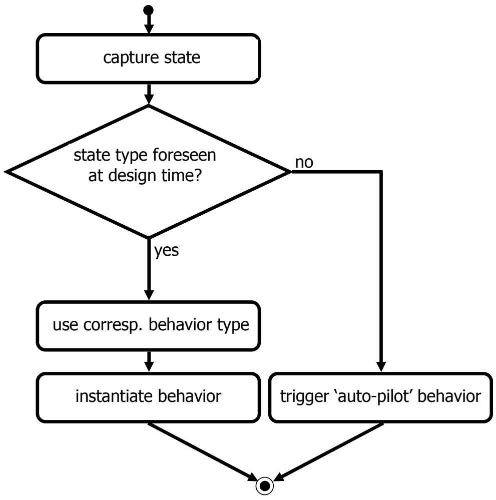

Figure 4: Weaving context-awareness in the software specification.

As it is seen from the figure, firstly the situation of the user (the user context state) is to be captured (as discussed already, this is usually done, facilitated by sensors). Secondly, it is important to establish whether or not the captured situation (state) is an instance of one of the situation (state) types foreseen at design time – if not, the system should switch to 'auto-pilot' behavior mode (by this we mean run-time rules-based behavior adaptation to the environment). If there is a match between the captured situation and a corresponding situation type foreseen at design time, then a corresponding behavior type (specified at design time) should be instantiated accordingly.

This way of weaving in *context-awareness* has been proposed inspired by the observation that: (i) there are high-occurrence-probability context state types suitable for consideration at design time; (ii) there are low-occurrence-probability context state types that are unpredictable and for this reason better addressable at run time.

In studying **RELATED WORK**, we have considered context-aware application practices. Due to the complexity and importance of handling *context-awareness*, many studies have tried to investigate different ways of developing context-aware applications. Many context modeling techniques have been created to enumerate and represent context information (Vieira et al., 2011). Many methodologies for architectural design were also proposed by researchers, such as: *Context Toolkit* (Dey, 2001) which aggregates context information, *Context Modeling Language* (Henricksen and Indulska, 2006) and *Model Driven Development* (MDD) and *UML- based approaches* (Ayed et al., 2007; Simons and Wirtz, 2007) which mainly describe the key steps and activities for modeling context-aware applications, the *Contextual Elements Modeling and Management through Incremental Knowledge Acquisition* (CEManTIKA) that supports the building of context-aware applications. Further, Jan vom Brocke, Sarah Zelt and Theresa Schimiedel have proposed a framework which consists of 4-dimensional factors to be considered in the design of context-aware applications, including 1) application goals, 2) characteristics of the process, 3) internal organizational specifications where context-aware applications are implemented, 4) the broader or external environment in which context-aware applications are built (Vom Brocke et al., 2016). Those factors can be used as guidelines when designing a context-aware application. In general, many current research projects are focusing on the development of context-aware applications, touching upon concept, networking aspects, middleware aspects, user-interface-related concerns, services, and so on. Still, this increasing attention has not been enough to inspire a widely accepted agreement on the development of context-aware applications. Hence, it is still a question how to weave context-awareness in the specification of software, and the current paper offers some contribution in this direction.

3.2 Privacy

As mentioned already, with regard to the (software) system-to-be, we are not only aiming at context-awareness but we are also willing to weave in values, such as privacy and transparency, for example. Particularly in this paper, we are focusing on **`privacy`** not only because it is one of the key values, as according to Hustinx (2010) but also because it is highly relevant with regard to the land-border security application domain addressed in the paper. Hence, in the remaining of the current sub-section, we will firstly discuss privacy in general (still assuming a border security focus), then we will present our view on how to weave in privacy enforcement in the specification of software, and finally we will particularly focus on privacy enforcement practices (related work) that are to be taken into account with regard to our case-driven modeling approach.

3.2.1 The Privacy Concept

Although the boundaries and specific contents of privacy vary significantly in different countries, the main definition of *information privacy* includes '**`the right to be left alone`**' and '**`control of`**

information about ourselves' (Pearson, 2009). Data can have various needs of privacy, whereas some information should always be opened to create transparency, other information should not be shared without proper authorization.

Although there is much information claimed to be *privacy-sensitive*, we consider the following information in border control as privacy sensitive information by using Pearson's privacy information classification (Pearson, 2009):

- *Personally identifiable information*: information that can be used to identify an individual:
  - *Data from records:* name, date of birth, biometrics, address, social security number, and so on;
  - *Surveillance data*: images, video, voice, and so on;
  - *Secondary data*: bank account number, credit card number, phone number, social media network ID, and so on;
- *Demographical information*: sex, age group, race, health status, religion, education, and so on;
- *Usage data*:
  - *Networking*-related data: mobile phone history data, Internet access point data, computer log files, and so on;
  - *Recorded online activities*: messenger records, contribution to social websites, and so on;
  - *Travel data*: ticketing / boarding pass data, reservations, cancellations, and so on;
- *Unique device identities*: any information that might be uniquely traceable to a device, e.g. IP address, device fabric number, Radio Frequency Identity (RFID) tags, and so on.

3.2.2 Weaving in Privacy Enforcement

Taking into account the privacy concept and the privacy-sensitivity issue, we propose the following way of weaving privacy enforcement in the SDBC-rooted enterprise-modeling-driven software specification: (i) when specified, a behavior instance is to be matched against a bank of pre-defined behavior types, such that it is clear what kind of behavior is that and what corresponding (pre-defined) privacy-related restrictions are to be weaved in; (ii) based on this, the behavior instance is to be refined accordingly. This is illustrated in Figure 5, using the notations of UML Activity Diagram:

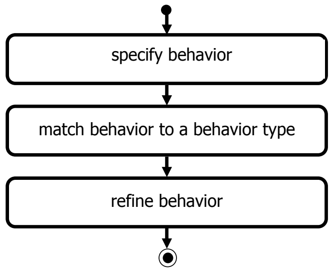

Figure 5: Weaving privacy enforcement in the software specification.

Hence, once specified, a behavior instance is to be refined in terms of privacy-driven restrictions.

3.2.3 Privacy Enforcement Practices – Privacy-by-Design and Related Work

Enforcement of privacy is often difficult. ICT enables the creation of systems that ensure the privacy of data, which is called **privacy-by-design** (Hustinx, 2010). *Privacy-by-design* has received attention within organizations as a way to always ensure that privacy is protected. *Privacy-by-design* suggests integrating *privacy* requirements into the design specifications of systems, business practices, and physical infrastructures. In the ideal situation, data is collected in such a way that privacy cannot be violated. This requires that both *governance aspects* (data updating processes and procedures, access rights, decision-making responsibilities, and so on) and *technical aspects* (encryption, access control, anonymization, and so on) are covered.

Since privacy enforcement solutions differ in different contexts, some general principles to guide the *privacy-by-design* can be used or sometimes must be compiled. For instance, the principles stated in Article 5 of the EU General Data Protection Regulation, need to be carefully considered, including: **lawfulness**, **fairness and transparency**, **purpose limitation**, **data minimization**, **accuracy**, **storage limitation**, **integrity and confidentiality**, and **accountability**. However, some principles would often be *in conflict with the characteristics of implemented information systems for border control*. For instance, the continuous collection of surveillance image data is against the principle of purpose limitation. Therefore, technical solutions should be a *trade-off* between privacy and (border-control-related) benefits (Könings et al., 2016).

Technical solutions regarding *privacy enforcement* would in general refer to **PET** – **Privacy-Enforcement Technologies**.

Those technologies assume secure communication and data storage by encryption, access control and auditing, anonymization of on-line activity, detection of privacy violators, and so on (Seničar et al., 2003; Zhu et al., 2015). Since *PET* can only partially address *privacy*-related problems, they need to be combined with **information governance features** in order to create comprehensive *privacy*-enforcement mechanisms.

Besides ***PET***s, ***PIT***s (**Privacy-Invasive Technologies**) and privacy threats are also frequently examined in various domains (Burghardt et al., 2008; Huberman et al., 1999; Johnston and Wilson, 2012; Seigneur and Jensen, 2004; Weber, 2015).

Nevertheless, there is still limited insight on how enterprises can *reduce privacy violation risks* for open data in particular, and there is no uniform approach for *privacy protection* (Janssen and Van den Hoven, 2015).

4 APPLICATION SCENARIO

Border control is one of Europe's biggest recent challenges, in the light of severe sea border problems in Greece and Italy in 2015-2016 (FRONTEX, 2017) and land border problems in Bulgaria and Croatia, for example. This leads not only to deadly incidents for numerous migrants who realize illegal sea/land border crossings in severe (weather) conditions but also to allowing terrorists mixed with regular migrants land on Europe's territory. According to many reports of the European Union - EU (www.europa.eu), this uncontrolled migration to Europe is causing societal tension and is stimulating extreme political views. Further, even though illegal migration to Europe is mainly fueled by smuggling channels, it is partially 'facilitated' by technical / organizational weaknesses at the EU external borders. In this paper, we abstract from the former and focus on the latter. Such a focus has been justified by numerous (current) efforts within the EU, aiming at improving security at its external borders – for example, new border facilities are constructed along those borders, police officers from some Western EU countries are sent to the Eastern EU borders to physically help, new organizational approaches and technical solutions are discussed, and so on (Ref.: www.europa.eu); all those efforts are directed towards *stopping* the illegal migration to the EU and it is widely agreed that any migrant should legally approach an EU border point where (s)he would be treated according to the laws and values of the EU.

In that sense, we consider an application scenario which concerns the EU **land border** control (our focus is particularly on the external EU borders) and this is about **monitoring** and **reaction to violations**. Fulfilling this assumes human actions because security-related decisions are always human-centric (LBS, 2012). Still, in what they are doing, border police officers receive useful technical support, assuming various channels: infrared images, visible images, proximity sensors, and so on, followed by some kind of intelligent data fusion algorithms (Shishkov and Mitrakos, 2016). We acknowledge this 'duality' – **human entities** and **technical entities**, and acknowledge as well the need to orchestrate this 'whole' in a sound way, allowing for objectivity and capability with regard to any situation that is possible to occur. Hence, we are approaching typical situations in this regard, and also the corresponding desirable reactions to those situations. Hence *context-awareness* is relevant with respect to land border security. Further, realizing that, the above-mentioned technology requires, among other things, IT-based services to recognize people (i.e. biometrics), we acknowledge the need for a special treatment of those issues as far as *privacy* is concerned because it is justified to distribute personal details of a terrorist but it is not justified to distribute personal details of anybody. We thus identify and approach some *privacy-sensitive* situations accordingly. In realizing all this, we take as example the situation at the Bulgarian-Turkish land border (Shishkov and Mitrakos, 2016); nevertheless, we abstract from many location-specific details in order to reach findings that are generic and widely applicable.

Monitoring the land border is a continuous process where: (i) *There is a (wired) border fence that is supposed to obstacle illegal migrants to get in*; still, this facility can be overcome using a ladder or by just destroying the wire. (ii) *There are border police officers who are patrolling (possibly using vehicles)*; still, no matter how many border police officers are sent to the border, it would be physically impossible to guarantee police presence at any time anywhere along the border, over hundreds of kilometres. (iii) *There are sensors and other (smart) devices*, as mentioned above; they are realizing surveillance; we assume the possibility that a device would perform local processing + artificial reasoning – based on this, it may generate contentful messages to be transmitted to corresponding human agents.

There are two main situation types at any point along the border, namely: (a) Normal Situation (NS); (b) Alarm Situation. We realize that both *context-*

awareness and *privacy enforcement* are 'under control' in (a) because:

- Within NS, all is just progressing according to pre-defined rules – hence, there is no need to adapt the system behavior with regard to surrounding context.
- Following pre-defined rules would also assume adequate treatment of privacy-sensitive data (for example: the border police officers are also monitored but it is not allowed to distribute their facial information).

What is more interesting thus is what is done in the case of (b) where *context-awareness* and related *privacy enforcement* are crucial.

Approaching (b) and taking into account the case information, we define three situation types concerning migrants possibly attempting to illegally cross the land border outside an official border crossing point: **1. Human-Triggered Alarm Situation (HTAS)**: *when a border police officer faces an attempt of one or more persons to illegally cross the border*. Then the officer can do ONE of three things, namely: 1.1. Try to physically stop the migrants from crossing, following the corresponding EU regulations; 1.2. Connect to colleagues and ask help; 1.3. Activate particular devices for taking pictures and video of the violators. It is important to note that in this situation, the person in charge has full decision-making capacity. **2. Device-Triggered Alarm Situation (DTAS)**: *when a device is 'alarmed' by anything and there is no border police officer on the spot*. Then, there are two possibilities: 2.1. The detecting device is 'passive' in a sense that the (video) information it is transmitting, is received in real-time and straightforwardly 'used' by a distant officer who intervenes, generating a decision and corresponding actions; 2.2. The detecting device is 'active' in a sense that based on information coming from at least several sensing units, the information is filtered and automated reasoning is performed, based on which a 'hypothesis' on what is happening is generated by the device and sent to corresponding human agents. **3. Outage Situation (OS)**: *when any unexpected (power, performance, or other) outage occurs*, not necessarily assuming illegal border crossing at the same time. This calls for urgent system recovery both in human and technical respect.

5 MODELING THE BORDER SECURITY SYSTEM

A logical starting point in our case-driven modeling is the 'translation' of the case briefing (see Section 4) into better structured information that would be featuring the original business reality and corresponding domain-imposed requirements. As it is well-known, this often assumes (partial) enterprise re-engineering such that the enterprise system being approached is adequately supportable by ICT / software applications (Dietz, 2006).

For the sake of brevity, we are not going in detail on how we analyze the case briefing and how we conduct such (partial) enterprise re-engineering. Moreover, this is not directly related to the main challenges addressed in the current paper, namely: the enterprise-IT alignment, with incorporation of context-awareness and privacy enforcement. Hence, we move directly to the textual reflection of the case briefing, holding in itself re-engineering-driven and requirements-driven updates:

Different situations may occur at the land border. Law requires that each situation type is addressed conforming to corresponding normative acts. This points to an exhaustive list of situation types that have to be pre-defined and stored in a corresponding 'bank' - we consider them as subclasses with regard to a Class 'Situation': Subclass 'NS', Subclass 'HTAS', Subclass 'DTAS', Subclass 'OS', and so on (see the previous section). Hence, we should have pre-defined accordingly legislation-driven behavior types - we consider them as subclasses with regard to a Class 'Behavior': Subclass 'Behavior 1', Subclass 'Behavior 2', and so on. Said otherwise, we should have behavior subclasses corresponding to respective situation subclasses. This means that any particular situation occurring at the land border is to be positioned as an instance of one of the situation subclasses, such that a system behavior is prescribed accordingly, by instantiating a corresponding behavior subclass. In order to achieve this, it is necessary that: FIRSTLY, the situation instance is captured; SECONDLY, the captured situation instance is positioned as relevant to a particular situation subclass; THIRDLY, a corresponding behavior subclass is identified and instantiated accordingly. This represents **CONTEXT-AWARENESS**: the system behavior depends on the situation at hand (in this, we abstract from the 'auto-pilot' option - see Figure 4). Further, it is necessary that privacy-driven restrictions are identified, corresponding to the behavior subclass, leading to a refinement of the instantiated behavior. This represents **PRIVACY-ENFORCEMENT**: the system behavior is refined to accommodate relevant privacy requirements.

Hence, this refined case briefing appropriately reflecting the business needs, is our starting point. *SDBC* has particular strengths on further structuring such information: *actor-roles* are methodologically identified as well as corresponding *transactions*, and so on. Because of the limited scope of this paper, we do not go in further detail here; still, for more information on those issues, interested readers are referred to (Shishkov, 2017).

The entities (featuring *actor-roles*) are:

- **S** (*Sensor*); **S** is capturing the occurring situations (situation instances), for example: "all looks normal during night time", "two persons are hanging over the border fence", "one person is running next to the patrolling vehicle", and so on, to give just several examples; in this, **S** is supported by sensing devices, sensor networks, cameras, data fusion engines, and so on.
- **PE** (*Pattern Engine*); **PE** is linked to two pattern banks, namely: 'sp' and 'pp' – they hold the subclass specifications ('sp' featuring situations and 'pp' featuring privacy-driven restrictions). Hence, **PE** is capable of providing such information as reference.
- **MM** (*Match-Maker*); **MM** is matching an instance to a subclass, for example: matching a situation instance captured by **S** to a subclass from Bank 'sp'.
- **TE** (*Task Engine*); **TE** is generating a desired system behavior description (a task), by instantiating accordingly a behavior subclass (the bank that holds the subclass specifications featuring behaviors is 'bp') corresponding to a respective situation subclass.
- *<comment>* For the sake of enforcing privacy, it is necessary to match each prescribed desired system behavior to corresponding privacy-driven restrictions stored in Bank 'pp'; Thus, **MM** should do a match, based on a prescribed behavior instance (delivered by **TE**) and privacy patterns (delivered by **PE**). *</comment>*
- **PrE** (*Privacy Engine*); **PrE** delivers a refined behavior recommendation accordingly.
- **C** (*Customer*); **C** is hence fulfilled by the corresponding border police officer(s) and/or other team member(s) using such a task specification (as RECOMMENDA-TION) in order to establish their actions accordingly.

Thus, next to identifying **`entities`** (featuring actor roles (Dietz, 2006; Shishkov, 2017)), we are to also identify corresponding **`transactions`** (see *Definition 2*): this we present as the Border Security Business Entity Model, expressed using notations inspired by DEMO (Dietz, 2006) – see Figure 6.

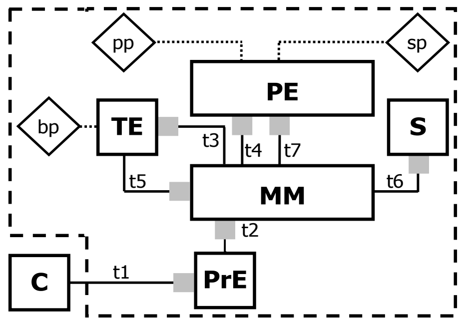

Figure 6: Business entity model for the border security case.

On the figure, the identified entities are presented in named boxes, while the small grey boxes, one at the end of each connection indicate the executor entity (Shishkov, 2017). The connections indicate the need for interactions between entities in order to achieve the business objective of recommendation generation – in our case, those interactions reflect **`transactions`**. Hence, with each connection, we associate a single transaction (**t**): **C**- **PrE** (**t1**), **PrE**-**MM** (**t2**), and so on. As for the delimitation, C is positioned in the environment of the recommendation generation system, and **PrE**, **MM**, **TE**, **PE**, and **S** together form the system, where we have included as well the three data banks mentioned above, namely: 'bp', 'pp', and 'sp'.

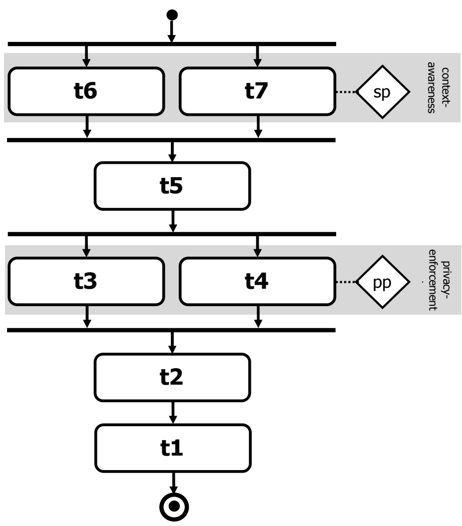

Figure 7: Modeling the causal relationships among transactions.

Further, we have to be explicit about the **causal relationships** among the transactions, and considering the business entity model, we establish that in order for **PrE** to deliver a refined task specification as a recommendation to **C**, it needs input from **MM** that in turn needs input from **TE** and **PE**. Further, in order for **TE** to deliver a desired system behavior description, it needs input from **MM** that in turn needs input from **S** and **PE**. Those causal relationships are presented in Figure 7, using the notations of *UML* Activity Diagram (UML, 2007).

As it is seen from the figure: (a) capturing a situation instance and considering corresponding situation patterns (viewed as subclasses) go in parallel firstly; (b) secondly goes a match between the two that establishes the relevant subclass (featuring situations) corresponding to a respective behavior pattern; (c) the behavior specification and consideration of relevant privacy-driven restrictions go in parallel thirdly; (d) fourthly goes a match between the two, that establishes the relevant privacy-driven restrictions with regard to the considered behavior; (e) finally, the refined behavior specification is delivered to **C** in the form of recommendation.

Hence, *context-awareness* and *privacy* are incorporated through corresponding modeling 'building blocks' featuring transactions 6+7 and 3+4, respectively, as suggested by Figure 7. Further, with regard to the *SDBC* modeling process, we have identified the *entity model* and the *causality relations*. What goes next are *transactions* (see Figure 1) and with regard to this, we use the *SDBC* interpretation of the transaction concept – see Figure 8:

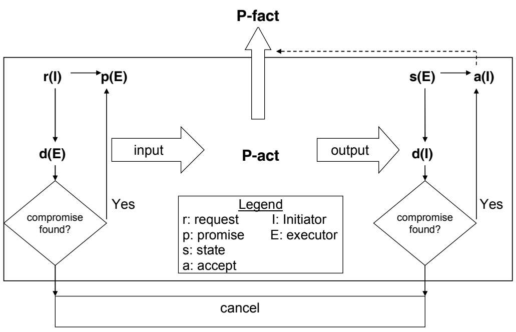

Figure 8: The *SDBC* interpretation of the transaction concept (Shishkov, 2017).

SDBC interprets the *transaction* concept as centered around a particular *production fact* (see *Definition 2*). The reason is that the actual output of any enterprise system represents a set of *production facts* related to each other. They actually bring about the useful value of the business operations to the outside world and the issues connected with their creation are to be properly modeled in terms of structure, dynamics, and data.

However, considering also the corresponding *communicative aspects* is important. Although they are indirectly related to the *production facts*, they are to be positioned around them. *SDBC* realizes this through its interpretation of the *transaction* concept. As seen from Figure 8, the *transaction* concept has been adopted, with a particular stress on the *transaction*'s output – the *production fact*. The order phase (left side of the figure) is looked upon as input for the *production act*, while the result phase (right side of the figure) is considered to be the *production act*'s output. The dashed line shows that a *transaction* could be successful (which means that a *production fact* has been successfully created) only if the *initiator* (the one who is initiating the *transaction*) has accepted the *production act* of the other party (called *executor*). As for the (coordination) *communicative act types*, grasped by an *SDBC transaction*, they are also depicted in the figure. The *initiator* expresses a request attitude towards a proposition (any *transaction* should concern a proposition – for example, a shoe to be repaired by a particular date and at a particular price, and so on). Such a *request* might trigger either promise or decline - the *executor* might either *promise* to produce the requested product (or service) or express a *decline* attitude towards the proposition. This expressed decline attitude actually triggers a discussion (negotiation), for example: 'I cannot repair the shoe today, is tomorrow fine?... and so on'. The discussion might lead to a compromise (this means that the *executor* is going to express a *promise* attitude towards an updated version of the proposition) or might lead to the *transaction*'s cancellation (this means that no *production fact* will be created). If the *executor* has expressed a *promise* attitude regarding a proposition, then (s)he must bring about the realization of the *production act*. Then the result phase follows, which starts with a statement expression by the *executor* about the requested proposition that in his/her opinion has been successfully realized. The *initiator* could either accept this (expressing an accept attitude) or reject it (expressing a decline attitude). Expressing a *decline* attitude leads to a discussion which might lead to a compromise (this means that finally the *initiator* is going to express an *accept* towards the realized *production act*, resulting from negotiations that have taken place and compromise reached) or might lead to the *transaction*'s cancellation (this means that no *production fact* will be created). Once the realized *production act* is accepted the corresponding *production fact* is considered to have appeared in the (business) reality.

Hence, one could ‘zoom in’ with regard to any of the transactions depicted in Figure 7 and elaborate each transaction, using the transaction pattern presented in Figure 8. This actually means modeling transactions at **two different abstraction levels**. At the highest abstraction level, the *transaction* is represented as a single action which models the *production fact* that is enabled. At a lower abstraction level, the *transaction*’s *communicative aspects* are modeled conforming to the *transaction* pattern. The transaction’s *request (r)*, *promise (p)*, *state (s)*, *accept (a)*, *decline*, and the *production act* are modeled as separate actions. This is illustrated in Figure 9 (abstracting from declines and cancellations), featuring only part of the model depicted in Figure 7, namely, focusing only on transactions 5, 6, and 7:

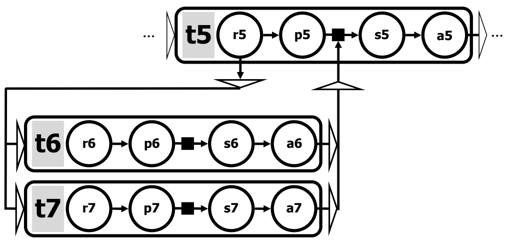

Figure 9: Detailed behavior aspect model featuring transactions.

As it is seen from the figure, in order for **t5** to be realized, both the realization of **t6** and the realization of **t7** are to be fulfilled. Hence, upon requesting **t5** and before the promise, it is necessary that **t6** and **t7** are initiated. If realized successfully, both *transactions*’ output is necessary for the delivery of the *production act* of **t5** (the *production acts* are depicted as *black boxes* in the figure).

This is how *transactions* are elaborated.

In summary, such an *enterprise modeling* featuring *entities* (and data aspects) and corresponding *causal relationships* as well as the *behavior elaboration* of respective *transactions*, represents an adequate basis for specifying software on top of it.

We now move to the specification of software - the derivation of *use cases* is the first challenge – see Figure 1. For detailed information concerning the *derivation of use cases from transactions*, interested readers are referred to (Shishkov, 2017) – for the sake of brevity, we go directly to a partial *use case model*, derived on the basis of the 7 transactions (see Figure 6 and Figure 7). The model is depicted in Figure 10:

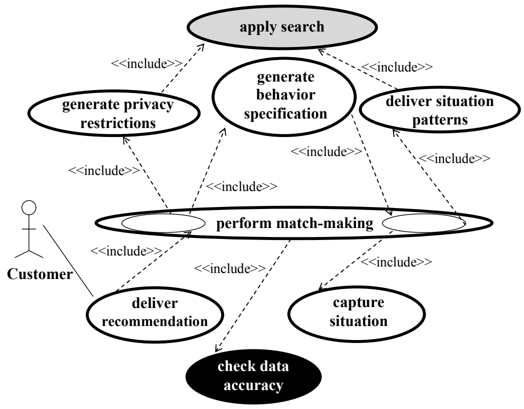

Figure 10: Partial use case model for the border security case.

As it is seen from the figure, all *use cases*, except for the ones backgrounded in black and grey, correspond to respective transactions: the SYSTEM’s DELIVERY OF RECOMMENDATION (assuming behavior refinement) to CUSTOMER includes MATCHING between: (i) BEHAVIOR SPECIFICATION and (ii) PRIVACY RESTRICTIONS. In turn, (i) includes MATCHING between (iii) CAPTURED SITUATION and (iv) A SITUATION PATTERN (this matching allowing to identify the right behavior pattern to consider).

Those are the so called **essential use cases** – the ones straightforwardly reflecting transactions (Shishkov, 2017). Those *use cases* usefully drive the alignment between *enterprise modeling* and *software specification*, guaranteeing that the software system-to-be is stemming from enterprise models. Then all enterprise models would be helpful accordingly with regard to the further software specification and elaboration, based on the *use case model*.

Nevertheless, next to the *essential use cases*, we have also: (a) **informational use cases**, reflecting informational issues (not essential); (b) **use cases reflecting user-defined requirements** with regard to the software system-to-be (Shishkov, 2017). An example for (a) is the use case APPLY SEARCH - delivering situation patterns and generating privacy restrictions are essential business tasks requiring in turn *informational activity*, namely: searching through the corresponding data banks. An example for (b) is the use case CHECK DATA ACCURACY - it may be required by the user that upon match-making, the accuracy of corresponding data is checked. Those two *use cases* are only to illustrate (a) and (b). Because of the limited scope of this paper, we have only considered a partial *use case model*, aiming at being explicit on the enterprise-software alignment that in turn builds upon the weaving of context-awareness and privacy at the enterprise modeling level.

For this reason, we are not going to address in the current paper the *elaboration of use cases* as well as the further software specification reflected in *behavior+states modeling* and *classification*. Interested readers are referred to (Shishkov, 2005) where this is considered and justified by means of a case study.

6 CONCLUSIONS

In this paper, we have considered in general the alignment between *enterprise modeling* and *software specification*, fueled by the *SDBC* Approach. In particular, we have addressed the challenge of weaving *context-awareness* and *privacy* in the enterprise models, such that context-awareness and privacy are then reflected accordingly in the specification of software. We have partially demonstrated our way of modeling by means of a case example featuring *land border security*. Hence, the contribution of the paper is two-fold: (i) We have contributed to the research concerning enterprise-software alignment, by studying how particular desired values (such as context-awareness and privacy) can be methodologically reflected in the specification of software. (ii) We have directed the current research to the border security application domain where context-awareness and privacy are of great importance, especially if they could be reflected in the functionalities of the (technical) systems facilitating the border control. As future research, we plan to consider a large-scale border security case study assuming software development activities.

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Towards an Integrated Architecture Model of Smart Manufacturing Enterprises

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Abstract: With the introduction of smart manufacturing, the scope of IT expands towards physical processes on the shop floor. Enterprise architects, software engineers and process engineers will have to work closely together to build the information systems that are connected to the shop floor and aligned with the business needs of smart manufacturers. However, it is unclear whether they have the means to do so. This research aims to provide enterprise architecture modelling support for smart manufacturers by investigating ArchiMate 3.0's fitness for this purpose. ArchiMate 3.0 meta-model is compared to the ISA-95 standard for enterprise systems and control systems integration. Modelling patterns are introduced, along with some new modelling concepts, to compensate for deficiencies found. The patterns proposed are validated as part of a case study.

1 INTRODUCTION

Manufacturing companies worldwide are facing the need to improve productivity and quality, as well as implement new products, while shortening innovation cycles. To this end, the manufacturing industry is currently in the process of adopting the new Smart Manufacturing paradigm, also known as the Industry 4.0 paradigm. Smart Manufacturing promises smart machine line operations, high-fidelity models of production processes and improved decision-making support (Davis et al., 2005).

For the benefits of Smart Manufacturing to materialize, manufacturers will need some way to maintain alignment between their business needs and the information systems that permeate increasingly through all levels of their operations (Henderson and Venkatraman, 1993, Wagner and Weizel, 2006). Maintaining alignment between a company's strategy (the business domain) and its supporting IT is one of the main benefits of enterprise architecture (EA) (Boucharas et al., 2010).

The management of processes at the shop floor and the systems used to operate the industrial control devices have traditionally fallen under the Operations Technology (OT) domain of process engineers. As OT increasingly starts to overlap with IT, it makes sense to consider the physical domain from an IT perspective. As a result, the dichotomy between IT and OT fades, in favour of a single EA for the manufacturing domain.

To make this integration between business, IT and OT successful, enterprise architects and process engineers must have a shared modelling language that can express all concepts required for modelling the EA of the manufacturing domain. One of the major requirements introduced by Smart Manufacturing is the modelling of cyber-physical systems (ISCPS). CPS is a type of information system that integrates computational and physical processes and allows these processes to interact (Lee, 2008). For example, an oven may report real time its temperature curve. If this curve is sub-optimal, the oven wastes energy. Such an insight could be used as input for operational excellence programs, or preventive maintenance.

The modelling of such systems will involve not just viewpoints and concepts related to applications and IT infrastructure, but also to the physical environment (i.e., conditions on the shop floor) (Sacala and Moisescu, 2014).

For this research, we adopt the international open standard ArchiMate as our EA modelling language of choice. The most recently published version of the standard, ArchiMate 3.0 (The Open Group, 2016), already includes several concepts for modelling the physical environment of enterprises. Being a new release, however, it has not been seriously validated or applied in the manufacturing domain.

To ensure that ArchiMate enables the modelling of a smart manufacturer's EA, the standard needs to be validated for that particular purpose. We adopt a process framework and a common object model published as part of the standards suite ANSI/ISA-95 (ISA, 2010a, ISA, 2010b) (alternatively, ISO/IEC 62264), or ISA-95 for short, to represent the manufacturing domain. The ISA-95 common object model (ISA, 2010b) describe entities at the shop floor level, where IT and OT interact, whereas the ISA-95 process framework describes exactly this interaction.

Conversely, while ISA-95 describes the physical domain, it does not describe the business or IT domains very well, nor was it intended to model EAs in the first place. Thus, to be capable of modelling the EA of a smart manufacturer, ArchiMate 3.0's meta-model needs to be able to express all architectural concepts from ISA-95. To that end, this paper tries to answer the following questions:

RQ1. To what extent can ArchiMate 3.0 express the EA of any smart manufacturer per ISA-95?

RQ2. If ArchiMate 3.0 cannot fully express the EA of any smart manufacturer per ISA-95, what changes to the meta-model of ArchiMate 3.0 are necessary to make this possible?

Thus, the contribution of this research concerns an analysis of whether the meta-model of ArchiMate 3.0 is expressive enough to model an EA in the manufacturing domain. Secondly, we propose a set of modelling patterns describing how ISA-95 concepts can be expressed in ArchiMate. These patterns can be simple direct mappings, or may involve a grouping of Archimate concepts. Finally, to enhance ArchiMate's expressiveness and enable the modelling of certain smart manufacturing concepts some change suggestions are made.

The remainder of the paper is organised as follows. In Section 2 we explain the methodology we followed to define a mapping from ISA-95 to ArchiMate, and to analyse the expressiveness of ArchiMate. Section 3 describes the results of the analysis, and contains the main contribution of the paper. Section 4 gives an account of how we validated our findings. We conclude the paper with a discussion of the related work in Section 5 and with conclusions and some pointers to future work in Section 6.

2 METHODOLOGY

To define a mapping from ISA-95 to ArchiMate and answer research questions, we followed a four-step approach. Firstly, we derived a subset of architectural concepts from the concepts defined by ISA-95. ISA-95 was written with IT/OT integration in mind. To apply its concepts to architecture modelling, an assessment is necessary to find out which concepts qualify as architectural. For this assessment, the same criteria that were used to define the current set of concepts in ArchiMate are applied to each concept in ISA-95. These criteria are explained in section 3.1.

Secondly, we make a comprehensive mapping of the architectural ISA-95 concepts onto ArchiMate 3.0. Criteria used for the mapping are the similarity of concept definitions, as well as similarity of direct relationships to other concepts (depth = 1).

Thirdly, the ArchiMate's expressiveness concerning the smart manufacturing domain is investigated by identifying semantic deficiencies in terms of the types defined by Wand & Weber (2002) (see Section 3.3). We assume that the ISA-95 common object model is a complete representation of entities at the shop floor level. Given our goal of representing this same domain in ArchiMate 3.0, the ISA-95 common object model should fully map onto ArchiMate 3.0. Whether ISA-95 can fully express ArchiMate is not of interest. Thus, we only consider deficiencies of type *construct overload*, where several ISA-95 constructs map to one ArchiMate construct, and type *construct deficit*, where an ISA-95 construct does not map to any ArchiMate construct.

The deficiencies identified are subsequently analysed and, if necessary, addressed. In the case of construct overload, an assessment is made concerning critical expressiveness loss as result of the higher abstraction level. In the case of construct deficit, it must be determined whether the intended meaning of the ISA-95 concept can be expressed using a combination, or 'pattern', of constructs currently present in ArchiMate 3.0's meta-model. If the current meta-model is found insufficiently expressive, we suggest a pattern that includes new constructs (i.e., new relationships or concepts).

Finally, the identified patterns are validated as part of a case study at SteelCorp. The validation aims to prove the usefulness of the patterns in modelling the EA of a manufacturer, as well to demonstrate the usefulness of such a model through two common manufacturing use cases: an impact of change analysis and an operational excellence analysis.

3 ANALYSIS

The results of several parts of the analysis have been summarized in a spreadsheet (from here on referred to as 'the spreadsheet') which is made available online via http://bit.ly/2amGJqi.

3.1 Excluding Non-Architectural Concepts from ISA-95

To determine the architectural concepts in the ISA-95 common object model, it is necessary to perform a 'normalization' of the ISA-95 concepts to a level of abstraction that coincides with that of ArchiMate concepts. The criteria for normalization are the same as those originally used to determine the ArchiMate concepts. ArchiMate uses for this a layered structure (Lankhorst et al., 2010). Starting at the lowest specialization level, concepts are simply highly abstract entities and their relationships. At the next level, concepts are specialized as either passive structure concepts, behaviour concepts or active structure concepts, corresponding to the basic structure of the ArchiMate language (dynamic system level). Concepts are then further specialized as EA concepts used to design architecture models. ArchiMate defines implementations of concepts in architecture models as its lowest level of abstraction.

At each specialization step, the utility of the specialization must be argued based on the modelling goals that the modeller has in mind. Following this structure, any ISA-95 concept that is architectural will need a specialization relationship to one of the concept types at ArchiMate's dynamic system level. The concepts at the dynamic system level are defined as follows (Table 1):

Table 1: Dynamic System Level Concept Types (Lankhorst et al., 2010).

Concept type	*Description*
Active Structure Concept	*An entity that is capable of performing behaviour*
Behaviour Concept	*A unit of activity performed by one or more active structure elements*
Passive Structure Concept	*An object on which behaviour is performed*

By eliminating all ISA-95 concepts that do not have a specialization relationship to one of these concepts, we end up with a normalized set of architectural concepts. The normalization analysis reveals that 66% of ISA-95 concepts are architectural. The remaining 33% are non-architectural. For example, 'person' qualifies as architectural concept since a person can perform behaviour. Properties describing that person are non-architectural concepts.

To review specifically which concepts classify as architectural, please refer to the spreadsheet.

3.2 Mapping ISA-95 to ArchiMate 3.0

To define a mapping from ISA-95 concepts to ArchiMate we follow a two-step approach: Firstly, for each architectural ISA-95 concept, a comparison is made between its definition and the definition of every ArchiMate concept. Secondly, if there is a fit with one or more definitions, a further comparison is made. In this comparison, each direct relationship (depth=1) of the ISA-95 concept is compared to each of the concepts directly surrounding the ArchiMate concept. This includes both the definition of the surrounding object and the definition of the connecting relationship. If these relationships are also in alignment, an ISA-95 concept maps to ArchiMate.

For 12% of ISA-95's architectural concepts the mapping to ArchiMate concepts is straightforward. 75% can be fit based on definition, but have one or more relationships that cannot be mapped. Finally, 13% of the concepts cannot be matched based on their definition. For an exact specification of the ISA-95 concepts that can be mapped onto specific ArchiMate 3.0 concepts, please refer to the spreadsheet.

N-to-M mappings

In some cases, it turns out that that several concepts from ISA-95 map to several other concepts from ArchiMate. These mappings are ambiguous, causing uncertainty with regards to which concept to use. According to the mapping, several concepts would be correct. These n-to-m mappings need to be addressed before moving forward. Particularly, this concerns the following two mapping scenarios.

Process Segment:

Process Segment, Process Segment Dependency, Operations Segment, Operations Segment Dependency

Map to

Business Process, Business Function, Business Interaction, Business Event

There appears to be an n-to-m mapping in this scenario. However, strictly comparing the definitions of the ISA-95 concepts, as well as the relationships they share to surrounding concepts (depth = 1), the ISA-95 concepts turn out to be synonymous. This resolves the n-to-m mapping to *concept redundancy*, which will be addressed in section 3.3. This case shall be further referred to as *Process Segment*.

Equipment:

Equipment Class, Equipment

Map to

Business Role, Location, Equipment, Facility

In this second scenario, Equipment and Equipment Class are not synonymous per the ISA-95 meta-model. However, given that ArchiMate does not distinguish between classes and instances, Equipment Class and Equipment can safely be abstracted to mean the same thing. This, again, resolves the n-to-m mapping to *concept redundancy*, which will be further discussed in section 3.3. This case shall be further referred to as *Equipment*.

3.3 Classifying Deficiencies in ArchiMate 3.0

Based on the previously established mapping of ISA-95 onto ArchiMate, several deficiencies in ArchiMate 3.0 can be identified. Classifying each deficiency will help find a suitable solution at a later stage. Four types of deficiency exist (Wand and Weber, 2002). Table 2 describes each type.

We assume that the ISA-95 common object model is a complete representation of the entities on the shop floor. Thus, if ArchiMate is capable of modelling the EA of a smart manufacturer, its meta-model should be capable of expressing ISA-95. Based on this analysis, several cases of construct overload, as well as construct deficit, are uncovered. The following sections discuss the occurrences of each type.

Table 2: Types of deficiencies (Wand and Weber, 2002).

Type	**Description**
Construct overload	Several ontological constructs map to one grammatical construct
Construct redundancy	Several grammatical constructs map to one ontological construct
Construct excess	A grammatical construct might not map to any ontological construct
Construct deficit	An ontological construct might not map to any grammatical construct

Cases of construct overload

Construct overload (i.e., more ISA-95 concepts map onto one ArchiMate 3.0 concept) occurs in the case of the following ArchiMate concepts:

Business Object is used to represent information objects that are used on the shop floor and may serve as a placeholder for more complex entities like a schedule or a bill of materials. Specifically, Table 3 describes the objects that map to Business Object.

Where a business object is used, the model will depend on relationships to other entities to provide the expressiveness needed to model the meaning that the user intends. If this level of expressiveness cannot be achieved, this causes a construct deficit.

Business Role - Personnel Class and Equipment map to Business Role. This happens specifically in the case where Equipment refers to an automated production unit. This abstraction loses the direct distinction between a manual and an automated role. However, depending on whether a given role depends on an actor or not, this distinction can still be derived.

Material - Material Class, Material Definition, Material Lot and Material Sublot map to Material in ArchiMate. Because of this, the distinction between a class of material and a specific type of material used as part of a process is lost. Furthermore, the difference between a class of material and an identifiable (group of) its instances is also lost.

Table 3: Construct overload to Business Object.

Qualification Test Specification	Operations Material Bill
Equipment Capability Test Specification	Personnel Specification
Physical Asset Capability Test Specification	Equipment Specification
Material Test Specification	Physical Asset Specification
Material Assembly	Material Specification
Material Definition Assembly	Material Specification Assembly
Material Class Assembly	Operations Schedule
Personnel Segment Specification	Segment Requirement
Equipment Segment Specification	Personnel Requirement
Material Segment Specification	Equipment Requirement
Material Segment Specification Assembly	Physical Asset Requirement
Physical Asset Specification	Material Requirement

Cases of construct deficit

Several deficits have been identified as part of the mapping analysis. When a deficit occurs, the ISA-95 concept cannot be expressed in ArchiMate. Each deficit is explained in the paragraphs below.

Test Specifications - Various concepts in ISA-95 are related to a test specification that is used to test certain properties of said concepts. A Test Specification maps to a Business Object. The ArchiMate meta-model only allows for an association relationship between Active Structure concepts and a Business Object. The dependency in ISA-95 is, however, stronger (<is tested by>).

Assemblies - An assembly is a collection or set of related elements. In ISA-95, they are represented as classes related to aggregation relationships between elements. In ArchiMate, every element can also have an aggregation relationship with an element of the same type. There is, however, no class that represents information about this relationship.

Process Segment Parameters - A process segment (maps to business process) in ISA-95 is a collection of several concepts, including specific parameters that do not fall into the category of personnel, equipment, physical asset or material. The 'other' parameters are known as process segment parameters. ArchiMate allows only well-defined concepts to be related to a business process.

Material Lots - While an ISA-95 Material can be directly mapped to an ArchiMate material, a problem occurs when attempting to map a Material Lot. A requirement for a Material Lot is that it should be possible to determine its current state based on the lot ID. This requires traceability to an information object, i.e., a Business Object. While it is possible to relate a Material Lot to a Business Object through an association, the relationship between a physical and an information object is deemed more meaningful.

Operations Definitions - The operations definition describes the relation between a production, maintenance, inventory or quality operation, the way in which it is implemented and the resources that are needed. A framework for these kinds of *manufacturing operations* is defined by the first part of ISA-95 (International Society of Automation, 2010a). ArchiMate only loosely defines business processes, independent of their context.

Operations Schedule - ISA-95 defines a schedule concept. It is implemented as a set of operations requests, which directly relate to an operations definition. There is no similar concept in ArchiMate.

Operations Performance - ISA-95 makes a distinction between the definition of a process, the planned process and the actual process. Once executed, Operations Responses are returned for every Operations Request (which make up the schedule). In ArchiMate, an Operations Response can be represented as either a Business Object or Data Object, depending on whether this information is collected digitally or not. The actual production information is, however, much too volatile to model as part of the architecture.

3.4 Addressing the Deficiencies Found

Now that several deficiencies have been identified, solutions can be defined that allow ArchiMate to express all the architectural concepts in ISA-95, thus making the language suited to model the shop floor and, by extension, the EA of a smart manufacturer.

The solutions to the deficiencies identified will be discussed below as modelling patterns. A pattern is a set of constructs from ArchiMate that expresses a certain aspect of ISA-95. Preferably, only existing constructs will be included in these patterns. If a new construct must be introduced, it will conform to the requirements for constructs in ArchiMate (The Open Group, 2016). The following paragraphs discuss the solutions per deficiency.

Test Specifications

Various concepts in ISA-95 are related to a test specification that is used to test certain properties of said concepts. Often, these concepts are mapped to active structure concepts in ArchiMate. For example, a Person (maps to Actor) relates to a Qualification Test Specification (maps to Business Object). A Business Object is, however, a passive structure concept. The ArchiMate meta-model only allows for an association relationship between Active Structure concepts and a Business Object. As discussed in section 3.3, we must rely on the context of the ArchiMate model to define the meaning of a Business Object. For a Test Specification, which has a very specific purpose in ISA-95, we deem an association relationship insufficient, since this association without context can be interpreted in many ways.

A stronger relationship (van Buren et al., 2004) between an Active Structure concept and a Business Object can only be established via a Behaviour concept, specifically the *assigned to* relationships (for Active Structure concepts) and *access* relationships (for Business Objects) to Business Service, Business Event and Business Process.

Since relationships from the physical layer are only allowed to Business Process, Business Function and Business Interaction (and not Business Service or Business Event), this leaves Business Process as the only option. Given this limitation, we define the Test Specification Pattern as shown in Figure 1.

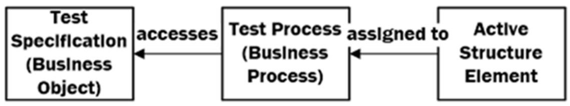

Figure 1: Test Specification Pattern for ArchiMate 3.0.

Assemblies

An assembly is a collection or set of related elements. In ISA-95, they are represented as classes related to aggregation relationships between elements. In ArchiMate, every element can also have an aggregation relationship with an element of the same type. There is no class that represents information about this relationship. For example, to express the size of an assembly in ArchiMate, it would be necessary to model an entity for each element in the collection. This makes sense in a scenario where each instance of a class is meaningfully different. For example, since every person has different qualifications, it is meaningful to model people separately as part of a team. However, in the case where the elements of a collection are *not* meaningfully different, e.g. a set of materials used for the production of a batch (bill of materials), it makes more sense to model each material as a class rather than as separate instances. When modelling only a class, however, the quantity of the material used for the production of e.g. a batch is still meaningful information. Both alternatives below present a solution that makes use of a parameter to a relationship to express meaning. Such a pattern can also be used to express the Operations Material Bill Item concept per ISA-95.

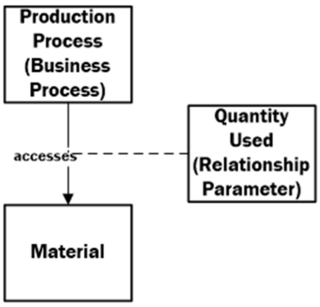

Figure 2: Implicit Bill of Materials pattern for ArchiMate.

Alternative 1

To model such information relevant to an assembly, parameters for the relationship between the class (e.g. a material) and the assembly (e.g., a bill of materials) is proposed. While ISA-95 defines assemblies broadly, in the specification they only occur in relation to materials. A placeholder mapping for assembly would be a business object. Currently, there exists an indirect relationship between Business Object and Material through Business Process. The information relevant to an assembly could be attached to the relationship between Material and Business Process as a (set of) parameter(s).

Alternative 2

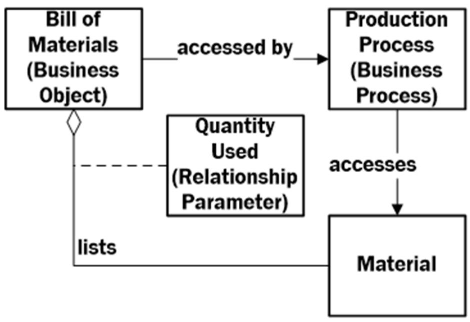

Figure 3: Explicit Bill of Materials pattern for ArchiMate.

This implementation eliminates the need for a separate Business Object by modelling the bill of materials implicitly through the set of relationships between said Business Process and the Materials used. Figure 2 illustrates the proposed pattern.

However, the solution presented in alternative 1 does not allow for a bill of materials to be modelled explicitly. A bill of materials is quite common in manufacturing, so the capability to include this concept explicitly may be desirable. To do so, a direct relationship between Business Object and Material is necessary. An association relationship is currently available between Material and Business Object. However, as explained in section 3.3, we feel that the use of an *association* relationship in this case is not sufficiently expressive.

Instead, an *aggregation* relationship is proposed. An aggregation relationship indicates that a concept (the bill of materials) groups a number of other concepts (materials). While Materials are meaningful independent of one another, the bill of materials groups them for the purposes of use in a production process.

The proposed parameters would be attached to this relationship. This solution is, however, not perfect either. The relationship between Business Object and Material makes the relationship between Business Process and Material redundant, since the Bill of Materials will always be related to a production process (Business Process).

Figure 3 shows a pattern for the modelling of an explicit bill of materials. There are two major differences between this pattern and the pattern for an implicit bill of materials. Firstly, this pattern includes a Business Object that denotes the bill of materials. This Business Object is related to the Business Process via an *access* relationship. This relationship currently exists in ArchiMate. The bill of materials lists one or more Materials via an aggregation relationship. This aggregation relationship is newly introduced for this purpose. Secondly, the information describing the assembly is related to the aggregation relationship between Material and Business Object, as denoted by the dotted line.

Process Segment Parameter

A process segment (maps to business process) in ISA-95 is a collection of several concepts, including specific parameters that do not fall into the category of personnel, equipment, physical asset or material. The ‘other’ parameters are known as process segment parameters. For a production process, an example might include the known lead time of a process step (e.g. the steel coil needs to be in the oven for 10 minutes). For a quality process, a parameter might be the size of the sample to be pulled (e.g., 1 coil).

ArchiMate allows only well-defined concepts to be related to a business process. The only concepts that fit with the description of Process Segment Parameter (i.e. related to business process and not a person, equipment or material) are Business Service and Business Event (behaviour), or Business Object (passive structure). A timer like in the oven example would typically be modelled as an event, but a parameter like sample size cannot be expressed formally in ArchiMate. If needed, such information can be included as part of the sub-process name (e.g. take a quality sample, size 1). Modelling this information as such works as a way to capture it informally, e.g. for presentation purposes. However, for analysis purposes, a more formal approach will be required, since information stored in a concept name cannot be queried easily.

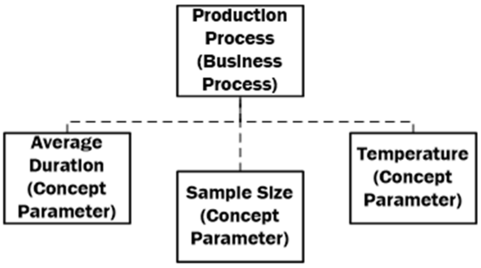

Figure 4: Process Parameter pattern for ArchiMate 3.0.

The proposed solution is to introduce parameters related to a business process. This is similar to the solution introduced to model assemblies, with the difference being that the parameters are related to a concept rather than a relationship. Examples of parameters are average duration, sample size or temperature. This parameter pattern can also be used to model other manufacturing object parameters, per the ISA-95 object properties. The parameter pattern for concepts is illustrated in Figure 4.

Material Lot

While an ISA-95 Material can be directly mapped to an ArchiMate Material, a problem occurs when attempting to map a Material Lot. The current state of a Material Lot should be accessible via its ID. This requires traceability to an information object, i.e. a Business Object. It is possible to associate a Material with a Business Process and a Business Object with a Business Process. It is even possible to draw an association between Material and Business Object. In the case of a Material Lot, however, the relationship between Physical Object and Information Object is more meaningful than an association. The relationship should describe how the informational object reflects the state of the physical object it represents.

To add this expressiveness, a realization relationship is proposed. A realization relationship links a logical entity with a more concrete entity that realizes it. Thus, a realization relationship could describe how a physical object is represented by an information object. Furthermore, a Data Object may realize a Business Object. This Data Object can, by means of an indirect relationship, be considered as the digital representation of said Material stored in some information system. This extrapolation would not be valid if a weaker relationship should be used between the physical object and the Business Object. Finally, by linking the data model of said Data Object to the architecture, it becomes possible to perform analyses of a material's production lifecycle.

The same logic also applies to other physical elements. For example, a piece of equipment may be used as part of a business process, causing it to change state (e.g. from 'idle' to 'in use'). Per ISA-95, entities associated with processes include materials, as well as physical assets, equipment and people. Because of this relationship in ISA-95, the same realization relationship that is proposed for ArchiMate between Material and Business Object is also proposed as a relationship between Business Object and Business Role, Business Actor, Equipment and Facility (see Table 4).

Table 4: Proposed relationships.

ArchiMate Concept	ISA-95 Concept	Relation-ship	Concept
Material	Material Lot	Realizes	Business Object
Business Role	Personnel Class	Realizes	Business Object
Business Actor	Person	Realizes	Business Object
Equipment	Equipment Class	Realizes	Business Object
Facility	Physical Asset	Realizes	Business Object

Finally, the Business Process concept is included to show that the newly added realization relationship is only intended for those concepts that have an access or assigned to relationship with Business Process.

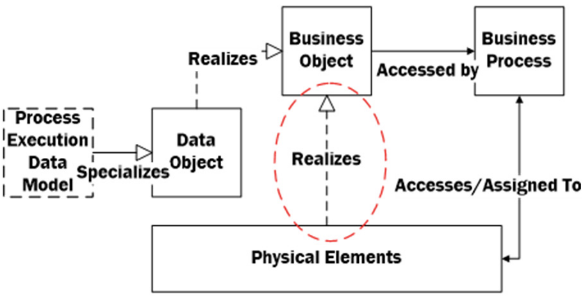

Figure 5: Informational Representation of a Material.

Figure 5 illustrates the proposed extension. The newly added realization relationship is marked with a red circle. For the sake of legibility, the 'Physical Elements' block serves as a placeholder for the ArchiMate concepts listed in Table 4. The figure also shows how an indirect realization relationship between Data Object and a Physical element can be derived using the realization relationship between Data Object and Business Object.

Operations Definition

The operations definition describes the relation between a production, maintenance, inventory or quality operation, the way in which it is implemented and the resources that are needed to carry out the process. A framework for these kinds of *manufacturing operations* is defined by the first part of ISA-95. ArchiMate only loosely defines business processes, independent of their context. However, the ISA-95 process framework (International Society of Automation, 2010a) can be implemented in ArchiMate. It can then provide structure through composition relationships from framework processes to processes that are company-specific.

Figure 6 shows a pattern for how to apply the ISA-95 process framework to company-specific business processes. Such processes are modelled as sub-processes (hence the composition relationship) of processes from the ISA-95 process framework. Since both ISA-95 processes and their sub-processes have flow relationships between them, sub-processes cannot compose more than one ISA-95 process. If a process in a currently existing model cannot fulfil this requirement (e.g. Batch Annealing in Figure 6), that process needs to be decomposed such that each sub-process only has one relation to an ISA-95 process.

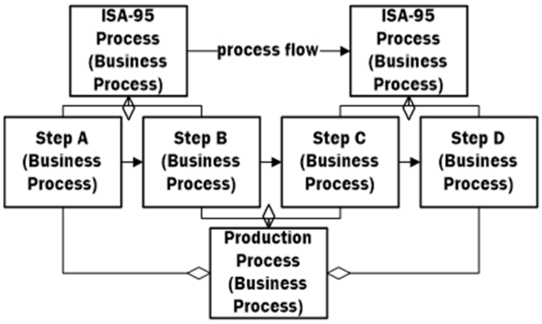

Figure 6: Operations Definition Pattern (incl. example).

ISA-95 also explicitly defines a Bill of Materials in relation to an Operations Definition. A business object best fits the definition, but a business object cannot have a relationship to a material (except through a business process). ArchiMate does implicitly define a bill of materials through the access relationship between business process and material. The pattern introduced for Assemblies solves this issue.

Operations Schedule

ISA-95 defines a schedule concept. It is implemented as a set of operations requests, which directly relate to an operations definition. There is no particular ordering (time sequence) to the set. There is no similar concept in ArchiMate. While the schedule itself could be modelled as a business object, another issue arises with regards to the relationship between a business object and a business process. A business process is typically modelled as a class in ArchiMate, while the schedule must relate to instances to be meaningful. It would either be necessary to model each instance of the process separately, or to model no relationships to business processes at all, effectively making the schedule a placeholder object. The first is preferable from an analysis standpoint, while the second is preferable from a complexity standpoint. A compromise between these two options is to, rather than model each instance as part of the architecture, include a reference to the data model used to store each instance (Figure 7). This data model can then serve as the basis for a query. The way in which this query is structured shall depend on the viewpoint for which the information is required. For example, a query based on product ID may reveal which execution path was followed for the production of that unit.

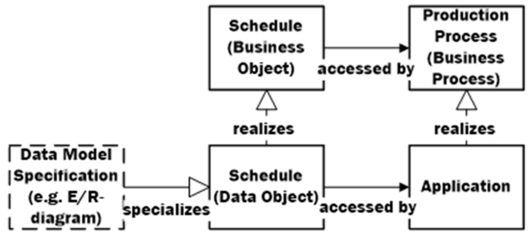

Figure 7: Operations Schedule Pattern.

Operations Performance

ISA-95 makes a distinction between the definition of a process (operations definition), the planned process (operations schedule) and the actual process (operations performance). Once executed, Operations Responses are returned for every Operations Request (which make up the schedule). An Operations Response is made up of 'actuals', which represent the people, equipment, materials and physical assets that were utilized. In ArchiMate, an Operations Responses can be represented as either a Business Object or Data Object, depending on whether this information is collected digitally or not. The actual production information, such as the actual execution of the process, any errors that may have occurred, is however much too volatile to model as part of the architecture. Instead, it is recommended to relate an Operations Response object to a specification of the data model, describing how the data can be obtained externally (e.g. an E/R-diagram). Based on this specification and the relationship to a data object accessed by some application, it will be possible to generate a query for analysis purposes. The proposed pattern is shown in Figure 8.

4 VALIDATION

A case study has been done to validate whether

ArchiMate (plus ISA-95 based modelling patterns) effectively introduces EA modelling capability to manufacturers. The case concerned a large steel manufacturer (named SteelCorp for the sake of anonymity) that intends to make a change in one of its production processes. Due to space limitations we do not provide here modelling details of this case study. Instead we discuss the results and main conclusions of the case.

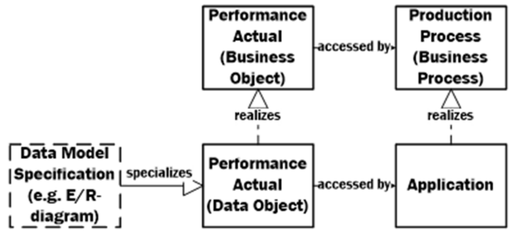

Figure 8: Performance Actual Pattern.

The process modelled as part of this case study concerns a batch annealing process for steel coils at one of SteelCorps factories. During batch annealing, a group of three coils is placed into an oven. Heat is applied over a period of time to change certain qualities of the steel. SteelCorp is looking to optimize this process and to harmonize its surrounding application landscape.

Proposed optimizations include the integration of information used in several activities preparatory to production into the production planning system (PPS). The PPS is used to manage the utilization of the ovens. Secondly, to increase oven utilization, SteelCorp plans to generate optimized batches of coils from the PPS, rather than having employees combine each batch manually. Thirdly, to minimize waiting times once a batch leaves the oven, SteelCorp wants to know how long it takes for a coil to cool down in inventory. For this reason, they will install thermometers that monitor each coil periodically. Finally, actual oven temperature curves will be recorded and stored in the data warehouse with the intent of using this data to optimize energy efficiency.

Creating a model of this process involved establishing the batch annealing process formally as part of the business domain, as well as modelling its relationship to the physical, digital and IT infrastructure domains. Notable physical objects include the steel coils and the ovens. Information is associated with these objects at several stages in the process and this information moves through several systems throughout the production lifecycle.

An as-is process model was made. This model could successfully be used to demonstrate the challenges SteelCorp was facing and to motivate the proposed changes. Finally, a to-be process model was presented to show how the proposed changes would contribute to the goals set forth by SteelCorp.

The proposed modelling patterns proved useful in several instances. Patterns based on existing ArchiMate concepts were enough to model most of the case. However, some aspects of the case could not be modelled and required the use of modelling patterns that make use of new elements. For example, the current utilization of an oven (and the discrepancy between the perceived utilization of an oven and its actual utilization) could not be modelled. This required a realization relationship to a business object per the pattern introduced in section 5.4.4. Another example of this is the temperature data related to a steel coil that is monitored at regular intervals during the process. Finally, usefulness of the model was successfully demonstrated through its application to two common manufacturing use-cases: an impact of change analysis, as well as an operational excellence analysis. Both analyses proved to be possible.

5 RELATED WORK

Urbaczewski & Mrdalj (2006) reviewed the EA frameworks available at that time. They identified DoDAF as the only framework that allows for the modelling of physical elements. In another literature review Hermann et al (2015) identify CPS as major principle behind smart manufacturing/industry 4.0. Furthermore, in, Sacala & Moisescu (2014) argue that modelling a CPS as part of an overall enterprise systems landscape requires a physical entity, an association with a business entity and an application with interfaces to both the business and the physical entity. Finally, The Open Group released in 2016 ArchiMate 3.0 (The Open Group, 2016), which introduced (among other things) several modelling concepts to describe physical elements and how these elements relate to applications and business entities. The current research draws upon all the above and relates ArchiMate to ISA-95, by exploring its current modelling capabilities for smart manufacturing.

6 CONCLUSIONS

With the introduction of smart manufacturing (or Industry 4.0), IT and operations technology increasingly intertwine. For large manufacturers, this means increasing digitization of the shop floor and, consequently, the need to control the information flowing from the physical domain and to manage changes from a multidisciplinary (IT and OT) perspective. This is where EA helps, but existing EA frameworks and languages were not designed with this type of requirements in mind.

This research provides EA modelling support for smart manufacturing companies. Based on the ISA-95 standard for the integration of enterprise systems and control systems in the manufacturing industry (International Society of Automation, 2010a, International Society of Automation, 2010b), this research has presented an analysis of ArchiMate 3.0 (The Open Group, 2016) in terms of its coverage of the manufacturing domain. The results of the analysis lead to the following answers to the research questions formulated in in the introduction:

RQ1: Since ISA-95 was written on a different abstraction level than ArchiMate, not all of its concepts may be of architectural nature. To determine which concepts are architectural, the ISA-95 concepts were normalized using the criteria used to determine which concepts should be part of the ArchiMate language (Lankhorst et al., 2010). The normalization revealed that only 66% of ISA-95 concepts qualify as such. Given the set of architectural concepts identified, a mapping was made of each architectural ISA-95 concept to ArchiMate 3.0. To be able to express the EA of any smart manufacturer, ArchiMate should be able to express each architectural ISA-95 concept. The mapping analysis revealed that, while 12% of concepts can be mapped one-to-one, construct overload or deficit (Wand and Weber, 2002) occurs in 75% of cases. Solving these issues requires the use of modelling patterns based on either indirect relationships or on new constructs.

RQ2: When a concept from the manufacturing domain cannot be mapped to ArchiMate, this will invariably cause issues when attempting to model the architecture of a manufacturing enterprise. Thus, this second question asks for a solution to the mapping difficulties uncovered as part of the mapping analysis.

For each identified issue, a pattern has been proposed that resolves the problem by using some combination of ArchiMate concepts to express the intended meaning of the ISA-95 concept, and/or by introducing some new constructs if ArchiMate's meta-model does not have sufficient expressive power. The following concepts are introduced:

- *Concept Parameter* and *Relationship Parameter*. These concepts describe information about a concept (e.g. a steel coil) or relationship (e.g., an item on a bill of materials) respectively.
- An *aggregation relationship between Material and Business Object* is proposed to enable the modelling of an explicit bill of materials.
- A *realization relationship between Business Object and Business Actor, Business Role, Material, Equipment and Facility* will allow for both the current physical and informational state of a physical object to be modeled.

The proposed modelling patterns enhance ArchiMate 3.0's coverage of ISA-95 architectural concepts from 12% to 92%, and were validated as part of a case study. They proved useful in modelling part of the production process at a steel manufacturer. The models could also effectively be used to perform two common analysis use-cases: impact analysis and operational excellence analysis.

Note that the proposed modelling patterns are applicable to ArchiMate only. Furthermore, the patterns should be further validated by testing them in more cases, also covering discrete and continuous processes, since SteelCorp is a batch process.

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Web Oriented Architectural Styles for Integrating Service e-Marketplace Systems

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Keywords: Service e-Marketplace, Web-Oriented Architecture, Web Services, REST, Integration.

Abstract: e-Marketplaces for services have faced many challenges in the last few years. Many factors, including user expectations, service specificity or technological development, influence the scope of requirements for integrated solutions on that market. Such an integration can help in creating the place in the cyberspace, where any user obtain an access to any service he or she actually needs. However, the integration isn't an easy task, especially in such a diversified environment. That is why there is a need to find a suitable way of integrating the service e-marketplaces. Using loose coupling and WOA principles can make this task easier, what was proved during the real-life experiment, using the "consortium research" method. In the paper authors proposed the concept of integration of service e-marketplaces that bases on three foundations: user interface, data & business logic and security. In that context authors described the integration procedure which takes into account not only the classic software lifecycle, but also agile development principles. Having such foundations, verification of this procedure on the example from ActGo-Gate research project was performed. The high-level architecture of the project IT solution was presented and the way of integration of the offer synchronization process was described.

1 INTRODUCTION

The technological progress and, most of all, the IT revolution have significantly affected the operation of the service markets. Many services have gained their electronic form, while others – which are difficult or impossible to provide remotely – have been given a broad range of visual and interactive solutions (including communication and transaction ones). Thanks to them the consumer can become familiar with the description of a given service, engage in a discussion with the service provider's representative or other customers of the company, place an order and pay online (Łysik et al., 2015).

e-Marketplaces are more and more fragmented, customized and personalized (Maciaszek et al., 2017). There are three most important factors determining the development of service e-marketplaces:

- user expectations and behaviours,
- service specificity,
- technological development.

Nowadays users have very simple access to different information. Thanks to the Internet and ICT technologies they have very good market recognition. On the other hand people don't have much time, so they expect to receive personalized offers in one place, effortless and immediately.

Services are very differentiated and varied. Some of them require coordination of appointments (one-time services), the others use recruitment and evaluation process (recurrent or long-term services) (Maciaszek at al., 2017).

There are many service providers which offer different services. They need efficient, quick and effective technology solutions, especially in case of increased traffic on web pages. That is why design patterns are implemented. The main elements of design patterns are typical and effective development solutions which relate to one or more regularly occurring problems (Fowler, 2003). The key feature of design patterns is that they are rooted in practical experience. They provide advices for developers how to proceed in such cases to work more efficient, transparent and orderly. Design patterns are often not original ideas, but rather an attempt to systematize observations of what is routinely used in practice. They consist of many implemented functions that can be called with one command (Gamma et al., 2008).

In order to streamline and optimize the web applications development process, design patterns are also reflected in web frameworks like Laravel, Symphony (PHP), Spring (Java), Django, Flask (Python) or AngularJS, ReactJS (JavaScript). The web framework consists of a collection of software components that help developers create and execute web-based user interfaces (Vosloo and Kourie, 2008). The framework manages the content displayed on the web interface, the pages that are to be displayed, and what actions are available to the user of the page. They also standardize the ways of communication between web applications.

Taking into consideration all these three factors: very personalized and precisely defined user expectations; different kinds of services and various types of available programming patterns and technologies - there is a need of a specific kind of integration in the service e-marketplace area.

This integration should take into account a set of requirements:

- viewing and managing of data in one place,
- ease of access to data (Single Sign On),
- safety,
- consistency of data presentation,
- a user-friendly interface,
- keeping current information and reminding about any user events.

The above-presented list of requirements has been established on the basis of analysis related to the feedback from scientific and research projects conducted by the authors and the development of web applications.

The aim of this paper is to present a concept of integration of service e-marketplace systems using web oriented architectural styles. The paper is a part of the ActGo-Gate project funded by the AAL Agency awarded on the basis of the agreement number AAL6/1/2015.

2 RELATED WORK

There are different types of integration. Among them the most common are (Hohpe and Woolf, 2004):

- information portals,
- data replication,
- shared business functions,
- service-oriented architectures,
- distributed business processes,
- business-to-business integration.

It is not a complete classification, it illustrates the kind of solutions that integration architects build. *Information portals* aggregate information from different systems into a single display. User may happen when many business systems require access to the same data. When a user change something in one system, all the other systems need to change this element. To avoid redundant functionalities developers can use a *shared business function* that is implemented once and available as a service to other systems. *Service-oriented architecture (SOA)* is applied when enterprise gathers a collection of useful services and managing them becomes a critical function. Remote services provided by other applications ae integrated as *distributed business processes*. A *business-to-business integration* manages the execution of a business function across multiple existing systems.

The paper is based on the experience from ActGo-Gate project. In this project developers have used a few types of integration simultaneously: information portals, shared business functions, but mostly SOA. It provides the basis of distributed application frameworks in which software components are delivered as modular and reusable services. The benefits of a SOA approach are evident in the flexibility of business processes involving loosely coupled services and resulting potential cost decrease, reduced complexity, reusability, and high flexibility (Thies and Vossen, 2009).

A software architecture style which extends SOA to web-based applications is called Web-oriented architecture (WOA). This architecture emphasizes generality of user interfaces and Application Programming Interfaces (APIs) to achieve global network effects.

Pautasso (2014) draws attention also to the Representational State Transfer (REST) architecture. This architectural style emphasizes the scalability of component interactions and promotes the reuse and generality of interfaces. It decreases also coupling between components. The basic principle of loose coupling is to reduce the assumption that two parties (components, applications, services, programs, users) exchange information with one another (Fowler, 2003). Although REST is usually chosen to build simple CRUD (create, retrieve, update and delete) services, there is a possibility to develop REST web services offering complex services and stateful behavior (Rauf, 2013). REST comes with 4 basic principles like: using HTTP methods explicitly, being stateless, exposing directory structure-like URIs and transferring XML, JavaScript Object Notation (JSON), or both (Fielding, 2000).

In practice, the web service typically provides an object-oriented web-based interface to a database server, utilized for example by another web server, or by a mobile application, that provides a user interface to the end user.

3 RESEARCH METHOD

During the research process two main research methods were used. First of them was literature review, that included both research and professional books and articles from the area of software engineering and project management that helps to build a scientific foundation for the paper.

The applied part of the article is based on the Consortium Research method (Österle and Otto, 2010a) (Österle and Otto, 2010b). It is the method of developing research artefacts which applicable in real-life environments. It is an extension of the Design Science research method (Österle et al, 2011) (Myers and Venable, 2014), which is widely used in IT & business-related research projects. It bases on the cooperation of practitioners and researchers in order to develop artefacts possible to be applied in real-life use cases.

The obtained results are coming from such a cooperation within a multinational consortium consisted of research and business partners.

Business partners are supporting the research and testing the developed research artefacts in the real-life use cases of service e-marketplace within local communities, while researchers, beside the creation process, analyse the feedback and improve the previous results. The result from the research are real-life pilot implementations in three cities in Germany and Switzerland, which support their users by offering them different occupational opportunities.

4 THE CONCEPT OF WOA INTEGRATION FOR SERVICE E-MARKETPLACE

With the evolution of the consumer behaviours in the Internet, service e-marketplaces gain more and more popularity. Analyzing the previously identified requirements there seems to be a strong need for contributing solutions, which are integrating different service providers at one place, with convenient and secure access by the user. Such a solution should take into account the differentiation of the essence of particular services and their processing. It influences on the extent to which the particular processes could be integrated. The conclusions obtained during the realization of the research project help in determining the foundations of the integration of service e-marketplace.

The conceptual illustration is presented in Fig.1.

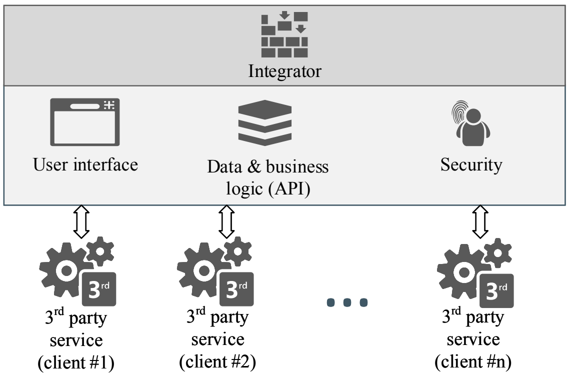

Figure 1: The high-level concept of integration of the service e-marketplace.

That concept indicates three main foundations for integration of service e-marketplaces (clients) under one system – the integrator (Maciaszek et al, 2017):

- User interface – assuring, by the frontend part of the application, the rich and seamless user experience when using an integrator. It should make the impression of using single and compact application, not only the gate for different 3rd party services / clients.
- Data & business logic – utilizing basic data flows, like messaging or asset (category, offer) data retrieved from connected 3rd party services / clients in common data views.
- Security – securing the communication (e.g. with reliable token-based solutions and using safe SSL channel) and managing user identity centrally, where a user can log in once and have access to all services (incl. clients) of the platform (Single Sign On). It should utilize popular and reliable mechanisms of user authentication and manage permissions within the whole ecosystem.

While the first foundation is related only to front-end adaptations within a particular system in compliance with the given standard, the two deeper ones depend strongly on data exchange and communication between clients and the integrator (Maciaszek et al, 2017).

The communication integrator – 3rd party service within data and security integration should be based on WOA principles and loose coupling paradigm, which meet the marketplace requirements in the most complete way. In fact, dependent on the function analyzed, the communication could be initiated with a particular request by both sides.

The basic communication schema is presented in Figure 2:

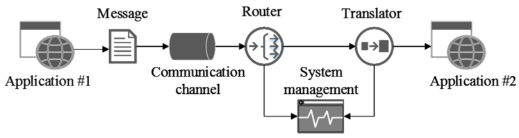

Figure 2: The communication between application within the integrated solution (Hohpe, 2004).

The communication process that occurs between two applications within the integrated system, begins with construction of the message. It should be possible to understand by both sides in the given context and needs to be transported via common communication channel, which is HTTP in case of REST web services. REST uses HTTP standard methods (GET, POST, PUT, DELETE, OPTIONS) to call for resources. Combination of the method, the Uniform Resource Identifier (URI) and some additional parameters (required or optional) sent via HTTP causes that the particular operation (explicitly indicated by the chosen method) is performed and the response message is sent with requested resource in various formats: Text, JSON or XML (JSON is the most widely used). Router in that process could be responsible for redirecting messages to the correct places. On the other hand, the translator's role is to decode the message, validate it and convert it to the form acceptable by the other application. System monitoring is a supportive actor in the process and is responsible for overseeing the data flow, verifying the status of all participants of the process, logging and reporting errors.

Service e-marketplaces require a set of endpoints within two last foundations previously mentioned: data & business logic as well as security. The first one involves mostly endpoints for each objective entity (like category or offer, where operations are defined by particular HTTP methods), while the second one – user endpoint and all supportive entities which help to authenticate him and grant proper privileges. Among those entities common structural elements should be defined and they should be treated as the basis for the integration. When, for example, the integrator is allowed to call directly the 3rd party's web service of creating a new instance of the entity (a concrete object) with the set of common data, this web service will be responsible for filling the missing specific data for that 3rd party application. It can do it automatically, or ask user for necessary additional information. The data & business logic foundation in more homogenous environments could also handle with integration of transactional entities (like appointment, order, recruitment, event, project etc.), however in general those entities are fundamentally diversified (as mentioned in the introduction) and there is a real challenge to find the commonly accepted solution for that problem. That is why in such systems it is allowed to let some processes to be performed only in 3rd party services (and use the information portal integration type for displaying 3rd party's view within the integrator view), which are fully specialized in such processes.

5 THE CONCEPT OF THE INTEGRATION PROCEDURE

The process of software integration is very similar to every other software development process, however usually involves more actors as well as requires more arrangements and iterations caused by unexpected problems on 3rd party side. That is why common understanding on all sides is very important factor for the final success of the integration. It can be achieved via preparing good documentation and using popular web standards and design patterns in the implementation.

Classic software development lifecycles are usually performed in compliance with architecture-first design paradigm (Booch, 2007). Initial architecture should provide fundamental concepts or properties of a system and usually consists of elicited elements, relationships, and the principles of its design and evolution (IEEE/AWG, 2017): However, the rapid expansion of agile software development techniques in recent years caused that the initial concepts are changing during the project. The short development cycles in agile (Agilemanifesto.org, 2001) and lean techniques (Poppendieck and Poppendieck, 2003) are bringing new functions / new versions of the application which can be quickly implemented, deployed and validated each time by real users or project collaborators. The input from real-world tests provides architects and developers with new requirements (remarks to the way of satisfying already known needs as well as new needs which are emerging). Those new requirements can change the initial concept significantly from the original version. That is why some agile techniques diminish the importance of the rich architectural documentation and limit it to the minimum. However, still the architecture is the most important way of getting the common clear understanding how the system works for all stakeholders, even non-technical ones.

Some agile techniques, like Agile Model-Driven Development (Eliasson et al., 2014) (Kulkarni et al (2011) has successfully combined agile with the approach of defining the abstract specification, which finally will be transformed into the implementation in compliance with the given architecture. Taking their experiences as well as the concept of WOA-oriented architecture modelling proposed by Thies and Vossen (2009) a procedure of developing an integrated system is proposed (Fig. 3).

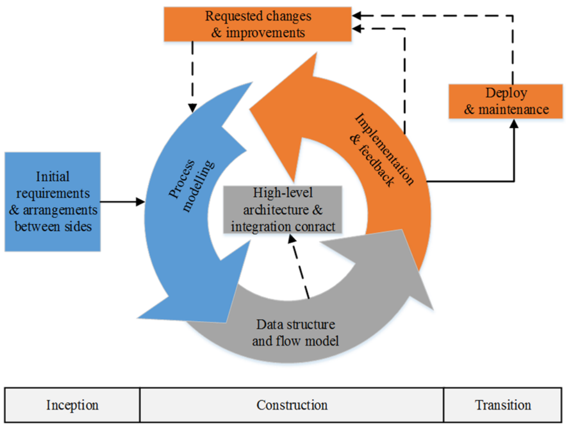

Figure 3: The procedure of developing an integrated system in Agile approach.

The proposed concept is based on Disciplined Agile Delivery (DAD) framework (DAD, 2014) It is a three-phase lifecycle, where a consumable solution is built over time. The process of integration begins with the inception phase, where the first requirements are gathered. In the meantime first arrangements between integration sides are made. Usually those arrangements are the basis for the integration contract, which finally will include basic parameters and uniquely identifies the access interface.

Having such a starting point the first iteration of construction phase can be started where the integrated business processes are modelled, usually in commonly understandable notation like BPMN (Business Process Modelling Notation). The involved systems and business roles should be identified and the detailed processes should be constructed. That step will show the complexity of the particular processes and help to identify all parties involved.

In the second step the basic data structures and flows are designed. The achievements of this step, together with the high-concept architecture schema, constitute the architectural documentation of the integrated system. All tasks within the flows, which require communication of at least two parties, should be described in a way that was arranged in the inception phase by all parties. The WOA concept is promoting an easy way of documenting APIs and therefore the WADL (Web Application Describing Language) gains popularity. The well-structured documentation in commonly-understood notation is an important factor for the better performance of the whole project. There are also many tools that enable the automation of the API documentation (like Swagger, Apiary, Apigee, Sphinx and so on), which could be useful especially in large-scale projects..

Third step is the implementation of the previously documented APIs by all sides involved and consequently bringing the WOA to life. The API owner implements proper web services and binds them to the process while other parties are implementing the necessary changes on their side, which make it possible to consume API. When the process is completed a series of tests should be performed to indicate possible errors in the communication between parties or in the data processing. The results from tests should be gathered and requested changes and improvements in particular processes should be reported. That will constitute the foundation for performing the next iteration within the construction phase. First iteration usually covers the most important processes and structures, while further ones introduce next features.

The third phase, the transition, includes the deployment and maintenance of the developed system. In a result the integrated system is available to its stakeholders who are allowed to use it in practice. According to lean software development technique, this phase should be initiated as soon as possible with a minimum viable product (MVP). MVP usually offers basic processes and is usable in its narrow scope. Then users can provide feedback from real-life usage. Their remarks could lead to important decisions about changes. New requirements are then provided to the construction phase which run the iteration with taking into account the new setup. If there are any changes affecting the high-level architecture, it also should be adapted to the new requirements to keep the architectural documentation up-to-date, what is extremely important for assuring the quality of the continuous development.

6 IMPLEMENTATION – AN INTEGRATED SERVICE E-MARKETPLACE FOR OCCUPATIONAL OPPORTUNITIES

Service e-marketplaces and their integrations generate many challenges for software architects and developers. This chapter contains the demonstration how the practical problem was solved in the particular service e-marketplace, using WOA architectural style. The essence of the e-marketplace, which is taken into consideration, is to provide occupational opportunities to elderly people. Specific offers are provided to them by separate specialized services: appointment coordination system (processing such types of offers as services and demands, developed in Python) and recruiting service (processing voluntary jobs, developed in Java). Users should be able to browse occupational offers as well as create their own offers and manage them. They should also be able to perform transactions (request for appointment, apply for job) and receive notifications about particular actions within the system. The application provides Single Sign On feature to users. More about this topic was discussed in (Kutera, 2016). The integrating application is built mainly on top of Laravel (PHP) and AngularJS (JavaScript) frameworks. The high-level architecture of the integrated solution is presented in Figure 4.

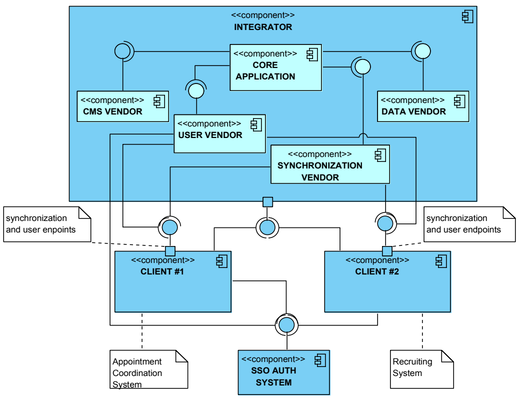

Figure 4: The high-level architecture of the integrated solution.

Because of the scale of the project for demonstration purposes one representative endpoint was chosen. The endpoint for offer synchronization is most important from utilitarian point of view. It allows for gathering offers from different sources and enables them to be displayed in a convenient form for users. It also allows for keeping the offer data structure consistent.

The previously described procedure for building the integrated solution for service e-marketplace begins with eliciting initial requirements for the integration process in the inception phase. For demonstration purposes they have been limited only to those connected with offer endpoints:

- Client applications repository,
- Adding an entity of neighborhood with its mapping with client neighborhoods,
- Central categorization of offers with category mapping from client categories,
- Support for registration of new offering,
- Support for management/editing of offerings via the Gate application,
- Search for offers with advanced tools,
- Browsing the catalogue with available filters,
- Presence of the common map view,
- Availability of news feed.

Not all of them are affecting the direct process of offers synchronization so they will be omitted in further discussion.

The most important business rules for the offer entity are following:

- offer has to be assigned to at least one neighborhood and category,
- offer has to be mapped with client offer index,
- offer has to be owned by one or more users;
- offer is obliged to have geographical coordinates set for displaying it on map,
- offer which don't have any active owner or assignment to an active category or neighbourhood has to be softly deleted.

Next, there is a basis for running the first iteration of the construction process. First, the business process is being modelled (Fig. 5 and Fig. 6). The most important is the fact, that before the direct request for offer is sent, neighborhoods and categories are synchronized (Figure 5). The synchronization process is invoked automatically with using CRON mechanism at a certain frequency. One of the assumptions, arranged in the integration contract, is the focus on the transmission of the small pieces of information frequently to keep the consistency of the data within all systems. That is why the data flows contain only information about recent changes (added as well as modified or deleted offers).

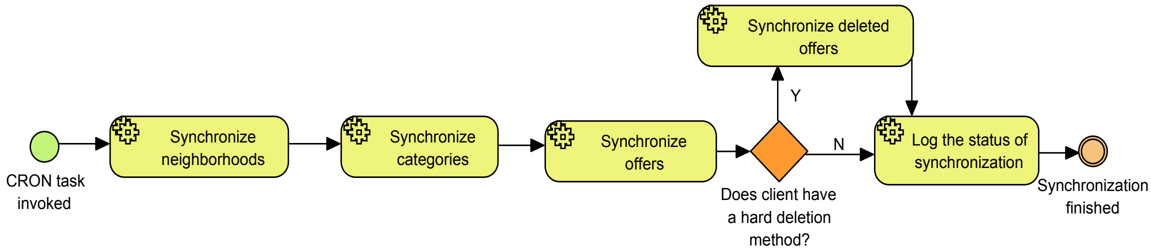

Figure 5: The high-level process of overall synchronization task.

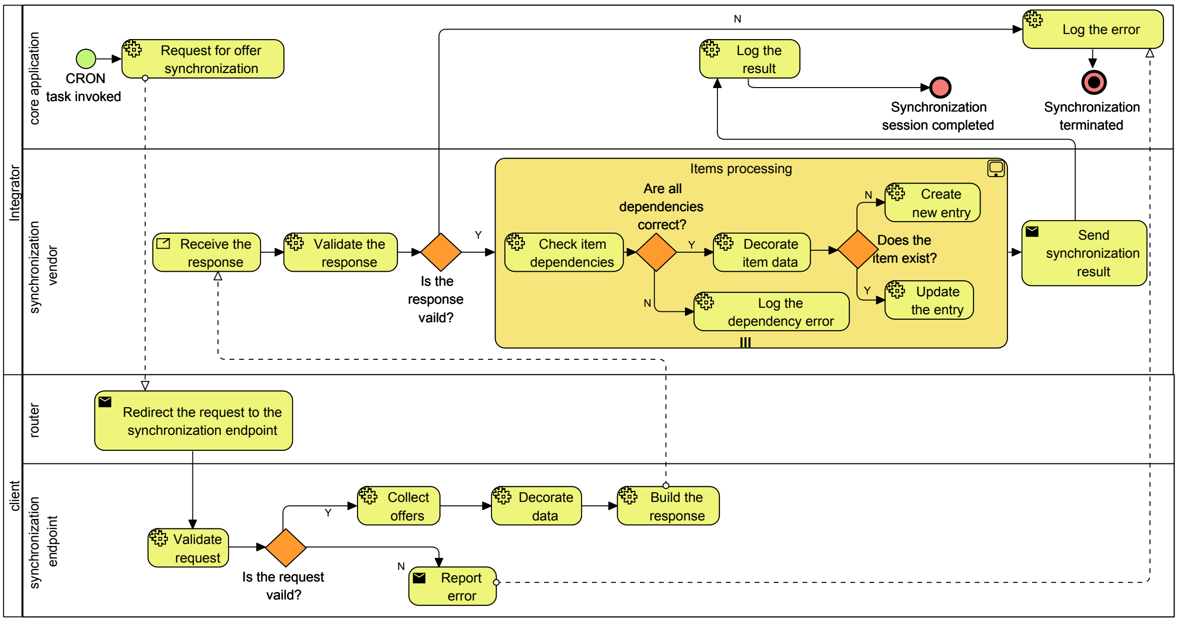

Figure 6: The low-level process of offer synchronization task.

The request for the offer synchronization (Fig. 6) is invoked automatically by CRON server tool (from CRONtab entry). The request is sent to the router (discovery API). It redirects it to the proper URI and the procedure of building the collection of offers and converting it to the JSON format is performed. As the web service get the parameter "FROM::" each offer is checked whether timestamp of last update operation fits the requested period (if the parameter is missing, all offers are added to the collection – this path is allowed for special maintenance purposes). If the collection is ready, it is being sent to the synchronization endpoint of the integrator. It validates the request for syntax (expected structure and data types) and verifies dependencies (neighborhood, category, user). If any dependency is returning errors (e.g. doesn't exist, aren't mapped), the offer is omitted and it is recorded in log files. If validation is successful the offer is being processed: the offer is being subjected to decoration (conversion to the form, in which data could be stored into the integrator's database). Decorator is also adjusting the timestamps and checking the availability status of the offer. If the offer already exists in the database (was only updated in the client), it is updated in the integrator's database. If the offer doesn't exist, it is added. Log counters are also updated. All offers from the collections are checked within a multiinstance loop and if it ends the synchronization result is logged. If any error occurs the respective status in logger database is set and the counter is updated. If the counter reach a limit value, the problem with synchronization is reported to the administrator.

In the next step of the process the four services (that were recognized before as necessary to be implemented in clients) were designed and described in REST/JSON notation. They are: neighborhood endpoint, category endpoint, offer endpoint and offer IDs endpoint. Due to the capacity limitations of the paper, only the offer endpoint will be discussed. The request and response are taking the form of:

The request:

```
GET http://clientapplication.com/
<AGG_API>/<API_VERSION>/offers[?fr
om=<TIMESTAMP>]
```

The response:

```
Content-Type: application/json [{
"client_offer_id": 455,
"client_users": [33],
"client_categories": [12,15],
"client_neighborhoods" : [5,6],
"is_recommended" : 0,
"is_active": 1,
"name": "Lorem ipsum dolor sit",
"type": "JOB",
"description": "Etiam malesua … ",
"image_url": "image_url",
"localization": {
     "latitude": 47.427438,
     "longitude": 9.376254,
},
"apartment_no": "33/5",
"street": "Kolorowa",
"city": "Warszawa",
"zip_code": "22-001",
"country": "Poland",
"language": "en-GB",
"created_at": 1456733752,
"updated_at": 1456733752,
"expired_at": 1456733752,
"deleted_at": 1456733752,
}]
```

The integrator is waiting for HTTP response and only the code 200 is treated as a success. All other answers are logged. Also the detailed restrictions for the particular fields are described (i.e. the expected data types, the policy of using null value, enum. values etc.).

Both sides (development teams of the integrator and the client) owning complete documentation, have to implement the code to handle these operations on such structures. The integration is performed using Laravel framework and vendor-based architecture. So the synchronization middleware takes the form of a vendor which collaborates directly with integrator's database via Eloquent ORM. The previously mentioned mapping of neighborhoods and categories could be performed in the administration panel using simple drag&drop feature. The mapping of users is being done automatically after the registration.

It is very important to setup of all participants (the integrator as well as clients) in the proper way.

The integrator offers a client repository where basic configuration data is stored (i.e. the URI of discovery API, URL's dynamic patterns (parametrized) for CRUD operations on particular types of offers, information about deletion policy, etc). That all makes the communication process easy to configure and helps in avoiding problems in synchronization.

7 CONCLUSIONS

The integration using WOA principles is very efficient and lightweight. Clear structure of requests and responses, explicit usage of HTTP methods and the independence from any programming language make this concept very pragmatic for developments teams.

The paper discussed process of building the integrated solution for service e-marketplace. The applied consortium research method has shown that there are many challenges that need to be overcome. The proposed loosely coupled integration based on three foundations: UI, data&business logic and security can provide users with rich and seamless experiences. It makes feeling of using one application instead of working with several systems. Thanks to Single Sign On authentication mechanism (OpenIDConnect) they do not have to put their credentials several times. The offers are gathered in one place, may be compared, added or managed on one window. The users can be informed about any operation on their account immediately via three parallel channels: the application notifications, SMS and e-mail. From the business point of view integration of service e-marketplaces can also bring profits to professional service providers, as they are able to reach much more potential customers.

Further research in the area of using WOA-based integration will concentrate on ways of securing the communication as well as sharing permissions between the integrated systems. Authors will also verify the current concept in the next real-life implementations and will adapt it in order to reach a satisfying level of its universality.

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Developing Information Systems with NOMIS
A Model-Driven Systems Development Approach Proposal

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Keywords: Information Systems, Information Systems Modelling, Human-Centred Information Systems, NOMIS, NOMIS Vision, NOMIS Models, NOMIS Modelling Notation, NOMIS Metamodel, Model Driven System Engineering, Metamodelling, Model Transformations, Domain Specific Language.

Abstract: NOMIS is a human centred information systems modelling approach that is based on human *observable* actions. It models a business domain through a set of views focusing on human actions, human interactions, context for actions and information. These views are represented by a set of tables and diagrams using the NOMIS graphical notation. The modelling elements depicted in these views are defined in the NOMIS metamodel. NOMIS metamodel and graphical notation are a first step for formalizing and automate the design and implementation of computer applications with NOMIS. In this paper, we propose to develop NOMIS applications using a Model Driven System Engineering approach. The suggested approach will define formally NOMIS models and notation and, using model transformations, will derive a code structure to be used by the computerized information system, and a schema for a relational database supporting business data. Additionally, other components of a specified application middleware will be created.

1 INTRODUCTION

NOMIS (Cordeiro, 2011) is a human centred information systems modelling approach based on human *observable* actions that intends to overcome the difficulty to define an information system with the necessary objectivity and precision. The key to achieve these goals is on the philosophical stance in which NOMIS is based – Human Relativism (Cordeiro et al., 2009). According to Human Relativism, reality is subjective, dependent on the observer, but there is an *observable part* that can be used objectively. The *observability* concept, used in NOMIS, is a starting point to model precisely an information system.

NOMIS models a business domain through a set of views focusing on human actions, human interactions, context for actions and information applying some ideas and perspectives from, respectively, the Theory of Organized Activity (Holt, 1997), Enterprise Ontology (Dietz, 2006) and, Organisational Semiotics (Liu, 2000). The information view is added by NOMIS. These Views are represented by a set of diagrams where NOMIS modelling elements defined in the NOMIS metamodel are shown following a graphical notation proposed also in NOMIS.

Despite NOMIS modelling formalisms, there is no formal use of NOMIS models to create an information system. For example, in Cordeiro, 2017 an e-learning prototype is modelled and created according to NOMIS, however, a model based strategy is used instead of a model driven one. Therefore, in this paper we propose to develop NOMIS applications that uses a Model Driven System Engineering approach. We suggest the creation of a domain specific language to represent NOMIS models based on NOMIS metamodel for the abstract syntax and NOMIS notation for the concrete syntax. It is also suggested some transformations to produce: 1) a code structure to be used by the computerized information system, 2) a schema for a relational database supporting business data and 3) a rule based system to store business rules.

This paper is organized as follows: Section 2 gives a brief overview of NOMIS. Section 3 presents a brief overview of MSDE, section 4 introduces and describes the detail of a NOMIS MSDE based solution, section 4 refers related work and, section 5 concludes and points some future research directions.

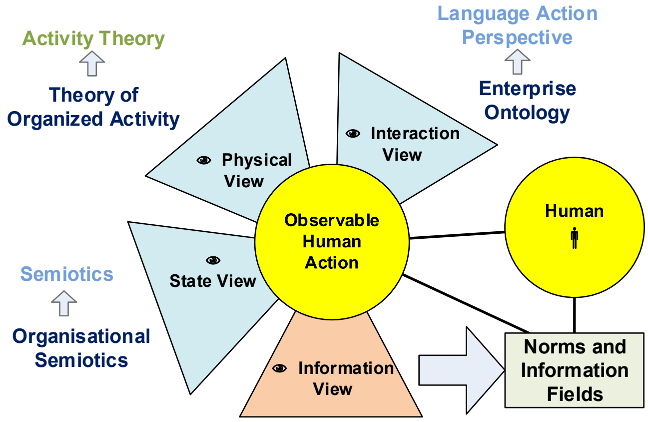

Figure 1: NOMIS Vision – its views and foundational theories.

2 NOMIS OVERVIEW

2.1 Introduction

NOMIS – **NO**rmative **M**odelling of **I**nformation **S**ystems is a human centred modelling approach to information systems development (Cordeiro, 2011).

Recognizing the difficulty to define precisely the requirements of an Information System, NOMIS proposes a solution that is based on the *observability* concept: "*what we observe is more consensual, precise and, therefore more appropriate to be used by scientific methods*". In NOMIS, an Information System is a human activity (social) system which may or may not involve the use of computer systems. In these systems what is *observable* are the human physical actions and the physical things and, what is *not observable* are 1) the human mental actions such as decisions, intentions, judgements, goals, etc. that are not externalized and, 2) the *conceptual or informational features* of physical things such as a price or a qualitative aspect of a specific good that are not shown.

Observability is a key concept in Human Relativism (Cordeiro et al., 2009), the philosophical stance in which NOMIS is based.

Seeking to use *observable* elements, NOMIS models information systems with a focus on *human observable actions* including both material and language actions. Straightly connected to human actions is *information*. In fact, information is used as an input, an auxiliary element, an output, even as a target element for human actions. As human actions information also has an observable part and a not observable one: *data* is an observable material support for information and *information* itself, as a meaning extracted by humans from data, is an immaterial part. NOMIS understands *information* as the result of an *interpretation* process coming after *perceiving* the *observed reality*. Information is only available from data after being interpreted by a human. There is no information without a human interpreter.

2.2 NOMIS Vision

Based on *human observable actions*, NOMIS proposes a *vision* of information systems composed by a set of four views – **Interaction View**, **Physical View**, **State View** and **Information View** – addressing, respectively, human interactions, action processes and, context for actions besides an additional view on information.

NOMIS views form a coherent and consistent information system vision from a human *observable* action perspective.

Considering the unpredictable nature of human actions, NOMIS adds *Norms* as human behaviour regulators. Norms addresses and regulates sequences of human actions. Expected (human) behaviour is derived from *systems of norms* or *information fields* as they were defined within Organisational Semiotics (Stamper, 1996). Within an information field people tend to behave in a certain, expected and controlled way. Examples of information fields could be an organisation, a department, or even a family or a team. Information Fields and Norms are a *glue* connecting human actions and information.

NOMIS Overall Vision is depicted in Figure 1.

2.3 NOMIS Models

Modelling, in NOMIS, is done through a set of tables and diagrams that represent NOMIS Views according to NOMIS Vision. The complete set of these diagrams and tables is presented and described in Table 1. The *elements* represented in these diagrams correspond to the key concepts in NOMIS, namely:

- Human Actions
- Actors – human performers
- Bodies – physical things
- Information Items – without physical support
- Language Actions (or Coordination-acts)
- Environmental States

To represent NOMIS elements a modelling notation is also provided (see Cordeiro, 2017).

3 MODEL DRIVEN SYSTEM ENGINEERING

Model Driven System Engineering (MDSE) is a software engineering approach that aims at derive software systems from models. Its core concepts are models and transformations. For specifying these models MSDE uses modelling languages. In a higher abstraction level, metamodels are used to model models themselves and, meta-metamodels to model metamodels. Usually meta-metamodels are the highest abstraction level. Metamodels are useful, specially to define new modelling languages. In this case, also modelling languages are specified by a model (its metamodel). The second core concept – transformations – is used to transform a model into another model according to a set of transformation rules. Ultimately, a transformation can be used to transform a model into code. Although there are other applications, code generation is perhaps the most important application of MDSE.

A good introduction to MDSE can be found in Brambilla et al, 2017.

3.1 Modelling Languages

As stated before, modelling languages are used to specify models and, metamodels can be used to specify modelling languages. Modelling languages can be classified as general-purpose modelling languages or domain-specific modelling languages. A well-known example of a general-purpose modelling language is UML that can be applied in different domains. A domain-specific modelling language, on the other hand, is used to model a particular domain. Examples could be HTML markup for creating Web Pages or SQL for database access. These are text based modelling languages.

A modelling language is defined by 1) an *abstract syntax* that describes the structure of the language, its primitives and the way they are combined, 2) a *concrete syntax* describing its visual representation and appearance and, its *semantics*, the meaning of its elements.

Table 1: NOMIS modelling artefacts.

Diagram		**Content**	**Used in…**	**Observations**
HID	Human Interaction Diagram	Actors and their interactions	Interaction View	A kind of Construction Model as used in Enterprise Ontology
ASD	Action Sequence Diagram	Sequences of actions	Interaction View and Physical View	A kind of UML activity diagram
BSD	Body State Diagram	The different states of a body	State View	A kind of UML state diagram
EDD	Existential Dependencies Diagram	Environmental States and their existential dependencies	State View	A kind of an Ontology Chart as used in Organisational Semiotics
ESD	Environmental State Diagram	Details each environmental state showing its elements	State View	A kind of an Ontology Chart as used in Organisational Semiotics
AVD	Action View Diagram	Show all the elements related to a single action	Physical View	Shows Information Items, Bodies, Actors related to an action
ABD	Action Body Diagram	Sequences of action related to body state changes	Physical View	A kind of Diplan as used in the Theory of Organized Activity
ICD	Information Connection Diagram	Information Items related to bodies and actors	Information View	Shows information interpreters and information supporting bodies
Table		**Content**	**Used in…**	**Observations**
HAT	Human Action Table	Human actions, actors, bodies and information items	Interaction View and Physical View	Collects human actions, actors, bodies and information items
HADT	Human Actions Dependency Table	Human actions, their dependencies on Bodies, Information and Context	State View	Collects dependencies for human actions
IIT	Information Items Table	Information Items	Information View	Collects details of information items

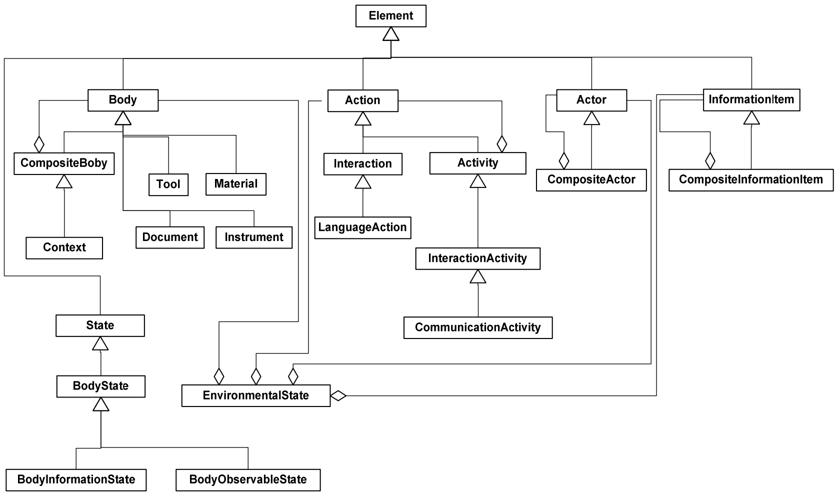

Figure 2: Metamodel of NOMIS Elements.

3.2 Model Transformations

Model transformations are the engine of MSDE. They can be used to transform models into code, to refine or refactor models, to translate models, etc. Usually model transformation can be applied between two graphical models, known as Model-to-Model transformations (M2M) or between a graphical model and a text model, these are Model-to-Text transformations (M2T). M2T are usually used to produce source code from graphical models.

4 A MDSE APPROACH FOR NOMIS

NOMIS allow us to model a business domain and give us guidelines for a computerized support system implementation. Effectively, in Cordeiro, 2017 an eLearning system was modelled using NOMIS models and implemented according to NOMIS vision. Also, a system infrastructure for NOMIS applications was proposed. In this system there was no clear connection between NOMIS models and system implementation. Therefore, in this section we propose a Model Driven System Engineering approach to derive part of the system implementation from NOMIS models.

4.1 From NOMIS Models to a MDSE Solution

As mentioned before, with NOMIS is possible to model a business domain using a set of tables and diagrams showing the key elements of NOMIS together with their relationships. What is shown in these diagrams is a representation of NOMIS Vision and is the way NOMIS sees the Information System reality. This is NOMIS language that is formalized with the metamodel reproduced in Figure 2 and a notation (see Cordeiro, 2017). These are the first steps for creating a domain specific language (DSL) for NOMIS. A DSL abstract syntax will be provided by the NOMIS metamodel, whereas a concrete syntax is obtained from NOMIS notation. A DSL is the best and required solution for implementing a MDSE approach for NOMIS.

4.2 Deriving the System Boundary

The central element of NOMIS are human *observable* actions. In a computerized information system these actions correspond to the functionalities to be provided by the system to a user. For example, if a user wants to “store a document” the system will provide this functionality. In this case, the system acts as a tool enabling and supporting human actions. In general, NOMIS human actions could be implemented as services by a system that would use a typical service oriented architecture (SOA). This is to be achieved by a model transformation where actions in models are transformed to service software interfaces that are used in the implementation of the corresponding functionalities. Also, interactions between two actors are modelled as two services, a request service from a first actor is delivered as a receive service by the second actor.

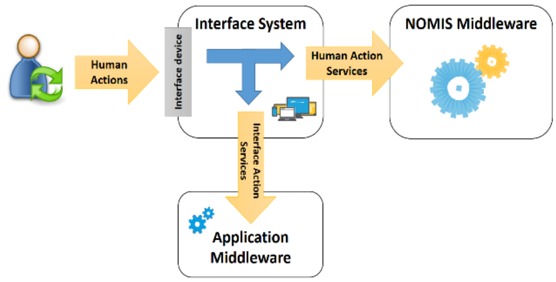

Figure 3: The Interface software component.

4.3 An Interface System

Human actors do not interact directly with a computer system. This is done through a mouse, a keyboard, a computer monitor or other type of input/output device. It will be the responsibility of a human interface software component to make the connection between user and services provided by the system. For example, the action "store a document" can be done through pressing an interface button in a monitor screen. The interface software component will be responsible to trigger the appropriate system service in response to this action. This solution permits to design and program the interface separately from the rest of the system. Designers can design the interfaces using different screen widgets and programmers can make the necessary connections to system services.

Some human actions does not need to be stored in the system or have system services for it. This is the case of simple interface actions. For example, in an application forum component, a user usually wants to check received messages. A service could retrieve these messages but the interface component would be responsible for implementing the actions of sorting or paging and, showing the messages freeing the main system from this *usability* task. A diagram of the interface software component is shown in Figure 3.

The separation of interface and system services provides a desired flexibility to adapt or use difference designs and interfaces with the same services in line with user preferences.

Besides the separation between interface functionalities and system services, an interface system can also make use of activity elements from NOMIS models. An *activity* in NOMIS corresponds to a composite of human actions. So, some activities can be mapped/transformed to an application window (or a browser window) in a windows based environment. In this case application windows will make available actions for the different human actions present in the activity. These actions will trigger the associated system services.

4.4 Persisting Business Data

Information is another central element of NOMIS that is represented by the *information item* element in NOMIS models. Each *information item* is associated with a business domain concept and is detailed within an Information Item Table. In Cordeiro, 2017, content of *information items* is stored as records in relational database tables. This is part of a NOMIS Middleware responsible for storing all business related information. In that work is proposed a flexible database structure that allows business terms and concepts to evolve and change without being attached to the underlying structure. Application data, on the other hand, is kept separated from business data outside NOMIS Middleware. Another model transformation should be applied to *information items* that will be used to persist NOMIS application business domain data. This transformation will generate or reuse the described database structure.

4.5 Considering Environmental States

States and Environmental States in NOMIS are used as context or condition for actions. The physical elements, or *bodies* can exhibit different states. A "special" type of body is the human actor. A human actor state, in this case, is a role or roles performed by an actor within a specific context. Different roles give access to different types of actions. Other *bodies* can have states as well. For example, a form can be "filled" or "not filled", a book in a library can be "for lend" or "not for lend", if it is "for lend" can also be "lent" or "not lent". A lent book cannot be lent again before being returned. Therefore, different body states lead to different possible actions. Environmental States (ES) represent a composite of NOMIS elements, namely: *actions*, *bodies*, *actors* and *information items* where *actors* and bodies may exhibit a particular state. An ES is an utmost important element in NOMIS, it constitutes the information system *anchors*. For example, in a library information system a "membership" ES is a required condition to lend a book (see Cordeiro, 2015). This ES is composed by an actor, in this case a library member, his/her membership data and a "paid membership fee" condition. Only with all this ES elements fulfilled, is possible for a library member to lend a book. "To lend a book" is a key action for a library information system. To acquire a "membership" state there is a registration activity that collects the registration data and the membership fee. This activity is a typical business process. In reality, it is possible to create different registration business processes but the states (ES) stay essentially the same. For a most complete MSDE solution also NOMIS ES and states need to be translated to system features and code using model transformations. In this case, all information necessary for ES is already stored in NOMIS Middleware database but, for example, a state machine can be derived or, at least, complemented with the necessary code to identify and process NOMIS ES elements.

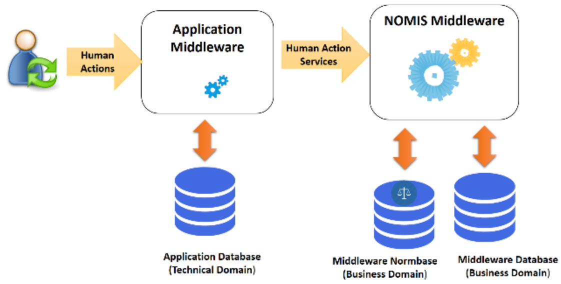

Figure 4: NOMIS Application System.

4.6 Normative Nature of Actions

In NOMIS, action sequences are regulated by (*Behavioural*) *Norms*. A *Norm* is defined by a semi-formal analytical representation as defined in Organisational Semiotics (See Liu, 2000):

IF condition **THEN** agent
ADOPTS attitude **TOWARD** something

The condition part refer to an Environmental State that induces a human actor (the agent) to perform a particular action (attitude). So, sequences of actions are not mandatory as they depend on human behaviour. Anyway, an implementation of a business process as a sequence of system services or a service orchestration may have an automatic implementation as long as it is possible to be easily changed. A possible solution, mentioned in Liu, 2000 is a rule based system to store norms known similar to a Normbase (Stamper et al., 1991). Norms are not shown directly in NOMIS Models, instead they can be attached as notes to some NOMIS elements. Norms are written in text and therefore, require a M2T transformation to derive the correspondent rule to be stored in the described rule system.

4.7 NOMIS Information Systems

Following our proposed approach, resulting information systems will have a clear separation between the technical and the business domain. NOMIS is used to model the business domain focusing on human actions and information. States, in NOMIS, are used to bring a necessary system stability but they depend mainly on information which is already addressed. On the other hand, the technical domain deals with technical aspects and can be modelled separately. The connection between both domains is derived from NOMIS models through the definition of (human action) services, the schema of a business information database (the middleware database) and a special database for NOMIS norms (the normbase). A diagram of these systems is shown in Figure 4.

4.8 Summary of the NOMIS MSDE Approach

NOMIS models provide a comprehensive, coherent and consistent view of an information system from a business domain perspective. By using an MSDE approach it will be possible to derive the business software elements that will be used by the technical system. This will be achieved by MSDE model transformations of NOMIS Models. For this goal, a first step it to create a Domain Specific Language (DSL) to be used with NOMIS. This DSL abstract syntax will be based on NOMIS Metamodel, whereas its concrete syntax will follow NOMIS notation. Next, model transformations will create part of the computerized information system. These transformations are applied to NOMIS modelling artefacts. As described, each NOMIS key element have a clear correspondence to a technical part: NOMIS actions and interactions are transformed in system services software interfaces, information items are transformed to database tables and bodies are simply registered as information although *electronic* bodies may also be stored in the technical database. Finally, norms will be stored in a specific database – the normbase.

By using this approach most of the technical part needs to be developed separately but, the boundaries are clearly defined simplifying the technical development work.

5 RELATED WORK

NOMIS was not formalized before as proposed in this work. Hence, there is no known previous work. However, some elements and diagrams in NOMIS have similar concepts in the underlying theories in which NOMIS is based. Effectively, except for the Information View, NOMIS Views are inspired by the theories of Enterprise Ontology (EO) (Dietz, 2006), Organisational Semiotics (OS) (Liu, 2000) and, the

Theory of Organized Activity (TOA) (Holt, 1997). Some diagrams in NOMIS are adaptations, improvements or extensions of the diagrams used in these theories. Therefore, related work can be found in written research on these theories, this will be exposed in the next sections.

5.1 Diplans in TOA

The Theory of Organized Activity (TOA) that is related to the Physical View in NOMIS, uses a diagrammatic language – Diplans (Holt, 1988) – to show human actions, bodies, states and their relationships. This is a language similar to Petri Nets but applied to a business environment. In NOMIS is possible to have a similar representation with ABD diagrams. In Cordeiro, 2007 there is a proposal to formalize Diplans with UML profiles. Unfortunately, UML was found not suitable for this task due to some adaption difficulties such as extended UML metaclasses with underlying features that did not match extension classes, limited UML relationship types or limited UML element combinations. To the best of author's knowledge there is no other related research work in Diplans.

5.2 Ontology Charts in OS

Organizational Semiotics (OS) is behind NOMIS State View, where some diagrams inspired by OS Ontology Charts are used to show states and their existential dependencies. This is the case of EDD and ESD diagrams used in the State View. Also, in Cordeiro, 2007, Ontology Charts are modelled with UML profiles. As with Diplans, similar adaptation problems were found with Ontology Charts.

Bonacin et al, 2004 proposes some heuristic rules for class diagram derivation from OCs. This work just gives some hints on how to obtain (and translate) the OC elements into UML elements. Used UML elements are limited to classes and associations, compositions and generalizations relationships between them.

Tsaramirsis and Poernomo, 2008 proposes the generation of a prototype system from Ontology Charts. The solution uses a database structure to store information from the elements in the OC. From NOMIS point of view, this solution is not consistent with the proposed theoretical framework. Tsaramirsis and Yamin, 2014 suggested later the generation of UML 2 use cases from Ontology Charts. They map agents to actors and communication acts to use cases. This transformation is not suitable as well for NOMIS as it does not cover the required detailing.

Santos et al, 2016 made an extensive review on OS literature from 2011 till 2015 covering conferences, journals, and book chapters with 91 publications found. We could not find any related research in those publications.

5.3 Aspect Models in EO

Enterprise Ontology (EO) uses aspect models to model a business system. These aspects models uses a set of diagrams, textual rules and tables for modelling purposes. From EO diagrams, NOMIS only has equivalents for Actor Transaction Diagrams (ATD) and Process Structure Diagrams (PSD) with, respectively, HID and ASD diagrams. They are used in the Interaction View. In Cordeiro, 2008, there is also a proposition for a UML profile for ATD, PSD and Actor Bank Diagrams. Again, there were issues in extending UML with specific profiles for these diagrams that excludes UML profiles as a suitable solution.

EO is the most studied and researched approach from the foundational theories of NOMIS. Therefore, we just mention some relevant research related to this work that can inspire a MSDE approach.

First, Wang et al, 2011 suggests the transformation of EO metamodels to a XML schema. This could be an interesting transformation to be used in a MSDE approach for NOMIS.

den Haan, 2009 provides a complete MSDE based approach for EO. It uses a SOA architecture with a process engine to execute EO models. The overall view is provided.

van Kervel et al, 2012 describes a EO processor that fully automates EO development. Also uses a MSDE approach.

6 CONCLUSIONS AND FUTURE WORK

This paper presented a proposal of a MSDE approach for NOMIS computerized information system implementations. The proposed solution uses a DSL for representing NOMIS models and establishes the guidelines for the necessary model transformations. As a result of these transformations part of the implementation code together with a persistency system for business information and business norms will be created. Using this approach, the technical and the business part will be modelled separately, but the connection points between these parts will be established and derived from NOMIS models.

As future work, it is our intention to create a DSL for this proposal using the Eclipse Modelling Framework. This DSL will include the creation of a concrete syntax using the Graphical Modelling Framework, model validation and model persistence. A prototype of a simple application will be used to validate this approach.

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Digitalization of the Process of Process Management
The BPM-D® Application

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Keywords: BPM, Business Process Management, Digitalization, Process of Process Management, Execution, Strategy, Process Design, Strategy Execution, Business Processes, Digital Technology, BPM-Discipline, Implementation, Enterprise Architecture, Process Modelling, Value-Driven BPM.

Abstract: Business Process Management (BPM) has become a key manage discipline that translates strategy into people and technology based execution. It helps organizations to realize the full potential of their digitalization initiatives. BPM is implemented through the "process of process management" (PoPM). To assure continuous improvements of the PoPM an appropriate digitalization approach for the PoPM itself is essential. However, little work has been done in this field and companies are failing to recognise the importance of an integrated digitalization of the PoPM. This paper presents a successful approach for the digitalization of the PoPM to enable a powerful BPM-Discipline. It includes experiences from a first pilot implementation of the developed prototype, the BPM-D Application.

1 INTRODUCTION

Business Process Management (BPM) is increasingly seen as a management discipline that has significant impact on an organization (von Rosing et al., 2015). It provides value by transforming strategy into people and technology based execution – at pace with certainty (Franz and Kirchmer, 2012). BPM plays a key role in realizing the full potential of digitalization initiatives (Kirchmer and Franz, 2016; Kirchmer, 2017). The discipline of process management enables ongoing strategy execution and digitalization in our volatile business environment.

The BPM-Discipline is also implemented through a process of its own, the process of process management (PoPM). The increasing importance of the BPM-Discipline for the success of an organization requires an appropriate performance improvement of the PoPM. First progress in this area has been made through the appropriate design of the PoPM (Kirchmer, 2015). In order to achieve the next performance level we apply digitalization systematically to the PoPM itself.

2 BPM FOR STRATEGY EXECUTION AND DIGITALIZATION

In a recent research study, the Gartner Group showed that only 13% of organizations reach their yearly strategic goals (Cantara, 2015). This situation can even get worse with more and more organizations starting their digitalization journey and thus increasing the requirement for and pace of change. According to the same study only 1% of business have their processes sufficiently under control to realize the full potential of digitalization. So the gap between expectations and reality grows even more. This is where the BPM-Discipline helps. It closes the gap between strategic expectation and reality.

2.1 Discipline of Strategy Execution

BPM has become the management discipline that enables an effective strategy execution across the organization (Swenson and von Rosing, 2015). It operationalizes strategy so that it can be executed through the appropriate combination of people and technology, fast and at minimal risk (Franz and Kirchmer, 2012). This is visualized in the BPM-D® Framework shown in Figure 1. This patent-pending framework summaries key aspects of a comprehensive definition of BPM and operationalizes them by an appropriate management of the process lifecycle from design, implementation, execution to control of the process.

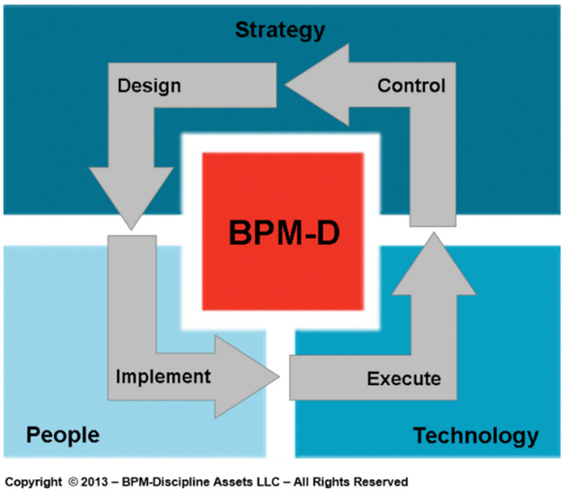

Figure 1: BPM-D® Value Framework.

It is possible to leverage the BPM-Discipline for enterprise-wide strategy execution mainly because of the transparency it creates as well as its organization-wide customer and outcome-oriented approach. The discipline of BPM enables cross-departmental initiatives to achieve values like quality and efficiency, agility and compliance, integration into enterprise networks and internal alignment as well as innovation and conservation of existing practices (Kirchmer, 2015). These typical values the discipline of BPM delivers are shown in the BPM-D Value-Framework in Figure 2.

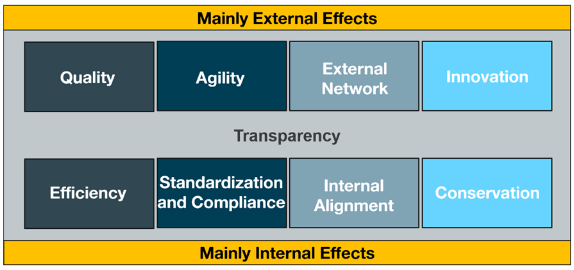

Figure 2: The BPM-D Value-Framework.

These values or a sub-set of them are systematically combined through the BPM-Discipline to make strategy happen. The supporting methods and models enable an efficient and effective approach to this strategy execution.

2.2 Value-Switch for Digitalization

A rapidly increasing number of organizations makes digitalization a part of their strategy. Digitalization is defined as the integration of physical products, people and processes through the internet of things (IoT) and related information technology (IT) (McDonald, 2012; Scheer, 2015). This definition is visualized in Figure 3.

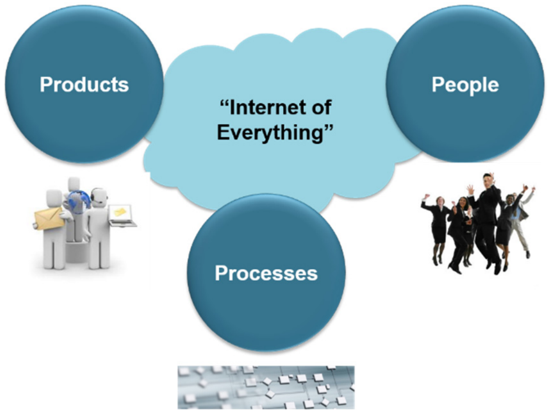

Figure 3: Definition of Digitalization.

Business normally have a solid management discipline around products they produce or buy, e.g. as equipment. Examples are product or asset management disciplines. They normally also have a good discipline around their people and their information technology. However, in many cases the discipline around their business processes is missing (Cantara, 2015). The BPM-Discipline closes this gap. It uses the opportunities of digitalization to create new or improved business processes which realize the strategy of the organization.

BPM provides the answers to the main issues business struggle with in their digitalization initiatives. Figure 4 shows key challenges organizations encounter – all of them addressed through the BPM-Discipline.

Figure 4: Key challenges of Digitalization Initiatives.

2.3 The Process of Process Management

The BPM-Discipline is implemented, just as any other management discipline: through the appropriate business processes. We refer to those processes realizing the BPM-Discipline as the "process of process management" (PoPM) (Franz and Kirchmer, 2012). This PoPM consists of project-related sub-processes, focused on improving the organization and realizing the targeted value, and asset-related processes, enabling efficient and effective improvements. In both groups we can distinguish planning and realization related sub-processes. A definition of the PoPM is described in the BPM-D Process Framework, represented in Figure 5 (Kirchmer, 2015; Kirchmer, 2017).

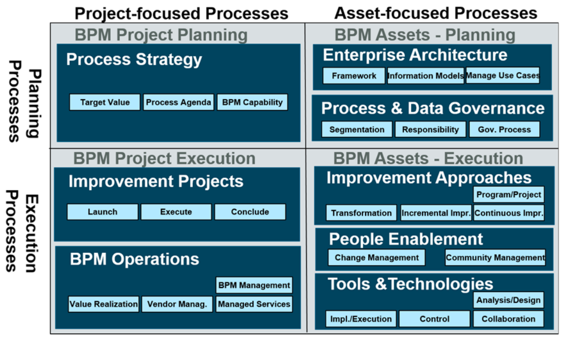

Figure 5: The BPM-D Process Framework.

To support the implementation and continuous improvement of this PoPM we have described this business process from all relevant views (Scheer, 1998): organization, functions, data, deliverables and control view (Kirchmer, 2015). In over 40 business transformation and improvement initiatives we have proven that this PoPM definition delivers significant value - adjusted and applied in the specific business context (Kirchmer, 2016). It is sufficiently complete and consistent.

The PoPM helps to focus on what really matters, improves or transforms processes in the specific context of an organization and sustains those improvements.

The high importance of the BPM-Discipline for strategy execution and digitalization requires and justifies and even more accelerated improvement of the PoPM and its application to specific organizations. This can be achieved by digitalizing the PoPM itself. This is illustrated in Figure 6.

Especially the "focus" and "sustain" effects of the PoPM are often underestimated and underdeveloped in traditional companies so that the BPM-Discipline helps here to move existing practices to the next level of performance. It becomes the key means that help the "Chief Process Officer" (Kirchmer and Franz, 2014a) guide his journey of ongoing strategy execution and digitalization.

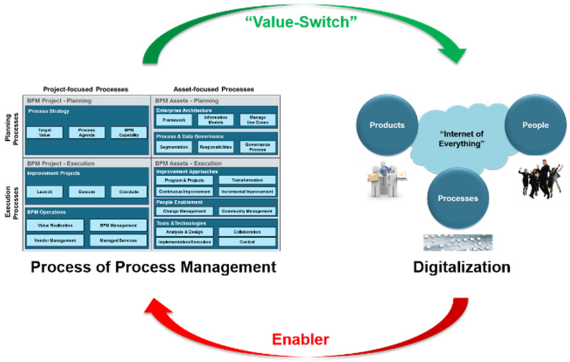

Figure 6: Digitalization of the Process of Process Management.

3 OBJECTIVES OF THE DIGITALIZATION OF THE PROCESS OF PROCESS MANAGEMENT

There are a large number of digital tools supporting the PoPM, such as process modelling and repository tools, process automation and workflow engines, robotic process automation, block chain, or process analytics and mining tools. Most of them target the execution or design of processes or some other small components of the PoPM. Those digital enablers are often not or only loosely integrated. In order to get best possible results, the digitalization of the PoPM needs to be more comprehensive. We have identified three core objectives:

- Focus on what matters most
- Don't re-invent the wheel
- Make process management fun

These objectives are realized based on the BPM-D Process Framework as an example. They can be applied the same way to other PoPM reference models and frameworks.

3.1 Focus on What Matters Most

An analysis of the different sub-processes of the BPM-D Process Framework based on over 200 process initiatives has shown that there are nine areas which are currently not well covered through digital tools. The operationalization of a company strategy through an appropriate process strategy is one important area that is not well supported. An organization only competes with about 15-20% of its processes (Franz and Kirchmer, 2012). All the others are commodity processes that do not really impact the competitive positioning provided that they are performed at least at an industry average level. It is key for an organization to know its high impact processes, align the process management capabilities with those and define a BPM agenda or roadmap consistent with these findings (Kirchmer and Franz, 2014b). The systematic support of this development of a value-driven process strategy is crucial for a successful BPM-Discipline and has to be adjusted with every major change of strategy or market. We have not identified any existing focused digital tools supporting this part of the PoPM, hence this should be part of a new more holistic digitalization approach.

While the management of improvement projects is normally well captured through project management systems, the value-realization after the project and the related process and data governance are not sufficiently covered. This is another area where an enhancement of digital support can lead to significant improvements of the PoPM.

In practice, the whole "people dimension" of process management is also not given adequate digital support in many BPM approaches. In most process transformation and improvement approaches the challenges are less on the technology side but rather on the people side (Spanyi, 2003). Since only some processes can be fully automated, people and their skills are often the bottleneck. While there is good progress made with digitally enabled change management approaches (Ewenstein et al., 2015), such as the use of eLearning or various communication tools, the active management of process communities and their integration with change management is still not sufficiently covered. Hence, this is another area for an improved digitalization of the PoPM. Figure 7 shows all the focus areas for an advanced digitalization of the PoPM.

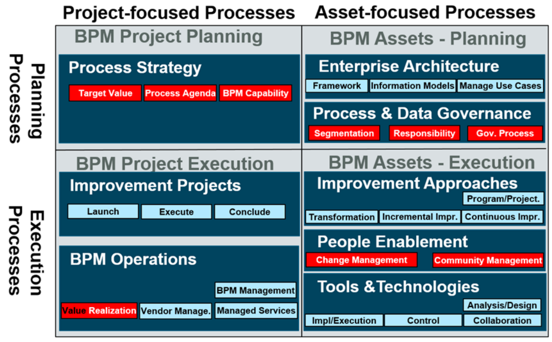

Figure 7: Functional focus of PoPM Digitalization.

In addition, there is a lack of integration between the different existing digital tools. Hence, a next generation digitalization of the PoPM needs to address this and deliver the right degree of integration enabling best performance of the overall PoPM.

3.2 Don't Re-invent the Wheel

This clearly defined functional focus of the PoPM digitalization initiative also prepares for the second objective. Existing digital process management tools and applications need to be re-used and integrated in the new digital BPM environment. This saves time and cost which is key in our fast-changing business environment. In addition, it makes the adoption easier for organization who often have already made significant investments into existing process management tools.

An important aspect is to re-use data available in other applications. The knowledge about processes stored in a repository as part of an enterprise architecture, for example, is excellent master-data for other digital tools. This data can be used to identify high impact processes, support the value-realization of a process improvement or guide the management of process communities.

The new PoPM digitalization needs to be complementary to existing tools and provide an integration environment to optimise the overall support of the PoPM – as efficiently as possible.

3.3 Make Process Management Fun

The acceptance of a PoPM with a significant higher degree of digitalization is again dependent on the people who have to use it. To motivate them and make the PoPM part of a positive process-oriented culture it is important that the new digital components are fun for the users to deal with.

This requires a simple and nice to work with user interface. It needs to make people feel familiar and comfortable with it by copying behaviours from existing widely used applications. On the other hand it must also bring innovations to the table that make it interesting to migrate, for example from the use of a spreadsheet, to the new PoPM application.

The integration of gamification, self-learning and data analytics components is another way to get people excited and make dealing with the new set of tools fun while improving PoPM performance. This is especially important when it comes to community management and application functionality that is used on a daily basis.

To make the use of the tool fun, its administration has to be efficient. Hence, a cloud-based approach is required. The cloud has become a main driver of digitalization. The PoPM digital initiative is not an exception to this (Abolhassan, 2016).

4 APPROACH OF THE DIGITALIZATION OF THE PROCESS OF PROCESS MANAGEMENT

In line with these objectives, work has progressed on the design and implementation of an integrated BPM-D Application that aims to properly support and digitalize the Process of Process Management (PoPM). The approach, initial implementation and early pilots demonstrate considerable progress in regard to the defined objectives.

4.1 Design of the BPM-D Application

To effectively digitalize the PoPM and achieve the defined objectives appropriate software must be developed. We call it the BPM-D Application. In order to meet the objectives, the following functional requirements have been identified, using a design science approach (Nixon, 2013):

1. Digitally manage Strategy execution
- Centrally document business strategy and the process impacted by it
- Translate strategy into executable value driven work packages using required process and BPM capabilities
- Define, manage, track and improve maturity level of BPM capability in an organization
- Track and continuously manage business process impact on projects
- Define, Track and manage role based controls, metrics and measurable outcomes of past project activities

2. Apply Analytics to a process and its execution
- Analyse maturity of PoPM and operational processes, visualize results in dashboards
- View, analyse, and manage selected process knowledge
- Leverage process knowledge to support various use case scenarios, for example the enforcement of process standards

3. Enable Gamification based collaboration of the BPM community
- Setup and manage the required process and data governance
- Enable and encourage collaboration across the BPM Community
- Support focused training of BPM community

4. Integration with existing technologies
- Track and manage a portfolio of business process-related technologies
- Identify integration-scenarios and solutions

4.2 Implementation of the BPM-D Application

The BPM-D Application is an intuitive tool that is being developed in an agile approach to meet these requirements (Sims and Johnson, 2014). It is a web-based platform delivering the defined objectives. Hence, it becomes an enabler of ongoing strategy execution and digitalization for the next generation enterprise.

The BPM-D Application provides the functionality in the key priority areas identified above in figure 7 and then integrates where appropriate with a series of other tools that currently digitalize other functional areas of the PoPM. The integration of the application to other modules is enabled by the prevalence of XML as a standard for data communication. Hence, the BPM-D Application supports from the first prototype on focused integration with existing tool, enhancing the value that those tools deliver and avoiding re-inventing existing digital solutions.

The application consists of a set of modules as shown in Figure 8. In a following commercialization phase of this prototype those modules could be licensed separately.

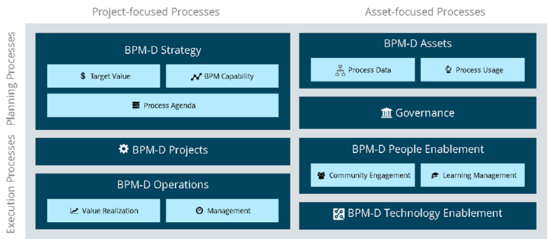

Figure 8: BPM-D Application Module.

The key develop tenets of the BPM-D Application are:

- Cloud based for easy access
- Mobility enabled (access through mobile phones, tablets)
- Intuitive user interface
- Open Source Architecture to facilitate ongoing development and improvement
- Service Based Architecture enabling integration and layered modular architecture that supports plug and play approaches for agile implementation

The Application modules are based on the BPM-D framework which segments into six main sections;

- BPM-S Strategy
- BPM-D Assets
- BPM-D Project Execution
- BPM-D People Enablement
- BPM-D Management
- BPM-D Technology Enablement

The overall architecture of the BPM-D application is shown in figure 9 in Figure 9. This is a high level view, stressing the importance of the integration into an existing PoPM-realted software environment.

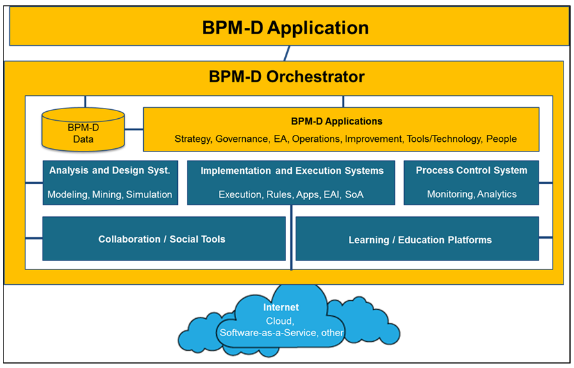

Figure 9: BPM-D Application Architecture.

The basis of the BPM-D Application is the effective management of process knowledge. The definition of business processes in form of process models are typically well supported through modelling and repository tools. The BPM-D Application focuses on contextual and management information about the processes as shown in the Process Master module in Figure 10. This has been developed using the comprehensive BPM-D Data Framework (Kirchmer, 2015), describing the data view of the PoPM.

Figure 10: BPM-D Process Master Module.

On basis of this master data, the BPM-D Application systematically fills the PoPM gaps identified earlier. The starting point is the connection of business strategy to the process hierarchy using the Value-Driver Tree and Process Impact Assessment (Kirchmer, 2015). The easy to us value-tree creation page is shown in Figure 11.

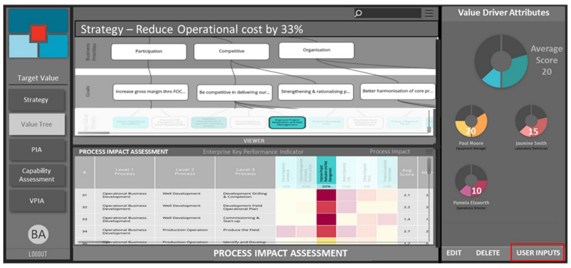

Figure 11: BPM-D Application Value Tree creation.

This intuitive interface helps to gather information relevant for process impact and maturity very collaboratively and then identifies the high impact and low maturity processes. Based on the ever-changing strategy, these priorities will also change. The BPM-D Application offers the process professional the ability to react to these changes in an agile manner, being well informed about possible impacts of this strategy change.

Another key component of the BPM-D Application is the Process Governance module. Identifying process performance gaps is only useful if it is clear who has responsibility and accountability for taking any process improvement action. Process governance is multi-dimensional as it needs to reflect three key organisational realities:

- Functional responsibility: Which processes can I touch?
- Organisational responsibility: What actions am I entitled to execute?
- Process management responsibility: Whom do I collaborate with from the BPM organization?

These realities need to be applied to all modules of the BPM-D Application to enable an effective support of the PoPM. This is a pre-condition for a holistic integrated digitalization approach.

Translating the identified process performance gaps (high impact, low maturity processes) into improvement actions is achieved through the definition of work packages in the Process Agenda module. Here the responsible process owner can review the work packages that are already in progress and check how well they address the performance gaps. As shown in Figure 12, a graphical interface assists in identifying how many current work packages are in progress in support of each process. It is clearly shown where there are misalignments in the focus of interventions. Where there are a number of work packages in progress impacting lower priority processes, these can be assessed and possibly stopped. High impact low maturity processes with no active work packages identify the need for initiating new action and where there are a number of overlapping work packages, these can be assessed for consolidation opportunities.

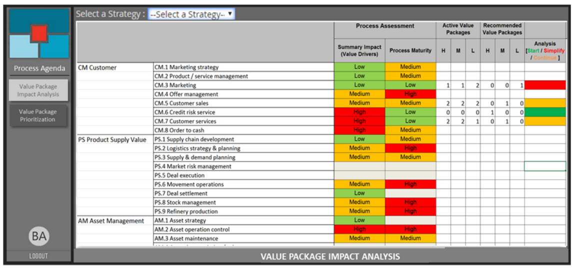

Figure 12: BPM-D Application work package analysis.

In early discussion with a number of organisations that are evaluating the use of the BPM-D Application they consistently mention that this approach has numerous benefits in better focusing and aligning the portfolio of improvement initiatives in an organisation. It also provides the capability to much better identify and manage the value realisation of initiatives. Each work package is assessed in terms of its impact on delivering process improvements. Then through the process impact assessment KPIs can be identified. The impact that work packages therefore have on the KPIs can be quantified into a much more representative business case. This also provides the basis for an effective value realisation approach.

5 EXPERIENCES WITH THE FIRST PILOT

The Beta version of the BPM-D Application is being developed with trial customers and some features are already live and used by the same clients.

5.1 Pilot Client Overview

One of the early adopters of the BPM-D Application is a large shipping company headquartered in Europe with offices globally. They manage over 100 vessels and live under a very robust regulatory and control environment. Their finance organisation is structured in a hybrid way with a combination of a corporate oversight, individuals in each business unit to support their management and a centralised global business services team executing many of the transactional and reporting tasks.

Alignment of processes and the necessary controls across these finance entities is important to ensure that actions are not overlooked and that there is the proper segregation of responsibilities. These controls were managed in a very manual way and were thus not as robust as was required. Their business processes were mapped in a diagramming tool which was little more than a pictorial representation of the workflow. The controls were highlighted on the workflow and they used a combination of a worksheet and email to manage the compliance and audit of these controls.

Changes to the processes and the controls were also difficult to implement as they were kept on a local server and not integrated. The controls team attempted to keep these up to date and then needed to distribute changes through email notifications.

The organisation required a much more integrated and accessible solution to achieve the controls objectives effectively.

5.2 Leveraging the BPM-D Application

The organisation therefore embarked on a programme of implementing a cloud-based full functional process modelling and repository tool. All of their financial processes were duly converted into this tool and verified through a collaborative on-line process. It proved to be a great opportunity for them to bring their process models up to date and to ensure that all of the globally-dispersed finance team had access to the same process information.

This only provided half the solution and they recognised the need for controls and compliance management that was more tightly coupled with these processes. An enlightened process professional helped them recognise that this was the first step towards more effectively digitalizing their process of process management, with controls simply being one of the many management requirements.

They therefore agreed to be one of the pilot adopters of the BPM-D Application. The financial process hierarchy was loaded into the application with integrated references back into the process repository to the detailed process information. The process models were developed in BPMN 2.0 (Fisher, 2012) notation and included references to the required controls. This is shown in Figure 13.

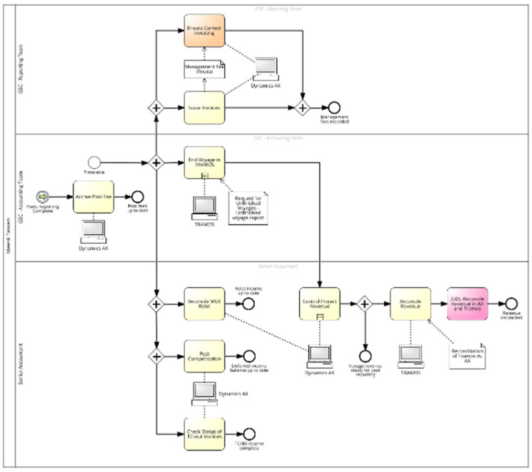

Figure 13: Process Model in BPMN 2.0 with Controls marked in Red.

These controls are accessed through the BPM-D Application and managed against the control objectives hierarchy. All of the context information related to the controls and their management responsibility was then managed using the BPM-D Application governance module. The controls could thus be seamlessly managed by the controls administrator as shown in Figure 14. The control related information is then instantly available through the cloud-based environment to the finance users globally.

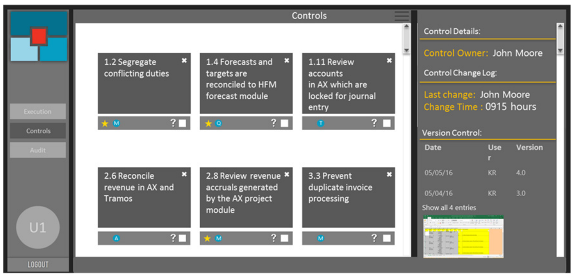

Figure 14: BPM-D Application Process Controls Management in the Process Governance Module.

Finance users then are assigned control related tasks that need to be performed periodically. These tasks are simply added into the BPM-D Application task management module alongside all other process management tasks. The application filters the tasks based on their governance profile and then makes it easy for them to display their tasks and capture their actions against these tasks. This is shown in Figure 15.

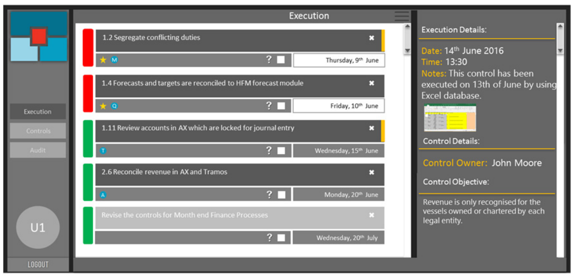

Figure 15: BPM-D Application Task Management.

A central control manager then manages their area of responsibility and checks on the progress of the periodic tasks. The BPM-D application has a graphical representation of the controls status and the ability to easily identify and act on delayed or outstanding actions, as shown in Figure 16.

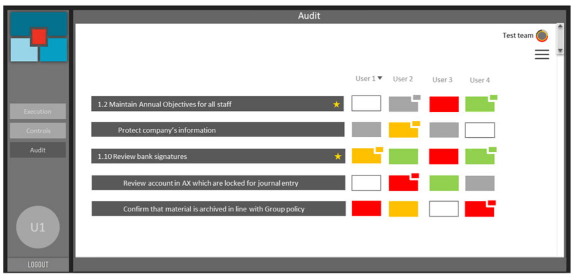

Figure 16: BPM-D Application Task Status Monitoring.

While the examples shown here for this pilot project are specific to controls management, the BPM-D application simply recognises control compliance to standards as one of the numerous process management tasks and these same modules cater for the effective process management activity across the organisation for a range of other PoPM usage scenarios.

5.3 Learnings and Further Development of the BPM-D Application

The integrated and intuitive nature of the BPM-D Application proved to be very popular with the pilot organisation's finance users. The compliance activities now require less time to execute and are thus more diligently performed. The fact that the user community works on-line ensures that they are executing the latest version of the controls and there is an excitement to apply the same approach in other parts of the group.

A very exciting by-product of the implementation was that the related process models now more accurately reflect the business operations and there is an incentive to ensure that they are properly understood and kept current. The ownership for these models has moved from being with one lonely process owner to being much more effectively managed in a collaborative way by the broader stakeholder community.

This has made the finance team much more aware of the benefits of value-driven process management. They are looking to extend their capability and simultaneously extending their adoption of the BPM-D Application functionality.

In the next steps of the agile development of the BPM-D Application the following modules will be added:

- Target Value – strategy-driven process impact assessment
- BPM Capability Assessment – capability assessments report maintenance
- Process Data – Managing and maintaining further process context
- Governance – the setup of user roles, responsibilities and content access rights
- Process Agenda – the ability to create business case reports as a result of assessments

These developments will be combined with the launch of the implementation of new usage scenarios for the process control related modules and the integrated support of people change management and process-oriented community management. In that way more and more of the discovered PoPM gaps will be closed while already creating benefits through existing BPM-D Application components.

6 CONCLUSION

The first step of the digitalization of the PoPM has proven the initial hypothesis that this will significantly increase the performance of the process management discipline. The continued development of the BPM-D Application will lead to a more efficient and far more effective approach to establishing a value-driven BPM-Discipline in an organization.

The permanent change of our business environment also impacts the PoPM. Hence, this process also changes continuously and with it the requirements for the BPM-D Application. Therefore, an agile ongoing development approach is required.

Ongoing research about the change of the PoPM in our digital world needs to deliver the requirements for this ongoing development. This makes the BPM-Discipline the execution engine for strategy execution and business digitalization, delivering fast results at minimal risk.

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A Systematic Review of Analytical Management Techniques in Business Process Modelling for SMEs Beyond What-if-Analysis and Towards a Framework for Integrating Them with BPM

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Keywords: Business Process Modelling, Modelling Requirements, Analytical Management Techniques, Game-Theory Modelling, Markov-Chain Modelling, Probabilistic Modelling, Cognitive Maps Modelling.

Abstract: Unquestionably, Business Process Modelling (BPM) is an increasingly popular research area for both organisations and enterprises due to its effectiveness in enabling better planning of resources, business reengineering and optimized business performance. The understanding of Business Process modelling is an essential approach for an Organization or Enterprise to achieve set objectives and improve its operations. Recent development has shown the importance of representing processes to carry out continuous improvement. The modelling and simulation of Business Processes has been able to show Business Analysts, and Managers where bottleneck exists in the system, how to optimize the Business Process to reduce cost of running the Organization, and the required resources needed for an Organization. Although large scale organizations have already been involved in such BPM applications, on the other hand, Small Medium Enterprises (SME) have not drawn much attention with this respect. It seems that SME need more practical tools for modelling and analysis with minimum expenses if possible. One approach to make BPM more applicable to SME but, also, to larger scale organizations would be to properly integrate it with analytical management computational techniques, including the game-theoretic analysis, the probabilistic modelling, the Markov-chain modelling and the Cognitive Maps methodology. In BPM research the Petri Nets methodology has already been involved in theory, applications and BPM Software tools. However, this is not the case in the previously mentioned as well as to other analytical management techniques. It is, therefore, important in BPM research to take into account such techniques. This paper presents an overview of some important analytical management computational techniques, as the above, that could be integrated in the BPM framework. It provides an overview along with examples of the applicability of such methods in the BPM field. The major goal of this systematic overview is to propose steps for the integration of such analytical techniques in the BPM framework so that they could be widely applied especially for SME since currently are well suited to smaller scale problems.

1 INTRODUCTION

Small and Medium-sized Enterprises (SMEs) account for more than 90 per cent of the world's enterprises and 50-60 per cent of employment. Their contribution to national and regional economic development and gross domestic product growth is well-recognized (Morsing and Perrini, 2009). In fact, SMEs are often characterized as fostering enhanced local productive capacities; innovation and entrepreneurship; and increased foreign direct investment in both developed and developing countries (Raynard and Forstater, 2002).

Hence, while SMEs account for more than 60 per cent of employment in developing countries, and although they are sometimes portrayed as key vehicles in the struggle against poverty (Luetkenhorst, 2004), there is still a critical lack of knowledge about the extent to which these firms may contribute to the achievement of broader objectives of sustainable and equitable development (Fox, 2005; Jeppesen et al., 2012).

In order to understand the possibility of such a contribution it is important to investigate how SMEs are involving analytical management techniques to better explore their possibilities and systematically optimize their performance in a complex financial world and global market. The focus and interest on complex data management, including big data analytics, has been increased over the recent years in the world of SME firms.

Several research reports attempt, through questionnaires, to understand the use of analytical management and planning tools and techniques in SMEs operating in different countries.

As a result of these studies, the most common used tools and techniques are strategic planning, human resources analysis, total quality management, customer relationship management, outsourcing, financial analysis for firm owners, vision/mission, PEST, financial analysis for competitors, benchmarking, STEP analysis, Porter's 5 forces analysis and analysis of critical success factors. According to Gunn and Williams (2007), the results of their research in the UK, SWOT analysis is the most widely applied strategic tool by all organizations surveyed. Benchmarking was ranked second in terms of its usage by all but manufacturing organizations.

However, it is important to perform a meta-analysis research on all these and most recent reports on the use of management tools and techniques in SMEs in order to clearly answer, in detailed tables, in what extend each technique is involved by SMEs depending on its sector of economy, on its country/continent as well as on other crucial meta-analysis factors.

Moreover, it is frequently noticed that the value of just data has significantly reduced in recent past. There are 2 main factors and open issues to consider:

a) There is an overdose of data and it's really hard for a resource strapped SME to be able to digest it;
b) There is an overdose of technology solutions and again it's really hard for SME's to understand this landscape and pick the right solution.

Actionable insights from data is what everyone, including SMEs, want, something with which, on a daily basis, they can uncover new opportunities to grow their business within a complex world, understanding completely their true performance.

The above two questions have not been answered so far by the research reports for SMEs. These questions are, also, highly correlated to the issue of "on what extend the different analytical management tools are really used by SMEs in the optimization of their performance".

In order, however, for an SME or a larger scale organization to apply such analytical techniques and for the research community to answer the above questions, modelling of the business processes (BPM) involved is absolutely necessary in order to establish a common language, a well-defined framework for the application of analytical management techniques. Therefore, more critical than the meta-analysis previously discussed on the use of data by SMEs and other larger scale organizations, is to review, discuss and provide a framework for the proper integration of BPM methodologies and analytical management techniques worthwhile to be utilized in SMEs and beyond.

The major goal of the paper is, therefore, to discuss suitable analytical management techniques that could be integrated in the BPM framework, and through examples to discuss the feasibility of establishing a well-defined framework for the application of these techniques to SME and larger scale enterprises.

With this respect we herein discuss and give examples of game theoretic analysis, probabilistic/stochastic methodology, Markov-chain analysis as well as Cognitive maps methodology in business modelling and analysis towards discussing the feasibility of a well-defined framework for the application of these techniques to SME and larger scale enterprises through the BPM approach

2 AN OVERVIEW OF SUITABLE ANALYTICAL MANAGEMENT TECHNIQUES THAT COULD BE INTEGRATED IN THE BPM METHODOLOGY

Most attempts to describe and classify business models in the academic and practice literatures have been taxonomic, that is, developed by abstracting from observations typically of a single industry. With only a few exceptions, these attempts rarely deal fully and properly with all its dimensions of customers, internal organization and monetization; see, for instance, Rappa (2004) and Wirtz et al. (2010). So far, the literature lacks clear typological classifications that are robust to changing context and time (Hempel, 1965). A typology has been proposed that considers four elements Baden-Fuller C. et al. (2010-2013): Identifying the customers (the number of separate customer groups); customer engagement (or the customer proposition); monetization; and value chain and linkages (governance typically concerning the firm internally).

In order to define a framework for the application of analytical management techniques through BPM methodology such a typology of business processes models is important in order to establish the ontologies, the conceptual links as well as the application paradigms. The herein systematic review attempts to describe the aforementioned techniques within this context.

2.1 The Game Theoretic Modelling Analysis

Every game has players (usually two), strategies (usually two, but sometimes more) and payoffs (the payoffs to each player are defined for each possible pair of strategies in a two-person game). There are also rules for each game which will define how much information each player knows about the strategy adopted by the other player, when this information is known, whether only pure strategies or mixed strategies may be adopted, etc. etc. Game theory is used to help us think about the strategic interaction between firms in an imperfectly competitive industry. It is particularly helpful for looking at pricing, advertising and investment strategies, and for looking at the decision to enter an industry (and the strategies that can be adopted to deter a firm from entering an industry – entry deterrence) as well as to formulate the outcomes of different strategies of specific business processes. There is a lot of terminology to when someone is first introduced to game theory.

For instance, games can be co-operative or non-cooperative. A co-operative game is one in which the players can form lasting agreements on how to behave. We focus our attention, however, on non-cooperative games in which such binding agreements are not possible, and players are always tempted to cheat on any temporary agreement if they can gain an advantage by cheating. Such games are well suited in the case for modelling different strategies for specific business processes.

Games can be "pure strategy" games or they can allow for "mixed" strategies. Most of the time we will discuss only pure strategy games (for example: if a firm has two strategies for a business process, which are to charge $50 and to charge $100, then a pure strategy game allows for only these two possibilities). However, we could consider some examples of mixed strategies (for example: if the firm has the two pricing strategies described above, it would also have the option of charging $50 thirty percent of the time and charging $100 seventy percent of the time – i.e., a probabilistic move).

Games can be single-period games or many-period games (many-period games are also called repeated-play games or multi-period games). A single-period game will only be played once and no one thinks about the future possible replaying of the game in making their decisions about the best strategy. However, many of life's strategic decisions (for business firms as well as individuals) require us to think about the payoffs that will occur if a game is played over and over and over again. Results in a one-period game can be overturned once you take repeated effects into account.

Games can be described as simultaneous games or sequential games. In a simultaneous game, the two players know what their possible strategies are, they know the identity of the other player, they know what the payoffs are for both players from any combination of strategies, but each player does not know what move the other player has decided to make. In other words, each player knows the incentives, but not the actual strategy adopted. On the other hand, in a sequential game, one player moves first and the other player moves second. The second player to move already knows what strategy the other player has adopted when the second player is making his/her decision.

What constitutes a dominant strategy? A dominant strategy is one that gives you the best result, no matter what the other person chooses to do. For example, consider the following game (note: in all the games herein discussed the payoff for the enterprise following the first process will always be listed first):

		Proc.#2	
		Strategy A	Strategy B
Proc.#1	Strategy Y	(100,50)	(70,60)
	Strategy Z	(40,30)	(60,10)

For process #1, Y is a dominant strategy, because process#1 always ends up with a higher payoff for the enterprise by choosing this strategy. For process #2 there is no dominant strategy, because process #2 does better by choosing A if #1 chooses Z, but process#2 does better by choosing B if #1 chooses Y.

A Nash equilibrium occurs when neither party has any incentive to change his or her strategy, given the strategy adopted by the other party. Clearly, the existence of a dominant strategy will result in a Nash equilibrium: in the game above, the enterprise following process #1 always chooses strategy Y; while the enterprise following process 2 then, chooses B; Y,B is a Nash equilibrium. However, games without any dominant strategies also often have Nash equilibria. A game may have no Nash equilibrium, a single Nash equilibrium, or multiple Nash equilibria.

In order for such a methodology to be applied it is important to completely define strategies, payoffs and of course the players. In our case the players are different competitive processes within an enterprise, but they could be within two different firms too. Regarding the payoffs could be even the number of customers attracted by the different strategies. Therefore, the applicability of this analytical management technique should be discussed within BPM framework in order to be established for wide use within SME or larger enterprises.

2.2 The Markov Chain Modelling Analysis

Many real-world systems, including enterprises functionality and operations, contain uncertainty and evolve over time. Stochastic processes (and *Markov chains*) are probability models for such systems.

A discrete-time stochastic process is a sequence of random variables $X_0, X_1, X_2, \ldots$ typically denoted by $\{ X_n \}$.

The state space of a stochastic process is the set of all values that the X_n's can take. (we will be concerned with stochastic processes with a finite # of states).

Time: $n = 0, 1, 2, \ldots$
State: v-dimensional vector, $s = (s_1, s_2, \ldots, s_v)$
In general, there are m states, $s^1, s^2, \ldots, s^m$
or $s^0, s^1, \ldots, s^{m-1}$.
Also, X_n takes one of m values, so $X_n \leftrightarrow s$.
A stochastic process $\{ X_n \}$ is called a *Markov chain* if
$\Pr\{ X_{n+1} = j \mid X_0 = k_0, \ldots, X_{n-1} = k_{n-1}, X_n = i \}$
$= \Pr\{ X_{n+1} = j \mid X_n = i \} \leftarrow$ transition probabilities
for every $i, j, k_0, \ldots, k_{n-1}$ and for every n.
Discrete time means $n \in N = \{ 0, 1, 2, \ldots \}$.

The future behavior of the system depends only on the current state i and not on any of the previous states.

$\Pr\{ X_{n+1} = j \mid X_n = i \} = \Pr\{ X_1 = j \mid X_0 = i \}$,
for all n (They don't change over time).

Normally, stationary *Markov chains* are considered. The one-step transition matrix for a *Markov chain* with states $\mathbf{S} = \{ 0, 1, 2 \}$ is:

$$\mathbf{P} = \begin{bmatrix} p_{00} & p_{01} & p_{02} \\ p_{10} & p_{11} & p_{12} \\ p_{20} & p_{21} & p_{22} \end{bmatrix}$$

where $p_{ij} = \Pr\{ X_1 = j \mid X_0 = i \}$

If the state space $\mathbf{S} = \{ 0, 1, \ldots, m-1\}$ then we have:

$\sum_j p_{ij} = 1 \ \forall \ i$ and $p_{ij} \geq 0 \ \forall \ i, j$

A relevant example for the application of *Markov chain* modeling in the field of SMEs or larger scale organizations, regarding the number of customers switching from enterprise to enterprise is as follows (adapted from https://www.analyticsvidhya.com/blog/2014/07/markov-chain-simplified/):

Let's say Coke and Pepsi are the only companies in a country. A soda company wants to tie up with one of these competitor. They hire a market research company to find which of the brand will have a higher market share after 1 month. Currently, Pepsi owns 55% and Coke owns 45% of market share.

Following are the conclusions drawn out by the market research company:

P(P->P) : Probability of a customer staying with the brand Pepsi for one month = 0.7

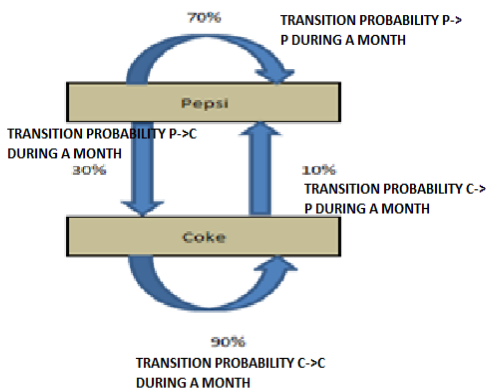
P(P->C) : Probability of a customer switching from Pepsi to Coke for one month = 0.3

P(C->C) : Probability of a customer staying with the brand Coke for one month = 0.9

P(C->P) : Probability of a customer switching from Coke to Pepsi for one month = 0.1

We can clearly see customer tend to stick with Coke but Coke currently has a lower wallet share. Hence, we cannot be sure on the recommendation without making some transition calculations.

Transition Diagram
The four statements made by the research company can be structured in a simple transition diagram



The diagram simply shows the transitions and the current market share (MS). Now, if we want to calculate the market share after a month, we need to do following calculations:

Market share (t+1) of Pepsi = Current market Share of Pepsi (t)* P(P->P) + Current market Share of Coke (t) * P(C->P)

Market share (t+1) of Coke = Current market Share of Coke(t) * P(C->C) + Current market Share of Pepsi (t)* P(P->C)

These calculations can be simply done by looking at the following matrix multiplication of course under the assumption of stationary only Markov processes.

Current State(t) X Transition Matrix(t->t+1) = Final State (t+1). When t=0, that is, at the initial state, we have:

$$\begin{pmatrix} MS\ Pepsi(t=0) & MS\ Coke(t=0) \\ 55\% & 45\% \end{pmatrix} X$$

$$\begin{pmatrix} & P & C \\ P & 70\% & 30\% \\ C & 10\% & 90\% \end{pmatrix}$$

$$= \begin{pmatrix} MS\ Pepsi(t+1) & MS\ Coke(t+1) \\ 43\% & 57\% \end{pmatrix}$$

As we can see clearly: Pepsi, although having a higher market share now, will have a lower market share after one month. This simple calculation is called stationary *Markov chain*. If the transition matrix does not change with time, we can predict the market share at any future time point. Let's make the same calculation for 3 months later:

$$\begin{pmatrix} MS\ Pepsi(t=1) & MS\ Coke(t=1) \\ 43\% & 57\% \end{pmatrix} X$$

$$\begin{pmatrix} & P & C \\ P & 70\% & 30\% \\ C & 10\% & 90\% \end{pmatrix} X \begin{pmatrix} & P & C \\ P & 70\% & 30\% \\ C & 10\% & 90\% \end{pmatrix} =$$

$$\begin{pmatrix} MS\ Pepsi(t=1) & MS\ Coke(t=1) \\ 43\% & 57\% \end{pmatrix} X$$

$$\begin{pmatrix} & P & C \\ P & 52\% & 48\% \\ C & 16\% & 84\% \end{pmatrix}$$

$$= \begin{pmatrix} MS\ Pepsi(t+2) & MS\ Coke(t+2) \\ 31{,}48\% & 68{,}52\% \end{pmatrix}$$

Steady State Calculations

Furthermore to the business case in hand, the soda company wants to size the gap in market share of the company Coke and Pepsi in a long run. This will help them frame the right costing strategy. The share of Pepsi will keep on going down till a point the number of customer leaving Pepsi and number of customers adapting Pepsi are equal. Therefore, we need to satisfy the following conditions to find the steady state proportions:

Pepsi MS (t)*(Prob(P->C) = Coke MS(t)*Prob(C->P)
=> Pepsi MS(t)*30% = Coke MS(t)*10%
Pepsi MS + Coke MS = 100%
4*Pepsi MS = 100% => Pepsi MS = 25% and Coke MS = 75%

The formulation of an algorithm to find the steady state is easy. After steady state, multiplication of Initial state with transition matrix will give initial state itself. Hence, the matrix which can satisfy following condition will be the final proportions:

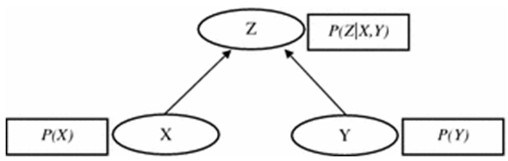
Initial state of Market Share X Transition Matrix = Initial state of Market Share

By solving for above equation, we can find the steady state matrix. The solution will be the same as above [25%,75%].

2.3 The Bayesian Network (BN) Modelling Analysis

Bayesian Networks are also known as recursive graphical models, belief networks, causal probabilistic networks, causal networks and influence diagrams among others (Daly et al. 2011). A BN can be expressed as two components, the first qualitative and the second quantitative (Nadkarni and Shenoy 2001, 2004). The qualitative expression is depicted as a directed acyclic graph (DAG), which consists of a set of variables (denoted by nodes) and relationships between the variables (denoted by arcs) (Salini and Kenett 2009).

The quantitative expression comprises probabilities of the variables. The figure below shows a Bayesian Network with three variables X, Y and Z. Variables X and Y are parents for variable Z, which indicates that Z is the dependent node. The probability for Z is a conditional probability based on the probabilities of X and Y.



The probabilities in a Bayesian Network are simplified by the DAG structure of the BN, by applying directional separation (d-separation) (Pearl, 1988) and a Markov property assumption (Jensen and Nielsen, 2007; Johnson et al., 2010), so that the probability distribution of any variable is solely dependent on its parents. Thus, the probability distribution in a BN with n nodes
($X_1,\ldots,X_n$) can be formulated as:

$$P(X_1, X_2, ..., X_n) = \prod_{i=1}^{n} P(X_i \mid Pa(X_i))$$

where $Pa(X_i)$ is the set of the probability distributions corresponding to the parents of node X_i (Heckerman et al., 1995; Johnson et al., 2010). For the above figure the above equation can be written as P(Z)=P(Z|X,Y)∗P(X)∗P(Y).

Bayesian Networks based modelling relevant to BPM framework has been recently investigated, although not in depth, and only in the field of customer modelling for some specific applications (Ashcroft M., 2012; Anderson et al., 2004; Chakraborty S., et. al., 2016).

2.4 The Cognitive Maps Approach in Modelling Analysis

Cognitive maps (Axelrod, 1976), (Eden, 1992) are a collection of nodes linked by some arcs or edges. The nodes represent concepts or variables relevant to a given domain. The causal links between these concepts are represented by the edges. The edges are directed to show the direction of influence. Apart from the direction, the other attribute of an edge is its sign, which can be positive (a promoting effect) or negative (an inhibitory effect). Cognitive maps can be pictured as a form of signed directed graph. Figure 1 shows a cognitive map used to represent a scenario involving some issues in public health.

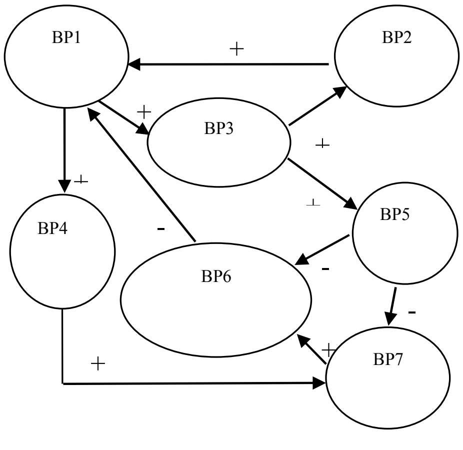


Figure 1: Cognitive map concerning causal relations in business processes within an enterprise.

The construction of a cognitive map requires the involvement of a knowledge engineer and one or more experts in a given problem domain. Methods for constructing a cognitive map for a relatively recent real-world application are discussed in (Tsadiras, 2003; Jetter, 2014).

The main objective of building a cognitive map around a problem is to be able to predict the outcome by letting the relevant issues interact with one another. These predictions can be used for finding out whether a decision made by someone is consistent with the whole collection of stated causal assertions. Such use of a cognitive map is based on the assumption that, a person whose belief system is accurately represented in a cognitive map, can be expected to make predictions, decisions and explanations that correspond to those generated from the cognitive map. This leads to the significant question: Is it possible to measure a person's beliefs accurately enough to build such a cognitive map? The answer, according to Axelrod and his co-researchers, is a positive one. Formal methods for analysing cognitive maps have been proposed and different methods for deriving cognitive maps have been tried in (Axelrod, 1976).

In a cognitive map, the effect of a node A on another node B, linked directly or indirectly to it, is given by the number of negative edges forming the path between the two nodes. The effect is positive if the path has an even number of negative edges, and negative otherwise. It is possible for more than one such paths to exist. If the effects from these paths is a mix of positive and negative influences, the map is said to have an imbalance and the net effect of node A on node B is indeterminate. This calls for the assignment of some sort of weight to each inter-node causal link, and a framework for evaluating combined effects using these numerically weight-ed edges. Fuzzy cognitive maps (FCM) (Caudill, 1990; Brubaker, 1996a; Brubaker, 1996b) were proposed as an extension of cognitive maps to provide such a framework.

Fuzzy Cognitive Maps

The term Fuzzy Cognitive Map (FCM) was coined in (Kosko, 1986) to describe a cognitive map model with two significant characteristics:

(1) Causal relationships between nodes are fuzzified. Instead of only using signs to indicate positive or negative causality, a number is associated with the relationship to express the degree of relationship between two concepts.

(2) The system is dynamic involving feedback, where the effect of change in a concept node affects other nodes, which in turn can affect the node initiating the change. The presence of feedback adds a temporal aspect to the operation of the FCM.

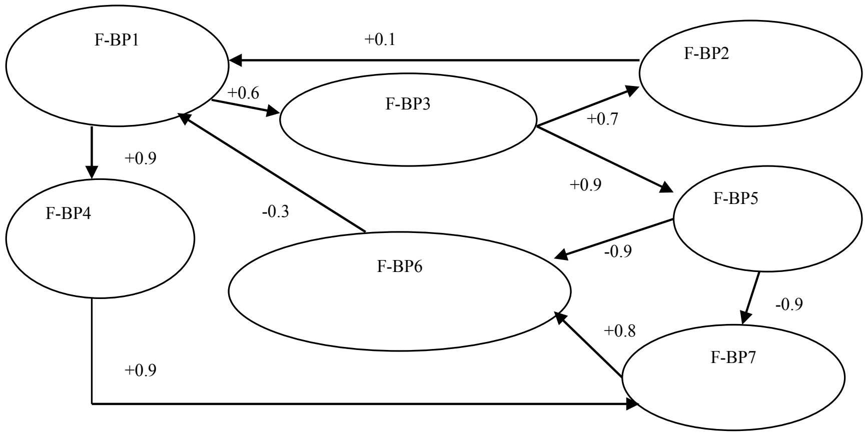


Figure 2: Fuzzified version of the cognitive map shown in Figure 1.

The FCM structure can be viewed as a recurrent artificial *neural network*, where concepts are represented by neurons and causal relationships by weighted links or edges connecting the neurons.

By using Kosko's conventions, the inter-connection strength between two nodes C_i and C_j is e_{ij}, with e_{ij}, taking on any value in the range -1 to 1. Values –1 and 1 represent, respectively, full negative and full positive causality, zero denotes no causal effects and all other values correspond to different fuzzy levels of causal effects. In general, an FCM is described by a connection matrix E whose elements are the connection strengths (or weights) e_{ij}. The element in the i^{th} row and j^{th} column of matrix E represents the connection strength of the link directed out of node C_i and into C_j . If the value of this link takes on discrete values in the set {-1, 0, 1}, it is called a simple FCM. The concept values of nodes C_1, C_2, …, C_n (where n is the number of concepts in the problem domain) together represent the state vector **C**.

An FCM state vector at any point in time gives a snapshot of events (concepts) in the scenario being modelled. In the example FCM shown in Figure 2, node C_2 relates to the 2^{nd} component of the state vector and the state [0 1 0 0 0 0 0] indicates the event "migration into city" has happened. To let the system evolve, the state vector **C** is passed repeatedly through the FCM connection matrix **E**. This involves multiplying **C** by **E**, and then transforming the result as follows:

$$C(k + 1) = T[C(k) . E]$$

where C(k) is the state vector of concepts at some discrete time k, T is the thresholding or nonlinear transformation function, and **E** is the FCM connection matrix.

With a thresholding transformation function, the FCM reaches either one of two states after a number of passes. It settles down to a fixed pattern of node values - the so-called *hidden pattern* or *fixed-point attractor*. Alternatively, it keeps cycling between a number of fixed states - known as the limit cycle. With a continuous transformation function, a third possibility known as the *chaotic attractor* (Elert, 1999) exists, when instead of stabilising, the FCM continues to produce different state vector values for each cycle.

Extensions of FCMs

A number of researchers have developed extended versions of the FCM model described above. Tsadiras (2003) and Jetter et al. (2014) describe the extended FCM, in which concepts are augmented with memory capabilities and decay mechanisms. The new activation level of a node depends not only on the sum of the weighted influences of other nodes but also on the current activation of the node itself. A decay factor in the interval [0,1] causes a fraction of the current activation to be subtracted from itself at each time step.

Park (1995) introduces the FTCM (Fuzzy Time Cognitive Map), which allows a time delay before a node x_i has an effect on node x_j connected to it through a causal link. The time lags can be expressed in fuzzy relative terms such as "immediate", "normal" and "long" by a domain expert. These terms can be assigned numerical values such as 1, 2, 3. If the time lag on a causal link e_{ij} is m ($1 \geq m$) delay units, then m – 1 dummy nodes are introduced between node *i* and node *j*.

Decision-makers often find it difficult to cope with significant real-world systems. These systems are usually characterised by a number of concepts or facts interrelated in complex ways. They are often dynamic ie, they evolve through a series of interactions among related concepts. Feedback plays a prominent role among them by propagating causal influences in complicated pathways. Formulating a quantitative mathematical model for such a system may be difficult or impossible due to lack of numerical data, its unstructured nature, and dependence on imprecise verbal expressions. FCMs provide a formal tool for representing and analysing such systems with the goal of aiding decision making.

Given an FCM's edge matrix and an input stimulus in the form of a state vector, each of the three possible outcomes mentioned above can provide an answer to a causal "what if" question. The inference mechanism of FCMs works as follows. The node activation values representing different concepts in a problem domain are set based on the current state. The FCM nodes are then allowed to interact (implemented through the repeated matrix multiplication mentioned above). This interaction continues until:

(1) The FCM stabilises to a fixed state (the fixed-point attractor), in which some of the concepts are 'on' and others are not.
(2) A limit cycle is reached.
(3) The FCM moves into a chaotic attractor state instead of stabilising as in (1) and (2) above.

The usefulness of the three different types of outcomes depends on the user's objectives. A fixed-point attractor can provide straightforward answers to causal "what if" questions. The equilibrium state can be used to predict the future state of the system being modelled by the FCM for a particular initial state. As an example based on figure 2, the state vector [0 1 0 0 0 0], provided as a stimulus to the FCM, may cause it to equilibrate to the fixed-point attractor at [0 0 0 1 0 0 0]. Such an equilibrium state would indicate that an increase in "migration into city" eventually leads to the increase of "garbage per area".

A limit cycle provides the user with a deterministic behaviour of the real-life situation being modelled. It allows the prediction of a cycle of events that the system will find itself in, given an initial state and a causal link (edge) matrix. For FCMs with continuous transformation function and concept values, a resulting chaotic attractor can assist in simulation by feeding the simulation environment with endless sets of events so that a realistic effect can be obtained.

Development of FCMs for Decision Modelling

FCMs can be based on textual descriptions given by an expert on a problem scenario or on interviews with the expert. The steps followed are:

Step 1: Identification of key concepts/issues/factors influencing the problem.
Step 2: Identification of causal relationships among these concepts/issues/factors.

Experts give qualitative estimates of the strengths associated with edges linking nodes. These estimates are translated into numeric values in the range –1 to 1. For example, if an increase in the value of concept A causes concept B to increase significantly (a strong positive influence), a value of 0.8 may be associated with the causal link leading from A to B. Experts themselves may be asked to assign these numerical values. The outcome of this exercise is a diagrammatic representation of the FCM, which is converted into the corresponding edge matrix.

Learning in FCMs

FCM learning involves updating the strengths of causal links. Combining multiple FCMs is the simplest form of learning. An alternative learning strategy is to improve the FCM by fine-tuning its initial causal link or edge strengths through training similar to that in artificial neural networks. Both these approaches are outlined below.

Multiple FCMs constructed by different experts can be combined to form a new FCM. FCM combination can provide the following advantages:

1. It allows the expansion of an FCM by incorporating new knowledge embodied in other FCMs.
2. It facilitates the construction of a relatively bias-free FCM by merging different FCMs representing belief systems of a number of experts in the same problem domain.

The procedures for combining FCM are outlined in (Kosko, 1988). Generally, combination of FCMs involves summing the matrices that represent the different FCMs. The matrices are augmented to ensure conformity in addition. Each FCM drawn by different experts may be assigned a credibility weight. The combined FCM is given by:

$$E = \sum_{k=1}^{k=N} W_k E_k$$

where E is the edge matrix of the new combined FCM, Ek is the edge matrix of FCM k, Wk is the credibility weight assigned to FCM k, and N is the number of FCMs to be combined. Siegel and Taber

(1987) outlines procedures for credibility weights assignment in FCMs.

McNeill and Thro (1994) discuss the training of FCMs for prediction. A list of state vectors is supplied as historical data. An initial FCM is constructed with arbitrary weight values. It is then trained to make predictions of future average value in a stock market using historical stock data. The FCM runs through the historical data set one state at a time. For each input state, the ‘error’ is determined by comparing the FCM's output with the expected output provided in the historical data. Weights are adjusted when error is identified. The data set is cycled until the error has been reduced sufficiently for no more changes in weights to occur.

If a correlated change between two concepts is observed, then a causal relation between the two is likely and the strength of this relationship should depend on the rate of the correlated change. This proposition forms the basis of the Differential Hebbian Learning (DHL). Kosko (1992) discusses the use of DHL as a form of unsupervised learning for FCMs. DHL can simplify the construction of FCMs by allowing the expert to enter approximate values (or even just the signs) for causal link strengths. DHL can then be used to encode some training data to improve the FCM’s representation of the problem domain and consequently its performance.

Business Models as Cognitive Maps

Drawing on the insights of the cognitive mapping approach in strategic management, we argue that the causal structures embedded in business models can be usefully conceptualized and represented as cognitive maps (Furnari S., 2015). From this perspective, a business model’s cognitive map is a graphical representation of an entrepreneur or top manager’s beliefs about the causal relationships inherent in that business model (Furnari S., 2015). By emphasizing the causal nature of business models, this definition is consistent with previous studies viewing business models as sets of choices and the consequences of those choices (e.g. Casadesus-Masanell & Ricart, 2010), and with studies that explicitly highlight the importance of cause-effect relationships in business models’ cognitive representations (e.g. Baden-Fuller & Haefliger, 2013; Baden-Fuller & Mangematin, 2013). Business models’ cognitive maps can be derived from the texts that entrepreneurs and top managers use in designing their business models, or to pitch their projects to various audiences (including investors, customers, policy makers); or they can be derived from primary interviews with entrepreneurs and top managers (Furnari S., 2015). Thus, the content of a business model’s cognitive map can be idiosyncratic, depending on the particular individual’s cognitive schemas and on the language they use. The raw concepts that entrepreneurs and top managers use in their causal statements identify the elements of a business model’s cognitive map that are induced empirically (Furnari S., 2015). At the same time, such maps may include elements deduced theoretically from extant theories about business models - i.e. the conceptual categories developed in such theories (such as “value proposition”, “monetization mechanisms”) - that can be useful to classify the raw concepts used by entrepreneurs and top managers, providing a basis for comparing different individuals’ cognitive maps Thus, business models’ cognitive maps include both inductive and deductive elements, as do other types of cognitive maps (e.g. Axelrod, 1976; Bryson et al., 2004)

For the sake of illustrating examples of business models’ cognitive maps, we focus particularly on the business model representation developed by Baden-Fuller and Mangematin (2013), (Furnari S., 2015). Among the several business model representations suggested in the literature, we adopt this typological representation because it strikes a balance between parsimony and generality, thus meeting the criteria typically recommended for solid theory-based typologies (e.g. Doty & Glick, 1994; Delbridge & Fiss, 2013). Specifically, this typology includes the essential building blocks of the business model as covered by other business model representations, thus having a general scope in terms of content. At the same time, it uses a more parsimonious set of categories than other business model representations in covering this general scope. For this reason, in the cognitive maps’ illustrations provided below, we used the four constructs characterizing this business model representation (“customer identification”, “customer engagement (or value proposition)”, “value chain” and “monetization”) as organizing categories (Furnari S., 2015). Although we use this specific business model representation here for illustrating business models’ cognitive maps, the cognitive mapping approach developed in this paper can be used, more generally, with any other business model representation, depending on the analyst’s preferences and research objectives (Furnari S., 2015).

3 CONCLUSIONS

In this study we have attempted to present and analyse some important analytical management techniques that are of value especially for SME, but through extensions, under research, to larger scale enterprises too. We have argued through examples relevant to Business Process Modelling that in order for these techniques to be widely utilized by enterprises a common well defined framework should be established based on BPM. BPM could provide the representation schemes that should be integrated in the associated formalisms. To this end, our presentation is a first step. Each analytical management technique herein presented should be analysed in depth in order to be integrated with BPM methodology in a common useful and well organized application framework that in the sequel could be employed in real world scenarios, managing even big data of the associated enterprises.

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Extending BPMN 2.0 With the Knowledge Dimension

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Abstract: This paper introduces BPMN4KM, an extension of the most suitable business process modeling formalism BPMN 2.0 for modeling knowledge dimension in Sensitive Business Processes (SBPs). The extension is designed methodically by application of the extension mechanisms of BPMN 2.0. We aim at incorporating relevant issues at the intersection of Knowledge Management (KM) and Business Process Modeling (BPM) in order to enrich the graphical representation of SBPs and improve the localization and identification of crucial knowledge mobilized and created by these processes.

1 INTRODUCTION

Sensitive Business Process (SBP) modeling has become primary concern for any successful organization to improve the management of their individual and collective knowledge. A SBP is characterized by a high number of critical activities with intensive acquisition, sharing, storage and (re)use of very specific knowledge «crucial knowledge», high degree of internal/tacit knowledge created and exchanged among experts (who carry out actions with high levels of expertise, creativity and innovation), diversity of information and knowledge sources, high dynamic conversion of knowledge and high degree of collaboration and interactions (intra/inter-organizational) between a wide range of agents/experts. Moreover, it is typically an unstructured or semi-structured BP, encompasses a highly dynamic complexity.

In order to enrich and improve the SBP modeling, we have proposed, in previous work, a conceptual specification of SBP organized in new multi-perspective meta-model, entitled «BPM4KI: Business Process Meta-Model for Knowledge Identification» (Ben Hassen et al., 2017b; Ben Hassen et al., 2017c). BPM4KI explicitly organizes the key concepts and relationships that characterize a SBP. It integrates all relevant perspectives/ dimensions relating to BPM-KM, i.e. the functional, the organizational, the behavioral, the informational, the intentional and the knowledge perspectives. In this research work, we focus more on the «Knowledge Dimension» which is not yet explicited, fully supported and integrated within BPs models and BPM approaches and formalisms.

However, while importance of knowledge dimension is well recognized, there is no clear theoretical background and successful practical experiments of inclusion and implementation of this dimension in BP/SBP models. In such languages as IDEF0, IDEF3, GRAPES BM in GRADE tool , EPC diagrams in ARIS tool (ARIS Expert Paper, 2007), UML 2.0 Activity Diagram (OMG, 2011) and BPMN 2.0 (OMG, 2013), data, information and material flows are often represented in BP models by the same symbols/artifacts and without any unambiguous definitions of the concepts. At the same time knowledge has poor or no modeling capabilities in these formalisms. On the other hand, knowledge modeling languages (KMDL (Gronau et al., 2005; Arbeitsbericht, 2009), GPO-WM (Heisig, 2006), PROMOTE (Woitsch and Karagiannis, 2005) and NKIP (Netto et al., 2013)) have shortcomings concerning their ability to explicitly and fully include the knowledge dimension within BPs models as well as relevant issues at the intersection of KM and BPM. They have limited process perspective representation, i.e. they do not address process logic to full extent and thus there is no possibility to represent data and information. To address this research gap, we propose to extend one of the best known modeling formalism, the Business Process Modeling Notation (BPMN) (OMG, 2013), with the knowledge dimension in order to explicitly incorporate all relevant aspects related to KM within BPs models, and on the other hand, to enrich the graphical representation of SBPs and improve the localization and identification of crucial knowledge mobilized and created by these processes. In fact, BPMN 2.0 was selected as the most suitable BPM notations for SBP representation, because addresses the highest representation coverage of the set of BPM4KI concepts and incorporates requirements for SBP modeling better than other formalisms (Ben Hassen et al., 2016a; Ben Hassen et al., 2017a). Nevertheless, the main weaknesses identified in this specification regards the knowledge dimension modeling.

The present work presents BPMN4KM: a BPMN 2.0 extension, including all relevant aspects related to knowledge dimension in SBP modeling. The proposed extension is developed using the extensibility mechanisms of BPMN (OMG, 2013).

The rest of the paper is structured as follows: Section 2 presents BPMN 2.0 and related works relevant to the research problem. Section 3 presents the central concepts that describe the knowledge dimension of SBP modeling. Section 4 presents the proposed approach for extending BPMN 2.0 with the knowledge dimension. Section 5 concludes the paper and underlines some future research topics.

2 BACKGROUND AND RELATED WORK

This section presents background research: section 2.1 describes BPMN as one of the most suitable BPM notations; section 2.2 briefly present related works relevant to the research problem.

2.1 BPMN 2.0

BPMN 2.0.2 stands for Business Process Model and Notation (OMG, 2013). It is a graphical representation for specifying BPs in a BP model, and a standard for BP modeling notations. BPMN is initiated as a standard BPM language for conventional business, B2B and services process modeling. It can be used within many methodologies and for many purposes, from high-level descriptive modeling to detailed modeling intended for process execution providing a standardized bridge for the gap between BP design and its implementation. BPMN considers notational elements grouped in five basic categories (Flow Objects, Data, Connecting Objects, Swimlanes and Artifacts). Besides, it has the capabilities of handling B2B BP concepts, such as public, private, collaboration processes and choreographies, as well as advanced modeling concepts, such as exception handling and transaction compensation in addition to the traditional BP.

Several surveys have evaluated the adequacy of BPMN for BPM. From our point of view, BPMN has six main advantages (Ben Hassen et al., 2017):

- It is the BPM standard backed up by OMG, which is based upon a meta-model (OMG, 2013) built with UML, the notation which is the de facto standard for modeling software engineering artifacts (OMG, 2007).
- It is very simple, easy to use, readily understandable and accessible by all business stakeholders.
- BPMN is one of the most recent and expressive BPM notations, grounded on the experience of earlier BPM formalisms, which ontologically makes it one of the most complete BPM formalisms (Recker et al., 2009).
- It is appropriate for modeling collaborative BPs actors that display complex flows with high degree of interactions among process' actors and high degree of information exchanged, developed and shared among participants.
- It is currently the BP notation most used among process modeling practitioners, with more BPM tools support available.
- BPMN is extensible. BPMN 2.0 defines an extensibility mechanism for both process model extensions and graphical extensions.
- Finally, BPMN 2.0 presents the broadest coverage of the set of BPM4KI meta-model concepts (except the knowledge dimension) (Ben Hassen et al., 2017a).

Based in the previous assessments, BPMN 2.0 is taken as a basis for the representation of SBP models**.**

2.2 BPMN 2.0 Shortcomings

BPMN stresses the process view representation, offering a number of symbols for modeling various decision points, process, activity and event types. BPMN constructs emphasize mainly the support of the control-flow and data perspective when expressing processes' orchestration and collaboration. As other BPM formalisms, BPMN constructs have a shallow coverage of informational, organizational and intentional aspects of BPM. Moreover, BPMN focuses entirely on the functional and behavioral aspects of the BP model.

Nevertheless, the main weaknesses identified in this specification regards the knowledge dimension modeling which represents the core and relevant dimension in SBP models (exploring the collaboration and interaction aspects). Currently, from the point of view of various ways how knowledge (including data and information) are used in organizations, the following issues are not yet fully supported in BPMN 2.0 (neither in any of the above-mentioned BPM and knowledge modeling formalisms):

- Opportunity to clearly distinguish between data, information and knowledge in the representation of flows between SBP activities. The information and data exchange constitutes the basis for knowledge dissemination and generation. Note that, BPMN provides opportunity to model only information and data flow using the same symbols/artifacts and without any unambiguous definitions of the concepts.
- Opportunity to identify the different owners/ sources of knowledge involved in the BP activities and location where knowledge can be obtained and can be clearly stated.
- Opportunity to consider the roles of humans in BP activities, be it as humans (single persons), teams, or communities of practice who bears the internal/tacit knowledge.
- Opportunity to integrate and separate the different types /kinds of knowledge (tacit/explicit dimension, internal/external dimension, factual/procedural dimension, individual/collective dimension, etc.).
- Opportunity to integrate and separate the different nature of knowledge (like experience, basic knowledge, scientific/ technical knowledge, general knowledge, etc.).
- Possibility to illustrate knowledge flows between sources and among activities.
- Possibility to represent the dynamic of acquisition, preservation, transfer, sharing, development, and (re) use of individual and organizational knowledge within and between BPs activities.
- Ability to specify more than two opportunities of knowledge conversions (between knowledge types) taking place in single SBP activity.
- Opportunity to enable modeling the critical/knowledge intensity dimensions of organizational activities which are important to determine the crucial knowledge mobilized and created by these activities.
- Opportunity to accurately represent collaborative aspects and specify how do interactions occur (information and knowledge exchange) in SBPs. These aspects are useful to characterize the SBPs, due to, for instance, the high degree of knowledge exchanged and developed and shared among agents through intra/inter-organizational collaboration, and its dynamic nature. In fact, BPMN 2.0 provides a specific choreography model which allows to concentrate only on conversation between performers. However, this model does not show how performer's knowledge changes during the conversation and communication.

To sum up, BPMN 2.0 diagrams are not adequate for the new SBP modeling requirements. So, to overcoming the discussed shortcomings, BPMN 2.0 will be adapted and extended to be convenient for a rich and expressive representation of SBPs, including all or at least most of the relevant issues at the intersection of KM and BPM.

2.3 Related Work

The integration of KM into BPs has rapidly become the most promising practical and theoretical task in KM. In this context, there have been several attempts to integrate the knowledge concept/dimension in BP models as well as in BPM and knowledge modeling formalisms, e.g, (Gronau et al., 2005; Woitsch et al.,2005; Weidong et al., 2008; Supulniece et al., 2010; Businska et al., 2011; Sulanow et al., 2012; Liu et al., 2012; Ammann et al., 2010; Ammann et al., 2011; Ammann et al., 2012; Netto et al., 2013; França et al., 2015; Gronau et al., 2016).

However, none of the proposed knowledge oriented BPM approaches and formalisms adequately and fully support and represent all relevant aspects of knowledge dimension within BPs models (e.g., differentiation between tacit and explicit knowledge, the different types of knowledge conversion, the dynamic aspects of knowledge, the different sources of knowledge, etc.). At the same time, BPM is challenging - these notations are weak in representing logic/ control flow of the BP and the process perspectives as a whole (i.e., the structural, behavioral, organizational and informational dimensions).

Besides, while importance of knowledge dimension is well recognized, there is no clear theoretical background and successful practical experiments of inclusion of this dimension in the well-known BPM standard. In particular, there are only a few initiatives in the BPM-KM area, which use the BPMN as core formalism and systematically enhance its capabilities and extend it by KM specific aspects (Ammann et al. 2008, Ammann et al. 2012; Ben Hassen et al., 2016). Ammann et al. (2008) defined an extension of BPMN 1.1 (OMG, 2008) for knowledge-related BPM, called BPMN-KEC (KEC stands for knowledge, employees, and communities). In this work different objects were used: objects for knowledge and information, for knowledge conversions, for associations and for persons. Nevertheless, the proposal has not the necessary expressivity and features to represent the relevant SBP elements, including the knowledge aspect. Another work by Supulniece et al. (2010), proposed an extension of BPMN which roots in concepts implemented in knowledge-oriented modeling language (KMDL) (such as an information object, knowledge object, type of knowledge conversion) (Gronau et al., 2005) with few additions and changes in graphical representation. However, experiments with the integrated notation revealed that the relationship between the phenomena behind the symbols is somewhat unclear in the BPM. Moreover, the relevant aspects of knowledge dimension do not fully supported and represented (like the different types of knowledge mobilized and created by each BP activity, the knowledge flow, the different sources/supports of knowledge, etc.).

To date, to the best of our knowledge, there is a lack of works providing systematic approaches for the development of extensions to the BPMN 2.0 meta-model to consider the knowledge aspect in BPM. However, there are previous works providing approaches to extend BPMN 2.0 (OMG, 2011) to represent their domain specific requirements. Some interesting extension proposals are presented in (Charfi et al., 2011; Stroppi et al., 2011; Baumgrass et al., 2014; Martinho et al., 2015; Jankovic et al., 2015 Braun et al., 2015). The differences between the different research works unveil the need for a unified method for the conceptual modeling of extensions and their representation in terms of the BPMN extension mechanism.

In this paper, we aim to solve the discussed shortcomings and address the gap between BPM and KM. Precisely, this research work presents a rigorous scientific approach to extend BPMN 2.0 for KM. This extension must consider and incorporate all relevant aspects of SBP modeling, including the knowledge dimension, in order to allow a rich and expressive representation of SBPs and improve the localization and identification of crucial knowledge mobilized and created by these processes.

3 MODELING SBPs: THE BPM4KI META-MODEL

This section first introduces the notion of SBP and then present an extract of BPM4KI, a BP independent generic meta-model common to current BPM formalisms which ensures the best suitability to model SBP.

3.1 Notion of SBP

According to Ben Hassen et al., (2016b; 2017a), a Sensitive Business Process is a BP which comprises a high number of critical organizational activities (individual/collective) with intensive acquisition, sharing, storage and (re)use of very specific knowledge « crucial knowledge». It mobilizes a large diversity of information and knowledge sources, consigning a great amount of heterogeneous knowledge. Moreover, an SBP requires a high dynamic conversion of knowledge and a high degree of collaboration and interaction (intra/inter-organizational) among participants. Its execution involves many external agents and the assistance of many experts, who apply, create and share a great amount of very important tacit organizational knowledge, in order to achieve collective objectives and create value. In addition, SBP are typically an unstructured or semi-structured organizational actions, requires substantial flexibility, encompassing a highly dynamic complexity. Due to those characteristics, modeling and organizing the knowledge involved in SBP is relatively critical.

3.2 BPM4KI: A BP Meta-Model for Knowledge Identification

In order to enrich and improve the SBP modeling, we proposed a semantically rich conceptualization for specifying a SBP organized in a new generic multi-perspective meta-model of BP representation, the Business Process Meta-Model for Knowledge Identification (BPM4KI). The enriched meta-model serves two purposes: (i) to deepen the elements and dimensions defining a SBP, by offering a coherent conceptual specification for this BP type, and (ii) to develop a rich and expressive graphical representation of SBPs to improve the localization and identification of crucial knowledge mobilized and created by these processes. The current version of BPM4KI offers a referential of generic concepts and relationships relevant to the BPM-KM domain semantically rich and well-based on «core» domain

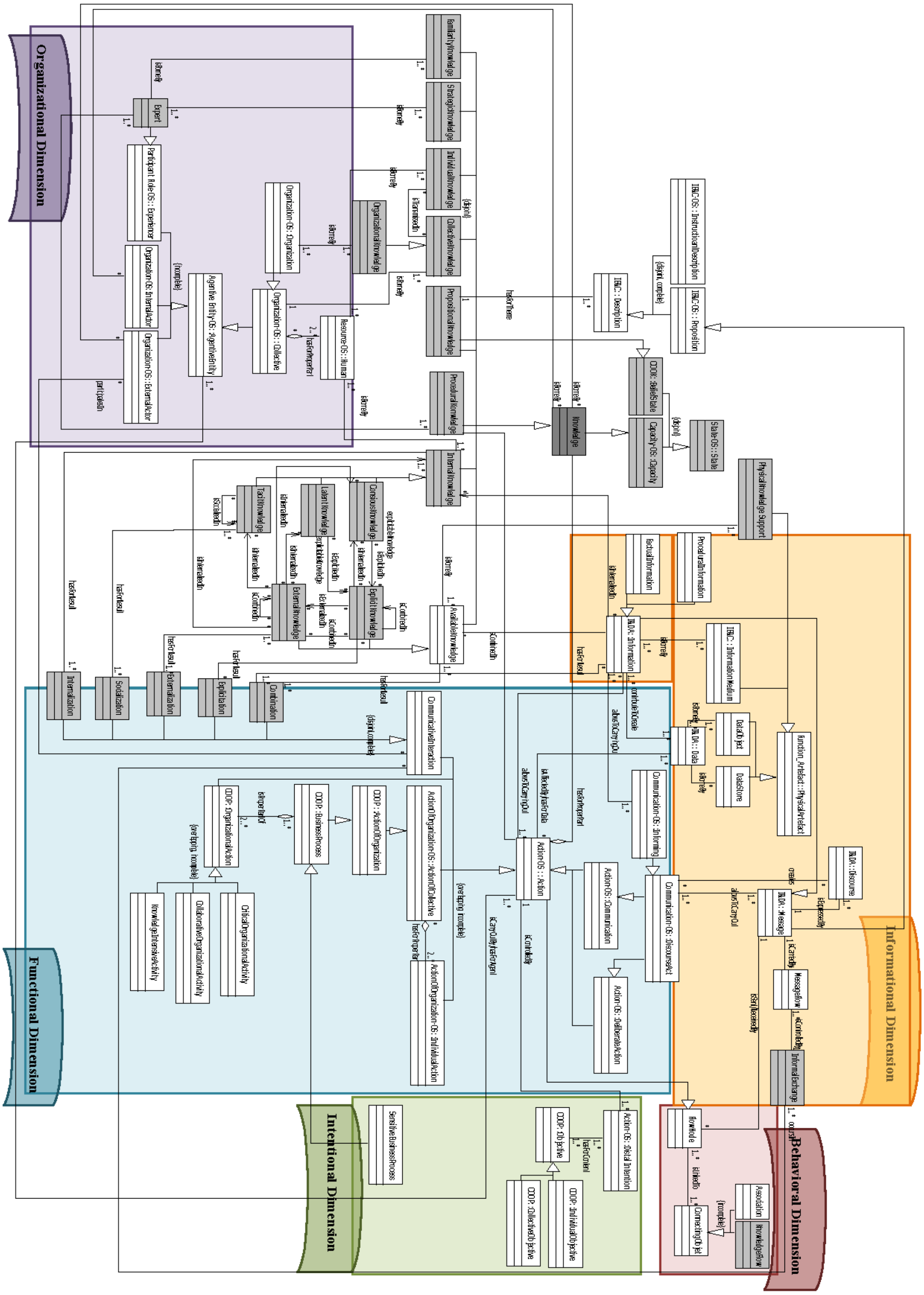

Figure 1: An extract of BPM4KI meta-model: conceptual ontology design pattern relating to the knowledge perspective/dimension of SBP modeling (with inter-aspects relationships).

ontologies (Kassel, 2005; Gangemi, 2006; Kassel, 2010; Kassel et l., 2012; Turki et al., 2016), which are based on top of the DOLCE foundational ontology (Masolo et al., 2004). BPM4KI were categorized in six perspectives (or dimensions), namely, the functional, the organizational, the behavioral, the informational, the intentional and the knowledge perspectives. The different dimensions are crucial for a complete understanding, characterization and representation of an SBP (Ben Hassen et al., 2016b; 2017b; 2017c).

The different aspects are required to characterize the SBPs, due to the high degree of knowledge exchanged and developed and shared among agents through intra/inter-organizational collaboration and to the frequent process evolution along time. We point out that the knowledge dimension (supporting the new SBP modeling requirements) is not yet, however, not yet explicited, fully supported and integrated within BPs models and BPM formalisms (Ben Hassen et al., 2016b; 2017c). So, we aim at obtaining new knowledge helpful for developing BPM formalisms that could adequately support above-mentioned issues in BP/SBP modeling.

The «Knowledge Perspective» is modeled as an Ontological Design Patterns (ODP) (Gangemi et al., 2006) represented as a UML class diagram. The Knowledge ODP is based on the reuse and the specification of central generic concepts (and the relationships between them) defined in different ontological modules of the global and consistent ontology OntoSpec (Kassel, 2005; 2010): *Action-OS*, *Action of Organization-OS*, *COOP*, *Partcipation-role-OS*, *Agentive Entity-OS*, *Organization-OS*, *Function & Artefact-OS*, *Capacity-OS*, *Artefact-OS*, *Resource-OS*, *Communication-OS*, *I&DA-OS (Information and Discourse Acts)*, *IE&C-OS (Inscription, Expression and Conceptualization)* and *Action Model-OS*. These ontological modules are available online (http://home.mis.u-picardie.fr/~site-ic/site/spip.php?article53), which are sufficient, on the one hand, to broaden and deepen the knowledge dimension elements, and on the other hand, to characterize the useful concepts for a rigorous specification and an enriched modeling of SBPs. Figure 1 organizes and explicit the central concepts of the knowledge perspective of BPM4KI (marked in gray), in addition to inter-aspects relationships, giving a view of all relevant aspects of the BPM4KI meta-model as a whole.

In this research work, we focus more on the description and analysis of the knowledge dimension which represents the most relevant aspects of SBP modeling, exploring the KM aspect, the collaboration and interaction and all relevant SBP elements (such as individual and collective dimension of activities; critical activities mobilizing crucial knowledge; knowledge intensive activities; dynamic aspects; collaboration and interaction among agents contributing to knowledge creation and sharing;

According to Ben Hassen et al. (2016b), a Knowledge is the `Capacity` (or disposition) to perform (and affects) a type of `Action` aiming to achieve an `Objective`. It `isBorneBy` an `Agentive Entity` (as `Human`, `Collective`, `Expert` or `Organization`). There are several typologies of knowledge according to different dimensions (Ben Hassen et al.. 2016b). For example, `Knowledge` is divided into `Internal Knowledge`, `Explicit Knowledge` and `External Knowledge` according to the *source of knowledge* dimension. Besides, `Knowledge` may be either `Propositional Knowledge` or `Procedural Knowledge` according to the *nature of knowledge* dimension; `Strategic Knowledge` and `Familiarity Knowledge` according to the *organizational value of knowledge* dimension. Moreover, knowledge can be divided into `Individual Knowledge` and `Collective Knowledge` according to the *organizational coverage of knowledge* dimension. With respect to the limited space of this paper, a comprehensive description of the different concepts present in this meta-model is detailed in (Ben Hassen et al., 2016 b, Ben Hassen et al., 2017b; Ben Hassen et al., 2017c).

Furthermore, it is important that an appropriate BPM formalism provides explicit representation of the different issues related to the knowledge dimensions in BPM. In this context, the SBPs can be graphically represented, using the well-known standard for BPM, BPMN 2.0 (OMG, 2013), in order to localize and identify the knowledge that is mobilized and created by these processes. However, as BPMN does not support the knowledge concept, we have extended it. The following section explains our extension proposal for including the knowledge dimension in SBP modeling.

4 BPMN4KM: BPMN EXTENSION FOR MODELING THE KNOWLEDGE DIMENSION

At the root of the success of modeling, design, reengineering, and running BPs/SBPs is effective use and support of organizational knowledge. Knowledge must be considered as one of the BP dimensions, because knowledge is related to action, it is implemented in the action, and is essential to its development. Knowledge is used to perform a process, it is created as a result of process execution, and it is distributed among process participants. However, while importance of knowledge dimension is well recognized, there is no clear theoretical background and successful practical experiments of inclusion, support and implementation of this dimension in BP meta-models and BPM approaches/formalisms (Ben Hassen et al., 2017c). In this paper, we aim at obtaining new knowledge helpful for developing BPM formalisms that could handle all relevant aspects related to knowledge dimension (including data and information). Indeed, extending BP models with the knowledge dimension would provide the following benefits (Ben Hassen et al., 2017c):

- Possibility to relate different forms of knowledge, information and data to the BP model.
- Possibility to identify data, information and knowledge inputs and outputs in different types of organizational activities.
- Illustrating and separating the data, information and knowledge sources/owner that are required to perform BP activities and knowledge that are generated, created and/or modified as a results of activities.
- Enhance the localization of knowledge (where knowledge can be obtained and clearly stated), experts who hold the (internal) knowledge) as well as their characterization.
- Integration and distinction of different knowledge types/nature.
- Specifying the different opportunities of knowledge conversion between knowledge types (the dynamic sharing, dissemination, generation and use of existing knowledge).
- Possibility to represent knowledge flows between sources, and among activities which are about creation, organization, distribution and reuse of knowledge among BP participants.
- Giving an opportunity to improve understanding about the knowledge usefulness, validity, and relevance for particular activities (i.e. critical activities) in an SBP.
- Possibility to evaluate the amount of lost knowledge if a person-owner of knowledge-leaves the organization (to identify which tacit knowledge in which cases should be transformed into explicit knowledge).

According to the above-mentioned arguments knowledge and BPs are directly related and their integrated consideration is indispensable. In this section, we propose a BPM technique that supports an integrated consideration of BPs and knowledge. The proposed technique is an extension of BPMN 2.0.2 (OMG, 2013), where the standard notation is supplemented with knowledge modeling related concepts. Despite its expressiveness, BPMN 2.0 does not yet explicitly represent the key concepts of the Knowledge perspective (such as `Individual Tacit Knowledge`, `Collective Tacit Knowledge`, `Expert`, `Explicit Knowledge`, `External Knowledge`, `Socialization`, `Externalization`, `Internalization`, etc.). To overcoming the shortcomings of BPMN 2.0, some of its concepts must be adapted and extended to include all or at least most of the relevant SBP elements. In this context, BPMN 2.0 defines four standard extension mechanisms that are important for extending SBP model with knowledge dimension. We have introduced the main concepts of the knowledge dimension into BPMN with a some additions and changes in graphical representation.

4.1 The BPMN 2.0 Meta-Model

The BPMN formalism definition is based upon a meta-model (OMG, 2013), which describee the notation’s abstract syntax (by means of meta-classes, meta-associations and cardinality constraints). The BPMN meta-model includes elements from three diagrams, targeting the following different purposes: (i) for modeling processes’ orchestration and collaboration diagrams; (ii) to simplify the perspective of collaboration diagrams through conversation diagrams and (iii) for modeling participant’s interactions through the choreography perspective. In this paper, from the full meta-model that includes 151 meta-classes and 200 meta-associations, we only consider the subset of elements concerning the orchestration and collaboration diagrams.

Main Concepts of BPMN 2.0. Meta-Model. The OMG's BPMN meta-model (OMG, 2013) considers the four main dimensions of BPM:

The functional and behavioral dimensions of BPs support the description of BP activities and their synchronization along with events happening during process execution through the notions of `FlowElementContainer` (which can be either a *Process* or a `SubProcess`) is a container of instances of `FlowElement`. A flow element can be either a `FlowNode`, a `SequenceFlow` or a `DataObject`. A `SequenceFlow` is used to show the order of various kinds of `FlowNode` elements and the interactions between the participants. A `SequenceFlow` may refer to an `Expression` that acts as a gating condition. Instances of `SequenceFlow` can link various kinds of `FlowNode` elements. A `FlowNode` can be one of the several different kinds of `Activity`, `Event` or `Gateway`. A `Gateway` is used to control how `SequenceFlow` interact within a process. An `Event` is something that happens during the course of a process. It can correspond to a trigger, which means it reacts to something (`catchEvent`), or it can throw a result (`throwEvent`). An `Event` can be composed of one or more `EventDefinitions`. There are many types of `Event Definitions`: `ConditionalEventDefinition`, `Timer EventDefinition`, etc. An `Activity` is a work performed within a process. An `Activity` can be a `Task` (*i.e.* an atomic activity), a `Sub Process` (*i.e.* a non-atomic activity) or a `CallActivity`. A `Task` is used when the work is elementary (*i.e.* it cannot be more refined). BPMN2.0 identifies different types of tasks: `Service Task`, `User Task`, `Manual Task`, `Send Task` and `Receive Task`. The meta-class `Process` describes a sequence of instances of `Activity` carried out in an organization with some specific objectives. If a process interacts with other processes, it must participate in a `Collaboration`. The collaboration is a way of grouping several participants. Each `Participant` (aka Pool) must address only one process. Given the fact that a `Participant` is also an `InteractionNode`, it can send or receive several instances of `MessageFlow`.

Regarding the organizational dimension of processes, an activity is accomplished by a `ResourceRole`. A `ResourceRole` can refer to a `Resource`. A `Resource` can define a set of parameters called `ResourceParameters`. A `ResourceRole` can be a `Performer`, which can be a `HumanPerformer`, which can be in turn a `PotentialOwner`. Besides, the `LaneSets` (i.e. pools and lanes) allow grouping BPMN 2.0 model elements according to participants of the process, information systems, organization structure, etc.

Regarding the informational dimension of processes, an `ItemAwareElement` references element used to model the items (physical or information items) that are created, manipulated and used during a process execution. The `ItemAwareElement` is an abstract meta-class, from which derives several data related meta-classes representing transient (`DataObject`) or persistent (`DataStore`) data containers, as well as input or output data to/from `Activity` by means of meta-classes derived from `Data Association`. It includes `DataObject`, `Data Object Collection`, `DataObjectReference`, `Property`, `Data Store Artifact`, `Data Input` or `Data Output` (Collection). Moreover, the `Artefacts` (i.e. *Group* and *Annotation*) allow representing process data.

4.2 Mapping BPMN&BPM4KI Meta-Models: Analysis of BPMN Support for the Knowledge Dimension Concepts

As shown in Table 1 BPMN lacks support for several concepts of the knowledge aspect meta-model (the ODP relating to the knowledge perspective of SBP modeling). Therefore, to remedy for this lacks, we define an extension of the BPMN specification, called BPMN4KM, which introduces the knowledge dimension aspects and provides a rich and expressive representation of SBPs to identify and localize the crucial knowledge mobilized by these BPs.

In fact, we argue that an extension should widely make use of standard elements in order to exhaust the vocabulary of BPMN and reduce new elements to a minimum. Based on both the specific SBP domain concepts and requirements, the comparison with standard BPMN is conducted in order to identify a reasonable need for extension. According to the presented knowledge ODP (Section 3.2), each concept is examined regarding its semantically equivalence with standard elements. Therefore, the respective element descriptions, rules and explanations within the BPMN specification (OMG, 2013) were analyzed in-depth. This leads implicitly

Table 1: Analysis of the BPMN support for the knowledge dimension ODP/ meta-model (with relevant inter-aspects relationships) and derivation of concepts for the BPMN meta-model of the extension.

BPM4KI Concepts		Equivalence Check/BPMN Concept	Support Level	Extended BPMN Meta-model
Knowledge Perspective	Knowledge	- (No equivalence)	-	Extension Concept
	Internal Knowledge	-		Extension Concept
	Tacit Knowledge	-	-	Extension Concept
	Latent Knowledge	-	-	Extension Concept
	Conscious Knowledge	-	-	Extension Concept
	Explicit Knowledge	-	-	Extension Concept
	External Knowledge	-	-	Extension Concept
	Procedural Knowledge	-	-	Extension Concept
	Propositional Knowledge	-	-	Extension Concept
	Strategic Knowledge	-	-	Extension Concept
	Familiarity Knowledge	-	-	Extension Concept
	Individual Knowledge	-	-	Extension Concept
	Collective Knowledge	-	-	Extension Concept
	Organizational Knowledge	-	-	Extension Concept
	Physical Knowledge Support	-	-	Extension Concept
Behavioral Perspective	Message Flow	Equivalence → Message Flow	+	BPMN Concept
	Association	Equivalence → Association	+	BPMN Concept
Functional Perspective	Action Of Collective	Conditional equivalence [1]→ Process	+	Extension Concept
	Organizational Activity	Equivalence → Activity, Task, Sub Process	+	BPMN Concept
	Deliberate Action	Conditional equivalence → Activity	Partly	Extension Concept
	Discourse Act	Conditional equivalence → Activity, Task	Partly	Extension Concept
	Critical Organizational Activity	Conditional equivalence → Activity	Partly	Extension Concept
	Collaborative Organizational Activity	Conditional equivalence → Activity, Choreography Activity	Partly	Extension Concept
	Knowledge Intensive Activity	Conditional equivalence → Activity	Partly	Extension Concept
	Communicative Interaction	Conditional equivalence → Activity, Choreography, Collaboration, Conversation	-	Extension Concept
	Socialization	- (No equivalence)	-	Extension Concept
	Internalization	-	-	Extension Concept
	Explicitation	-	-	Extension Concept
	Externalization	-	-	Extension Concept
	Combination	-	-	Extension Concept
Organizational Perspective	Agentive Entity	Conditional equivalence → Resource Role/Performer, Participant (Partner/Role Entity)	Partly	Extension Concept
	Collective	Conditional equivalence → Resource Role/Performer, Participant	Partly	Extension Concept
	Organization	Conditional equivalence → Resource Role	Partly	Extension Concept
	Human	Equivalence → Resource Role, Human Performer	+	BPMN Concept
	Experiencer	Conditional equivalence → Human Performer, Potential Owner	Partly	Extension Concept
	Expert	- (No equivalence)	-	Extension Concept
Information Perspective	Information	- (No equivalence)	-	Extension Concept
	Information Medium		Partly	Extension Concept
	Physical Artefact	Conditional equivalence →Data Object	Partly	Extension Concept
	Data	- (No equivalence)	-	Extension Concept
	Discourse	-	-	Extension Concept
Intentional Perspective	Sensitive Business Process	Conditional equivalence → Process	Partly	Extension Concept
	Distal Intention	- (No equivalence)	-	Extension Concept
	Objective	-	-	Extension Concept

[1] Process only define the Action of Organization (Business Process) which is an Action of Collective performed by a group of individuals affiliated with the organization (Kassel et al., 2012). However, Process cannot be used to specify the actions that can be carried out collectively by the individuals making up the Collective.

to the derivation of the BPMN4KM meta-model and its stereotypes.

According to (Braun et al., 2015), the following rules are defined for the equivalence check

(correspondence between concepts of the knowledge perspective ODP/meta-model (extract of BPM4KI) and the BPMN mata-model):
- ***Equivalence***: There is a semantically equivalent construct in the BPMN in the sense of a permitted combination of elements or just a single element. In this case, no extension is necessary and the domain concept is represented as BPMN concept.
- ***Conditional equivalence***: There is no obvious semantic matching with standard elements, but rather situational discussion is necessary in order to provide arguments for a possible mapping or to explain why it is not feasible. This situation is caused by the partial under specification of BPMN elements (OMG, 2013). Consequently, the concept is either treated as equivalent concept or as non-equivalent concept.
- ***No equivalence***: There is no equivalence to any standard element for three reasons: First, the entire concept is missing. In this case, the domain concept is represented as Extension Concept in the BPMN4KM meta-model. Second, a relation between two concepts is missing. Therefore, an association between the affected concepts is constructed in the BPMN4KM meta-model. Third, properties of a concept are missing. Then, an owned property is assigned to the element in the extended model. Table 1 provides the conducted equivalence check and its implications for the extended BPMN meta-model. As result of the correspondence check, the concepts of the BPMN4KM meta-model are classified/characterized as *BPMN Concepts* (are those that match with some concept of the BPMN meta-model) or as *Extension Concepts* (are those defined in the domain of the extension).

The following section shows the developed BPMN meta-model extension using the BPMN 2.0 extensibility mechanisms.

4.3 The BPMN4KM Meta-Model

The BPMN meta-model (OMG, 2013) can be extended by integrating new domain-specific concepts to standard and predefined BPMN elements. This is supported by a standard extension mechanism consisting of four elements:

- `ExtensionDefinition`- specifies a named group of new attributes, that can be used by standard BPMN elements. Thus, both new concepts and new additional attributes can be defined (jointly added/attached to the original BPMN elements).
- `ExtensionAttributeDefinition`- defines new /particular attributes that can be specified for an `ExtensionDefinition` element.
- `ExtensionAttributeValue` - contains the value assigned to an extension attribute of a BPMN element.
- `Extension`- binds/imports the entire `ExtensionDefinition` element and its attributes to a BPMN model definition in order to make them technically accessible.

Figure 2 presents the Class Diagram of BPMN extension. By associating a BPMN element with an `ExtensionDefinition`, every BPMN element which subclasses the BPMN `BaseElement` can be extended with additional attributes. Therefore, BPMN 2.0 with their different extension mechanisms appear to provide the most complete coverage of the concepts and constructs needed for analyzing and modeling most of the SBP characteristics.

Despite the fact that BPMN offers a well-defined extension interface, only very few BPMN extensions make use of it (Braun et al., 2014), what hampers comprehensibility, comparability between developed extensions and impedes the straightforward integration of extensions in modeling tools. We suppose, that the missing procedure model for extension building in BPMN causes this lack of rigor.

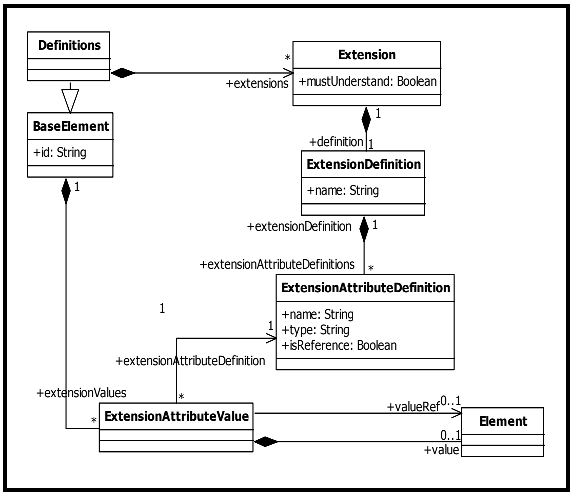

Figure 2: BPMN extension class diagram.

Based on the model transformation rules stated in Stroppi et al. (2011), we define the BPMN4KM extension model (BPMN+X model). Figure 3 below presents the resulting extended BPMN meta-model. In this figure only the relevant standard BPMN classes are shown in white. The BPMN4KM concepts are shown in grey. We associate

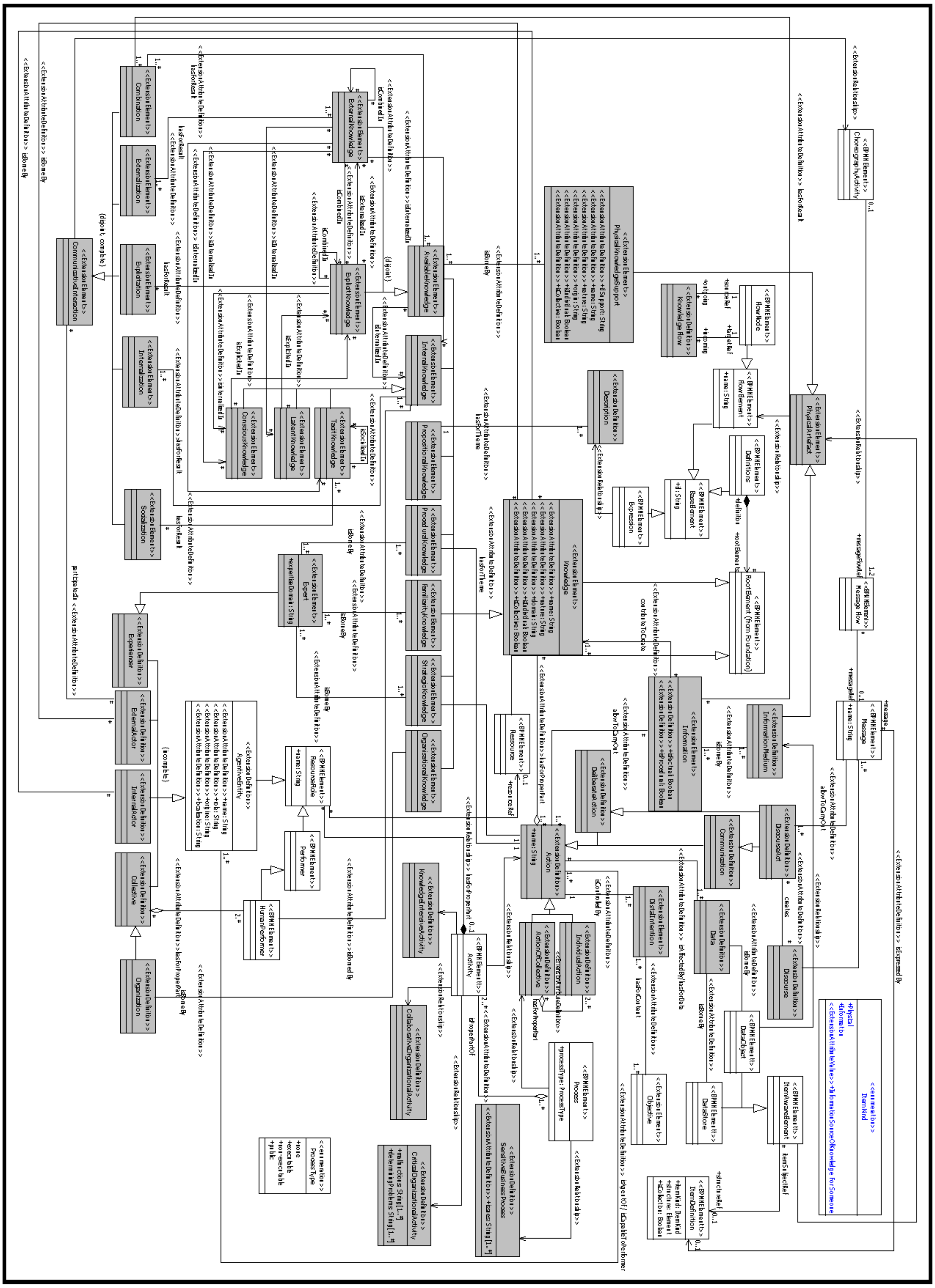

Figure 3: Abstract syntax of the BPMN4KM extension.

Knowledge concept with the RootElement of the BPMN specification. The semantics and the abstract syntax of the BPMN4KM elements are based on the specification of the BPMN extension mechanism (OMG, 2013). *BPMNElement* allows representing an original element of the BPMN meta-model. *ExtensionElement* allows representing a new element in the extension model which is not defined in the BPMN meta-model (such as Knowledge, InternalKnowledge, TacitKnowledge, ExplicitKnowledge, ProceduralKnowledge,ExternalKnowlede , PhysicalKnowledgeSupport, Information, DistalIntention, Combination, Socialization, Internalization, Externalization and Explicitation). *ExtensionDefinition* allows specifying a named group of attributes which are jointly added to the original BPMN elements (such as KnowledgeFlow, Experiencer, Collective, Information Medium, KnowledgeIntensiveActivity, CriticalOrganizationalActivity, CollaborativeOrganizationalActivity, and Sensitive Business Process). *ExtensionDefinition* has the same meaning than the ExtensionDefinition element of the BPMN metamodel. The semantics defined by the *ExtensionAttributeDefinition* element of the BPMN meta-model is captured by the *Property* metaclass of the UML metamodel. Thus, *ExtensionAttributeDefinition* is represented in BPMN4KM models by UML properties, either owned by the ExtensionDefinition elements or navigable from them through associations. The properties of *ExtensionDefinition* and *ExtensionElement* elements can be typed as a *BPMNElement*, *ExtensionElement*, *BPMNEnum*, *ExtensionEnum* or UML primitive type.

Finally, *ExtensionRelationship* specifies a conceptual link between a *BPMNElement* and a *ExtensionDefinition* element aimed to extend it. The BPMN extension mechanism cannot express the BPMN element to be extended by an extension definition. Thus, the definition of an *ExtensionRelationship* does not produce any effect in the resulting BPMN extension. *ExtensionRelationship* is provided to help conceptualizing extensions since extensions are generally defined to customize certain elements of the BPMN meta-model.

With respect to the limited space of this paper, the application of each applied transformation rule cannot be presented.

5 CONCLUSION AND FUTURE WORK

This research work presents BPMN4KM: a BPMN extension to explicitly represent, integrate and implement the knowledge dimension in BP/SBP models. It allows a rich and expressive representation of SBPs in order to improve the localization and identification of crucial knowledge mobilized and created by these processes. The proposed approach extension is developed using the extensibility mechanisms of BPMN.

Our current research activities focus on achieving the implementation of the proposed extension according to BPMN4KM meta-model.

As further work, we will validate the BPMN4KM meta-model by instantiating it in depth (using extended BPMN) with real medical care processes in the context of the Association of Protection of the Motor-disabled of Sfax-Tunisia (ASHMS) (Ben Hassen et al., 2017a), in order to verify the completeness of the proposed concepts.

Another issue we will address with BPM4KI and BPMN4KM is to propose a solution to model and specify SBPs integrating relevant aspects related to all BPM4KI dimensions. The general framework we will propose for supporting SBP representation advocates a model driven engineering approach considering at the CIM level, a specific meta-model, the BPM4KI meta-model for modeling SBPs, and at the PIM level, an extension of BPMN (BPMN4SBP meta-model). We aim at automatically generating SBP models to enhance the knowledge identification.

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The Strategy Blueprint
A Strategy Process Computer-Aided Design Tool

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Abstract: Strategy has always been a main concern of organizations because it dictates their direction, and therefore determines their success. Thus, organizations need to have adequate support to guide them through their strategy formulation process. The goal of this research is to develop a computer-based tool, known as 'the Strategy Blueprint', consisting of a combination of nine strategy techniques, which can help organizations define the most suitable strategy, based on the internal and external factors that influence their business. The research methodology we adopted is design science. To visualize the Strategy Blueprint tool, we use a spreadsheet-based implementation. Our first evaluation of the tool in real-life settings indicates that the tool is both useful and easy to use.

1 INTRODUCTION

Nowadays, organizations are faced with continuous and fast-paced changes in their environments, which in turn requires them to provide quick responses. To adapt to these changes, organizations need to design and implement planned change at a faster rate (Burke, 2013). However, this can prove to be quite a challenging task. A recent study on the pitfalls of strategic alignment that organizations were experiencing, indicated that about 50% of the participating organizations witnessed problems during strategy formulation, and between 50% and 90% of the organizations considered they experienced problems with implementing their strategies (Roelfsema et al., 2016). More often than not, organizations experiencing problems with strategy formulation and implementation face issues, such as conflicting priorities regarding reaching strategic goals. Moreover, strategy formulation and strategy implementation are seen as separate processes. Also, the strategy is often unsupported by existing information systems (Roelfsema et al., 2016). Ultimately, these problems can lead to poor strategic alignment within an organization, which can have a negative impact on organizational performance. Therefore, it is important for organisations to have a clear, unambiguous strategy backed up by sufficiently detailed plans (Economist Intelligence Unit, 2004; Kaplan and Norton, 2005; Acur and Englyst, 2006; Sull, 2007; Franken, Edwards and Lambert, 2009;).

Acknowledging the importance of organisations' ability to formulate, align, and implement their strategies in order to remain competitive, many tools and techniques to support this process have already been introduced. At an operational level, many standards have been developed, which have been implemented in a multitude of software solutions, such as Business Process Management (BPM) and Enterprise Resource Planning (ERP). Similarly, at a tactical level, domains such as Business Intelligence (BI) and Enterprise Architecture (EA), have been supported by software tools.

However, when looking at a strategic level, very few software solutions are currently available, most of which do not support the well-known and used strategy techniques such as, the Business Model Canvas (BMC), the SWOT analysis, and the Balanced Scorecard (BSC). Strategy techniques are recognized as helpful and even necessary in streamlining strategy development and execution (Nohria, Joyce and Roberson, 2003). Therefore, a software tool implementation of such techniques could possibly prove valuable to organizations.

Teece (2010) argues, when looking at business modelling, that there is little support for designing and analysing business models, which can lead to poor understanding of an organisation and ultimately, to commercial failure. The lack of support for designing and analysing aspects pertaining to the strategic level is also recognised by Osterwalder and Pigneur (2013). The authors argue that Information Systems (IS) research could provide beneficial guidance on this topic by offering a common language, conceptual frameworks, and visual schemas that can help with understanding and designing strategy techniques, by transforming the strategy process into a design activity, and by offering guidance for Computer-Aided Design (CAD), similar to the one that EA has developed over the years.

Drawing on the observations of Teece (2010), Osterwalder and Pigneur (2013), in this paper we argue that for a software tool to be able to help organizations with designing their strategies, it should include well-known strategy techniques (e.g. BMC, SWOT, BSC). As Aldea et al (2013) indicated, these strategy techniques can also be combined and linked to each other in order to provide comprehensive support for the different phases of strategy design. In this paper, we design such a software tool, named the Strategy Blueprint. It is a decision-making tool which includes nine well-known strategy techniques. These are integrated within the phases of the strategy process and are also linked to each other.

Furthermore, we adopt the argument of Osterwalder and Pigneur (2013) that a software tool for strategy formulation should use guidance from IS research. Specifically, for the Strategy Blueprint, we use knowledge from the EA discipline, in the form of the ArchiMate modelling language (The Open Group, 2016). ArchiMate serves as a common language between the different strategy techniques. This facilitates a better understanding of the role of each technique and of how the core concepts of each technique can be related to each other. Moreover, we applied a qualitative concept mapping approach (Carnot; 2006; Kinchin, 2008) in order to create a mapping between the concepts that are used in the selected nine strategy techniques included in our tool (i.e. the Strategy Blueprint), and the ArchiMate modelling language. We did this to ensure that the results generated with the help of the Strategy Blueprint can be reused by those practitioners in the organization that manage the implementation of the formulated strategy, such as Business Architects or Enterprise Architects. Such an approach could also provide valuable insights into how the new ArchiMate 3.0 can relate to strategy techniques. We make the note however that our mapping is qualitative in nature as in the works of Carnot (2006) and Kinchin (2008), and does not mean to provide a (possibly automatic) translation of a strategy described in terms of one technique into a strategy described in terms of another technique. In the same vein, our mapping exercise was not aiming at establishing any transformation rules between the descriptive concepts of each technique and Archimate. In contrast to this, we wanted to compare how the nine strategy techniques organize the strategy-relevant information that they handle and how the concepts that these techniques are using, could possibly share meanings with the meanings of the conceptual constructs of the ArchiMate modelling language.

Finally, in this paper we address the need for an appropriate visualization supporting the combinations of strategy techniques. We do this by designing a spread-sheet-based tool. Our main design goal for this tool is to provide organizations a strategy formulation instrument that can be used without prior knowledge about the specific strategy techniques included in the tool. From a practical standpoint, this implies that the tool would guide managers and other strategy-oriented practitioners while using multiple strategy techniques for strategy formulation, without prior knowledge.

For the purpose of this research, we follow the design science research methodology according to Peffers et al. (2007). This had an impact on the organization of our paper. In what follows, Section 2 presents background and related work. Section 3 describes the development of the Strategy Blueprint and its visualization. Sections 4 and 5 contain a demonstration and evaluation of our proposed approach and visualization by using a real-life case study. We conclude with discussion, limitations, future works, and recommendations in Section 6.

2 BACKGROUND AND RELATED WORKS

This section provides background on three topics: (1) strategic alignment and strategy techniques, (2) reasoning approaches and specifically the approach of reasoning trees that we will employ to help define the logic behind designing our tool, the Strategy Blueprint, and (3) Design Science as a method for industry-relevant research.

2.1 Strategy Techniques

Strategic alignment means that all elements of a business - the way the company is organized, the resources it employs, its assets — are arranged in such a way as to best support the fulfillment of its long-term purpose (Santana Tapia, Daneva and van Eck, 2007). While a company's purpose is enduring, strategy includes choices about e.g. what products and services to offer, which markets to serve, and how the company should best set itself apart from rivals for competitive advantage. While a company's purpose does not change, strategies and organizational structures do, which can make chasing "alignment" between strategy and the organization feel like chasing an elusive target. Careful formulation, planning and re-planning of strategy is therefore of paramount importance. According to Aldea et al. (2013), the strategy formulation process involves the following phases: visioning process, environmental analysis, strategic options, strategic choices, strategic objectives and metrics. In the following paragraphs, we present those strategy techniques that can be used within these phases. Based on Aldea's systematic literature review (2017), we identified nine strategy techniques that we consider as 'good candidates' for inclusion and adaptation in our computer-aided tool, the Strategy Blueprint. These techniques are: Brainstorming, BMC, Porter's Five Forces, PESTEL, SWOT, Resource Base View, Confrontation Matrix, BSC, Blue Ocean Strategy. We chose these strategy techniques for inclusion, because of their ability to capture the type of information that is needed for formulating strategies. While most of these strategy techniques are well-known (SWOT, BMC, BSC), a few of them are relatively less popular (Resource Based View, Six Paths Framework), however they were selected due to their potential to connect to the other techniques.

In order to provide support for analyzing the potential impact of certain decisions, we also include risk analysis concepts. According to literature, there are four methods that are commonly used in performing risk analysis in relation to strategy: real option analysis (Mikaelian et al., 2011; Rowley, 1989), sensitivity analysis (Lindič et al., 2012), scenario analysis (Ide et al., 2014), probability and impact matrix (Project Management Institute, 2008), and the Monte Carlo simulation (Luko, 2014).

As part of preparing this paper, we considered the advantages and disadvantages of each type of risk analysis put forward in these techniques. We ended up choosing the following two for inclusion in the Strategy Blueprint: scenario analysis, and the risk probability and impact analysis. Last, we make the note that in our tool, we also use the tornado diagram (Borgonovoa and Plischke, 2016) as a graphical visualization for opportunity and threat analysis, instead of using it for risk analysis.

2.2 The Concept of Reasoning Tree

Scholars in psychology, cognitive science and education define 'reasoning' as the process of drawing conclusions or inferences from information (e.g. see Lohman and Lakin, 2011). In Strategic Management literature, however, the concept of reasoning has so far been mostly combined with decision-making and problem-solving. E.g., in a recent publication (Xu, 2011), evidential reasoning is one of the reasoning concepts addressed in combination with decision making.

For the purpose of our research, we chose to use the technique of reasoning trees. It has been widely used in psychology, artificial intelligence, and knowledge-based systems, and authors in those fields indicated its worth. However, we make the note that its usage in the business domain is under-represented, especially in relation with strategy formulation. While studying the available literature on reasoning trees, we have identified three pairs of reoccurring reasoning types, namely: (1) inductive and deductive reasoning, (2) case-based reasoning and rule-based reasoning, and (3) forward chaining and backward chaining.

We think that, for the purpose of our research, backward-chaining (goal-driven) and forward-chaining (data-driven) are the most suitable reasoning types. The main reason for this is that backward-chaining can be very useful to users that already have a specific goal in mind to achieve. In the case of forward-chaining, users can take into consideration all the available information (without a specific goal in mind) in order to choose the alternative which provides the highest benefit. Both of these reasoning types are in line with our vision for the design of the Strategy Blueprint.

2.3 The Design Science Method

Design Science is the design and investigation of artifacts in context (Wieringa and Daneva, 2015). As a research method, it is solution-oriented and is focused on the interaction of a proposed solution and the context in which the solution is used. The design science research process starts with a study of a real-world problem as experienced by those working in the field (Hevner et al., 2004). It includes the following steps (Peffers et al., 2007): problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication. Our research followed these steps. Their detailed description is in (Febriani, 2016). Because of space limitations, in this paper we report mostly on the solution design, its demonstration, and its first evaluation.

3 THE STRATEGY BLUEPRINT

This section presents our tool, the Strategy Blueprint, which can support the strategy design process of an organization. First, we summarize the mapping between the concepts of the included nine strategy techniques, and the ArchiMate modelling language. Second, we describe how the reasoning tree helps with designing the logic of the Strategy Blueprint. Finally, we discuss several aspects related to the visualization of the reasoning tree, which are further used in the spread-sheet implementation.

3.1 Our ArchiMate Concept Mapping

To better understand and design the relationships between the phases of the Strategy Blueprint, we have mapped the core concepts of the nine chosen strategy techniques to the ArchiMate 3.0 modelling language, based on the guidelines provided by Aldea et al. (2015). Table 1 presents our concept map. Therein, the "x" symbol identifies the concepts included in those techniques that generate an output usable by another model. The "-" symbol identifies the concepts included in those techniques that need input from another model.

Table 1: Mapping of strategy technique concepts to ArchiMate.

	Goal	**Course of Action**	**Capability**	**Resource**	**Actor**	**Value**	**Interface**	**Collaboration**	**Assessment**	**Driver**	**Metric**	**Product/Service**
Vision	x											
Mission		x										
BMC			x	x	x	x	x	x				x
SWOT			-	-		-			x	-		
PESTEL										x		
BSC	x	x									x	
TOWS		x										
Brainstorming		x								x		
Porter's 5F					-					x		
Risk analysis									x	-		
Blue Ocean		x			-	-			x	-		-

Based on this mapping (Table 1), the scope of the strategy techniques, and of the phases of the strategy formulation process, we have designed the logic of the Strategy Blueprint. This logic is presented in the form of a reasoning tree, which illustrates the different routes that users can take to formulate their strategies with the help of the Strategy Blueprint.

3.2 Our Design of the Reasoning Tree

The design of the reasoning tree draws on the work of Aldea et al. (2013) about strategic planning and enterprise architecture. According to these authors, there are three main steps in the strategic planning process: Visioning Process, Strategy Formulation, and Strategy Implementation. As mentioned earlier, the strategy implementation is outside the scope of this research, and is not covered by the reasoning tree. However, our research includes two additional phases that are different from the work of Aldea et al. (2013), namely, market analysis and risk analysis. These two phases are not mandatory in strategic planning, yet we consider them helpful for organizations, for optimizing the results of their decisions. Based on the method proposed in Aldea et al. (2013), and the 11 strategy techniques mentioned in Section 2, we develop our reasoning tree for strategy formulation, as shown in Figure 1.

The reasoning tree contains six main phases and five alternate paths. Some phases of the reasoning tree can generate an output which can be used, as an input for a next phase. An example of this is the Strategy Formulation phase which depends on the result of the Environmental Analysis phases.

Other phases, though related, are not directly dependent on each other. Visioning Process and Business Modelling are examples of two phases that are not explicitly dependent on other phases, but they do relate to each other. An organization's vision and mission influence its business model, and vice versa. The components of the business model are essential parts for realizing the vision and for ensuring that a mission can be accomplished.

Thus, while going through the different phases of the reasoning tree, analysis and decisions can be made based on the cumulative outputs of the previous phases. As it can be seen in, each phase in the reasoning tree consists of several strategy technique that can be related to the each other.

3.3 Visualization

In order to visualize the Strategy Blueprint, we utilize Numbers, the spreadsheet application provided by Apple. Numbers has several benefits: its overall look,

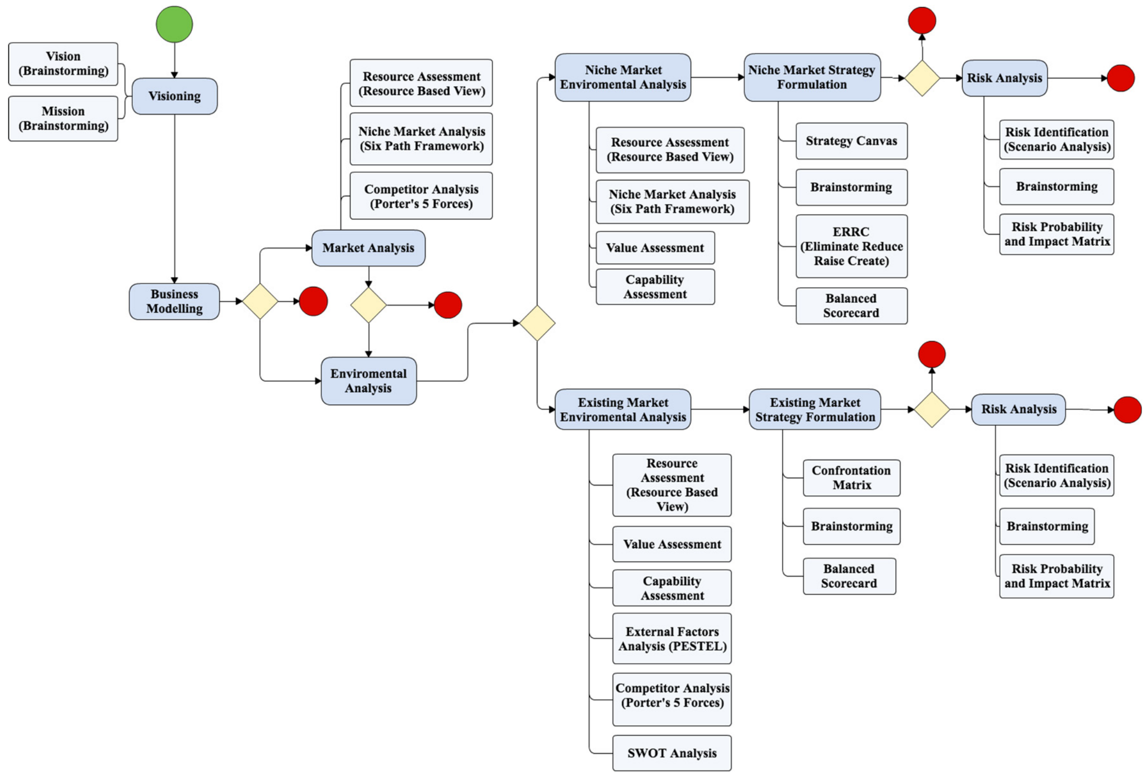


Figure 1: The reasoning tree supporting the Strategy Blueprint.

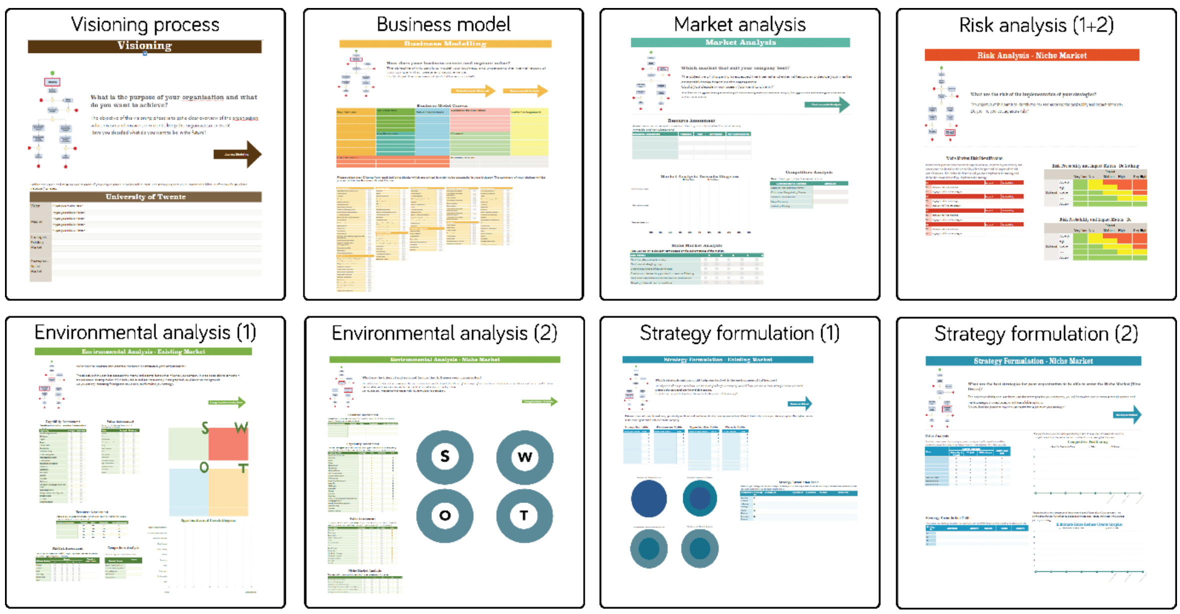


Figure 2: Overview of the phases of the Strategy Blueprint.

its user interface and its simplicity. Although, Microsoft Excel is more powerful in terms of features and complex data processing, we opted to use Numbers because of its ease of use, and because we do not need to use complex data processing. This choice is based on the argument that users of a strategy formulation tool do not have to possess advanced programming or modelling skills. Using simple formulas and the available features in Numbers, we can visualized and implement our reasoning tree, mostly with the help of charts and tables. Drawing upon the work of Eppler, Platts and Kazancioglu (2009), our visualization offers a ready-to-use structure for organizing and synthesizing information (e.g., line chart, tornado diagram, matrix, and pie chart). To generate these visualizations, different types of inputs are used: self-type, checkbox, stepper, and drop down list. Figure 2 illustrates an overview of the Strategy Blueprint phases.

4 CASE STUDY AND DEMONSTRATION

This section demonstrates the application of the Strategy Blueprint in a real-world case study in the context of a public organization in Europe. Because of confidentiality agreements, we anonymized the organization and its data. The organization is a Higher Education institution, from here on referred to as 'the University'. We use the visualizations created in Numbers to illustrate how the different phases of the tool can be used in practice.

4.1 Our Case Description

The University is a relatively young organization, with only half a decade of history. It has a distinctive entrepreneurial character, and a strong focus on new technology development and its significance for people and society. Despite its entrepreneurial spirit, in the past few years, the University was facing several internal challenges (e.g. unclear profile, low graduation rates of students, relatively undervalued research) and external challenges (e.g. regulation changes, decreasing market share, and reduction of government funding) which have forced a significant change in the overall strategic intent. Since 2008, the University has developed a very detailed strategic plan, which covers solutions for addressing the above mentioned challenges. We used some of the details of this strategic plan in order to illustrate how the Strategy Blueprint tool can be applied.

4.2 The Case Demonstration

4.2.1 Visioning Phase

The University's vision, which is already defined, sets a strategic direction that needs to be followed for the next 4 years. It describes what kind of university they want to be and outlines what they want to do to further develop and achieve that vision. It includes the following statements:

- Facilitate spin-offs founded by student entrepreneurs;
- Provide a full range of high-quality education programs at both undergraduate and graduate levels, with differentiation/specialization and profiling in the Master's phase, based on the strengths of University's research;
- Strengthen the University's international, national, and regional networks and alliances;
- Make a difference through the University's research and ensure that its results are used to improve and, if possible, even save lives.

4.2.2 Business Modelling

This section defines the University's business model using the BMC (Osterwalder and Pigneur, 2010). The number of items per building block of the BMC is limited to 5 or less, so that we can focus on the most important aspects of the organization. Based on the vision, the available information that has been provided, our own knowledge, and our assumptions about how the University runs its business, the BMC shown in Figure 3 has been created.

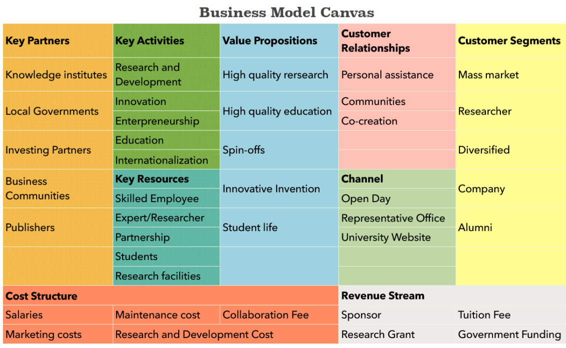


Figure 3: Business Model Canvas of the University.

4.2.3 Market Analysis

In this phase, we present the results of the market analysis for the University. Three aspects are analyzed: the competitors (Porter's 5 Forces), the resources, and the alternative market (Blue Ocean Strategy). Based on the information filled in the business model phase, for the Key Resources block, five resources are defined: skilled employees, experts and researchers, partnerships, students, and research facilities. The resource assessment is performed based on the four criteria in the Resource-Based View of the firm, which are: rare, valuable, inimitable, and non-substitutable (Barney, 1991).

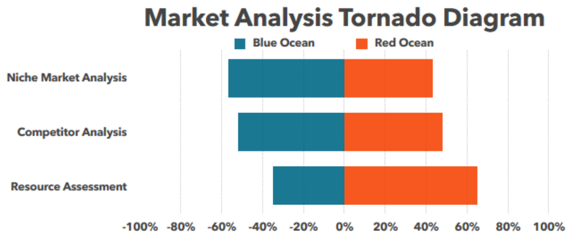


Figure 4: Market Analysis Diagram of the University.

Based on these criteria, the weaknesses of the University are identified as the number of skilled employees and the students. Regarding the other three resources, the University can be considered as quite competitive. As it can be seen in Figure 4, the overall results of the assessment in this phase show that the University leans more towards the existing market rather than a niche market. Thus, the next step is the Environmental Analysis phase, for the existing market.

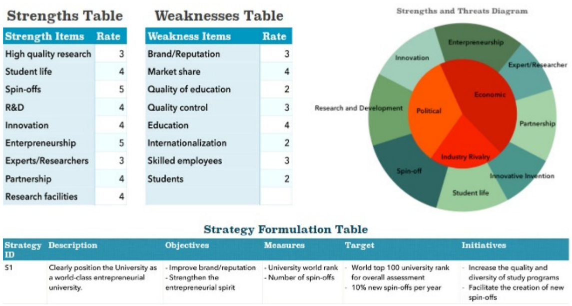
4.2.4 Environmental Analysis

In this phase, five aspects are analyzed: capabilities, value, resources, competitors, and the macro-environment. Capabilities, values, and resources are the internal factors of the organization that are linked to the Key activities, Value proposition, and Key Resources are building blocks of the BMC. The competitors and macro-environment are considered as the external factors of the organization, which are analyzed with the help of Porter's 5 Forces and the PESTEL analysis. The results are presented in a SWOT matrix format (see Figure 5).

Figure 5: Internal/External factors of the University.

4.2.5 Strategy Formulation

In this phase, we detail the strategy of the University by using the Confrontation Matrix and the BSC. The results are presented in four pie charts, depicting the elements of the Confrontation Matrix. Based on these results, several alternative strategies are detailed in a BSC, which normally consists of four perspectives (financial, customer, internal, learning and growth). We adjust these perspectives to facilitate a clear connection between the Confrontation Matrix and the BSC, hence renaming them as follows: reactive, offensive, adjusting, and defensive strategy. Each perspective is related to different Confrontation Matrix pie charts. The formulated strategies are further elaborated with the help of the BSC. Figure 6 illustrates an excerpt of the SWOT factors, the Confrontation Matrix pie chart, and the BSC table.


Strengths Table

Strength Items	Rate
High quality research	3
Student life	4
Spin-offs	5
R&D	4
Innovation	4
Enterpreneurship	5
Experts/Researchers	3
Partnership	4
Research facilities	4

Weaknesses Table

Weakness Items	Rate
Brand/Reputation	3
Market share	4
Quality of education	2
Quality control	3
Education	4
Internationalization	2
Skilled employees	3
Students	2

Strategy Formulation Table

Strategy ID	Description	Objectives	Measures	Target	Initiatives
S1	Clearly position the University as a world-class entrepreneurial university.	- Improve brand/reputation - Strengthen the entrepreneurial spirit	- University world rank - Number of spin-offs	- World top 100 university rank for overall assessment - 10% new spin-offs per year	- Increase the quality and diversity of study programs - Facilitate the creation of new spin-offs

Figure 6: Excerpt results of Strategy formulation.

4.2.6 Risk Analysis

In this phase, the risks of the strategies formulated in the previous phase, are identified. To simplify this assessment, two types of risks are identified: the risk of not pursuing the strategy and the risk resulting from the implementation of the strategy. These risks are assessed based on the probability to materialize, and the impact they would have (Figure 7).

S1	Improve and maintain the student life experience to attract more student both local and international.	Impact	Probability
R1	The attraction level of the university is low, low market share	High	Low
R2	the student passing grade and graduation rate decrease as student not focus on study	High	Medium
S2	Focus on key research areas that play to the U's strengths and the community's needs	Impact	Probability
R4	Low competitiveness rating compare to other universities	High	High
R5	Decrement of research quality for other areas that are not the key research ares	Medium	Low
S3	Improve the quality of education by maximising the technology.	Impact	Probability
R7	Low competitiveness, attractiveness compare to other universities and bad reputation	Very High	High
R8	Need additional cost for improvement	Medium	Medium
S4	Clearly position the U as a world-class entrepreneurial university.	Impact	Probability
R10	Doesn't have the unique point to attract more customers (students, parents, companies)	Very High	Medium
R11	Need a lot of work and money to do improvement in a lot of aspect	Medium	Very High

Figure 7: Risk analysis of the formulated strategies.

5 EVALUATION

A preliminary evaluation of our approach was performed by means of a workshop with five practitioners. During this workshop, we briefly introduced our research and demonstrated its implementation. At the end of the workshop, each participant was asked to fill in a survey to provide their feedback regarding our research. For this purpose, we designed a questionnaire based on the guidelines proposed from the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). UTAUT can be used to understand user acceptance of technology, but can also be adapted to methods, models, and approaches. Since the objective of the evaluation process is to analyze the user acceptance of our approach regarding guiding organizations during strategy formulation, we consider the UTAUT to be highly suitable for this task. From the many constructs proposed by Rowley (1989), we chose the following six to use in our questionnaire: performance expectancy (Q1.1 – Q1.3), effort expectancy (Q2.1 – Q2.2), facilitating conditions (Q3.1 – Q3.4), attitude towards using technology (Q4.1 – Q4.3), self-efficacy (Q5.1 – Q5.4), and behavioral intention to use the technology (Q6.1 – Q6.3). The full list of constructs and statements used in the evaluation workshop is shown in Table 2, where we also report four descriptive statistics for the questionnaire statements such as: minimum (Min) and maximum (Max) values, average (Avg.) values, and the standard deviation (Std. dev.). A 7-point Likert scale was used to rate the statements of the questionnaire, with '1' representing the lowest (don't agree), '7' representing the highest (agree), and '4' representing a neutral response.

As can be seen in Table 2, the majority of the statements from the questionnaire received an average rating from the respondents of 4 or above. From this, we can conclude that overall rating provided by the respondents was at least neutral with most statements receiving a positive average rating. Furthermore, most the standard deviations for the statements in the questionnaire were lower than 1. This suggests a consensus among respondents in a majority of cases. Therefore, we can conclude that the opinions of the respondents were in many cases similar and positive towards the Strategy Blueprint.

While evaluating the results of the first category of statements relating to performance expectancy (Q1.1 – Q1.3) we can conclude that our respondents considered the Strategy Blueprint as a useful tool for strategy formulation (avg. 5,8), which is easy to use (avg. 5,6), and can increase their productivity (avg. 5,2). Therefore, we can argue that these results support our claim that the Strategy Blueprint is a suitable tool for strategy formulation.

In case of the effort expectancy statements (Q2.1 – Q2.2), similarly to the previous category, we can conclude that the respondents considered that the Strategy Blueprint is an easy to use (avg. 5,6) and easy to learn tool (avg. 5,2). Similarly, we can observe that the opinions of the respondents are alike, with both statements having a standard deviation of lower than 1. Therefore, we can argue that these results support our claim that the Strategy Blueprint is a tool which can be used and learned by practitioners with ease.

The third category of statements, which focuses on the attitude of the respondents towards the Strategy Blueprint (Q3.1 – Q3.4), also indicates an overall positive opinion of the respondents (avg. 5,4 - 5,8). In the case of these statements, we can also observe a standard deviation lower than 1, which suggests similar opinions of the respondents. Therefore, we can argue that these results support our claim that using the Strategy Blueprint for strategy formulation is a good idea (avg. 5,8; std. dev. 0,44).

In terms of the statements regarding the facilitating conditions (Q4.1 – Q4.3), the average scores provided by the respondent were lower than in other categories of statements (avg. 4 – 4,8). Furthermore, the opinions of the respondents regarding these statements are also very dispersed, with a standard deviation between 1,3 and 2,16. This indicates that some of the respondents consider that the facilitating conditions needed to use the Strategy Blueprint are sufficient, while others disagree. One of the possible explanations for these results could be that the choice of using Numbers as the platform for the Strategy Blueprint is not seen as equally favorable by all respondents (Q4.3). This is also reflected in the statement concerning the resources need to use the tool, where respondents also provide disparate responses (Q4.1). Therefore, in a future iteration of the Strategy Blueprint, an alternative to the Numbers spreadsheet tool should be considered.

Regarding the statements concerning self-efficacy (Q5.1 – Q5.4), we can also observe a difference in the opinions of the respondents, with average scores ranging from 4 to 6,2 and standard deviations ranging from 0,44 to 1,41. Therefore, we can conclude that the respondents consider that they can accomplish a task using the Strategy Blueprint, provided that there is sufficient guidance, in the form of built-in guidance or a person to aid in this task. However, we can argue that given more time to explore the existing built-in guidance and semi- automation included in the Strate-

Table 2: Descriptive statistics for the evaluation workshop.

Questionnaire statements	Min	Max	Avg	Std. dev.
Q1.1: I would find the Strategy Blueprint is useful in helping me formulate the strategy.	5	6	5,8	0,4472
Q1.2: Using the Strategy Blueprint enables me to accomplish strategy formulation tasks more quickly.	4	6	5,6	0,8944
Q1.3: Using the Strategy Blueprint increases my productivity.	4	6	5,2	0,8366
Q2.1: I would find the Strategy Blueprint is easy to use.	5	6	5,6	0,5477
Q2.2: Learning to use the Strategy Blueprint is easy for me.	4	6	5,2	0,8366
Q3.1: Using the Strategy Blueprint for strategy formulation is a good idea.	5	6	5,8	0,4472
Q3.2: The Strategy Blueprint makes strategy formulation more interesting.	4	6	5,6	0,8944
Q3.3: Working with the Strategy Blueprint is fun.	4	6	5,4	0,8944
Q3.4: I like working with the Strategy Blueprint.	5	6	5,8	0,4472
Q4.1: I have the resources necessary to use the Strategy Blueprint.	2	6	4	1,5811
Q4.2: I have the knowledge necessary to use the Strategy Blueprint.	3	6	4,8	1,3038
Q4.3: The Strategy Blueprint is compatible with other systems I use.	2	7	4,2	2,1679
Q5.1: I could complete a job or task using the Strategy Blueprint if there was no one around to tell me what to do as I go.	2	5	4	1,4142
Q5.2: I could complete a job or task using the Strategy Blueprint if I could call someone for help if I got stuck.	6	7	6,2	0,4472
Q5.3: I could complete a job or task using the Strategy Blueprint if I had a lot of time to complete the job for which the method was provided.	4	7	5,4	1,1401
Q5.4: I could complete a job or task using the Strategy Blueprint if I had just the built-in guide for assistance.	4	6	5,2	0,8366
Q6.1: I intend to use the tool in the future for helping me formulate the strategy.	4	5	4,4	0,5477
Q6.2: I predict I would use the tool in the future for helping me formulate the strategy.	3	5	4,2	0,8366
Q6.3: I plan to use the tool in the future for helping me formulate the strategy.	2	5	4	1,2247

gy Blueprint, the respondents' opinions might become more positive. Finally, in the case of the statements regarding the intention to use the Strategy Blueprint (Q6.1 – Q6.3), the average opinion of the respondents is neutral to slightly positive (avg. 4 – 4,4), with a standard deviation ranging from 0,54 to 1,22. These results indicate that the respondents are mostly neutral towards using the Strategy Blueprint for strategy formulation. We argue that these results could be motivated by the opinions of the respondents regarding the facilitating conditions and self-efficacy statements. This indicates that, even though the Strategy Blueprint is seen as a useful and easy to use strategy formulation tool, the chosen platform for its implementation (Numbers) and the short amount of time allotted to the built-in guidance and automation of the tool, might have influenced their intention to use the Strategy Blueprint in a negative manner.

6 CONCLUSION

In this paper we proposed a computer-based tool for strategy formulation − the Strategy Blueprint. It integrates strategy techniques, a reasoning tree, and is implemented in a spreadsheet-based application. The tool is meant to help the organizations by providing guidance through the strategy formulation process, by giving an overview of factors that influence their organization, and by facilitating decision-making and risk analysis. This has been achieved by combining nine strategy techniques and a risk analysis technique. The relationships between these techniques have been designed with the help of a concept mapping to the ArchiMate constructs, in order to determine those concepts that are shared between the techniques and also those outputs of one technique that could be used as inputs for another technique. Furthermore, the logic of the Strategy Blueprint has been designed with the help of a reasoning tree. This reasoning tree includes all the six main phases and five alternate paths, each of them supported by several interlinked techniques. Moreover, the Strategy Blueprint is implemented in the spreadsheet-based application Numbers, which includes several crucial features that have made semi-automating the process of strategy formulation possible.

The results of our first evaluation − the workshop with the practitioners, indicate that the respondents consider the Strategy Blueprint as a suitable tool for strategy formulation, which is easy to use and learn. However, the choice of the implementation platform might need to be revisited in future research. Similarly, the built-in guidance and the semi-automation of the Strategy Blueprint might need to be given more attention in a future workshop in order to ensure that the participants are able to better experience its benefits.

6.1 Limitations and Future Work

Our research has several limitations. First, we selected nine strategy techniques, while many more exist in both literature and practice. In future work, alternative combinations of strategy techniques should be considered in order to determine those that are the most suitable for formulating a strategy.

Second, further improvements of the Strategy Blueprint should include implementations in platforms compatible to Windows-based systems. We consider that such an approach would address many of the results regarding the facilitating conditions statements included in the questionnaire, and possibly even the ones regarding the intention to use. Furthermore, in future evaluation workshops a stronger emphasis should be made regarding the built-in guidance and semi-automation of the Strategy Blueprint. We argue that such an approach would help address the results regarding the self-efficacy statements in the questionnaire, and possibly even the ones regarding the intention to use.

Third, following Wieringa and Daneva (2015), we acknowledge the need for more evaluation to improve the generalisability of the results. A central question in this respect is evaluating the extent to which our current results could be observable in other similar but different organizations (e.g. other Higher Education organizations, and in other countries). Additionally, the participants in these future evaluation workshops should be selected based on their involvement in the strategy formulation process.

Finally, there are also several recommendations regarding the tool, such as the link between the tool and ArchiMate should be elaborated, to facilitate automatic import/export of information to other tools that support the ArchiMate modelling language. This could prove very helpful for EA practitioners, as they will be able to create strategic models with ArchiMate in an easier and more automated manner. Furthermore, an extension for “positive” risks (opportunities/benefits) in the risk analysis could be included in the tool to give a more complete overview of all types of risk. Moreover, our tool is just a prototype that demonstrates the concept. Nevertheless, the design of the tool (possibly with some adaptation) can be used to create a similar implementation, for example using Microsoft Excel.

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An Intelligent Approach and Data Management in Active Security Auditing Processes for Web Based Applications

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Keywords: Active Information Security Audit, Vulnerability Scanners, Intelligent Approach, Fuzzy Expert Systems, Information Security Audit, Fuzzy Data Management.

Abstract: Currently we observe increasing popularity of web technology that allows for reflecting traditional businesses into web-based applications (web applications, for short). Such web applications are often interesting to hackers aiming at stealing (confidential) user information; they would use such information for personal gain. For providing the enough security level of computer and information systems the companies should be interested in the regular information security active auditing. This process often accompanies the checking and control of the security systems of enterprises but it is usually expensive by finance, time and human resources consuming. The one of the tools for active security audit is the using of vulnerability scanners especially for web applications security assessment. During the process of the web applications checking the vulnerability scanners discover a lot of bugs in applications security system and inform the users (auditors) by providing the list of vulnerabilities. Despite of the various types of vulnerability scanners only few of them may contain the intelligent tools which can facilitate the auditing process. Therefore, there is a high demand for the development of intelligent security scanners that are compliant with the de facto security standard of OWASP - the Open Web Application Security Project. We argue that embedding intelligent tools (expert systems) in such vulnerability scanners would not only increase effectiveness but would also decrease the cost of an OWASP auditing process. We can claim that using fuzzy sets and logic theories may facilitate this process in terms of processing that concerns the human expert contributions.

1 INTRODUCTION

Currently, many enterprise applications (such as e-commerce applications, Internet banking applications, blogs, web-mail applications, and so on) are developed as web-based applications.

The increasing prominence and usage of such applications has made them more susceptible for hacker attacks because the applications store huge amounts of sensitive user information.

Traditional security facilities, such as network fire-walls, intrusion detection systems, and encryption enabling, are capable of protecting the network but cannot mitigate attacks targeted at web applications.

For providing the enough security level of computer and information systems, companies should be interested in the regular information and computer security active auditing. This process often accompanies the checking and control of the security systems of enterprises but it is usually expensive by finance, time and human resources consuming.

One of the ways for active security auditing is using vulnerability scanners especially for web applications security assessment. During the process of the web applications checking the vulnerability scanners discover a lot of bugs in applications security system and inform the users (auditors) by providing the list of vulnerabilities. This list is often very long and has a lot of repeating information that should be analysed by auditors. Despite of the various types of vulnerability scanners only few of them may contain the intelligent tools which can facilitate the auditing process. Therefore, there is a high demand for the development of intelligent security scanners that are compliant with the de facto security standard of OWASP - the Open Web Application Security Project.

Vulnerability scanners represent tools for monitoring and management. They can be used to check for security problems not only computer networks and separate computers but also applications, including web applications.

Many researchers have tackled the use of vulnerability scanners for solving security problems in web applications: Richard R. Linde, 1975; Kals S. et el. 2006; The Government of the Hong Kong Special Administrative Region, 2008; Fong E. et el., 2008; Suto Larry, 2007; Kulmanov A and Atymtayeva L, 2016; Nurmyshev S, et el., 2016.

Analysing the mentioned research and practical experience, we realize that even though vulnerability scanners are often used in web application security assessment, there is little done on the development of web-based vulnerability scanners using intelligent expert-based tools. We can argue that embedding expert systems in such vulnerability scanners would not only increase effectiveness but would also decrease the cost of an OWASP auditing process.

We can currently observe a great potential for using expert systems in the process of information security auditing, justified by research reported in Atymtayeva L. et el., 2011, 2012, 2013, 2014; Kanatov M. et el., 2014.

Summarizing the findings in the mentioned research, we draw the conclusion that expert systems can usefully help in decreasing the cost of information security auditing that is characterized by high complexity features.

For this reason, it is not surprising that recently publications are increasing that are touching upon this and envisioning adaptive network security: Crispan Cowan et al., 1998; Robert E. Gleichauf et.al., 2001; Wahyudi, Winda et al., 2007; Xiangqian Chen, 2009; Ksiezopolski B. et al, 2009; Karthick R et al., 2012 and etc.

We can distinguish between two major technologies, namely: security analysis (safety assessment) and detection of attacks (intrusion detection).

The current paper focuses particularly on security analysis. With regard to this, considering the traditional active auditing process, we establish that the network consists of communication channels, routers, switches, hubs, servers, and so on. All those network elements must be assessed for their effectiveness as it concerns prevention of attacks.

Vulnerability scanning tools allow us to explore the network, by looking for 'weak places' and by analysing identified issues, taking into account corresponding scanning results; in this, different kinds of reports can be generated.

A current web security scanner represents a multi-functional and highly complex product. Therefore, it must be tested and compared with similar solutions which have a number of features. It is therefore interesting to analyse and test such scanners, and compare their features with similar solutions.

Below we list several problem types that may pop up during a scanning process:

–Backdoor in code from third-party libraries;

–Use of default or weak passwords;

–Misconfiguration of the firewall, web-servers and other server infrastructure;

–Unnecessary network services;

--Discover the SQL Injections consequences.

These and other security problems may become a reason for the high level of vulnerability of web based applications.

Hearing 'panacea' success stories about powerful security analysis systems (scanners), one would come to believe that those systems are the definitive security solution. However, it is not rare that a user may encounter new kinds of vulnerability, for example, in operating system that cannot be captured by network security scanners. Usually, it would happen because this vulnerability in operating system work is not presented in the vulnerability scanner database, and this is one of the aspects that are inherent in all security analysis systems. Those systems are intended to detect only known vulnerabilities whose description is contained in their databases. In this they are similar to anti-virus applications that need to constantly update their signature databases in order to work properly.

Thus, as mentioned already, we consider as a possible solution direction the use of the multiple expertises of auditors (referring to this as to a knowledge base) in the productive OWASP auditing process; this could be an effective update with regard to the use of vulnerability scanners (Paul E., 2006; Wichers D., 2013).

In the following sections we consider the questions regarding the selection and using of vulnerability scanners (Section 2), design and simulation of fuzzy expert system in combination with vulnerability scanners (Section 3). In conclusion we summarize the research information of the topic of this paper and give the directions for further development.

2 VULNERABILITY SCANNERS (VS): ARCHITECTURE, LIMITATIONS AND TESTING PROCEDURES

2.1 Architecture of VS

In their work, vulnerability scanners can simulate the actions of hackers who try to find "security holes" in the networks of potential "victims".

Referring to Kals et al. (2006) and Nurmyshev et al. (2016), we claim that usually vulnerability scanners comprise four main modules, as illustrated in Figure 1, namely:

1. a Scan Module;
2. a Database Module (so called "Vulnerability Database");
3. a Report Engine (generating the results);
4. a User Interface.

- The Scan Module performs system checks for vulnerabilities, conforming to corresponding specified settings. The vulnerability scan logic is incorporated in this module. There is a possibility to scan multiple parallel resources.

- The Vulnerability Database Module contains information about vulnerabilities and their methods of use (for the attack vectors). That data is supplemented by recommendations concerning the measures on addressing vulnerabilities. Performing such recommendations results in reducing the security system risk. As studied by Stepanova et al. (2009), that database module is used for both security analysis and intrusion detection.

- The Report Engine (based on the collected information) generates reports that describe the discovered vulnerabilities. An important point is that reports contain recommendations that address the detected problems. Detailed reports help to remove quickly the detected defects without losing time to search for descriptions of detected vulnerabilities. Reports can be obtained in a convenient form for the end user.

- The User Interface allows to make the vulnerability scanner operational. Often scanners would have a GUI (Graphical User Interface) that would nevertheless also offer the option of running the scanner just in a command line interface.

As mentioned above, this all is illustrated in Figure 1 where one can see the interaction between different vulnerability scanner modules, by processing the received information. The figure demonstrates various graphical notations of the modules that mean different contribution of each part of scanner to the scanning process. The Targets (or different web applications) may be processed in parallel by the using of the special Scan Module logic. The module "Generating Results" represents the special format of report that is usually performed by .csv format with tracking of the discovered vulnerabilities.

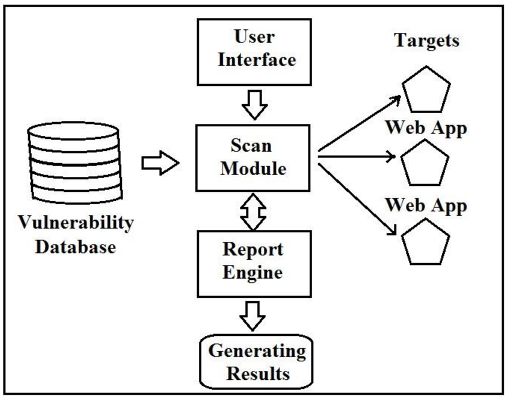


Figure 1: Architecture of a vulnerability scanner.

Any information/computerized system is characterized by vulnerabilities. A software maker would often release updates (called "patches"), corrections, and so on. Then the computers that have not installed immediately those patches, would become vulnerable to virus attacks.

New vulnerabilities appear constantly, and hackers know this. A hacker or attacker usually tries to find a weak spot in the defense and use it for further penetration in the enterprise network. Auditing vulnerabilities of critical systems is becoming a vital necessity nowadays for enterprises.

There are special tools to detect vulnerabilities in a timely manner. Most of them allow us to evaluate the extent to which particular systems are vulnerable and recommend ways of fixing specific vulnerabilities.

2.2 Limitations of VS

The usual practice is to conduct vulnerability scanning as part of a general security audit and penetration test. This approach is potentially dangerous for enterprises since new critical vulnerabilities occur almost every day. To ensure its protection, the company must conduct vulnerability scannings more often.

Inspired by related work (The Government of the Hong Kong Special Administrative Region, 2008; Nurmyshev S, et al., 2016), we have identified the following limitations of vulnerability scanners.

1. Single scan. Vulnerability scanners perform a safety assessment of a system or a network only in a certain period. That is why security scanning of the system should be carried out as often as possible because new vulnerabilities may appear due to changes in the system configuration, and new "security holes" may pop up due to used software updates.

2. Necessity of human judgment. Most of the vulnerability scanners can only detect vulnerabilities that are already described in their logic and exist in their knowledge base. After the completion of scannings the security expert must review the final report and take decisions accordingly.

3. Vulnerability Scanning identifies only the potential gaps in the computer or information system. However, it does not show us a real possibility to exploit this vulnerability in the penetration, and whether this vulnerability has already been used by someone previously. For this purpose, it is necessary to complete a penetration test with regard to the targeted system.

4. Vulnerability scanners have a certain percentage of false positives, i.e., discovered vulnerabilities may be missing or incorrectly interpreted by the program.

5. Others. Scanners cannot identify other security threats, such as those associated with logical, procedural errors.

Functionally, vulnerability scanners perform a variety of anti-virus scannings. Some are better, some worse. For more accurate detection the usage of multiple scanners is more preferable. For small businesses the buying of multiple or even one scanner can be very expensive, moreover all manufacturers provide a license for a limited period (usually for 1 year).

Furthermore, many vulnerability scanners use plug-ins to identify potential vulnerabilities. Plug-ins are related to knowledge driven by logic, instructions, and so on; this allows the scanner to detect vulnerabilities.

The scanner can identify only those vulnerabilities that exist in the set of plug-ins. Despite the fact that scanning to identify vulnerabilities is a powerful tool to analyse the security of systems, vulnerability scanners themselves cannot fix the situation only based on the security-related information that is available in the enterprise.

Scan results should be interpreted correctly and, based on these results, adequate measures to protect information assets need to be taken. Also, drawbacks of all scanners should be noted: there is no possibility to add own reviews.

2.3 Testing of VS as Software

Most scanners can detect the vulnerabilities that are described in the WASC Thread Classification. We can look at some issues related to the testing of information security scanners as software (ISO IEC 27002 2013).

A modern web security scanner is a multifunctional and highly complex product. For selecting the best one, it should be tested and compared with similar solutions which have a number of features. In comparing various web application scanners, a possible approach is to test their procedures (Fong E. et el., 2008).

In a slightly modified form the procedure can be represented as follows.

1. Preparing the test content necessary for a functional check of all technical requirements and deploying test stands.

2. Initializing tests, receiving all necessary settings for the tests.

3. Configuring the scanned web application and selecting accordingly a corresponding vulnerability type and a protection level.

4. Starting up the scanner with the selected settings on the tested web application and passing a set of functional tests.

5. Counting and classifying the web objects (such as unique references, vulnerabilities, attack vectors, and so on) accordingly.

6. Repeating steps 2 to 5 for each vulnerability type and for each level of protection.

The changes after each iteration have to be entered in a summary table (take as an example Table 1) reflecting results that concern the detection of objects.

Obviously, not all web application scanners have the same set of scanning modules. Still, such a table can be used for the sake of reducing the rating of the scanner in the absence of certain modules of a particular functionality (ISO/IEC. ISO/IEC 27002:2013).

Preparing a test application, knowing in advance the exact number of certain types of vulnerability is impossible. Therefore, while preparing such a table, we would inevitably be facing difficulties with regard to the determination of the number of real objects to be identified.

Table 1: Test methodology.

Module of scanner	Protect Level	Found vuln	False Positive	False Negative	Total scan objects	Scan time in sec
Crawler module	0	100	0	50	150	500
	1	90	0	60		600
	2	80	0	70		700
	...	...	...	...		...
XSS Module	0	2	0	2	4	15
	1	1	1	3		20
	2	0	2	4		30
	...	...	...	...		...
SQL Inject module	0	1	2	1	2	60
	1	0	3	2		120
	2	0	4	2		240
	...	...	...	...		...
Broken Auth and Session Management	0	3	0	0	3	50
	1	1	2	2		60
	2	0	2	3		70
	...	...	...	...		...
...						

Hence, we consider the following as a possible solution:

1. In approaching a vulnerability instance, one could consider a relevant class of vulnerabilities, taken from the test web application. For example, classes reflecting equivalences of SQL-injection vulnerabilities, can be considered with regard to all vulnerabilities found for the same GET-request parameter of the application.

In other words, if there is a vulnerable parameter ID, which causes a change in failure Web server or database, all attack vectors, using this option can be considered equivalent to a permutation of parameters, for example:

test.com/page.php?id=blablaid

˜test.com/page.php?a=1&id=bla&b=2.

2. Developing simple test applications that implement or simulate some vulnerability. Still, those applications are using:

(i) different frameworks and turning them into a variety of options for operating systems;

(ii) different web servers;

(iii) different databases, with access to various types of network protocols, as well as through a variety of proxy chains.

3. Deploying Content Management Systems (CMS), vulnerable applications (DVWA, Gruere, OWASP, Site Generator, and so on) and scanning them using various security scanners. Taking the references to the total number of vulnerabilities that is found by all scanners and using them in further tests.

One could use for example the OWASP Site Generator tool to configure test applications and manage them, installing the required level of protection. Such a configuration can be stored and edited in an usual XML file. Unfortunately, at the moment, this tool has been deprecated and it is recommended to create custom applications to emulate today’s vulnerabilities.

The types of vulnerabilities for the implementation of the tests content and testing the scanner can be taken from the WASC Threat Classification.

It is not surprising that in a test procedure, the expected number of runs with regard to all possible combinations of installed applications will be very high.

This number can be reduced through the use of technology pair wise analysis testing.

As a result of the scan, we get the numerical vectors of the form (Protection level, the number of detected objects, False Positive, False Negative, all objects, scan time).

Then we can enter the scan quality metric that may be used in comparing the performance of scanners among themselves. These metrics can be considered as fuzzy parameters that would facilitate the process of scanners comparison and make it more effective.

For selecting the scanners and providing the process of comparison we can use four types of testing (Suto L, 2007):

1. Run a Web application scanning mode, Point and Shoot (PaS) and determine the number of vulnerabilities found and confirmed.

2. Perform a re-scan after a preliminary "training" and configure the scanner to work with this type of application, determine the number of vulnerabilities found and confirmed in this case.

3. Rate accuracy and completeness of the description of the found vulnerabilities.

4. Estimate the total time spent by experts in the preparation and conduct of testing, analysis and quality assurance of the scanning results.

To determine the amount of time that professionals need to spend to get good results, we can use a simple formula:

$T_{total}=T_{learning}+F_{pos}*T_{fix}+F_{neg}*T_{fix}$,

where

T_{total} is Total Time; $T_{learning}$ is Learning Time ;

F_{pos} is False Positive ; F_{neg} is False Negative;

T_{fix} is fixed time (about 15 minutes);

The next step in the procedure of scanner selection can be choosing of appropriate test type and test procedure. The diversity of test types, test procedures, and test results may be described as follows.

1. For example, basic functionality (smoke) tests should check the efficiency of the basic low-level scanner units such as work of the transport subsystem, a configuration subsystem, logging, and

others. If during the scanning there were not discovered the error messages, exceptions and trace-back in the log files, the scanner may not stop using different transports, redirects, proxy servers, and so on.

2. Functional tests must implement major test scenarios to check the technical requirements. It is necessary to check the function of each of the scanning modules in order to find the different module settings and test environment. For these purposes test procedures include the processing of positive and negative test scenarios, various stress tests using large arrays of valid and invalid data, recovering the scanner to the response from a web application.

3. Tests for the comparison of functionality may be performed by quality and average speed of objects. The test procedure includes the searching of the appropriate module with similar functionality in the selected competing products (scanners). Each specific scanning module is checked by quality of search and speed of object interaction.

4. The performance of evaluation criteria may be represented by special comparison tests for the previous versions. During this test procedure the speed and quality of search are checked by comparing old and new version of the scanner systems. The appropriate criteria should show that all features were not deteriorated in the new version of the system.

Summarizing the above-mentioned, we can say that scanners selection procedures and quality metrics can be successfully applied to any process of choosing the appropriate security system. (Fenz S.and Ekelhart A., 2009). As a development of this idea we can consider fuzzy indicators, scales and metrics that can simplify the process of scanners comparison.

3 COMBINING VULNERABILITY SCANNERS AND EXPERT SYSTEMS IN INTELLIGENTLY AUDITING PROCESSES

3.1 The Process of Discovering the Vulnerabilities

As mentioned before, there are many security issues requiring attention (and human presence).

Because of the high dynamics in vulnerabilities and attacks, we have to provide the security control very often and add new vulnerabilities to the database of scanners.

However, those procedures alone cannot provide sufficient protection and an active system auditing needs to be performed regularly.

To facilitate the process of discovering new vulnerabilities and identifying the level of security risks of a computer systems or web-applications we have to use the possibilities of vulnerability scanners.

Obviously, the combination of adequate human decisions and good scanning results would contribute to the realization of appropriate system protection measures and also to the prediction of "security holes".

Therefore, as mentioned before, a major contribution of the current paper is proposing the idea of using the principles of fuzzy expert systems in combination with vulnerability scanners, in order to better fulfil the security challenges discussed in the paper. The way we envision the combination between the two has been inspired by Van Deursen (2013).

The experts can analyze the vulnerabilities, which are found by the scanner during the process of scanning, and then make a final decision about the general risk level of vulnerabilities and give some recommendations how to fix that. These recommendations can be added to the main knowledge base of the expert system and then be easily used during the next procedure of security control.

These measures can decrease the time for identifying the risks of the computer system during the process of active security audit and reduce the cost of all related expenses for system owners.

Some vulnerabilities may also be used in combination with each other and by applying the procedures of social engineering can define the critical risk level. After the procedure of multiple experts assessment by combining or choosing the best opinion and recommendations from the knowledge base (Stepanova, D., et el., 2009), the system may report about many potential attacks, which cannot be detected by the traditional vulnerability scanners (Farahmand, F. F., 2013).

It is often difficult to find optimal solutions to practical problems, based solely on classical mathematical methods. This is because often adequate analytical descriptions are missing that reflect the problem.

Even in cases of successful implementation of the analytical problem description, to solve this requires excessive time and costs.

However, there is another approach to solve this problem. We can use the fact that the human is able to find optimal solutions, using only abstract information and subjective perceptions of the problem. However, in this case during the process of the determining the security risks level of the system we can use only human judgement which is an inaccurate knowledge and cannot formally define the main concepts - in our case, the system's risk level and the level of expertise of each expert.

Therefore, the usage of concepts related to fuzzy expert systems (Atymtayeva L. et. el., 2012) may become the useful tool facilitating the security checking process and reducing the related costs.

3.2 The Design of Fuzzy Expert System in Combination With Vulnerability Scanner

The main principles of the development of fuzzy expert system in combination with vulnerability scanner can be described by the following. Proposed expert system uses principles of fuzzy sets and logic (Zadeh, L., 1978) to analyze experts' assessments in discovering the vulnerabilities and making a final decision about general risk level and the recommendations for the scanned targeted system. The system is designed to provide an information security active audit process more faster. It also helps to facilitate this process for the end users (experts) by making available the recommendations of several experts.

The used vulnerability scanner is the scanner OWASP Zed Attack Proxy (ZAP) (Fong E., et al., 2008). It is one of the most popular tool for free security checking of web applications. ZAP helps to find automatically the security vulnerabilities of the targeted system. Nowadays it is actively supported by hundreds of international volunteers.

Any integration of system with a security scanner may have some problems. For example, the availability of API(Application Programming Interface) of vulnerability scanner may become a problem that requires making changes in scanner's program code for calling the necessary functions from the expert system side. For this purposes it is very critical to have an open source and code for making changes.

ZAP as an open source scanner contains the special API interfaces that make the process of integration more easy. Such features make it possible to develop system integration without any modifications in source code. This advantage of ZAP Attack Proxy scanner could give us possibility to save time and spend it to another tasks of the project.

The fuzzy expert system focuses on the defining the level of security risks for targeted system based on the notes of experts, their assessment and recommendations. In this process we use the main principles of fuzzy logic (Zadeh, L., 1978). The priority of the proposed recommendations is identified by the level of expertise of each expert. This parameter is also fuzzy metrics.

The principles of using fuzzy metrics can be described in the next steps.

The basic building blocks of fuzzy logic are linguistic variables described by fuzzy numbers. In our case each vulnerability could be defined by linguistic variables "low", "middle", "high".

The areas for assessment for each expert we defined as the following:

1.Risk level of the vulnerability.

2. Confidence of an expert.

3. Urgency of fixing vulnerability.

4. Use of vulnerability in combination with other ones.

5. Expert's level in this area (expertise)

6. Solution and recommendation

The parameter "Vulnerability Risk Level" has the values from 1 to 10 by which expert can gradate the potential risk level of a vulnerability.

The parameter "Confidence" is also chosen from 1 to 10. This indicator shows how expert is confident in his assessment.

The "Urgency of fixing" is the set of parameters "immediate", "later" or "ignore". This special parameter "Immediate urgency" means that bug fix must be done quickly as possible. The other one "Later urgency" means that bug can be fixed slowly after some time. "Ignore" means that the risk is not critical, and alert can be ignored by developers and may be not fixed.

The option "Can be exploited with another vulnerability" means that this alert can be combined and be exploit with other vulnerability. This fact in general makes risk level of vulnerability more higher since the results of these risks may be expressed in appearing the security hole that is vulnerable for future attacks and actions of other vulnerabilities.

The "Expert level in given area (expertise)" has the gradation from 1 to 5, which indicates the expert's background and his/her experience with this types of alerts.

The "Solution" is a text field where expert writes his recommendations how to fix the problem and mitigate the risk. This recommendation will be reviewed by other experts and they will decide whether to accept or decline that recommendation.

The "Final Solution" is available in final report form for user. After expert submits his recommendation the general risk for the given vulnerability can be calculated (Bojanc, R., 2013).

The fuzzy expert system is developed as a thin client application (Sheriyev M. and Atymtayeva L., 2015) with Vaadin Java Framework user interface (UI) framework.

The UI is developed in a such way when user (expert or company owner/worker) can scan the selected targeted system without any difficulties. On the user page "My Scans" for experts there are three statuses: "scanning", "reviewing", and "ready" so the expert can scan, or review (propose suggestions/ assessments about the level of security risks and describe the problem), or finish the reviewing (make the status "ready").

In the system each expert can see the review of other experts and make some adding or correction if he/she disagrees.

3.3 Matlab Simualtion of Fuzzy Expert System

For development and design of the proposed Fuzzy Expert System we use the algorithm that is laid in Mamdani's fuzzy inference method (Zadeh, L. 1978). To calculate the output of the Fuzzy Inference System (FIS) inputs, we go through the main four stages:

- Fuzzification of the input variables
- Rule evaluation
- Aggregation of the rule outputs
- Finally defuzzification

For simulation of the Fuzzy Expert System to identify the general risk we used the fuzzy logic toolbox in MatLab.

With crisp inputs for alerts we used the rules for calculating the general risk (Figure 2) which can be defined by applying the natural language (if-then statements).

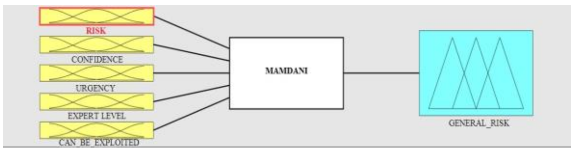


Figure 2: Crisp inputs for alerts.

These statements are usually made by experts to get an optimal result, for example:

1. If (risk is high) and (confidence is low) and (urgency is ignore) and (is-comb-avail is impossible) and (expert-level is low) then (general-risk is low)

2. If (risk is high) and (confidence is high) and (urgency is later) (is-comb-avail is possible) and (expert-level is med) then (general-risk is med)

3. If (risk is high) and (confidence is high) and (urgency is immediate) and (is-comb-avail is for-sure) and (expert-level is med) then (general-risk is high),

and so on.

We have generated 3^4=81 rules (by ignoring some repeating rules the number of rules can be reduced to 57). According to these rules the general risk can be calculated (see Figure 3).

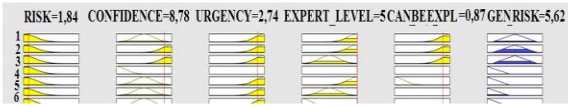


Figure 3: Calculation of general risk.

Currently we have 3 experts, so when we calculate general risk from every expert we use another rules to combine the obtained results in order to calculate the final risk level.

The used algorithm is the same, while rules and inputs are different (Zhao, X., 2013). Calculated general risk from experts is used as an input. Rules are described below, total count of rules is 3^3=27 (by ignoring some repeating rules the number of rules were reduced to 21). The obtained result can be shown to the end user as a final risk level:

1. If (expert1 is low) and (expert2 is low) and (expert3 is low) then (general-risk is low)

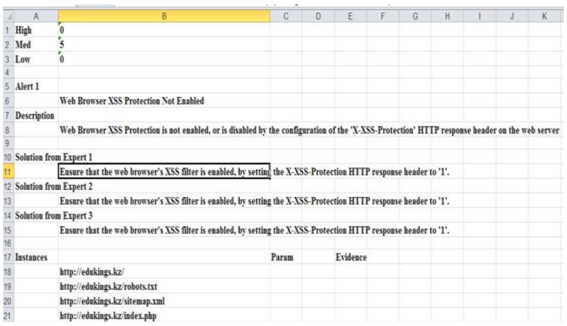
2. If (expert1 is low) and (expert2 is low) and (expert3 is high) then (general-risk is med)

3. If (expert1 is med) and (expert2 is low) and (expert3 is low) then (general- risk is low)

and so on.

If the number of experts will be increased the number of rules would also be increased as 3^n, where n is a number of experts. In this case the technique of smoothing the final assessments and finding the level of agreement of the experts' opinions could be successfully applied (Akzhalova A., et el., 2005).

At the end of scanning and reviewing process the expert system generates the report in .xls format with specifying the level of general risk based on the analysing of expert judgements, types of serious alerts with description and probable solutions. (see Figure 4).



	A	B	C	D	E
1	High	0			
2	Med	5			
3	Low	0			
4					
5	Alert 1				
6		Web Browser XSS Protection Not Enabled			
7	Description				
8		Web Browser XSS Protection is not enabled, or is disabled by the configuration of the 'X-XSS-Protection' HTTP response header on the web server			
9					
10	Solution from Expert 1				
11		Ensure that the web browser's XSS filter is enabled, by setting the X-XSS-Protection HTTP response header to '1'.			
12	Solution from Expert 2				
13		Ensure that the web browser's XSS filter is enabled, by setting the X-XSS-Protection HTTP response header to '1'.			
14	Solution from Expert 3				
15		Ensure that the web browser's XSS filter is enabled, by setting the X-XSS-Protection HTTP response header to '1'.			
16					
17	Instances		Param		Evidence
18		http://edukings.kz/			
19		http://edukings.kz/robots.txt			
20		http://edukings.kz/sitemap.xml			
21		http://edukings.kz/index.php			

Figure 4: Generated report in .xls format.

4 CONCLUSIONS

Summarizing what was already mentioned, we can say that the usage of intelligent scanners and development of knowledge base system may improve efficiency of information security OWASP auditing processing. In addition, the combining of expert system and vulnerability scanners may reduce the cost of the auditing process.

This work was done to prevent the problems which occur immediately in information security auditing process. We have described the process development of fuzzy expert system in the integration with vulnerability scanners for web application security checking. The selection of a proper vulnerability scanner and its integration with an expert system may encounter with different problems such as finding the relevant API functions, constructing the proper algorithm for fuzzy inference system and development of appropriate fuzzy metrics.

There are many security scanners but they do not use the analytic capabilities of human thinking, which capabilities help see some potential threats that a scanner is unable to recognize. For this reason, we argue that the usage of expert systems in security auditing may become a solution. Such a solution can have a significant value as it concerns the development of intelligent vulnerability scanners that work in combination with human experts. The prospective development of this work we see in the following directions:

- Making an integration with the best commercial scanners;
- Using several scanners;
- Making system more scalable;
- Using additional algorithms, for example, genetic algorithms for achieving best results;
- Making a new commercial product.

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Opening More Data
A New Privacy Risk Scoring Model for Open Data

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Abstract: While the opening of data has become a common practice for both governments and companies, many datasets are still not published since they might violate privacy regulations. The risk on privacy violations is a factor that often blocks the publication of data and results in a reserved attitude of governments and companies. Additionally, even published data, which might seem privacy compliant, can violate user privacy due to the leakage of real user identities. This paper proposes a privacy risk scoring model for open data architectures to analyse and reduce the risks associated with the opening of data. The key elements consist of a new set of open data attributes reflecting privacy risks versus benefits trades-offs. Further, these attributes are evaluated using a decision engine and a scoring matrix intro a privacy risk indicator (PRI) and a privacy risk mitigation measure (PRMM). Privacy Risk Indicator (PRI) represents the predicted value of privacy risks associated with opening such data and privacy risk mitigation measures represent the measurements need to be applied on the data to avoid the expected privacy risks. The model is exemplified through five real use cases concerning open datasets.

1 INTRODUCTION

Governments and publicly funded research organizations are encouraged to disclose their data and to make this data accessible without restrictions and free of charge (B. 2009, Commision 2011, B. 2012). Opening public and private data is a complex activity that may result in benefits yet might also encounter risks (Conradie and Choenni 2014, Zuiderwijk and Janssen 2014, Zuiderwijk and Janssen 2015). An important risk that may block the publication of the data is that organizations might violate the privacy of citizens when opening data about them (Conradie and Choenni 2014). Moreover, when opening data, organizations lose control on who will be using this data and for what purpose. Once data is published, there is no control over who will download, use and adapt the data.

To avoid privacy violations, data publishers can remove sensitive information from datasets, however, this makes datasets less useful. In addition, even published data, which may seem privacy compliant, can violate user privacy due to leakage of real user identities when various datasets and other resources are linked to each other (Kalidien, Choenni et al. 2010). The possibility of mining the data afterwards to get meaningful conclusions can lead to leakage of private data or users real identities. Although organizations remove identifying information from the dataset before publishing the data, some studies demonstrate that anonymized data can be de-anonymized and hence real identities can be revoked (Kalidien, Choenni et al. 2010).

Various existing studies have pointed at the risks and challenges of privacy violations for publishing and using open data (Kalidien, Choenni et al. 2010, Conradie and Choenni 2014, Janssen and van den Hoven 2015, Perera, Ranjan et al. 2015). Some studies have identified privacy risks or policies for organizations in collecting and processing data (Drogkaris, Gritzalis et al. 2015, Kao 2015), some have provided decision support for opening data in general (Zuiderwijk and Janssen 2015), and some have focused on releasing information and data on the individual level (James, Warkentin et al. 2015). Nevertheless, there is still limited insight in how organizations can reduce privacy violation risks for open data in particular, and there is no uniform approach for privacy protection (Janssen and van den Hoven 2015). From existing studies it has not become clear which open data model can be used to reduce the risk on open data privacy violations. An open data model is needed that helps making decisions on opening data and that provides insight in whether the data may violate users' privacy.

The objective of this paper is to propose a model to analyse privacy violation risks of publishing open data. To do so, a new set of what are called open data attributes is proposed. Open data attributes reflect privacy risks versus benefits trade-offs associated with the expected use scenarios of the data to be open. Further, these attributes are evaluated using a decision engine to a privacy risk indicator (PRI) and a privacy risk mitigation measure (PRMM). In particular this can help to determine whether to open data or keep it closed.

This paper is organized as follows. Section 2 discusses related work while section 3 presents privacy violation risks associated with open data, followed by section 4 which introduces the proposed model. The model helps identifying the risks and highlights possible alternatives to reduce these risks. Section 5 exemplifies the model by providing some use cases and preliminary results. Section 6 discusses the key findings and concludes the paper.

2 RELATED WORK

Public bodies are considered the biggest creators of data in the society in what is known as public data. Public data may range from data on procurement opportunities, weather, traffic, tourist, energy consumption, crime statistics, to data about policies and businesses (Janssen and van den Hoven 2015). Data can be classified into different levels of confidentiality, including confidential, restricted, internal use and public (ISO27001 2013). We consider public data that has no relation with data about citizens as outside the scope of this work.

Anonymized data about citizens can be shared to understand societal problems, such as crime or diseases. An example of citizen data is the sharing of patient data to initiate collaboration among health providers which is expected to be beneficial to the patient and researchers. The highly expected benefits behind this data sharing are the improved understanding of specific diseases and hence allowing for better treatments. It can also help practitioners to become more efficient. For example, a general practitioner can quickly diagnose and prescribe medicines. Nevertheless, this sharing of patients' information should be done according to data protection policies and privacy regulations.

A variety of Data Protection Directives has been created and implemented. Based on the Data Protection Directive of 1995 (European Parliament and the Council of the European Union 1995), a comprehensive reform of data protection rules in the European Union was proposed by the European Commission (2012). Also the Organization for Economic Co-operation and Development has developed Privacy Principles (OECD, 2008), including principles such as "There should be limits to the collection of personal data" and "Personal data should not be disclosed, made available or otherwise used for purposes other than those specified in accordance with Paragraph 9 except: a) with the consent of the data subject; or b) by the authority of law." In addition, the ISO/IEC 29100 standard has defined 11 privacy principles (ISO/IEC-29100 2011).

Nowadays a relatively new approach for privacy protection called privacy-by-design has received attention of much organization such as the European Network and Information Security Agency (ENISA). Privacy-by-Design suggests integrating privacy requirements into the design specifications of systems, business practices, and physical infrastructures (Hustinx 2010). In the ideal situation data is collected in such a way that privacy cannot be violated.

The Data Protection Directives are often defined on a high level of abstraction, and provide limited guidelines for translating the directives to practice. Despite the developed Data Protection Directives and other data protection policies, organizations still risk privacy violations when publishing open data. In the following sections we elaborate on the main risks of privacy violation associated with open data.

A number of information security standards were estalished to achieve effective information security governance, among which are ISO (2013), COBIT5 and NIST (2016). Most work on privacy risk assessment aim to conduct surveys or questionnaires that assess companies' ways of dealing with personal data according to regulatory frameworks and moral or ethical values. When it comes to open data, such frameworks to assess privacy risks cannot be used since the data to be published will contain no identifying information as a pre-requisite by the law. Having said that, normal ways of assessing privacy risks cannot be applied and new ways are needed that outweigh the benefits of sharing the data compared to expected privacy risks of the leakage of personally identifiable information.

3 PRIVACY THREATS FOR OPENING DATA

3.1 Real Identities Disclosure

Privacy can be defined as a person's desire to manage information and interaction about him or her (James, Warkentin et al. 2015). It appears that privacy threats are caused mainly by the risks associated with anonymizing the data and making it public for re-use. Privacy legislation and data protection policies force organizations and governments not to publish private information. In this context, organizations are asked to remove any identifying information from the data before making it available online. Nevertheless, some studies in anonymization techniques show that anonymized data can be de-anonymized and hence real identities can be revoked. For example, Narayanan and Shmatikov (2008) showed that an adversary with very little information about a user, could identify his or her record in the Netflix openly published datasets of 500,000 anonymized subscribers. In addition, removing real names, birth dates and other sensitive information from datasets may not always have the desired effect. For instance, the Dutch police has started to publish open data about cars and bicycle thefts after removing real names of people involved. Although removing these names might sound satisfactory for user privacy protection, more research is needed to analyse whether user identities are safe and whether this is a robust approach.

3.2 Privacy Leakage through Linked - Data

The combination of variables from various datasets could result in the identification of persons and reveal identities (Zuiderwijk and Janssen 2015). Data attributes, referred to with the term 'quasi-identifier', can be linked to external data resources and hence can lead to the release of hidden identities (XU, JIANG et al. 2014). Examples of quasi-identifiers are a person's age, gender and address.

Figure 1 shows an example of privacy leakage through data linkage. In this example, an attacker may identify the person John from this dataset. By combining information about the gender, birth place and the city where John lives, John may be identified in the open dataset. Therefore, these data types are important to be hidden as well. In addition, sensitive data such as diseases should be removed from the datasets. However, data providers often cannot predict in advance which combination of variables will lead to privacy leakage (Zuiderwijk and Janssen 2015), and thus this prediction is a complex activity.

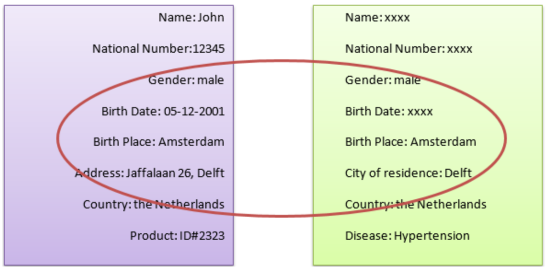

Figure 1: Privacy leakage through data linkage.

3.3 Data Mining

Open data makes data available online for researchers and companies. Companies use data mining techniques to conclude meaningful information from these datasets which help them in their businesses. When doing so, they can violate users' privacy because mining the data can deduce private information. In order to help overcome these issues, privacy preserving data mining techniques should be used to reduce privacy risks (XU, JIANG et al. 2014).

3.4 Data Utilization versus Privacy

Once a dataset has been transferred from the data owner to the data publisher, the data owner is no longer in control over his or her data. Data control has transferred to the data publisher who is responsible against the law for the protection of people's privacy. Before publishing the data online, the data publisher anonymizes the data and removes any sensitive data that makes it possible to identify persons.

Most of the times, the data publisher does not know who will receive the data and for what purpose he or she will access the data. Further, the data publisher does not necessarily know what mining techniques will be used by the data receiver and how much sensitive information can be deduced from the anonymized data. If the data publisher removes all identifying information, alters associated quasi-identifiers, and removes sensitive data, the published data can lose its value. Hence, there should be a balance between what can be published, in order for users to be able to derive useful information, and at the same time ensuring privacy protection. Complete privacy protection might result in no use of the data at all, and hence the published data can become of no value.

4 PRIVACY RISKS SCORING MODEL

Uncertainty associated with the disclosure of data makes it difficult to come up with a good approach to protect users' privacy. When published, unknown third-party organizations and other users can get access to sensitive information. Sharing information under uncertainty conditions while being able to guarantee user privacy represents one of the challenges in these environments (Ali Eldin and Wagenaar 2007). Since assessing privacy and security risks is critical for enterprises (Jones 2005), we expect the same is needed for open data environments for the sake of protection of user data.

The key elements of the proposed model are presented as follows (see Figure 2):

4.1 Open Data Attributes

Based on authors' observations from previous case studies on open data architectures, five open data attributes are assumed in this research. The first four are shown at the top left corner in Figure 2, whereas the fifth attribute is shown at the top right corner. The five open data attributes are as follows:

- Need for openness: referring to the need for publishing the data openly. If the data criticality level is high but the need of openness is high, then a trade-off exists and the need for openness can outweigh the high criticality level or vice versa.
- Criticality level: this attribute represents the importance of the data, analogous to the importance of the benefit of data publishing to the community.
- Security alarm/threat: this refers to what degree is the expected cyber security threat alert. If the security threat is set to high, then this can have impact on the nature of data being published and made available to others.
- Trust level: refers to how the data publisher is rated by others with respect to his or her trustworthiness. Reputation of the data publisher influences the quality of the data and the way privacy is dealt with. For example, whether the data publisher is trusted that he or she will comply with privacy regulations and whether the quality of data will be high.

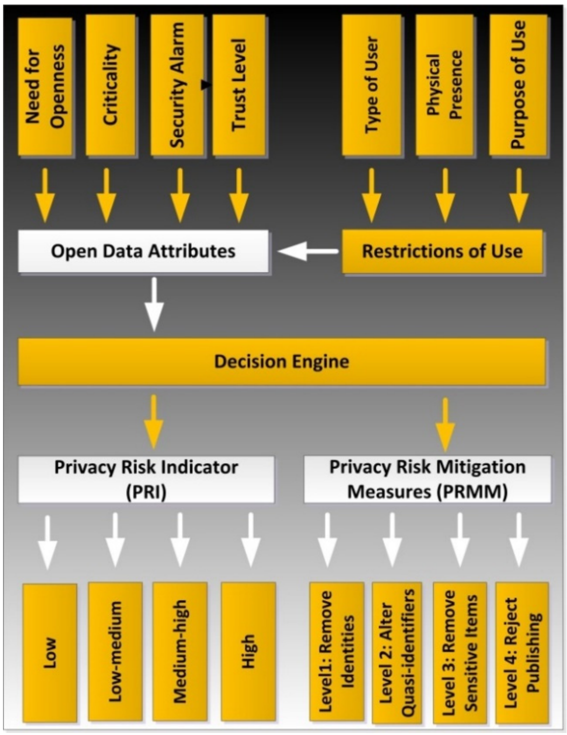

Figure 2: Proposed Privacy Risks Scoring (PRS) Model.

- Restrictions of Use: Restrictions of use represents access privileges allowed on the data. We distinguish three ways to describe this restriction:
  - Type of user. This means a restriction is applied on basis of the role the user plays.
  - Physical Presence. This means that data access depends on the physical location where it is accessed from.
  - Purpose of use. This means different types of restriction may apply depending on the purpose data is needed for.

4.2 Decision Engine

A box in the middle of Figure 2 depicts the decision engine. The decision engine component is responsible for deciding upon perceived privacy risks and recommends a suitable privacy risk mitigation measure. This is done based on a scoring matrix and a rule engine having scores of open data attributes as input. Rules are specified by subject matter experts and by analysis of the model associated data access records.

4.3 Privacy Risk Indicator (PRI)

The PRI represents the predicted value of privacy risks associated with opening such data. PRI can have four values; low, low-medium, medium-high and high. A high PRI means the threat to privacy violation is expected to be high. PRI is determined by the decision engine based on the scoring matrix and the rules associated with the decision engine.

4.4 Privacy Risk Mitigation Measures (PRMM)

Based on the decision engine, a privacy risk indicator score is predicted together with a privacy risk mitigation measure. For example, what should be done if there is a risk that the identity of an owner of a stolen bike can be tracked down if we publish stolen bike records online? The following measures are used in our framework:

- Level 1: Remove identifiers. This is the least measure that needs to be taken by a data publisher when the risk indicator is classified as low risk. By doing that, they adhere to the European data directives and data protection laws. The use of database anonymization tools is mandatory in order to remove the identities and make the data anonymous. Examples of such tools are (Anonymizer , ARX , Camouflage's-CX-Mask).
- Level 2: Alter Quasi-identifiers. Changing quasi-identifiers' data values can help reduce identity leakage. Quasi-identifiers are data types which if linked with other datasets can reveal real identities. Examples are age, sex and zip code (Ali Eldin and Wagenaar 2007, Fung, Wang et al. 2010). Researchers in this area developed algorithms that can detect and find quasi-identifiers (Shadish, Cook et al. 2002, Motwani and Xu 2007, Shi, Xiong et al. 2010). To meet PRMM level 2, PRMM level 1 activities must be completed as well.
- Level 3: Remove Sensitive Items. For some cases, there are data items such as medical diseases which are considered sensitive and need to be protected when publishing the data if the risk indicator is high risk. The type of data that is considered sensitive varies from dataset to another which makes it complex to safely identify and remove it. Some commercial tools exist that could be used which can be adjusted for specific data type and specific operating systems. An example of such tools is Nessus (Nessus). To meet PRMM level 3, PRMM levels 1 and 2 activities must be completed as well.
- Level 4: Reject Publishing. In case that the threat is high, it is advised not to publish the data at all, and therefore the recommended measure would be to reject publishing.

5 IMPLEMENTATION AND RESULTS

In this section, we describe five use cases to illustrate the proposed model. These cases are based on real scenarios. In each case we determine the Privacy Risk Indicator (PRI) and the Privacy Risk Mitigation Measure (PRMM). The cases involve different types of actors who conduct different activities. Some of the actors upload datasets, others use them or both upload and use them. The type of data provided varies between the cases, since some of the opened data are provided real-time, while others are static with or without updates.

The criticality of the data ranges from low to high, and the data use is restricted in various ways. The use of some datasets is not restricted, whereas for other datasets the restriction depends on the purpose of use, the type of data user, the physical presence of the data user at a certain location or the type of user. The level of trust in data quality is different for each of the cases, ranging from large issues (low trust level) to very limited issues (high trust level).

5.1 Decision Engine

Before we can assess the different cases, we need to specify the rules used in the decision engine. For the sake of simplicity, a scoring matrix is used where attributes are given scores on a scale from 0 to 1 according to their threat to privacy. Table 1 shows an example of the scoring approach based on the authors' experiences.

Each attribute is valuated with a score s such that $s \leq 1$. These scores are created based on assumptions on privacy risks associated with each attribute value. Each attribute category A_i has a weight ($0 < w_i \leq 10$) associated with it such that when aggregating all scores they get weighted as follows:

$$PRI = \frac{1}{n} * \sum_{i=1}^{n} w_i * Max(s_i)\, , PRI \leq 1 \quad (1)$$

Max (Si) means that if more than one score is possible within one attribute category because of the existence of more than one attribute value like for example two types of use, then the maximum score is selected to reflect the one with the highest risk. The advantage of using weights is to introduce some flexibility such that the influence of each attribute category can get updated over time according to lessons learned from gathered data and previously found privacy treats. Table 2 shows how PRI value is mapped to a corresponding privacy mitigation risk measure level (PRMM).

5.2 Case 1: Use and Provision of Open Crime Data

A citizen of a large European city wants to know how many crimes occur in her neighbourhood compared to other neighbourhoods in the city.

She searches various open data infrastructures for the data that she is looking for. When she finds real-time open crime data, she downloads and analyses them. According to the license, the data can be used in various forms, both non-commercially and commercially. Data visualizations help the citizen to make sense of the data. Nevertheless, she has only limited information about the quality of the dataset and about the provider of the data, which decreases her trust in the data.

The open data infrastructure that the citizen uses does not only allow governmental organizations to open datasets, but offers this function to any user of the infrastructure. This citizen also wants to share some data herself. She has collected observation of theft in the shop that she owns, and publishes these data on the internet as open data. This means that the citizen both downloads and uploads open data. Using the proposed model, an overview of open data attributes for this case can be given (see Table 3).

From table 1, the PRI can be calculated using equation (1): $PRI = 0.61$. PRI can be seen to be medium-high meaning a relatively high privacy risk with associated PRMM set at level 3: *remove sensitive data*. The data publisher should filter the published data from identifying information, quasi-identifiers and sensitive data to avoid this expected relatively high privacy risk.

Table 1: Open Data Attributes Scoring Matrix.

Attribute (A)	Weight (w)	Attribute Value	Score (s)
Type of User	1	Government	0.2
		Researcher	0.4
		Citizen	0.6
		Student	0.8
		Company	1.0
Purpose of use	1	Information	0.2
		Research	0.4
		Commercial	0.6
		Sharing	0.8
		Unknown	1.0
	1	Static	0.33
Type of data		Updated	0.67
		Real-time	1.0
Data Criticality	1	Low	0.25
		Low-medium	0.50
		Medium –high	0.75
		High	1.00
Restrictions of use	1	None	0.25
		type of user / purpose of use	0.50
		Restricted by country	0.75
		Restricted by network	1.00
Need for Openness	1	Low	0.33
		Medium	0.67
		High	1.00
Trust in Data Quality	1	Low	0.25
		Low- Medium	0.50
		Medium – High	0.75
		High	1.00

Table 2: Mapping PRI to PRMM.

PRI	Score	PRMM
Low	0.00-0.25	Level 1: Remove identities
Low - Medium	0.25-0.50	Level 2: Remove Quasi-identifiers
Medium – High	0.50-0.75	Level 3: Remove Sensitive data
High	0.75-1.00	Level 4: Reject publishing

Table 3: Case 1 Overview.

Case Attributes	Case 1
Type of User	Citizen
Purpose of use	Use and upload open data about neighbourhood
Type of data	Real-time
Data Criticality	Low
Restrictions of use	None
Need for Openness	High
Trust Level	High

5.3 Case 2: Provision of Open Social Data

An archivist working for a governmental agency maintains the open data infrastructure of this agency. Datasets cannot be uploaded by anyone but only by an employee of the governmental organization. The archivist has the task to make various social datasets that are found appropriate for publication by the agency employees available to the public. The archivist uploads static datasets that are non-sensitive, so that the risk on privacy breaches is minimized. The datasets can be reused by anyone; there are no restrictions regarding the type of user or the purpose of use. Since the datasets are provided online with much metadata, including data about the quality of the dataset, this reduces the trust issues that data users may have. Using the proposed model, an overview of this case's open data attributes is shown in Table 4. The PRI for case 2 is 0.39 with Low – medium privacy risks. PRMM is set at level 2: remove Quasi-identifiers. This implies removing identifying information as well.

Table 4: Case 2 Overview.

Case Attributes	Case 2
Type of User	Governmental Archivist
Purpose of use	Upload open social data
Type of data	Static
Data Criticality	Low
Restrictions of use	None
Need for Openness	High
Trust Level	Low-Medium

5.4 Case 3: Use of Restricted Archaeology Data

A student conducts a study in the area of archaeology. To obtain access to the data, the student needs to submit a request at the organization that owns the data. In his request, the student needs to provide information about himself, his study and about the purpose for which he wants to use the data. The data are not completely open, since access to the data is restricted by a data request procedure.

Since the data user needs to provide the governmental agency with information, the governmental organization can decide to provide more sensitive data than the data that they offer with open access.

For study purposes, more sensitive data can be disclosed to this single user, under the condition (contractually agreed) that he will not provide the information to others. Since the user can personally contact the data provider, trust issues are less common than they may be for other (open) datasets. Using the proposed model, an overview of this case is given in Table 5. $PRI = 0.54$, PRMM is at level 3: remove sensitive data. Again as mentioned earlier, special contractual agreement can be put in place with this particular student before sensitive data can be shared with him otherwise sensitive data has to be removed.

Table 5: Case 3 Overview.

Case Attributes	Case 3
Type of User	Student
Purpose of use	Use open data for study
Type of data	Static
Data Criticality	Low-medium
Restrictions of use	Purpose of use, type of user
Need for Openness	Medium
Trust Level	Medium-high

5.5 Case 4: Use of Physically Restricted Statistics Data

A researcher would like to use open statistical data that is provided by a governmental statistics organization. The statistics office has been opening data for many years and has a good reputation in this area, since it offers high-quality data. The researcher therefore trusts the data of the statistics office and believes that he can reuse these data for his own research. While the researcher can access various open datasets on the internet, some datasets are provided in a more restricted form. To access the more sensitive datasets, the researcher needs to physically go to the statistics office.

The statistics office does not open these sensitive data, since this may lead to privacy breaches. The researcher can analyse the data at the location of the statistics office, yet it is not allowed to take any data along with him and to publish these data as open data. Since the researcher physically needs to travel to the statistics office, the office can obtain insight in the purposes for which the researcher wants to use the data, and based on this purpose, they approve or disapprove the use of their data. Using the proposed model, an overview of this case is given in Table 6. Accordingly, $PRI = 0.51$, and the PRMM is at level 3: remove sensitive data. This means before sharing this data openly, all sensitive data has to be removed together with identifying information and quasi-identifiers.

Table 6: Case 4 Overview.

Case Attributes	Case 4
Type of User	Researcher
Purpose of use	Use open data for research
Type of data	Static, updated frequently
Data Criticality	Medium-high
Restrictions of use	Physical presence, type of user
Need for Openness	Low
Trust Level	Low

5.6 Case 5: Use of Physically Restricted Agency Data

A civil servant may not only be involved in opening datasets, but may also reuse datasets that are provided by her own organization. The agency's data can only be accessed internally by its employees who are present at the agency, and is therefore restricted by type of user and by physical barriers. The datasets are both real-time and static, yet they are updated frequently. The agency's data are highly sensitive; since they have not been anonymized and sensitive information has not been removed. The data cannot be used by anyone and are not open. Trust of the data user is high, since the user is familiar with the context in which the data have been created and has access to colleagues who can answer questions about the data if necessary. Using the proposed model, an overview of this case is given in Table 7. Accordingly, $PRI = 0.68$, and the PRMM is at level 3: remove sensitive data.

In the previous cases, the security threat is assumed to be low and thus it was not included in the computations. From the above, we see that for the different use cases of the same dataset, we can have different privacy risks and thus we need to consider applying measures for privacy risks mitigation. The application of the proposed model has given insight into this association between the datasets and the use cases based on privacy risks scores associated with these cases (see Figure 3). This insight will help in applying the suitable privacy risk mitigation measure (PRMM) before publishing the data openly.

Table 7: Case 5 Overview.

Case	Case 5
Type of User	Civil servant
Purpose of use	Use data provided by own organization
Type of data	Real-time and static, updated frequently
Data Criticality	High
Restrictions of use	Physical presence, type of user
Need for Openness	Low
Trust Level	Low

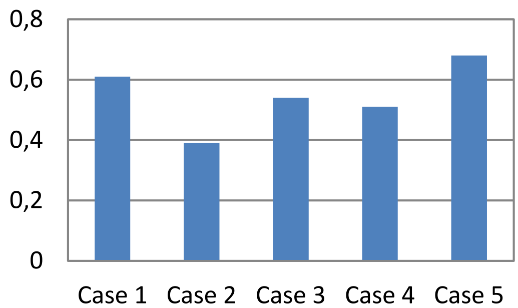

Figure 3: PRI scores for five different open data cases with equally weighted Open Data Attributes.

6 DISCUSSION AND CONCLUSION

The opening and sharing of data is often blocked by privacy considerations. Most work on privacy risk assessment evaluates privacy risks based on assessment of companies' ways of dealing with personal data and their maturity in doing so according to standards and common practices. These frameworks cannot be applied in open data architectures because the data does not contain personally identifiable information (PII) by default if published in public. However, in this paper, we showed that PII can still be disclosed even after being removed through different ways. We also argued for the need of evaluating the different use cases associated with the dataset before a decision to be made on whether to open the data.

In this paper, a new model for privacy risk scoring in open data architectures was proposed. The model is based on defining a new set of, what is called, open data attributes and privacy risk mitigation measures. Each open data attribute is given a score according to a predefined scoring matrix. From the implemented cases, it was clear that different privacy risk mitigation measures are considered depending on risks associated with these attributes. Each defined privacy risk mitigation measure should be applied before making this dataset available online openly.

Further research is needed to define a common basis for the scoring matrix and all possible open data attributes. Statistical analysis should be conducted to validate the possible generalizability of the proposed model. In addition, details of the realization architecture should be discussed together with the implementation details of the privacy risk mitigation measures.

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Fast Deduplication Data Transmission Scheme on a Big Data Real-Time Platform

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Abstract: In this information era, it is difficult to exploit and compute high-amount data efficiently. Today, it is inadequate to use MapReduce to handle more data in less time let alone real time. Hence, In-memory Computing (IMC) was introduced to solve the problem of Hadoop MapReduce. IMC, as its literal meaning, exploits computing in memory to tackle the cost problem which Hadoop undue access data to disk caused and can be distributed to perform iterative operations. However, IMC distributed computing still cannot get rid of a bottleneck, that is, network bandwidth. It restricts the speed of receiving the information from the source and dispersing information to each node. According to observation, some data from sensor devices might be duplicate due to time or space dependence. Therefore, deduplication technology would be a good solution. The technique for eliminating duplicated data is capable of improving data utilization. This study presents a distributed real-time IMC platform -- “Spark Streaming” optimization. It uses deduplication technology to eliminate the possible duplicate blocks from source. It is expected to reduce redundant data transmission and improve the throughput of Spark Streaming.

1 INTRODUCTION

In recent years, with the development of Internet and prevalence of mobile devices, a very huge amount of data was generated daily. To be able to carry out some operations on larger and more complex data now, techniques for Big Data were presented. In 2004, Google released a programming model MapReduce (Dean, 2008) for processing and generating large data sets with a parallel, distributed algorithm. Packages have been developed and widely used nowadays. They can make big-data analysis more efficient. For instance, one of the mostly used packages is Hadoop (Shvachko, 2010). It provides an interface to implement MapReduce that allows people use it more easily.

Hadoop MapReduce adapts coarse-grained tasks to do its work. These tasks are very heavyweight for iterative algorithms. Another problem is that MapReduce has no awareness of the total pipeline of Map plus Reduce steps. Therefore, it cannot cache intermediate data in memory for faster performance. This is because it uses a small circular buffer (default 100MB) to cache intermediate data, and it flushes intermediate data to disk between each step and when 80% of the circular buffer space is occupied. Combined these overhead costs, it make some algorithms that require fast steps unacceptably slow. For example, many machine-learning algorithms were required to work iteratively. Algorithms like training a recommendation engine or neural networks and finding natural clusters in data are typically iterative algorithms. In addition, if you want to get a real-time result from the trained model or wish to monitor program logs to detect failures in seconds, you will need for computation streaming models that simplify MapReduce offline processing. Obviously, you want the steps in these kinds of algorithms to be as fast and lightweight as possible.

To implement iterative, interactive and streaming computing, a parallel in-memory computing platform, Spark (Zaharia, 2010), was presented. Spark is built on a powerful core of fine-grained, lightweight, and abstract operations by which the developers previously had to write themselves. Spark is lightweight and easy to build iterative algorithms with good performance as scale. The flexibility and support for iterations also allow Spark to handle event stream processing in a clever way. Originally, Spark was designed to become a batch mode tool, like MapReduce. However, its fine-grained nature makes possible that it can process very small batches of data.

Therefore, Spark developed a streaming model to handle data in short time windows and compute each of them as “mini-batch”.

Network bandwidth is another bottleneck that we wish to resolve. Bandwidth shortage is not from its architecture but from the gateway between sensors and computing platform (Akyildiz, 2002). The bridge that collects data from sensors and transmits data to server is performed by one or more gateways. Their bandwidth is often low because of the wireless network environment. Our proposal is to utilize these transmitted data fully for low-latency processing applications. In order to maintain or even improve the throughput of computing platform, we adopt the real-time parallel computing platform based on data deduplication technology. It allows the efficient utilization of network resources to improve throughput.

Data deduplication is a specialized data compression technique for eliminating duplicated data. This technique is used to improve storage utilization and can also be applied to network data transmission to reduce the amount of bytes that must be sent. One of the most common forms of data deduplication implementation works by comparing chunks of data to detect duplicates. Block deduplication looks within a file and saves distant blocks. Each chunk of data is processed using a hash algorithm such as MD5 (Rivest, 1992) or SHA-1 (Eastlake, 2001). This process generates a unique number for each piece which is then stored in an index. If a file is updated, only the changed data is saved. For instance, Dropbox and Google Drive are also cloud file synchronization software. Both of them use data deduplication technique to reduce the cost of storage and transmission between client and server. However, unlike those cloud storages, there is no similar file between gateway and computing server. Hence, we propose a data structure to keep those duplicated part of data and reuse them. This is the part where our work is different from those cloud storages. In our work, the data stream from sensors can be regarded as an extension of a file. In other words, the data stream is also divided into blocks to identify which blocks are redundant. So data deduplication has quite potentials to resolve the problem of bandwidth inadequate.

In this study, we propose that the deduplication scheme reduces the requirement of bandwidth and improves throughput on real-time parallel computing platform. Interestingly, the data from sensors has quite duplicated part that can be eliminated. This is the tradeoff between processing speed and network bandwidth. We sacrifice some CPU efficacy of gateways and computing platform to exchange more efficient utilization of network bandwidth. In brief, we applied data deduplication technique completely to improve the data re-use rate on distributed computing system like Spark.

2 DATA DEDUPLICATION TRANSMISSION SCHEME

In this section, we elaborate on the details of our system design. We first clarify our problem in Section 2.1 and then the implementations and the parameter definition are listed in the following sections. In Section 2.2, we outline our system overview and provide a series steps explanation then formulate our bandwidth saving model. In Section 2.3, we describe how to choose block fingerprint and give a benchmark for hash functions to compare to select the option. In Section 2.4, we give some concept to guide users how to implement the data chunk preprocess model.

2.1 Problem Description

The main problem we want to resolve is to reduce the duplicated data delivery so that it can send more data in limited time. This problem can be divided into several sub-problems. The first one is that how to chunk data so that we can make the set of data blocks smaller. In other words, when the repetition rate of data blocks is higher, the bandwidth saving becomes more. However, if remote does not have similar data, these chunking methods would not effective.

The second problem is that how sender decides whether this data block has received or not. With Rsync algorithm (Tridgell, 1998), it uses a pair of weak and strong checksums for a data block to enable sender to check whether the blocks have not been modified or not. This gives a good inspiration to solve it. In order to find the same data block, Rsync uses strong checksum to achieve it. So, hash function is the solution that is able to digest block into a fingerprint. Block fingerprint can represent the contents of the block and utilize less space, this is we want. However, MD5 used in Rsync is not the best choice for our work. This will be analyzed in Section 2.3.

2.2 Scheme Overview

Before describing solutions of these sub-problems, we assemble these notions into a data block deduplication scheme. We believe this scheme helps us to reduce bandwidth utilization between gateway and computing platform. Figure 1 shows the scheme overview that illustrates how we implement it.

Here we explain the meaning of control flow and data flow. In Figure 1, the two biggest dotted boxes represent a remote data source (i.e. Gateway) and a real-time parallel computing platform (i.e. Spark) respectively. The rectangles represent data handlers that compute these data blocks like Data Block Preprocessor and Block Fingerprint Generator and communication interfaces that deliver and receive control information and raw data. The cylinder represents a limited memory data structure to store data. In addition, all arrows are data flows that illustrate how these data or blocks flow in our scheme. The arrows around dotted box are related with metadata that is used to control data transmission. All steps in this scheme will be described as follow.

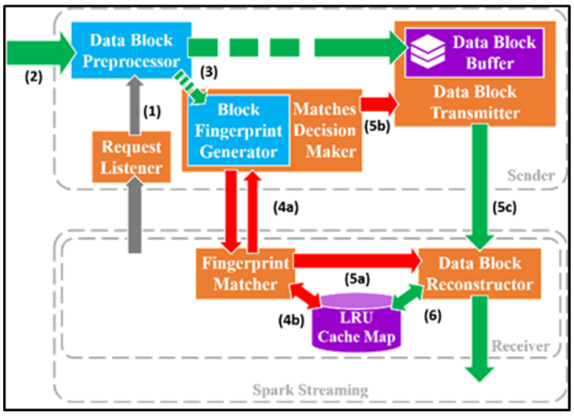

Figure 1: Scheme overview.

Step 1: Once the receiver triggers Request Listener, the listener accepts the connection and notifies Data Block Preprocessor to handle raw data stream.

Step 2: In Data Block Preprocessor, no matter if the source of raw data stream is from a reliable disk or sensor, it is spitted into data blocks. This preprocess for raw data is so important that it influences the whole data block deduplication scheme. The detailed explanation and implementation are presented in Section 2.4.

Step 3: These data blocks are pushed into Block Fingerprint Generator and Data Block Buffer. In this phase sender prepares the block fingerprints and data blocks that are ready to send. The Data Block Buffer has a memory space to cache these data blocks from preprocessor and records the sequences of blocks that will be used in data block transmitter. Its data structure is a first in, first out(FIFO) Queue. Besides, this process needs Block Fingerprint Generator to generate hash value for each block, the detail implementation is showed in Section 2.3.

Step 4: The Matches Decision Maker will exchange metadata with Fingerprint Matcher in arrow (4a). First, the Decision Maker sends the fingerprints that belong to blocks stored in buffer to Fingerprint Matcher. The matches that contain the information whether or not blocks have been sent are returned to Matches Decision Maker by Fingerprint Matcher. In arrow (4b), Fingerprint Matcher uses these fingerprints as key to ask the LRU cache map to find out if this block has received or not. It uses a Boolean array as matches, and the Boolean array retains the order information which Data Block Transmitter needs. Before returning matches, we need to do an additional checking for fingerprints. Because some duplicated data blocks are too close to each other, the results of matches from LRU Cache Map do not identify these duplicated data blocks. Before the data blocks are stored into LRU Cache Map in Step 6, these blocks are not in LRU Cache Map. This situation makes some blocks identified as unique. Hence, the additional checking is required.

Step 5: In Step 4, the metadata has been exchanged between sender and receiver, and this said that sender knows which data blocks do not need to retransmit while the receiver knows how to reconstruct these blocks as well. For arrow (5a), the sequence of fingerprints and match information notifies Data Block Reconstructor about how to receive next data block. For example, the sequence is like [(f_1, F), (f_2, T) , (f_3, T), …] where f presents fingerprint, F is false, and T is true. At that time, arrow (5b) also indicates the result of matches as a sequence like [F, T, T, …] to Data Block Transmitter. After the metadata notifies the data communication interfaces, it begins to pass blocks of raw data sequentially. This is the reason why data block buffer is a first-in, first out (FIFO) queue. It is used to correspond matches sequence. Figure 2 illustrates the data flow of arrows (5a) and (5b) across network. This data flow completely shows how this scheme saves bandwidth. We can observe that some blocks are ignored to transmit on network, and this is reason why our scheme works well. In addition, we can also use some compression algorithm like gzip (Levine, 2012) to compress data and further reduce bandwidth utilization. Moreover, to prevent blocks from waiting for metadata, it is suggested to set a timer. When the timer expires, send must transmit data without control. This mechanism is to prevent receiver from waiting data too long.

Step 6: This is the last step for this scheme. The Data Block Reconstructor arranges received data blocks and matches and puts these received blocks to LRU cache map, which stores the pairs of fingerprint and block data with a limit size. This is the point that makes reduplicated data utilization more efficient. Because Spark requires much memory, the amount of memory for this scheme to utilize is limited. Hence, the LRU cache map is implemented with a least recently used least recently used (LRU) Java hash map data structure to reduce the influence of data reusing. To prevent from occupying excessive memory in receiver, we present the analysis about the parameter for the data structure in the next section. Finally, the duplicated data blocks could be ignored and not required to store again. After storing these blocks which are not received in LRU cache map, receiver uses *store* API to notify Spark how many blocks have received and need to compute with the sequence of pairs of a fingerprint and a match Boolean from matcher.

Suppose that sender sends a set of h-byte hashes as fingerprints to receiver, and that receiver uses these hashes to check for match of each data block. Suppose that the k-th block size is b_k bytes and the size of a match is 1 bit (equal to $1/8$ byte) as a constant symbol α. In addition, we also suppose the match of the k-th block is m_k. Finally, if there is n blocks handled in a time interval t, it will give a bandwidth-saving model, thus the bandwidth this scheme saves in terms of bytes is

$$\sum_{k=1}^{n} r_k \big(b_k - (h + \alpha)\big). \quad (1)$$

Note that r_k is $\begin{cases} 1, m_k \text{ is } true \\ -1, m_k \text{ is } false \end{cases}$. The symbol r_k means that if the block has been transmitted, this scheme will save bandwidth, or it will increase additional costs. Equation (1) shows that the reduction of network utilization by using this scheme is probably low because of the low repetitive rate, and the worse thing is probably a negative value. The repetition rate is a pivotal factor and it is expressed as

$$\frac{\sum_{k=1}^{n} c_k}{n}. \quad (2)$$

Note that c_k is $\begin{cases} 1, m_k \text{ is } true \\ 0, m_k \text{ is } false \end{cases}$. The repetition rate affects reduction of network utilization a lot, and it is a positive correlation between both of them. So, in order to gain the highest benefit for our work how to chunk raw data into most of identical blocks becomes the most crucial issue. In addition, size of data fingerprint and size of a data block are also factors. Thus, further analysis is required. We based these two formulas to experiment with various parameters in Section 3.

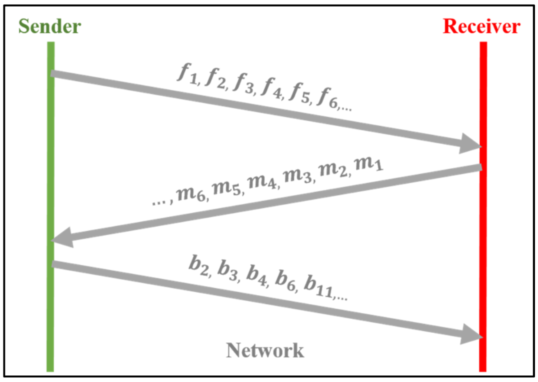

Figure 2: Data flow of Step 5.

2.3 Block Fingerprint

After chunking data blocks, it needs to further process these blocks. To identify the identical blocks, the fingerprints of their content are required. In Rsync, it uses two different types of checksum, weak checksum and strong checksum. The weak checksum used in Rsync is a modified blocks checker because of its fast process speed, and Rsync uses the rolling checksum based on Mark Alder's adler-32 checksum (Deutsch, 1996) as implementation. However, the weak checksum has no ability of determining which blocks are the same owing to its high hash collision probability, and therefore weak checksum is not our option. The another strong checksum used in Rsync is MD5. MD5 is a cryptographic hash function producing a 128-bit hash value equal to 16 bytes. Unlike rolling checksum, MD5 is able to identify the blocks of the same content, it might be a choice.

We can observe the factor that fingerprint influence is parameter h. This makes sense that once h is smaller, the benefit for this scheme is better. In other words, it can use less information to represent the data blocks. Hence, 128-bit hash value is not so ideal for our work. It needs to find a smaller size of hash function to substitute it with a premise, and the hash function can determine the same blocks as well.

The next property considered in Block Fingerprint Generator is fast process speed. Although the concept of this scheme is to utilize the compute resource of remote node and achieve a benefit for bandwidth saving, it could not lead to another bottleneck. So, the throughput of the hash function used in Fingerprint Generator must be as fast as possible. Obviously, MD5 has been ruled out in our implementation on account of its slow speed. It means it requires a more suitable hash function.

In summary, the implementation of Fingerprint Generator must have three properties, ability of identification, smaller size and fast process speed. The solution which we choose is xxHash (Collet, 2016). xxHash is an extremely fast non-cryptographic hash algorithm, working at speeds close to RAM limits. It is widely used by many software like ArangoDB, LZ4, TeamViewer, etc. Moreover, it successfully completes the SMHasher (Appleby, 2012) test suite which evaluates collision, dispersion and randomness qualities of hash functions.

Although xxHash is powerful and successfully completes the SMHasher test suite, its 32-bit version still has collision. Here we provide a simple test to verify 32-bit xxHash collision rate with a real-world data. The data is from a GPS trajectory dataset (Yuan, 2011) that contains one-week trajectories of 10357 taxis. The sum of points in this dataset is about 15 million and the total distance of the trajectories reaches 9 million kilometers. We use some data reprocessing to filter the raw data and gather them into a handled dataset. The file size of the handled dataset is about 410 MB. Figure 3 illustrates the repetition rates of the handled dataset with two hash functions SHA-1 and xxHash.

We can see from Figure 3 that the repetition rate of the first row is undoubted by using 160-bit SHA-1 function. We find that the repetition rate of xxHash32 is higher than SHA-1 about 0.1% in field Hash Map which does not have any restriction. This 0.1% difference means that the 32-bit xxHash occurs collision in this simple test. In contrast, xxHash64 has the same repetition rate with SHA-1. The collision rate of xxHash64 is lower than xxHash32, but xxHash64 also has higher cost because its longer hash value size for our scheme. Even the xxHash32 has the risk of collision, we still prone for it. There are two reasons that mitigate the influence of collision. The first one is about its probability; hence, we consider that 0.1% deviation could not affect the result a lot. On the other hand, this error can be handled in computing phase by some operations. Another one is the implementation of hash map is LRU hash map, so the limitation not only prevents to occupy excessive memory but also reduces the occurrence of collision with an extra cost of having the repetition rate a little lower. Because after discarding the least recently used data blocks, the occurrences of collision have high possibility to eliminate. In summary, we said the defect of xxHash32 used in this scheme is ignorable.

The memory size of LRU Cache Map is based on two factors, one is the size of hash value, and another one is its parameter. In Table 1, it shows that the standard hash map can store all fingerprints and data block, but it leads to out of memory. That is why we pick LRU hash map. The average size of records in the dataset is about 25 bytes. It shows xxHash32 has the smallest memory size for the LRU hash map.

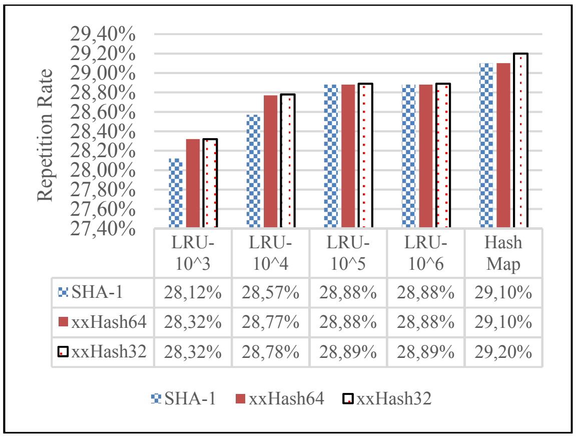

Figure 3: Repetition rate and LRU Cache Map analysis.

Table 1: Memory size of each data structure.

	Hash Map	LRU-10^3	LRU-10^4	LRU-10^5	LRU-10^6
SHA-1	OOM	50KB	500KB	5MB	50MB
xxHash64	OOM	35KB	350KB	3.5MB	35MB
xxHash32	OOM	30KB	300KB	3MB	30MB

2.4 Data Chunk Preprocess

In file synchronization systems, most of the time, the content difference between local node and remote node is slightly small. So, the methods of file synchronization are focus on how to find out the different parts between two files. Note that the data generated by sensors in a time interval comes in record by record. For instance, consider the GPS dataset. The average size of the record in the GPS dataset is about 25 bytes. On the contrary, the parameter s in Rsync is at least 300 bytes, let alone the average block size in LBFS is 8KB. Therefore, a fine-grained chunking method is essential for our work.

The data block in our scheme is like a record that sensor generates in a time interval. Spatial dependence leads to a neighbour cluster of sensors to detect similar values; time dependence leads to each record from the same sensor to measure smooth data. Therefore, we split raw data and obtain duplicated records as possible as it can be.

In sensors network, a cluster head collects the real-time data from many sensors. There is so much noise that causes low probability to distinguish the duplicated part. To identify the difference, we require some measure to filter out noise. Take the GPS dataset as an example. Figure 4 shows the mapping from original trajectory dataset to the handled dataset. We observe that the original dataset has four fields which are separated by commas. These fields are taxi id, data time, longitude, and latitude. For the field of data time we call it the dynamic field, because it always changes so that it causes our scheme gain benefit with difficulty. After eliminating the dynamic field, the handled dataset exhibits several duplicated records set.

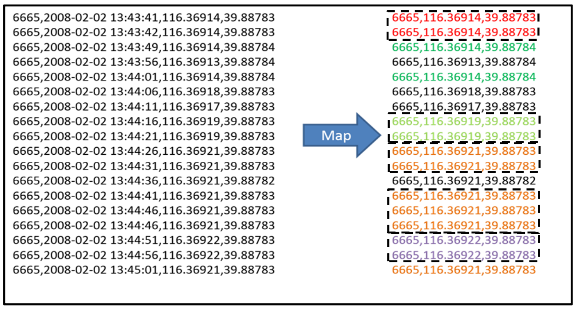

Figure 4: Filter out the dynamic field.

According to this case, the average size of records is obviously smaller than original. According to the parameter b_k in Equation (1), this causes some loss of bandwidth savings. So, how to keep original information of raw data with data preprocess is considered as a challenging problem. The balance between data integrity and data repetition rate depends on how users identify the dynamic fields.

Dynamic fields are often commonly found for data from sensors. The occurrences of dynamic fields are because the sensors are too sensitive or a lot of other factors. To face these situations, some methods from data mining can be used to preprocess data. One of methods is data generalization, for instance, there are three sensors in a room, and these sensors are able to sense someone entering this room with a distance by infrared ray. Suppose an application only cares when the person enters and leaves, the distance data is applied by concept hierarchy to map a value which shows if the person is in the room or not. It replaces the relatively dynamic distance value with a Boolean. Hence, the handled data from infrared ray sensors has higher probability to have duplicated part. Other methods also have similar idea that makes data general. Fuzzy sets (Zadeh, 1965) and fuzzy logic can also be used to process raw data. If we use fuzzy logic to classify continuous value, the data will be more general and generate duplicated part. Our another concern is complexity of the method. Because the gateway has limit processing resource, the complexity of the method must be low. In summary, we present a data deduplication scheme which eliminates the duplicated data that does not need to be retransmitted to improve the effectivity of data utilization in low bandwidth network environment.

3 IMPLEMENTATION

In this paper, we take Spark as the platform and introduce the implementation of the data deduplication scheme on the sender and the receiver sides. We also conduct several experiments with various parameters to show the significance of our scheme.

3.1 Experiment Environment and Setting

We use a peer-servicing cloud computing platform that contains eight homogeneous virtual machines. The software and hardware specifications of the receiver are detailed in Tables 2 and 3 respectively.

Table 2: Receiver environment.

Item	Content
OS	Ubuntu 15.10 Desktop 64bit
Spark	2.0.0
Java	1.7.0_101
Scala	2.11.8
Maven	3.3.9

Table 3: Hardware specification of receiver.

Item	Content
CPU	Intel(R) Xeon(R) E5620 @2.40GHz x 2
RAM	8 GB
Hard Drive	80GB
Network Bandwidth	1Gbps
Maven	3.3.9

Besides, to simulate the gateway used in the real world, we use raspberry pi 2 as the sender. The hardware and software specification for the raspberry pi is detailed in Tables 4 and 5 respectively.

Table 4: Sender environment.

Item	Content
OS	Raspbian-32bit
Java	1.8.0_65
Scala	2.9.2
Linux Kernel	4.1.19

Table 5: Hardware specification of sender.

Item	Content
CPU	Broadcom BCM2836 ARMv7 Quad Core Processor @900 MHz
RAM	1 GB
Hard Drive(SD card)	32GB
Network Bandwidth	1Gbps

3.2 Implementations

Both of the sender and receiver use Scala (Odersky, 2007) as the programing language. First we introduce the implementation of the sender. Sender accepts a TCP connection as Request Listener. Then it begins to read experimental data from SD card in raspberry pi, and pushes these data into Matches Decision Maker and Data Block Buffer. The Matches Decision Maker computes each fingerprint for each data block as Block Fingerprint Generator with xxHash32. These fingerprints are sent to receiver and then sender waits for the matches. The Data Block Buffer is implemented by a Java API, ArrayBlockingQueue class, which is thread safe and provides synchronous data access. Data Block Transmitter receives the responses of matches and decides which block needs to be transmitted to receiver.

On the receiver side, the implementation of receiver is based on the Spark platform. Nevertheless, our scheme can work well on other parallel computing platforms too. The original Spark only receives data from a reliable data storage such as storage, database, and HDFS. In order to receive data as stream, Spark Streaming lets user choose the interface of data source. Spark Streaming provides these interfaces like fileStream, socketStream, kafkaStream (Kreps, 2011), twitterStream, etc. Most importantly, Spark Streaming also provides an API to customize the data receiving interface. An API call *Receiver* is the place that allows us to implement our approach into Spark platform. Its native Receiver API implements simple operations. These operations include opening a socket, receiving each line from the socket, putting them into Spark to compute with *Store* API. Therefore, we augment the Spark with the data deduplication scheme to accept streaming data. Table 7 presents the parameters of the first experiment.

Before receiving data blocks, the scheme needs to exchange metadata between sender and receiver. Then, the data blocks that are required to receive must be determined. A TCP connection is used as a trigger to notify sender to start the whole process. The customized receiver gets fingerprints from the sender. Fingerprint Matcher uses these fingerprints to query LRU Cache Map whether the data block is received or not. The LRU Cache Map is implemented by LRU hash map described in Section 2.3. Another TCP connection returns the result of matches to sender. After metadata exchanging, the native line reading process is revised to Data Block Reconstructor. With metadata, Data Block Reconstructor rebuilds data from two sources: sender and LRU hash map. If the block was received before, it retrieves the data block from LRU hash map with the fingerprint of the data block; otherwise, it requests the sender a new data block by the third TCP connection and also puts the new data block into LRU hash map. Finally, Data Block Reconstructor reorganizes raw data as sequence and uses *Store* API to feed these data blocks to Spark Streaming to compute in parallel and batch.

4 EXPERIMENTAL RESULTS

The application of Word Count was tested to evaluate the performance of the scheme on Spark Streaming. It performs a sliding window count over 5 seconds. Table 6 presents the experimental configurations in Spark Streaming.

4.1 Empirical Result

In order to evaluate our proposed scheme, several evaluation scenarios are defined and conducted in this section. First, we explain the evaluation scenarios and assumptions. Equations (1) and (2) indicate the three parameters that have impact on the performance of our work. These parameters are the data block length, the length of fingerprint, and the repetition rate. Moreover, another environment parameter that is also an important factor for our scheme is bandwidth. So, the following experiments will be conducted to adjust one single parameter and fix the other three parameters. Consider a streaming application that computes data continuously. It generates a result in a specified time interval (5 seconds). We sample the result with 120 time intervals (600 seconds). We use a probability value to simulate the repetition rate of test data.

Table 6: Configuration in Spark Streaming.

The memory size of the driver	4GB
The memory size of each executor	1GB
The number of executors	8

4.1.1 Length of Data Block

The first experiment we study is the impact of the length of data block, namely b_k in Equation (1), on the system throughput. The length of data block in this experiment is an average value in terms of bytes. Other parameters are shown in Table 7. The experimental results are given in Figure 5.

Table 7: Parameters of the first experiment.

Bandwidth	1Mbps
Repetition Rate	25%
Length of Fingerprint	32 bits
Limitation of LRU Cache Map	1,000,000

We see from Figure 5 that the throughput for the original scheme in Spark is almost the same for all lengths of data block. However, with our deduplication scheme, the throughput increases as the length of data block becomes bigger. These results conform to Equation (1). It means that if a fingerprint can present data blocks with a bigger size, it saves more bandwidth when a data block is repeated. The throughput improvement reaches the top when the length of data block is 30. When a data block with more than 30 bytes is used, the system throughput does not get higher.

4.1.2 Repetition Rate

The most crucial factor in our scheme is the repetition rate. In Section 2.2, the repetition rate is expressed in Equation (2). In this experiment, we focus on how the throughput goes with the changing of repetition rate. Parameters for this experiment are shown in Table 8. The experimental results are given in Figure 6.

We see from Figure 6 that the throughput for the original scheme in Spark is almost the same for all lengths of data block. With our deduplication scheme, the throughput increases as the repetition rate becomes bigger. Furthermore, we can see that the throughput only improves about 10% when repetition rate is 5%. Nevertheless, the improvement approaches dramatically to 60% when the repetition rate is 40%. We conclude that the proposed scheme can transmit more data in a limited bandwidth.

Table 8: Parameters of the second experiment.

Bandwidth	1Mbps
Avg. Length of Data Block	25 bytes
Length of Fingerprint	32 bits
Limitation of LRU Cache Map	1,000,000

4.1.3 Length of Fingerprint

The factor studied in the third experiment is the length of fingerprint. In our work, a 32-bit version of xxHash is chosen as the implementation. In this experiment, we compare the performance of 32-bit version with the version of 64-bit xxHash. Parameters of this experiment are shown in Table 9. The experimental results are given in Figure 7.

Figure 7 shows that, for both 64-bit version and 32-bit version, the throughput improves when the repetition rate increases. However, it is noted that when the length of fingerprint becomes longer, the cost of metadata will be increased. Hence, the throughput for 64-bit version gets less improvement (compared with the 32-bit version) with longer length of fingerprint. We observe from the results that the performance of 64-bit version has only about half improvement over that of 32-bit version. It conforms that parameter h influences the saving of bandwidth in Equation (1). In other words, if the speed of hash functions is about the same, a shorter hash value will be a better choice for our scheme.

Table 9: Parameters of the third experiment.

Bandwidth	1Mbps
Repetition Rate	25%
Avg. Length of Data Block	25 bytes
Limitation of LRU Cache Map	1,000,000

4.1.4 Bandwidth

Bandwidth usage can be reduced by our proposed scheme. In this experiment, we investigate how the availability of network bandwidth impacts on the system throughput. Parameters of this experiment are shown in Table 10. The experimental results are given in Figure 8.

When the bandwidth gets higher, both the original scheme and the proposed scheme have bigger throughput. We also see that the throughput gap between these two schemes grows exponentially. The improvement ratio runs around 25% to 35%. It means that our scheme works better than the original scheme by at least one quarter of the system throughput.

Table 10: Parameters of the fourth experiment.

Repetition Rate	25%
Avg. Length of Data Block	25 bytes
Length of Fingerprint	32 bits
Limitation of LRU Cache Map	1,000,000

4.1.5 Physical World Taxi GPS Trajectory Dataset

In the last experiment we use the real-world taxi GPS trajectory dataset to evaluate the performance of our scheme. Table 11 presents the parameters setting in this experiment.

Table 11: Taxi GPS trajectory dataset.

Bandwidth	1Mbps
Avg. Length of Data Block	25 bytes
Length of Fingerprint	32 bits
Limitation of LRU Cache Map	1,000,000

Figure 9 illustrates the performance of our data deduplication scheme and that of the original scheme in Spark. Since the data in the dataset has different repetition rates over various time intervals, we present the repetition rate as time goes by in the low part of the figure. The axis for the repetition rate is shown at the right hand side of the *y* axis, while the throughput of the original scheme and our proposed scheme are indicated by diamond dots and circle dots respectively.

We can observe that the repetition rates of the real-world GPS trajectory data are not evenly distributed. Obviously, under different repetition rates, the improvement of throughput varies. Overall speaking, the maximum of improvement is about 57 %, while the minimum of improvement is only about 2.6%. The least improvement happens when the repetition rate is very low (about 9 %). Nevertheless, our proposed scheme performs better in all cases of the real dataset.

5 CONCLUSIONS AND FUTURE WORK

In this paper, we propose a fast deduplication data transmission scheme for parallel real-time computing platform like Spark Streaming. The proposed scheme does not need for the specialized data compression technique. Therefore, CPU resource will not be wasted to eliminate redundant chunk by compression and decompression.

According to these experiments, we draw a conclusion that our scheme works most effectively in the following situations:

- The average length of data block is long enough.
- The length of fingerprint is shorter.
- The repetition rate is higher.
- The bandwidth is required to be high.

In the last experiment, we use real-world taxi GPS trajectory dataset to prove that our method also works well on real-world data.

In the future work, we wish to further optimize our scheme. One of the possible directions is parallel transmission. In fact, Spark can execute several receivers to receive raw data. As we know, distributed messaging system like Apache Kafka exploits parallel transmission to send data in parallel to improve performance. It will be an interesting issue to follow. Additionally, the data preprocess can be improved further.

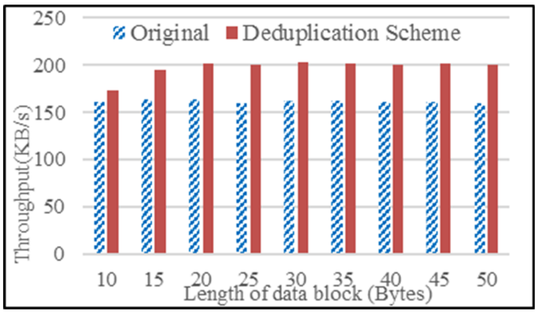

Figure 5: Length of data block versus throughput.

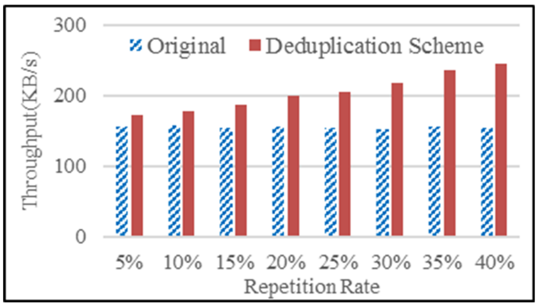

Figure 6: Throughput versus repetition rate.

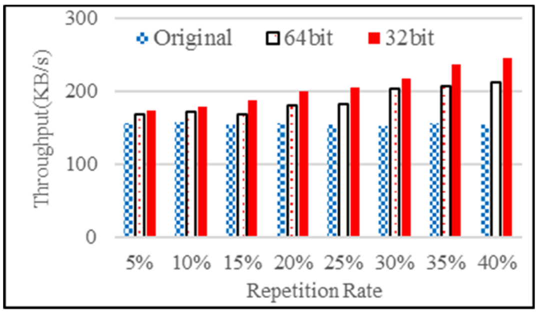

Figure 7: Fingerprint versus throughput (32-bit and 64-bit versions).

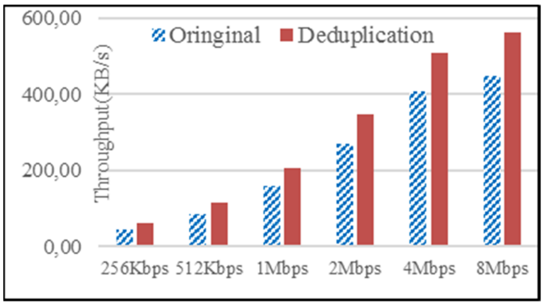

Figure 8: Bandwidth experiment.

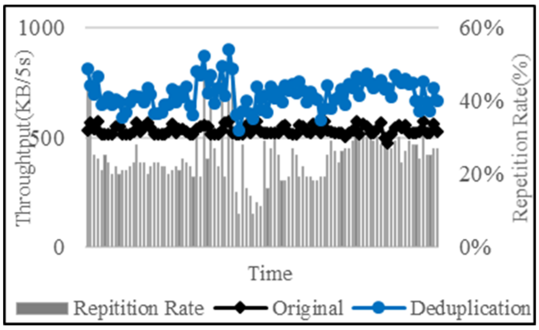

Figure 9: Throughput for taxi GPS trajectory dataset.

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SHORT PAPERS

Assigning Business Processes: A Game-Theoretic Approach

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Keywords: Business process, market, assignment game, characteristic function, coalition formation.

Abstract: Business processes are essential for the successful growth of an organisation. Business models aim to organise such processes and invoke the necessary processes for particular tasks. Such a mechanism is responsible for the appropriate response and time management of the business strategy of a corporation. To this end, we formulate a scenario where business processes need to be invoked according to the expenditures of their operation, in order to complete a transaction in a market model. We model such a mechanism using game theory and we produce a characteristic function that we maximise, in order to reduce the cost of the business processes. We employ the well-known assignment game to form business process coalitions and minimise the business operation cost in the market.

1 INTRODUCTION

A current trend in the business oriented research is the emergence of business intelligence, since it reflects on real problems that businesses deal and their respective solutions (Chen et al., 2012). In particular, bid data has shown specific trends that businesses follow in their market domains (Minelli et al., 2012). Bid take place in a real-time fashion; hence, real-time strategic interactions constitute a major issue in business intelligence. Such decisions may introduce enormous consequences to the development of a business; thus, uncertainties must be taken into serious considerations by managers. A risk-minimum estimate needs to be identified, in order to proceed with business process deployment. This belongs to a class of problems named strategic business planning (Sonteya and Seymour, 2012).

Business analysts face unique issues when attempting to address a specific strategic problem. Decision time is usually limited. The potential of a wrong decision increases the cost and overall consequences of a business plan. In most of the cases, real-time strategic planning is associated with cost. Hence, a business analyst needs to have expert knowledge, in order to act in a timely fashion and address the business problem by keeping the cost at reasonable levels. Business planning can be thought of a complex system (Snowden and Boone, 2007); hence, often, debates in meeting rooms are at hand, in order to come up with the ideal strategic plan. Business processes can assist to such a problem by trying to automate responses to real world business problems (Scheer et al., 2004).

Game theory utilises models of conflict and cooperation (Von Neumann et al., 2007), between business processes in this paper. Aumann (Aumann and Dreze, 1974) provides the difference between cooperative and non-cooperative games. We deal with the class of cooperative games in this paper. Agreements between players can take place before the start of a cooperative game. The cooperation in such games is given by a set of players a set of strategies, and a set of payoffs that represent the outcome of the strategies played, in the form of a utility. A coalition is characterised by the achievement of the coordination of the members' strategies (Saad et al., 2009), (Curiel, 1988). As we read in (Weber, 1994), should we consider the business process assignment as a market game, a business process not participating in the coalition does not affect the trading within the coalition. Thus, the corresponding strategy profiles and their respective utilities define the characteristic function of our game formulation. Furthermore, when considering a Cournot game in which business processes will select quantities, the outcome of the coalition depends on the behaviour assumption of the business processes outside the coalition.

We aim to construct a cooperative model and define a characteristic function in order to maximise the efficiency of a business process network. There has been other research works that dealt with business issues in a game theoretic and cooperative manner (Binmore and Vulkan, 1999), (Yahyaoui, 2012), (Katsanakis and Kossyva, 2012), (Li et al., 2002), (Yasir et al., 2010). We encapsulate the characteristic function to indicate the formed coalitions between business processes. Games that involve forming of coalitions are distinguished between the ones which include transferable utilities and the ones that with non-transferable utilities. In the former, utility is divided within a coalition and in the latter, it is difficult to show what the utility can define when a coalition is formed.

In this paper, we address the assignment of business processes to operational business processes that need to be executed with time constraints. We produce a cooperative coalition formation game-theoretic model and we solve it to provide the optimal business process assignment. Specifically we show the following contributions:

- We build a game theoretic model of the business process assignment problem
- We construct a characteristic function based on the time/cost for an execution of a business process
- We show that it may be more efficient for a business process to form a coalition with another process to fulfill a business process if the time spent is less than the direct business process assignment
- We show the distribution of the time of completion with our model

This paper is structured as follows: Section 2 provides the method of our game-theoretic formulation, section 3 gives results on a specific scenario and section 4 provides the conclusions of our approach.

2 COOPERATIVE BUSINESS PROCESS ASSIGNMENT

We consider a simple market model where business processes may be assigned to intermediate (relay) business processes within a time frame, in order to save cost. Initially, we produce a cooperative model for the relay business process selection problem and we attempt to distribute the saved completion time between different business processes. This will be accomplished once we manage the completion time appropriately. To this end, we propose a sellers - buyers approach based on (Shapley and Shubik, 1971) to solve the completion time distribution issue. We define the coalition formation game as an ordered pair $< N, \phi >$, where $N = 1,2,3...N$ is the set of business processes and ϕ is the value of the characteristic function, which is given over 2^n possible coalitions of N. Also, note that $\phi(\emptyset) = 0$. If we have a set of all business processes in a coalition, then we can claim that we have formed a grand coalition. On the other hand, if our set does not include the entire set of the business processes, the resulting subset is called coalition. The price that a coalition C is worth, is obtained by the value of the characteristic function $\phi(C)$. This value constitutes the maximum common payoff of the business processes in C upon cooperation. We denote the T value that a source business process j requires to complete by allocating it to another business process further up the process stack k by T_{jk}. Also, denote the time demand of completion time required for a buyer business process be allocated to a seller business process by T_{ji}. Furthermore, denote the completion time value of the i^{th} seller to her own offer to the completion time saving of the cooperative coalition by c_i and the the value of the j^{th} buyer to the cooperation of the i_{th} seller by T_{ij}. We denote the value required by the relay business process to reach the target next business process as T_{frwd}. At this point, we assume that $c_i = T_{frwd}$, since a seller business process has T_{frwd} amount of completion time, favouring its corresponding source business process. Note that the sellers payoff will not be maximised unless its time of completion is compensated. On the contrary, the cooperation between a buyer and a seller and the completion time that will be saved constitutes the requirement of each buyer to form a coalition with a seller business process. Therefore we calculate T_{ij} as

$$T_{ij} = T_{jk} - T_{ji} \quad (1)$$

if $T_{ji} > c_i$, then a value exists that both the sellers and buyers select. When we refer to time of business process completion saving, we mean the selection of the best completion time required to finish the process and move to the next business process of the business plan network.

2.1 The Characteristic Function

We define the characteristic function $\phi(C)$ as the maximum completion time saving that the business processes accomplish by cooperating between them, in order to form a coalition. Let B and S denote the buyers and the sellers respectively. If there is only one business process present in the coalition, the business process has no cooperation process; hence, its preference is the direct transmission to the business process with the less completion time T. Thus, we have

$$\phi(C) = 0 \text{ if } |C| = 0 \text{ or } 1 \quad (2)$$

since, there is no improvement we have

$$\phi(C) = 0 \text{ if } (C \cap B = \emptyset) \text{ or } (C \cap S = \emptyset) \quad (3)$$

In order to further explain equation (3), for a connection efficiency improvement to take place, a coalition that consists of buyers and sellers business processes must be established. Hence, we will separate business processes into buyer and seller pairs respectively. Before we move into business process assignment, we provide the simplest form of coalition, which is given below:

$$\sigma_{ij} = \max[0, T_{ij} - c_i] \text{ if } i \in B \text{ and } j \in N \quad (4)$$

Equation (4) states that cooperation between a buyer and a seller business process will be instantiated only if the direct connection requires a larger completion time than the cooperative connection. In the case that the direct connection is better than the cooperative connection, $\sigma_{ij} = 0$. Our aim is to calculate the function ϕ for reasonably large coalitions; hence, we are trying to identify the best buyers assignments to the respective sellers business processes, which maximize the time efficiency and minimise the cost. This is represented as

$$\phi(C) = \max[\sigma_{i_1,j_1} + \sigma_{i_2,j_2} + ... + \sigma_{i_n,j_n}] \quad (5)$$

where $n = \min[|C \cap B|, |C \cap S|]$. We maximize (5) through all the arrangements of the players i in $C \cap B$ and j in $C \cap S$. As we can see, we can formulate the assignment game as a linear programming (LP) problem. Let mn be a set of binary decision variables that satisfy

$$x_{ij} = \begin{cases} 1, & \text{if } i \text{ relay process assigned to process j} \\ 0, & \text{otherwise} \end{cases} \quad (6)$$

where $i = 1,2,3...m$ and $j = 1,2,3...n$. Each binary variable indicates whether a business process i acting as a relay process will be allocated to a business process j that is wishes to execute.

We denote as ξ the total time saving of the cooperative coalition formation and we formulate the business process relay selection problem as an LP.

$$\text{Maximize } \xi = \sum_{i \in B} \sum_{j \in S} \sigma_{ij} x_{i,j} \quad (7)$$

s.t

$$\sum_{i \in B} x_{ij} \leq 1 \text{ for } i = 1,2,...m$$
$$\sum_{i \in S} x_{ij} \leq 1 \text{ for } i = 1,2,...n$$

The first constraint states that each relay business process may be assigned to at most one business process. The second constraint specifies that every business process has to be connected to at least one relay business process. Solving this LP problem will give us the maximum completion time saved when a coalition is formed of B relay business processes and S source business processes. Hence, we have

$$\xi_{max} = \phi(B \cup S) \quad (8)$$

Thereafter, we transform the LP problem to its equivalent matrix formulation.

$$\begin{aligned} &\max \mathbf{c^T x} \\ &\text{s.t. } \mathbf{A \cdot x \leq b} \\ &\mathbf{x \geq 0} \end{aligned} \quad (9)$$

Note that the constraint $\mathbf{x} \leq 1$ has been folded into the constraint $\mathbf{A \cdot x \leq b}$

2.2 Business Process Selection Core

We proceed to the core of the coalition, which should not be empty or consisting of one business process only. According to Shapley and Shubik (Shapley and Shubik, 1971), the core of the relay selection game is the set of solutions of the dual LP problem of the assignment problem. In this paper, we introduce the Lagrangian dual. We take the nonnegative Lagrangian multipliers $(\mathbf{y}, \lambda)$ to the constraints $\mathbf{Ax \leq b}$ and $\mathbf{x \geq 0}$ as follows

$$\mathcal{L}(\mathbf{x}, \mathbf{y}, \lambda) = \mathbf{c^T x} + \mathbf{y^T (b - Ax)} + \lambda^T \mathbf{x} \quad (10)$$

which serves as an upper bound of the characteristic function (9), whenever $\mathbf{x}$ is feasible or not. Therefore, $\max_x \mathcal{L}(\mathbf{x}, \mathbf{y}, \lambda)$ bounds the optimum of (9). In order to obtain the upper bound, we have to solve the following

$$\begin{aligned} &\min_{\mathbf{y},\lambda} \max_{\mathbf{x}} \mathcal{L}(\mathbf{x}, \mathbf{y}, \lambda) = \\ &\min_{\mathbf{y},\lambda} \max_{\mathbf{x}} \mathbf{c^T x} + \mathbf{y^T (b - Ax)} + \lambda^T \mathbf{x} \end{aligned} \quad (11)$$

We have the third equality since $\mathbf{c} - \mathbf{A^T y} + \lambda \neq 0$ and we may select an appropriate $\mathbf{x}$ such that $\mathcal{L}(\mathbf{x}, \mathbf{y}, \lambda)$ goes to infinity. Therefore, we have a finite bound when $\mathbf{c} - \mathbf{A^T y} + \lambda = 0$. By taking the strong duality of the linear program, the optimum of (9) coincides with (Boyd and Vandenberghe, 2004). We can make the formulation more simple by assuming that $\mathbf{b} > 0$, since T is always positive. We denote P as a convex set on $\mathbf{x}$ and $f_i(\mathbf{x}) = (i = 1, ...m)$ as a set of convex functions. Moreover, we define the general min-max problem as

$$\min_{x \in P} \max_{i \in [k]} f_k(\mathbf{x}) \tag{12}$$

where $[k] = \{1, ...m\}$ is a set of indexes. For detailed report on the solving method of this problem, we refer the reader to (Spyrou and Mitrakos, 2017).

We have to mention that the dual problem consists of $m + n$ variables

$$\mathbf{y} = [q_1, ...q_m, r_1, ..., r_n]$$

Moreover, we can see that the constraints of the problem are

$$q_i + r_j \geq \sigma_{ij} \ \forall i \in B \text{ and } \forall j \in S \tag{13}$$

Essentially, the solution of min-max problem is equivalent to the solution of $\phi(B \cup S)$. The remark above dictates the incentive of relay and source business processes to cooperate. Specifically, q_i and r_j comprise the T values that a relay business process i and a source business process j receive, in order to perform a cooperative transmission. Furthermore, the vector $\mathbf{y} = [q_1, ...q_m, r_1, ..., r_n]$ provides the distribution of the T enhancement and the equivalence of the dual problem with the solution of $\phi(B \cup S)$ constitutes an imputation of the coalition formation relay selection game. Additionally, from (5) and (13)

$$\sum_{i \in C \cap B} q_i + \sum_{C \in S} r_i \geq \phi(C), \forall C \subset S \tag{14}$$

Thus, we defined the core of the relay selection game using (12) and (14),since we encapsulate the imputation efficiency and the fact that an improvement move on the coalition cannot be made.

2.2.1 Completion Time Distribution

The enhancement of completion time T is shared between the business processes. On the other hand, the T completion time enhancement cannot be transferred to the relay business processes, unless the source business processes receive the value first; however, every source business process my be a relay business process; thus, transferring the completion time T enhancement. Thereafter, we construct the T function, distinguished between the cooperative and selfish business processes and prevents any undesired behavior. The T function of the relay business process i at a cooperative scenario is given by

$$T_i[n] = T_i[n-1] + c_i + q_i \tag{15}$$

Note that c_i is the T completion time received by the relay business process i and q_i is the amount of T available for the relay business process to proceed with a cooperation. On the other hand, the T compensation of the relay business process needs to be provided by the source business process. Thus, the T function of source business process j is given by

$$T_j[n] = T_j[n-1] - c_j - q_j \tag{16}$$

Note that, even after transferring $c_i + q_i$ amount of completion time T to the relay business process i, the source business process j will have ϕ_j of T enhancement.

3 RESULTS

We consider a simple market and we take two scenarios on board; the first scenario is a single source process - relay business process and the second is a multiple source - relay business processes scenario.

3.1 Single Source and Relay Business Process

As we can see in figure 1, the source business process executes by reaching the end-business process directly, since its incentive is not to cooperate with the relay business process. This is the case due to the fact that the completion time of going directly to the end-business process is less than the completion time after forming the coalition with the relay business process.

On the other hand, in figure 2, we see that the source process forms a coalition with the relay business process, since it is in its benefit to cooperate, since it saves completion time. This is only the simplest scenario. We investigate thoroughly a more complicated scenario with a network of business processes. In both figures the solid lines represent the preferences of the source business process, while the dashed lines the discarded choices.

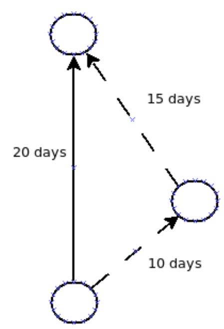

Figure 1: Source Business Process Direct communication with End-Business Process.

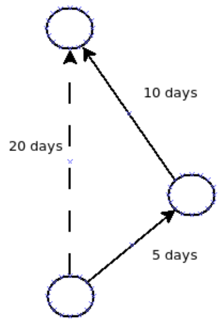

Figure 2: Source Business Process Direct forming Coalition with Relay Business Process.

3.2 Multiple Source and Relay Business Processes

The objective is to maximise the time completion of the business processes that will be formed after the cooperation and the coalitions formed. In our scenario, business process 1 is the business process that the business plan leads to, business processes $2-4$ are the relay business processes and business processes $6-8$ are the source business processes. The source processes do not form coalitions with all the relay business processes. In particular, source business processes 6 and 8 form 3 coalitions respectively and source business process 7 establishes 4 coalitions respectively. These coalitions include a connection to the end business process, in order to show the difference in the T value and the necessity of cooperation between the business processes. The respective completion time values reside in table 1. Finally the completion time values between the relay business processes $2,3,4$ and the end-business process are $1,1.5,3$ respectively.

Table 1: Network connections and T values.

Source Process	Seller Connections	T
6	1,2,3	23,20,16
7	1,2,3,4	16,12.5,11,12
8	1,3,4	21,15.10,14

Thereafter, we provide the reader with the valuations of the business processes (sellers and buyers). Notably, the sellers' valuations are calculated by simply obtaining the completion time values required to transmit operate a business process to business process 1. On the other hand, the valuations of the buyers are estimated by the result of equation (1), which gives us the difference of completion time between the one-hop connection of each buyer with the end business process and the completion time of each buyer with a seller. Note that when a connection does not exist between a seller and a buyer, we set the result of (1) as 0. We provide the valuations in the table 2, which is counted in days of completion time.

Table 2: Business Processes and Completion Time Values.

Source	Seller Val	Buyer Val		
(i)	(c_i)	T_{i6}	T_{i7}	T_{i8}
2	1.5	3	3.5	0
3	2	7	5	6.5
4	2	0	4	7

The result of the assignment of the most appropriate seller to a buyer is the enhancement of completion time value per pair. The outcome of the game is a profit matrix that shows the resulting completion time enhancement from coalitions between source and relay business processes. We provide this information in table 3. Furthermore we highlight the optimal assignment between relay and source business processes in bold numbers, which indicate the maximisation of the completion time enhancement for each pair that form a coalition.

We are able to identify the core solution of the problem by solving the dual LP problem described in the previous section. However, we are not in the position to claim that the core solution is unique. One of the core solutions obtained, which is close to the Shapley value (Shapley, 1988)

$$y = [2.1708\ 0.95\ 2.55\ 0.55\ 3.30\ 2.44] \qquad (17)$$

Furthermore, we can derive from Table 1 that the completion time required for a direct communication of the buyer business process with the destination - business process 1 - is 45. On the other hand, the successful cooperation between the sellers and the buyers is 17.5, which gives us an completion time enhancement of 68.1%. In order to accomplish that we need to connect business process 6 with business process 2, business process 8 with business process 3 and finally, business process 7 with business process 4. We

Table 3: Completion Time Enhancement.

		Buyers		
		6	7	8
Sellers	2	1.5	**2**	0
	3	**5**	3	4.5
	4	0	2	**5**

can see the final configuration of the business process selection process in figure 3.

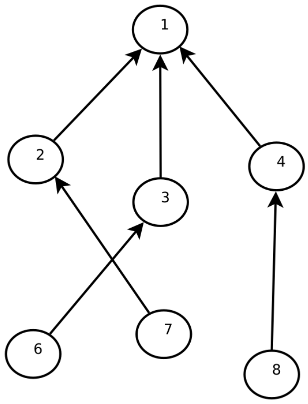

Figure 3: Final Transmission Configuration.

4 CONCLUSIONS

In this paper we attempted to approach the collaboration between business processes in order to accomplish tasks of a business plan. To that end, business processes either connect directly with the business process they require to finish the task or they form coalitions by finding a relay business process to connect to, depending on the business process completion time.

Subsequently, the business processes establish a cooperative network in a game theoretic manner. Our model is based on combinatorial optimisation, which target the maximisation of the completion time enhancement when a relay and a source business process cooperate. We derived the characteristic function used in our game, the coalition core and the credit that each business process has for playing the relay selection game. We evaluated a simple and a more complicated scenario, which indicated the fact that using cooperative business process cooperation the process network exhibits a better completion time. This is due to the fact that each source business process gets assigned to the relay business process that has the best completion time enhancement.

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Software Development Business Model for Top Level Process With Competitive Bidding

Is Requirement Analysis the Unpaid Work?

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Keywords: Software Process, Competitive Bidding, Top Level Process, Requirement Analysis, System Design.

Abstract: Recently, large-scale system development is ordered through competitive bidding in various computer system. If competitive bidding runs in order to choose a best system proposal, development process is greatly different from conventional software development process of the conventional software engineering. Before developers and customers sign a contract document, requirement analysis and system design activities are started. Of course, the activities are unpaid work because developers do not yet sign the contract with customers. Therefore, we discussed software development business model with competitive bidding. Problems in real competitive bidding are (1) unpaid work such as requirement analysis, (2) judging a best system proposal by customers, (3) budget and schedule are determined before requirement analysis activities. Based on the problems, we show a revised process of top level activities of planning phase and competitive phase for developers' profit and customers' high satisfaction.

1 INTRODUCTION

Software engineering research field mainly focuses on development techniques for large-scale software such as requirement analysis, design software, programming techniques, test techniques, and operation and maintenance. Almost all the themes are development techniques for developers. In addition, because developers have to make high quality software, software engineering researchers frequently discuss the techniques without customers' constraint such as budget and time.

However, large-scale computer system and software consume much money. Of course money is paid by customers. Customers are various organization such as hospitals, banks, private companies of public transportation, government and local government, and educational organizations. These customers have strong social responsibilities in order to control modern societies' system and human life. Software and computer system should be delivered by due day, and software and computer system should be developed within their budget.

Therefore, we discuss "software development business model". Especially, we focus on top level process with competitive bidding before making a contract with customers. The top level process may be beyond the scope of the conventional software engineering research area. However, in current industry, competitive bidding among system development companies is popular and usual. Especially, large-scale system should be bidded in orde to keep low cost. Therefore, we propose a software development busines model.

In this paper, we mainly discuss a top level activities of software development process including competitive bidding before making a contract. Atfter that, an outline of the new software development business model is shown. We show related work in section2, in section3 we explain real competitive bidding before signing a contract document. In section 4, dilemma of customers and developers are shown. We discuss software development business model in section 5. Section 6 shows summary and future researchers.

2 RELATED WORK

In conventional researches, Edward et al., shows a

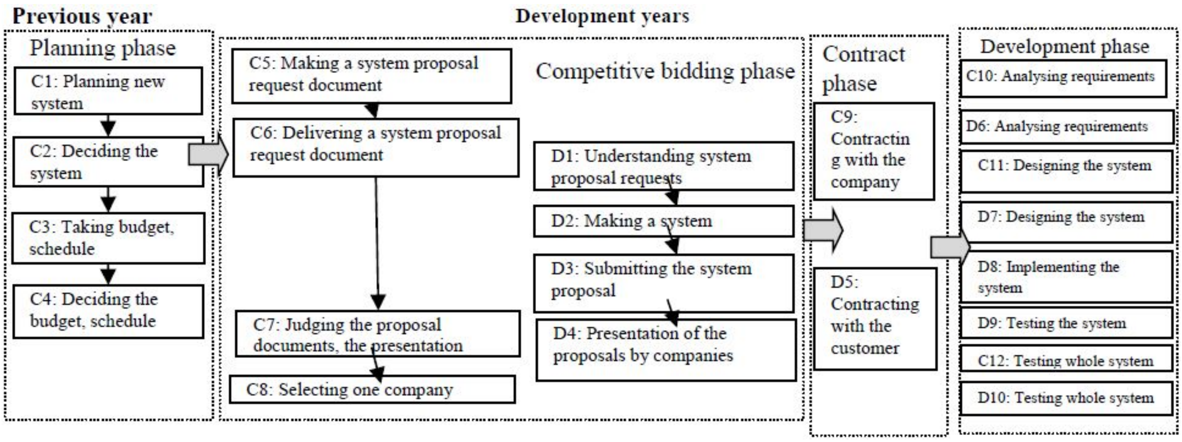

Figure1: A software development top level process for large-scale infrastructural system in Japan.

model of the early estimating/planning stages of a project (EEPS model) (Edwards JS., Moores TT. 1994). Because of unclear data in requirement analysis, there were 30% budget error. Jamieson et al. gave a model for pre- and post-contract phases in agile development [12]. These researches mostly cover our research topics. However, environment surrounding development computer system continuously change. We have to consider the changes in the present day.

On the other hand, in recently, “Cho-joryu” for software engineering has been proposed by Muroya(IPA Software Engineering Center, 2012]. Muroya also provided a method of a contract for software development , and important of customers’ activities in top level software development process. Breiner et al. also discuss requirement engineering in the bidding stage(K. Breiner, M. Gillmann, A. Kalenborn, C. Müller, 2015). These researches claim importance of competitive bidding. However, research of competitive bidding process in software engineering just have started. Concrete research results are not described. In addtion, Takano et al. show effective bidding strategy in a competitive bidding simulation (Takano Y., Ishii N., Muraki M., 2014). Pablo et al. propose effective competitive bidding model in scoring and position probability graph (Ballesteros-Pérez P., González-Cruz M. C., Cañavate-Grimal A., 2013). Also the other researches discussed effective bidding and accuracy of cost estimation. Management fields actively study bidding way, bidding accuracy, and bidding simulation. However, these researches discuss just ways of bidding. Our research target is not bidding system. Our research target is whole development process including competitive bidding in software engineering research field.

3 CURRENT PROCESS

3.1 Planning Phase

Fig.1 shows a typical top level software development process for large-scale infrastructural system in Japanese industry (Hanakawa N., Akazawa Y., Mori A., Maeda T., Inoue T., Tsutsui S., 2006) (Hanakawa N., Obana M., 2010).

At first, customers make a plan of a new system. Customers make a plan in order to take budget in an organization. Managers decide to make a new system according to planning documents. In addition, managers decide budget and schedule. The budget is decided by managers according to strategies of the organization. The budget usually is built during the previous year. Because budget for new system is a part of whole budget of the organization, it is difficult to revise the budget. In addition, the plan includes concrete due date and schedule.

3.2 Competitive Bidding Phase

Competitive bidding phase includes the following activities.

(1) C5: Making a system proposal request

Customers make a system proposal request document. The document includes as follows;

- System purpose
- Target users, and the round number of users
- Images of several use scenes
- Vague requests such as “improving our performance” or “our workload reduces”.
- Rough schedule and concrete due date.
- Rough images of functions of the system

In addition, various constraints are shown in the proposal request documents. For example, system administrators consume workload as little as possible. These constraints are not described concrete quantitative values of performance requirements. Although concrete requests are not described, many images of customers' request are enumerated as sentences and simple figures. Developers and sales engineers should satisfy all requests even if the requests are vague and not clear.

(2) C6: Delivering the system proposal request

The system proposal request documents are opened to development companies in industry. The system proposal request are uploaded a Web site that everyone can access.

(3) D1:Understand system proposal requests

Salesmen, sales engineers, and system engineers read the system proposal request document. Often, the number of page of a system proposal request document is 100 pages more over. The reading and understanding workload is also huge.

(4) D2: Making a system proposal

Salesmen and sales engineers and system engineers discuss the new system. Examples of workload for making a system proposal in our university's case are as follows;

- Reading and understanding the system proposal request documents (1man-month)
- Investigating new technologies (3 man-months)
- Investigating similar system and trend of the similar system in industry (1 man-month)
- Interviewing customers and analysing customers' problems (3 man-months)
- Estimating workload and cost (2 man-months)
- Making a system proposal document including the billed amount (4 man-months)

Total workload is 14 man-months.

(5) D3: Submitting system proposal

The completed system proposal is submitted to customers by due day. Of course, customers receive several system proposals from several companies.

(6) D4: Presentation of proposals by companies

The companies present their proposals. This presentation is most important in a competitive bidding phase. Developers may consume several man-months' workload. The presentation strongly influences results of the competitive bidding.

In our university's case, one company's presentation time is 2 hours, and question and answer time is 1 hour. 6 companies submitted the system proposals. So, it took 18 hours. It takes three days for finishing all presentations.

(7) C7: Judging the proposal documents

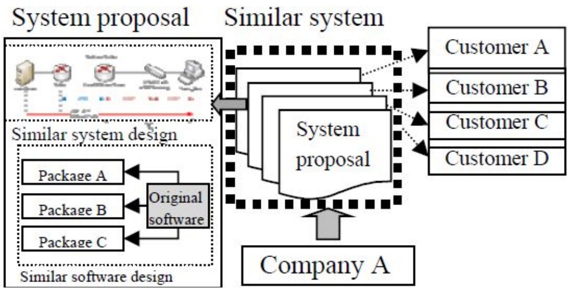

Figure 2: Similar proposals for similar systems.

Customers determine a best proposal. Customers check whether the proposals satisfy requests. Next, proposals are evaluated by various points; completeness, innovativeness, technical quality, and consistency of system design. That is, the customers evaluate essences of system proposal. If evaluation is low, the system proposal will be rejected.

After that, the full amounts are compared. A system proposal with smallest full amount is selected. Competitive bidding is finished. A development company are determined.

3.3 Contract and Development Phases

A development company that won the competitive bidding makes a contract with customer. The due day and the full payment amount are written on the contract document. Of course, because details of requirement analysis have not yet determined, developers do not almost know what they should develop. Customers clearly know only payment amount and due day. Next phase is development of new system. Activities run according to the conventional software engineering.

4 PROBLEMS IN BIDDING

4.1 Is Analysis the Unpaid Work?

Developers consume large efforts to make a system proposal. At first, developers should be clear vague requests. Developers often visit customers, and have many meetings in order to clarify their requests. Sometimes, meetings take several hours. Meetings are just like requirement analysis activities in development phase. To achieve more detailed system design and more complete system proposal, developers have to do long interview even if the interview activities are the unpaid work.

Customers felt enthusiasm in the long interviews. Because customers often judge a best proposal subjectively, the enthusiasm of developers is important. Almost requirement analysis finishes in competitive bidding phase. Of course, these activities are the unpaid work. On the other hand, developers have to describe full amount in a system proposal (Lopez-Martin C., Isaza C., Chavoya A. 2012). To estimate cost, developers need more detailed requests. The full amount is calculated by workload, computer and software cost.

As a result, a company wins the competitive bidding. A company can receive money for work of the following development phase. However, companies that did not win the competitive bidding cannot receive any money

4.2 Comparing System Proposals

On the other hand, customers also have to make a difficult decision in competitive bidding. Although customers have only vague requests, customers have to assess submitted system proposals. It is difficult to judge whether proposals satisfy their requests.

Therefore, easiest judgement is to check completeness of system proposals. For example, customers check how a proposed system design is complete. More detailed design and deeper investigation are assessed at good proposals. That is, if developers consume more workload for making a system proposal, customers feel better because developers sincerely make a system proposal. Judgement is subjective rather than objective. Customers do not usually have sufficient knowledge in order to judge objectively system proposals.

5 TWO DILEMMAS

5.1 Making Proposals with Profit

Companies that challenge competitive bidding have to keep profit. Even if a company did not win a competitive bidding, a company can keep profit. Fig.2 shows how companies make system proposals with keeping profit. Developers submit a system proposal for similar system. Almost all parts of system proposals are re-used in similar system proposal bidding. That is, developers consume little workload for making system proposals. System proposals describe similar system design and similar software design. These designs are already proposed to the other customers. However, a part of the design is original design. For example, although software design consists of several package software, original software design is combined package software (Kataoka N., et al. 1998).

Because workload for making a system proposal is a little, companies keep profit even if companies did not win competitive bidding. However, if developers submit same system proposals without any revisions, the system proposals will be rejected. Customers can easily know that developers skimp their effort to make a system proposals. Original requests are not satisfied in the proposal. Such system proposals will not win competitive betting.

Developers struggle with a dilemma between unpaid work and winning of bidding. If developers want to win bidding, developers should consume unpaid work. If developers want to avoid unpaid work, developers could not win competitive bidding.

5.2 Fixing Budget and a Delivery Day

Business of company should be improved more efficient through information technology. However, they do not have sufficient knowledge of information technology. Therefore, managers cannot design computer system. They have only rough images of several use scenes, then, they do not have sufficient skill for making concrete system requests.

In addition, development of computer system needs much budget. New system greatly influences business process and business concept. Sometimes managers employ several new faces, and new sections for new business process. Therefore, budget and schedule of the new system is not only elements of the new system but also elements of the company strategies. Therefore, budget and schedule are usually determined as an annual plan of the previous year. Budget and schedule for new system are one of important strategies of a company. Budget and schedule cannot be easily revised. Even if new functions or new system design are proposed by developers at requirement analysis activity, customers cannot pay additional fee for new functions. Moreover, time for developing additional functions is also unacceptable.

On the other hand, when customers judge a best system proposal in bidding, customers want more detailed system design and system proposals and investigation. Customers want to choose a best system proposal and a best developers' team.

Customers' dilemmas are (1) budget and schedule are fixed as an annual plan although development has not yet started, (2) it is difficult to explain detail requests, (3) customers require high completeness of system proposal in order to judge a best proposal against vague customers' requests.

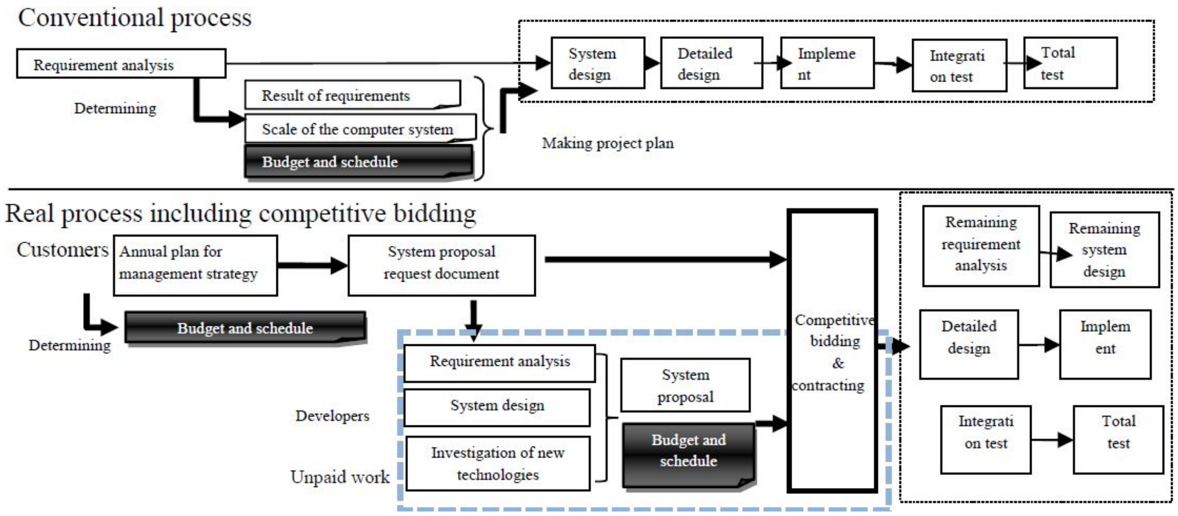

Figure 3: Gaps of between conventional development process and real process including bidding.

6 AN OUTLINE OF SOFTWARE DEVELOPMENT BUSINESS MODEL

Fig. 3 shows gaps between development process of conventional software engineering and real development process including competitive bidding. The following sub-sections explain an outline of software development business model with the gaps.

6.1 Development Process of Model

Development process reflects real process including competitive bidding in Fig.3. Main process is as follows;

(1) Determine budget and schedule in an annual plan in customers' company
(2) Making system proposal request by customers
(3) Making system proposal including system design, requirement analysis, investigation, and budget and schedule by developers
(4) Competitive bidding and making a contract
(5) Development phase including requirement analysis, design, implement, and test.

Basically, unpaid works for developers are the above process (3), the above process (4). In the above process (5), developers can earn money from customers. Moreover, of course, customers do not pay any money before making a contract.

6.2 To Avoid Unpaid Work

Various products are clearly divided to two steps; the first step is unpaid work, the second step is paid work. In the first step, developers make a system proposal as unpaid work. In the second step, developers make a system design as paid work. Fig.4 shows outline of the two steps.

In the first step, developers make a system proposal as typical system design and software design. Typical system design means normal system design without original design and original customization. Therefore, system designs of proposal are same as system design of the other customers. Of course, system design does not require results of requirement analysis. Likewise, software design consists of commercial packages without original software. That is, developers prepare system proposal packages for competitive bidding. Of course, correct total cost and time are not clear in the first step. Therefore, for example, budget is 30 % increase money of the typical design, and schedule is 30 % long of typical design. The additional money and the extended time are rough estimation for original system design and original software in the second step.

After developers win competitive bidding, developers start development phase including requirement analysis, system design, and investigation of new technologies according to customers' requests. Results of requirement analysis reflect to original system design and original software. These design and software are customized the system proposal. In this way, developers earn proper money as requirement analysis, system design, and investigation of new technologies.

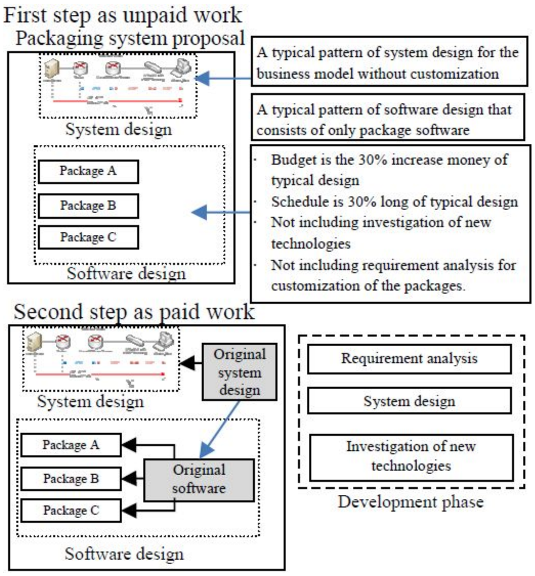

Figure 4: Products between unpaid and paid work.

6.3 To Achieve Effective Bidding

To achieve effective bidding, customers check gaps between their requests and system proposals. Customers do not evaluate satisfaction of their all request in system proposals at competitive bidding. Customers understand how system proposal is different from their requests. Customers know what requests are not satisfied in system proposals. Most important customers' action is to understand gaps between customers’ requests and package software and normal system design. Of course, the understanding of gaps does not need deep knowledge of information technologies. Customers only know whether packages support their request functions. Customers do not need to understand mechanisms of software packages. If customersasked question whether packages support their request functions at competitive bidding, developers would easily answer the questions.

Customers make a list of non-supported functions and unsatisfied performance on each system proposal. Customers should select a system proposal that includes fewest non-supported functions and unsatisfied performance. If customers have difficulty of making the list, customers should employ engineers who can make the list of non-supported functions and unsatisfied performance. The list of non-supported functions and unsatisfied performance are implemented as “original system design” and “original software” in Fig.4.

7 SUMMARY

We showed real top level software development process including competitive bidding. Problems of top level process are (1) unpaid work such as requirement analysis, (2) judging a best system proposal by customers, (3) budget and schedule are determined before requirement analysis activities. Therefore, we discuss an outline of software development business model for developers’ profit and customers’ satisfaction. Limitation of system proposals submitted to competitive bidding are clarified. We suggested a way of select a best proposal with a list that described non-support functions and unsatisfied performance.

In future, reconstruction of competitive bidding for large-scale computer system will start little by little in Japan.

ACKNOWLEDGEMENTS

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Understanding BPMN Through Defect Detection Process

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Keywords: BPMN, Business Process, Diagrammatic Reasoning, Defect Detection.

Abstract: BPMN (Business Process Modelling Notation) diagrams enhance the perception of the business analysts to better understand and analyse the processes of the organizational setting and provide a common communication medium both for business analysts and IT professionals. The changes in the business systems require business analysts to understand the processes and improve them and IT professionals to comprehend and implement these processes as a software system. The main aim of this study is to analyse which type of defects can be detected in a given BPMN diagrams easily by novice users. We believe the results of this study will provide a guide for the educators in teaching, for business analysts and IT professionals in understanding and improving business processes.

1 INTRODUCTION

As diagrams transfer, and leverage knowledge that is essential for solving problems, they can be more powerful than sentential representations depending on the usage. Diagrams provide compressed information; hence, they are very effective in information systems for transferring information between stakeholders of the system.

Business process modelling emphasizes business activities and their interaction. Their purpose may include revealing the problems, changes in the operational issues, improving/understanding systems. These models are used for the communication of the business processes between business analysts and software developers/IT professionals. Therefore, it's crucial for them to be clear and coherent (Figl and Laue, 2011)

In this study, defect detection process in BPMN reviewing process is analysed to obtain insights about the cognitive processes of the first-year Computer Engineering students of Cankaya University who have basic knowledge about computer programming. The research question 'Which types of defects are easy to detect in BPMN representations?' is aimed to be answered.

We intended to answer this question through an experiment in which participants were given a BPMN diagram with different type of defects and they were expected to detect these defects. With the help of the data we collected, we believe that such analysis would provide insights about the design of BPMN diagrams and defect detection process. The results of this study are expected to enlighten the researchers, businesses, and educators to improve BPMN cognitive process. Background section below contains related studies found in the literature, Methodology section explains the experiment, Result section analyses the experiment results and Discussion and Conclusion section talks about the insights gained through this study.

2 BACKGROUND

The Business Process Modeling Notation (BPMN) is an important standard for process modelling and has enjoyed high levels of attention from academia and business world.

There are many studies analysing suitability of various representations' suitability to business domain like UML2.0, BPMLs, BPDM, RAD, EPC and Petri nets (Gou et al., 2000; List and Korherr, 2006). The results state that even though these representations provide adequate capability to represent dynamic behavior, organizational and informational dimensions can be partially characterized.

Many studies have compared the diagrams' understandability based on participants' comprehension of the given diagrams (Birkmeier and Overhage, 2010; Geambaşu and Jianu, 2013; Cruz-

Lemus et al., 2010). They have concluded the superiority of one of the diagram's comprehension of the business process representations. However, none of them mentioned which defects are more important and easier to be comprehended by participants in BPMN diagrams. Usually, in system development process, business process analysis is performed during requirements elicitation phase. As a results, analysts and developers use different visual representations to incorporate information they grasp for the design and development of software artefacts. During this process, they also compare diagrams with textual requirements to reveal discrepancies or incomplete information (Hungerford, 2004). It is important to detect and correct mistakes at the design stage of the system development. Given that; there are also defect types which cannot be detected in the runtime (von Stackelberg et al., 2014). With this research we aim to find out which types of defects are easier to detect by novice users from IT field.

In the literature, there are not many studies conducted to better understand the reviewers' performance during the defect detection process in BPMN models. For instance, Moser and Biffl report that the missing or incorrect type of information is often detected in a later engineering process step (Moser and Biffl, 2010). Hence understanding the defect types that cannot be detected easily could help the software system designers to better represent this type of information in their models. Additionally, this information also can be used to better guide the reviewers in different phases of software development process accordingly.

3 METHOD

We have performed an experiment to observe and collect data for defect detection process of novice participants. The experimental study was conducted with 6 participants using a study material which was derived from the study of Geambaşu and Jianu, which is adapted to the current settings of this study and translated into Turkish (Geambaşu and Jianu, 2013). Moreover, they were provided with the description of the symbols that would be used in the diagrammatic representation. Participants of this study were first year students of Computer Engineering Department of Cankaya University. The inspection against a requirements document is called vertical reading technique (Travassos et al., 1999) which aims to reveal omission, incorrect, inconsistent type of defects which can be applied to all documents in any of the software development stage whenever the necessary documents are available.

We have prepared a scenario about package holiday booking process of a travel agency. According to this scenario 6 defects seeded into the BPMN diagram of the system. The participants have been provided the process description one week before the experiment. During the experiment, participants were asked to find the defects seeded into the BPMN diagram, based on the scenario description.

The defects are categorized into three types: Missing Task (MT), Missing Dataflow or information (MD), incorrect or missing Information (I). Table 1 summarizes the number of defects according to each category defined here.

Table 1: Number of Defects in Each Category.

Code	Description	# of Defects
MT	Missing Task	2
MD	Missing Dataflow/information	2
I	Incorrect/ Incomplete	2
	Total	6

Table 2 depicts the defects seeded into the BPMN with their defect types. Figure 1 shows the locations of the defects.

Table 2: Defect Explanations.

Defect	Description	Defect Type
01	"Receive invoice" is missing	MT
02	"Send travel requests" is missing	MT
03	Data flow to "receive cancel request" is missing	MD
04	Data flow to receive travel documents is missing	MD
05	Instead of "receive unavailability notice", "receive success message"	I
06	Instead of "cancel bookings" , "cancel invoice"	I

In Figure 1, there are several tasks performed by a customer or travel agency. These processes define the top-level diagram of package holiday booking process of a travel agency. The tasks connected to each other through data flows. Moreover, data is accumulated in data stores called customer ac-count, work order/proposal and personnel.

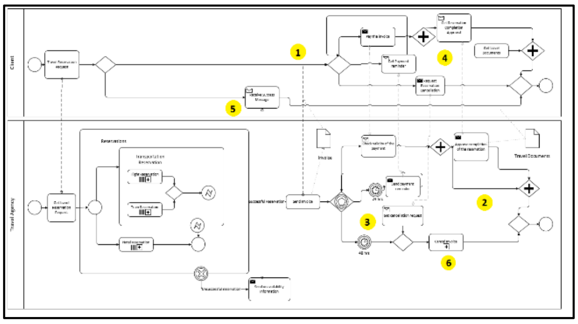

Figure 1: Defects' Placements in BPMN.

The participants were asked to detect the defects by comparing it with the scenario provided to them. In order to note the defects they found, they were asked to use a web-based tool to record the time at which they noticed the defect and its explanation (Figure 2).

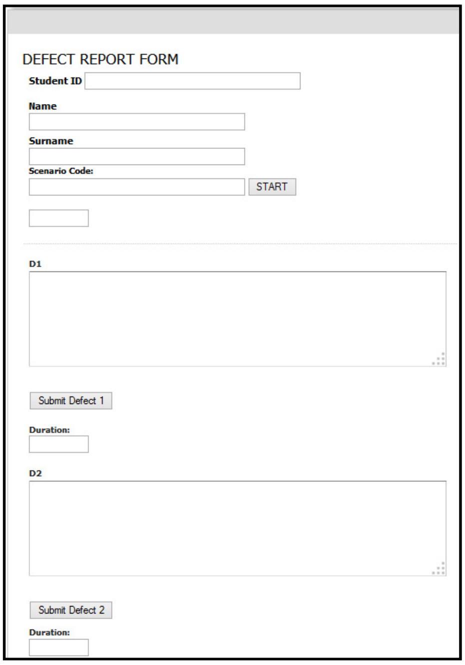

Figure 2: Defect Collection Tool.

In this study, data is collected through defect collection tool by the reviewers, questionnaire and semi-structured interview sessions conducted by each reviewer. The defect detection report generated by the tool includes the defect number, explanation for the defects found and the time of the defect notice. By using this form, the reviewers were asked to note each defect that they detect and describe their opinions about this defect as explained in the explanation document provided in Appendix A. The observations were conducted by one researcher and observation notes were taken during each reviewer's defect detection process. Additionally, questionnaire and a semi-structured interview session was conducted by each reviewer individually. The semi-structured interview questions were formed as below:

1. Which types of defects were easier to detect?
2. Which defects were harder to detect?
3. Which factors do you think helped you to detect the defects easily?
4. Which factors do you think make it hard to detect the defects?

Since the main research question of this study is based on the defects, the results of this study based on 36 cases (6 x 6). Additionally, this study aims to focus on the behaviours of the participants in order to uncover the complexity of human behaviour in such a framework and present a holistic interpretation of what is happening during the review process. Nielsen and Landauer also report that studying with four or five subjects is enough to understand and explain more than 80% of the phenomena (Nielsen and Landauer, 1993). Accordingly, in this study, the participants' behaviours are analysed in depth from different dimensions. In the following section, the results of the defect detection process are provided.

4 RESULTS

Table 3 shows the duration in seconds that each participant (DPij) spent during each defect detection process.

Table 3: Defect Detection Duration Data.

Defect Type	Defect (Di)	Dp1i	Dp2i	Dp3j	Dp4i	Dp5i	Dp6i
MD	3					1500	
MT	1	780					720
MD	4		480	660	1140		60
MT	2	420	420			300	
I	6			240			
I	5	240	180				240

As an example, in this table, Dp1 is calculated from the defect collection tool which shows the duration in seconds that the participant p1 spend time for detecting the defect i (Di). It is the duration starting from the time point of last defect detection process until the defect detection of Di. ADi in Table 4 is the average of the durations spent by each participant to detect defect i (Di). Among the detected defects, type I defects were detected in relatively less time (D_5, D_6). Similarly, the participants spent more time for detecting defects of type MD (D_3) and only one participant could be able to detect MD type defect D_3.

Table 4: Defect Detection Duration Average.

Defect Type	Defect (Di)	ADi	Frequency of Di
MD	3	1500	1
MT	1	750	2
MD	4	585	4
MT	2	380	3
I	6	240	1
I	5	220	3

We have analysed this data according to the defect types, as shown in Table 4. Accordingly, the detection rate for missing Information (I) type of defects is calculated as 4/12=0.33. Defects of type MT were detected mostly; on the other hand, the defects of type MD were detected seldom.

Table 5: Detected Defect Type.

Defect Type	Total Possibilities	Total Detected	Detection Rate
MD	12	5	0.42
MT	12	5	0.42
I	12	4	0.33

The detection frequency Fi of defects is shown in Table 5. In this table, Fi represents the frequency of a detected defect by participants. Its value is calculated by adding 1 point for each defect's detection for defect i (Di). For example, if the defect is detected by only one participant this value is 1, if it is detected by three participants the Fi value for that defect is calculated as 3.

Table 6: Defect Frequency F_i.

Defect Type	Defect	F_i
MD	4	4
MT	2	3
I	5	3
MT	1	2
MD	3	1
I	6	1

Based on the defect detection average duration and order, we have calculated defect difficulty using formula derived by Cagiltay et al. (2011). Difficulty of a defect means how much a participant spend effort to find it in terms of time to find and order to find it.

$$DF_j = \frac{D_j \bullet O_j}{\frac{R_j}{m}} \tag{1}$$

where,

DF_j: Defect detection difficulty level of the j^{th} defect
D_j: Average duration spent by all participants for finding defect j
O_j: Average score of all participants for detecting j^{th} defect
R_j: Number of people who detected defect j
m: Total number of participants

The average frequency of defect detection according to the defect types are given in Table 7. As seen from this table, MD type defect D_3 was the most difficult defect in the diagram found by 1 participant.

Table 7: Defect Difficulty Levels.

Defect Type	Defect	DF_j
MD	3	9000.0
MT	1	3375
MT	2	2026.7
MD	4	1462.5
I	6	1440.0
I	5	733.3

According to Table 7, MD type defects were the most difficult ones whereas I type defects were the easiest defects. 4 of the participants stated that they have followed the scenario to detect the defects which made it easier to find them. 5 of the participants think that the modelling language was complicated for them which made defect detection process difficult.

5 DISCUSSION AND CONCLUSION

In this study, an experiment is conducted to analyse defect detection performance of novice users in reviewing BPMN diagrams. During the experiment, we had provided materials to the participants, one week before the experiment (Appendix A) and requested to find defects on BPMN diagrams compared to the explanations given. The defects they have found recorded through a defect collection tool.

The results of this study show that, missing information type defects (MP and MD) are harder to detect than the incomplete or incorrect type (I) of defects. Hence the defect detection frequency of defects in average is higher for type I defects (2.67) than that of type MP (2.00) and type MD (1.20) defects. Similarly, the detection rate of type I defects (0.67) is higher than that of type MP (0.50) and type MD (0.70) defects.

In this study we used a business process to study the defect detection process. Hence, there is a threat to the validity of the findings in that the study results could be a specific to the nature of the process or the type of the defects that were seeded. A future study would focus on several processes to be able to generalize the results.

According to the results, the business process designers may reconsider their designs especially for the defects of type missing dataflow, which are harder to be detected in the future and may increase the cost of the projects. We believe that further analysis of the BPMN defect detection process is expected to provide more insights to the researchers, businesses, and to the educators to improve BPMN cognitive process.

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APPENDIX A- SCENARIO

In This Experiment;

You are required to find the defects in the diagram, according to the description given below. Defects could be Missing Process (MP), Missing Dataflow/Data (MD) or Incorrect Definition /Data (I).

Travel Reservation Scenario

Travel Agency (TA) makes travel reservation based on the customer requests. TA receives a travel reservation request from a Client including airline transportation and hotel reservation. The request is examined; transportation and hotel availability is checked, reservation is made and accordingly an invoice is created. If reservation is not possible, the Client is informed correspondingly.

Client can make the payment upon reception of the invoice or can request reservation cancellation. If the payment is performed, TA checks the validity of the payment and a confirmation of the reservation message is sent to the customer with travel documents. If Client requests cancellation, TA cancels the reservation.

If Client does not make the payment, 24 hrs after the reception of the bill, a payment reminder is sent. Client can make the payment or cancel the reservation after this reminder.

If Client does not make the payment in 48 hrs after the reception of the bill, TA cancels the reservation.

Questionnaire

Open-Ended Questions

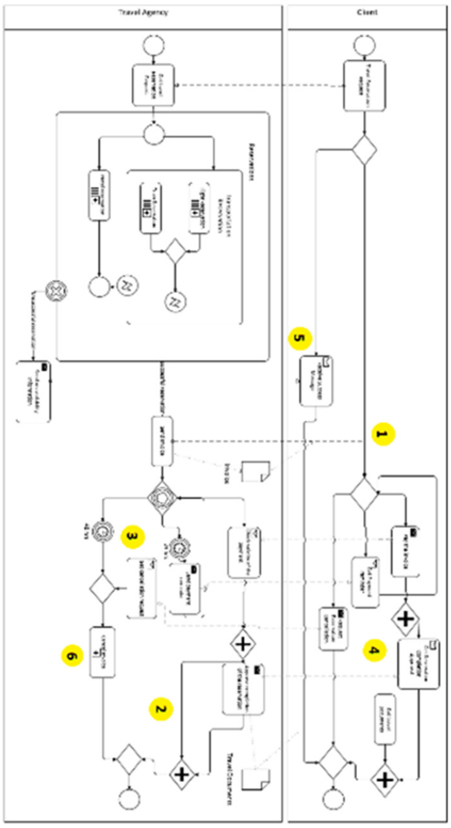
1. Which factors made you find the defects easily?
2. Which factors made it difficult to find the defects?
3. The easiest defect I found is:
   What is the reason?
4. The most difficult defect I found is:
   What is the reason?
5. During defect detection process, which strategy have you followed?
6. While working with the diagram, did you follow any defect order of your choice or the system has forced you to follow a certain order?

7. Which diagram element is easier to understand?
8. Which diagram element is more difficult to understand?
9. Which effect type was easier to find? Missing Process (MP), Missing Dataflow/Data (MD) or Incorrect Definition /Data (I)
10. Which effect type was more difficult to find? Missing Process (MP), Missing Dataflow/Data (MD) or Incorrect Definition /Data (I)

Lickert Scale (5-level) Questions

1. I understand this modelling language well
2. This modelling language is difficult
3. Diagram is complicated
4. Understanding the relationship between Client and Travel Agency is easy
5. The scenario description is compatible with the diagram
6. I understand modelling languages like ER, UML, DFD well
7. Modelling language concept is difficult for me

BPMN DIAGRAM DEFECTS



BPMN Symbols

	Start event- Untyped start event that triggers a new process instance
	Intermediate Error Event- Catches a named error, which was thrown be an inner scope (e.g. subprocess). This event needs to be attached to the boundary of an activity
	Intermediate Timer Event- Process execution is delayed until a certain point in time is reached or a particular duration is over
	Intermediate Multiple Event- Process execution is delayed until one out of a set of possible events is triggered
	Intermediate Cancel Event- Reacts only on a transaction, which was canceled inside an inner scope (e.g. subprocess).
	Task- A task is a unit of work – the job to be performed. It is an atomic activity within a process flow
	Receive Task-wait for a message to arrive from an external Participant
	Send Task-send a message to an external Participant
	Collapsed Subprocess- An event-subprocess is placed within another subprocess
	Collapsed Parallel Subprocess- An event-subprocess is placed within another subprocess working parallel
	Exclusive Gateway- creates alternative paths in a process flow, only one of the paths can be taken
	Parallel Gateway-combines parallel flows
	Sequence flow - connects flow objects in proper sequential order
	Message flow - represents messages from one process participant to another
	Association - shows relationships between artifacts and flow objects
	Data Object- provides information about what Activities require to be performed and/or what they produce
	Text Annotation- provides additional text information

An Approach for Transforming IT-Network Diagrams into Enterprise Architecture Models

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Keywords: Network Diagram, Enterprise Architecture Model, ArchiMate, Model Transformation, CISCO.

Abstract: Enterprise Architecture (EA) models propose to capture the activities of an organization, going from its business aspects to its IT infrastructure. Such an approach is promising to support reasoning on specific concerns, especially those relying on the business-to-IT stack, such as enterprise transformation, security, IT investment, etc. However, most of the organizations do not have existing EA models, and are reluctant to establish them, especially from scratch, mainly due to the length and complexity to do so. Our insight is that we can leverage on network diagrams, one of the most common kind of models available in organizations, to generate part of EA models. In this paper, we propose an approach to transform network diagrams into EA models. In this context, we focus on CISCO as the reference for network concepts, and ArchiMate as the standard modelling language for EA.

1 INTRODUCTION

Enterprise Architecture Management (EAM) has shown to be a valuable and engaging instrument to face enterprise complexity and the necessary enterprise transformation (Saha, 2013; Zachman, 1987). It offers means to govern enterprises and make informed decisions: description of an existing situation, investigation and expression of strategic direction, analysis of gaps, planning at the tactical and operational level, selection of solutions, and architecture design (Op't Land et al., 2008). As part of a global EAM adoption, describing Enterprise Architecture (EA) with a suited language (i.e. EA modelling) is considered as a key activity (Lankhorst, 2005) and the scope of our paper is focused on this concern.

However, the current problem is that most organisations pay few attention to the modelling of their structure. Among the current limitations to a broader adoption of EA modelling, we particularly noticed (Lankhorst, 2005):

- EA modelling is a complex task and requires specific skills
- EA modelling is a time consuming task, especially when started from scratch
- There are numerous and disregarded modelling tools that can be used

To deal with these issues, our main assumption is that the reuse of existing material (i.e. existing models) would help in the development and adoption of EA models and also reduce their development length. In this context, IT network diagrams are usual existing material in the structure of an organization, and appear to be a good basis to EA modelling. Indeed, each structure needs network models in order to support infrastructure design and most of them have them available.

In this paper, our aim is to propose an approach to use IT network diagrams to generate (part of) EA models. Our insight is that it is a relevant and realistic beginning to develop EA models, allowing saving time by accelerating part of the EA modelling tasks. It is worth to note we consider that such an approach would never produce complete and satisfactory EA models, but we see it as an interesting trigger to start the design of such models. In order to limit the scope of this project, we will focus on ArchiMate (The Open Group, 2013) as the exploited EA Modelling Language (EAML), but we are aware that others could be relevant too (BPMN (Object Management Group, 2011), UML (Fowler, 2003), etc.).

This paper is structured as follows. In the subsequent section, we provide some background knowledge about the main literature we use: CISCO as a *de facto* standard for Network Architecture Design and the ArchiMate Language, especially its technology layer. Section 3 describes the first step of our research method that is the definition of a network concept classification, followed, in Section 4, by the integration of these concepts into ArchiMate. We finish with concluding remarks and future work.

2 BACKGROUND

2.1 CISCO as a *de facto* Standard for Network Architecture Design

Network architecture design is the science to design good networks, making them safe and available (Stewart et al., 2008). IT Network concepts are numerous, especially because of the number of different technologies, products, companies, etc. We found a lot of information in uncertified articles or unprofessional tutorial to design a network diagram. However, to the best of our knowledge, there is a lack of standard or reference model depicting the concepts at stake, and in our context, it is a major issue. The current state-of-practice is actually the use of technology-specific terms and concepts. By reviewing major modelling software proposing network architecture modelling features (VISIO, Gliffy…), our conclusion is that CISCO is considered as a *de facto* standard. Hence, we decided to focus on CISCO concepts, expecting to cover a major proportion of existing concepts. The survey of literature for network architecture is consequently focused on CISCO. We distinguish three main sources of reference material related to CISCO:

- **CISCO documentation**: a set of documents listing main CISCO network concepts (e.g. Technology, protocol, or product). In this category, we identified the following documents: CISCO Iconography (Cisco Systems Inc., 2014), CISCO Product Quick Reference Guide (Cisco Systems Inc., 2013).
- **CISCO Website**: the CISCO website is a field-based source. It is the first interface between CISCO up-to-date products and clients.
- **Modelling Software**: most of modelling software uses modelling set of objects called "stencils", one among the available ones being generally based on CISCO concepts. We have only used those for which the CISCO stencil was sufficiently developed and specified, and we have set apart the others (e.g. Microsoft VISIO). The analysed modelling software are:
  - **Gliffy** (Gliffy, 2017): Gliffy is a cloud-based diagramming web application founded in 2005, allowing collaborative work. In our work, we focus specifically on the library concerning CISCO objects.
  - **CISCO Packet Tracer** (Cisco Systems Inc., 2017): Packet Tracer is a simulation program designed by CISCO Systems. The software allows users to create network topologies and reproduce nowadays computer networks.

2.2 ArchiMate Technological Layer

Enterprise Architecture (EA) is defined as a coherent whole of principles, methods, and models that are used in the design and realisation of an enterprise's organisational structure, business processes, information systems, and infrastructure (Lankhorst, 2005). To provide a uniform representation for diagrams that describe EA, the ArchiMate modelling language (The Open Group, 2013) has been produced by The Open Group, an industry consortium developing standards. It offers an integrated architectural approach to describe and visualize the different architecture domains and their underlying relations and dependencies. The role of the ArchiMate standard is to provide a graphical language for the representation of EA over time, as well as their motivation and rationale. It is today a widely accepted open standard for modelling EA (Vernadat, 2014), with a large user base and a variety of modelling tools that support it.

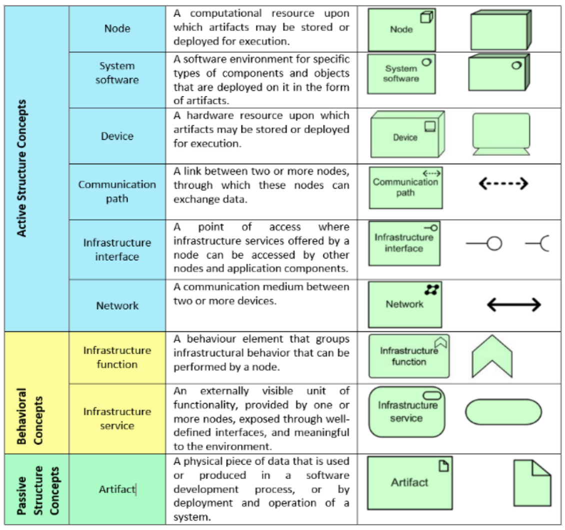

Figure 1: Definitions and visual representation of concepts of the ArchiMate technology layer.

ArchiMate proposes a 3-layered architecture for structuring its core concepts: the Business Layer, Application Layer, and Technology Layer. In our perspective focused on the modelling of network infrastructure, we will particularly analyse the Technology Layer that provides infrastructural services needed to support business. Figure 1, extracted from the ArchiMate 2.1 Specifications (The Open Group, 2013), gives an overview of the Technology Layer concepts, including definition and visual representation for each concept.

3 ALIGNMENT AND INTEGRATION BETWEEN CISCO AND NETWORK CONCEPTS

Alignment between CISCO and network concepts is the first phase of our contribution. First, for each analysed literature reference, we need to determine concept classes (i.e. a concept classification for each literature reference). Each class can be seen as a set of modelling objects (or instances of generic concepts) and the set of classes creates a taxonomy of network concepts of a given literature reference.

Then, we need to map the defined taxonomies together thanks to a classification methodology. The objective of this alignment is to propose a consolidated list of network generic classes. The classification methodology uses refinement cycles based on criteria to do the most relevant arrangement between network classes. Thus, each chosen classification pass through each criterion cycle, which correspond to different levels of details and analysis:

- **Syntax:** the first level is the semantic analysis of the class *i.e.* name's similarities or spelling syntax. For example, a grouping called "*Routing*", can easily be associated to another grouping called "*Routers*".
- **Network subdomains:** the second level of analysis aims at determining, for each instance of the class, to which network fields it belongs. For example, "*Connecting Safety and Security*" gather physical security concepts (doors, cameras, etc.) and IT security concepts (firewall, guards, etc.). It helps us to exclude concepts which are out of our scope (in that case *Physical Security* concepts).
- **Functionality:** To remove any ambiguity, a detailed analysis of each instance functionalities is required. In fact, an instance can belong at a time to different classes (or to different network subdomains). There is a need to analyse objectively to which class each instance belongs the most. For example, a wireless router can belong to the "*Wireless class*" and to the "*Router class*". Thanks to the predominant functionality, we can say that a wireless router is a router and effectively belong to the "*Router class*".

We mainly focus on the most relevant sources of our survey, in order to make these "instance's groups" the most significant towards the network engineering field. First, we focus on the CISCO Documentation (Cisco Systems Inc., 2014, 2013), also including the CISCO website. Then, we chose Gliffy Online Platform (Gliffy, 2017), and finally, the simulation software CISCO Packet Tracer (Cisco Systems Inc., 2017). Then, we applied the classification methodology described previous1y on each reference, to refine the network classification. The output of the process creates a classification for our instances. We're getting the so-called *"Network concepts classification",* presented below.

This consolidated list expresses main CISCO-based generic network concepts. By using this classification, we will be able for instance to classify other concept's instances coming from other brand models. We use a granularity generic enough, which allows us to have a viable classification on time. We give a description for each class of our network concepts classification and examples of what we find in each of them:

Collaboration: It regroups all instances that aim with the teamwork. We find conferencing devices, IP phones, communicating software, etc.

Security: This class regroups all security products including physical security and IT security. Thus, we have devices such as monitoring cameras, firewalls, etc. Also, we can find some security software products (e.g. IOS Firewall).

Switch: The class gather all different types of switches that exist in some various forms depending on the technology used or the functionalities incorporated (e.g. Multilayer Switch, etc.*)*.

Router: The class regroups the various types of routers (e.g. Router with Firewall, NetFlow Router, etc.*)*.

Wireless: Collection of wireless devices, or wireless modules (e.g. access points, WLAN controller, etc.)

Software: This is a class which gather different type of software solutions, mainly from CISCO. We especially find system software, like OS.

Transport/Telephony: This class gather all devices that concern the physical devices of telephony and transport. We find mainly devices that deals with the first layer of the OSI model like modems, DSLAM, etc.

End Device: It concerns end devices like personal computers, TVs, printers, etc.

Physical Server: It regroups the different types of existing servers like Web servers, certificates servers, file servers, etc.

Data Storage: This class is derived from the physical servers' class. Indeed, because of the huge number of existing data storage types' instances (storage module, data monitoring software, etc.) it is essential to distinguish it from the physical devices.

Management: It is a field's class that gathers management devices, modules and software. In big networks, it is crucial to consider management devices, or management software to access, control, or monitor devices.

Hub: Similarly, to the *Router* class or the *Switch* class, it regroups hub concepts and instances. This type of devices is tending to disappear because of the technological advancement. However, we have to take into account old networks that could still have this type of devices.

Protocol: This class is particular because in general, protocols cannot be depicted in an architecture, apart from writing the name besides a device or a connections. However, CISCO has created protocols' concepts like IP protocols, or FDDI Ring that allow representing some kind of protocols.

Topology: Such as the protocol class, it is possible to represent the topology of a network.

Connections: In a network diagram, connections are represented in different manners. For example, in CISCO Packet Tracer, we are able to recognize optical link, wireless communication, etc. This class collects all type of connections that can be materialized in a network diagram.

Network Architecture: It represents different types of network architectures like Cloud, CISCO layered architecture, etc. In diagrams that use modularization, it is possible to represent a network architecture through a dedicated icon representing this concept.

4 CONSTRUCTION OF A NETWORK-ARCHIMATE METAMODEL

4.1 Conceptual Alignment

After having analysed CISCO concepts with their instances, we have created the network concepts classification following our methodology, as depicted in the previous section. As a reminder, the goal of our research work is to use network diagrams so as to generate a basis of EA models. Therefore, this second step aims at creating a relationship between our network concepts classification and ArchiMate Technology Layer concepts. Thus, in order to integrate these global concepts (*i.e.* classes*)* into the ArchiMate metamodel, we need to respect the ArchiMate structure (*i.e.* rules and concepts) and use the ArchiMate metamodel as an input. We called this relationship the "integration step".

In order to do this, it is necessary to add network generic classes to the ArchiMate Technology Layer metamodel. Consequently, we will be able to represent a network diagram with the ArchiMate Technology Layer concepts, thanks to the metamodel rules (*i.e.* links between concepts of the metamodel).

To allow this conceptual alignment, we use relationships inspired from the approach of semantic correspondence between concepts from Zivkovic et al. (Zivkovic et al., 2007). Themselves inspired by UML relationships (Fowler, 2003), we explain these relationships below:

- ***Equivalence***: *concept A* is semantically equivalent to *concept B*;
- ***Generalisation***: *concept A* is a generalisation of *concept B*, i.e. *concept B* is a specific class of *concept A*;
- ***Specialisation***: *concept A* is a specialisation of *concept B*, i.e. *concept B* is a generic class of *concept A*;
- ***Aggregation***: *concept A* is composed of *concept B*, i.e. *concept B* is a part of *concept A*;
- ***Composition***: *concept A* is composed of *concept B* (with strong ownership), i.e. *concept B* is a part of *concept A* and does only exist as part of *concept A*;
- ***Association***: *concept A* is linked to *concept B*

By confronting each instance (of network generic classes) with ArchiMate, we realize that we can affect to each instance one of the Active Structure concepts of the ArchiMate Technology Layer, i.e. Node, System software, Device, Communication path, Infrastructure interface and Network. Actually, the ArchiMate framework can represent its own network diagrams, as CISCO, that's the reason there are some similarities between our created network generic classes and Active Structure concepts. Table 1 show these equivalences we identified. Table 1 presents two types of equivalences:

- First, we have equivalences between some instances of (network generic classes) and leaf's concepts of the ArchiMate metamodel (Device, Node, System Software). These latter are the most used concepts for network diagram conception in the EA context.

- Secondly, we noticed that some classes can be mapped as is to ArchiMate main concepts. For example, instances of our *Connections* class are in some way equivalent to the ArchiMate *Communication Path* class instances.

Table 1: Equivalence between type of instances and ArchiMate concepts.

Type of classes instances	ArchiMate	Semantic mapping
Devices instances	Device	*Equivalence*
Modules instances (Node)	Node	
System Software	System software	
Connections	Communication Path	

To use Network generic classes as concepts of ArchiMate, we have to add our concepts to the ArchiMate metamodel without modifying its structure. In fact, we can only improve the metamodel by specializing ArchiMate concepts or finding equivalence between both types of concepts. Thus, there is two relevant relations from Zivkovic et al. we can use: specializations and equivalences.

Specialization is a type of semantic mapping used for concepts that are a part of ArchiMate concepts (see Figure 1). For example, physical router devices of our *Router* class are specializations of the ArchiMate *Device* concept. Thus, there is a need to split our network generic classes in order to make possible the addition of instances to the ArchiMate metamodel, and thus to be compliant with ArchiMate.

Table 2 expresses the different partitions we had to make in order to be able to specialize the ArchiMate metamodel with our concepts. Table 2 presents three main type of classes:

- Network generic classes that are enough generic to propose Device instances, System Software instances and Module instances, which are the most used ArchiMate concepts for network diagramming in EA context. We called these classes "*Field*" because of their huge number of different type of instances.
- Some network generic classes are specifically concerning hardware instances. In the ArchiMate context, it concerns only physical type of instances (Physical router, End devices, etc.)
- Remaining network classes can't be divided, because of too specific instances, such as specific topologies, or protocol. In that context, it is irrelevant to subdivide these network generic classes. We called them the "*Support*" classes.

Table 2: Partition of network generic classes.

	Network Generic Classes	Subdivided Network Generic Classes
Field	Collaboration	Collaboration Device
		Collaboration System Software
		Collaboration Module
	Security	Security Device
		Security Module
		Security System Software
	Data Storage	Data Storage Device
		Data Storage Module
		Data Storage System Software
	Transport / Telephony	Transport/Telephony Device
		Transport/Telephony System Software
		Transport/Telephony Module
	Management	Management Device
		Management System Software
		Management Module
Hardware	Switches	Switches Device
		Switches Module
	Wireless	Wireless Device
		Wireless Module
	Routers	Routers Device
		Routers Module
	Physical Servers	Physical Servers Device
		Physical Servers Module
	End Devices	End Devices Device
		End Devices Module
	Hub	Hub Device
		Hub Module
Support	Protocol	Protocol
	Topology	Topology
	Network Architecture	Network Architecture
	Connections	Connections

Then, we create a detailed alignment table between previously subdivided network generic classes and ArchiMate concepts. Table 3 presents the semantic mapping:

Table 3: Detailed alignment table.

Subdivided Network Generic Classes	ArchiMate	Semantic mapping type
Collaboration Device	Device	Specialization
Collaboration System Software	System Software	
Collaboration Module	Module	
Security Device	Device	
Security Module	Module	
Security System Software	System Software	
Data Storage Device	Device	
Data Storage Module	Module	
Data Storage System Software	System Software	
Transport/Telephony Device	Device	
Transport/Telephony System Software	System Software	
Transport/Telephony Module	Module	
Management Device	Device	

Table 3: Detailed alignment table. (cont.)

Subdivided Network Generic Classes	ArchiMate	Semantic mapping type
Management System Software	System Software	Specialization
Management Module	Module	
Switches Device	Device	
Switches Module	Module	
Wireless Device	Device	
Wireless Module	Module	
Routers Device	Device	
Routers Module	Module	
Physical Servers Device	Device	
Physical Servers Module	Module	
End Devices Device	Device	
End Devices Module	Module	
Hub Device	Device	
Hub Module	Module	
Protocol	Interface	
Topology	Network	
Network Architecture	Network	
Connections	Communication Path	Equi.

4.2 Proposed Network-ArchiMate Metamodel

Based on the alignment performed, we need to integrate the classes of our network classification into the existing ArchiMate metamodel, following and complying with the existing structure and associated rules. The mapping table permits us to integrate the concepts into the ArchiMate metamodel. Thanks to the semantic rules, we are able to propose the integrated Network-ArchiMate metamodel, as represented in Figure 2. We give also the example of Firewall instances, which we scattered into corresponding type of concept (*i.e.* Device, System Software, Module).

5 CONCLUDING REMARKS

The approach presented in this paper aims at proposing a way to transform network diagrams into EA models. First, we had to suggest a network concepts taxonomy that allows us to classify each network concept and its instances in these generic classes. Then, by aligning these classes with ArchiMate concepts, we proposed a metamodel which allows us to integrate network-specific concepts with ArchiMate.

The approach presented here, and especially the integrated metamodel, have been used in a fictitious case to experiment the transformation from network diagram to an ArchiMate model. This experiment, not described here for sake of brevity, has shown that our

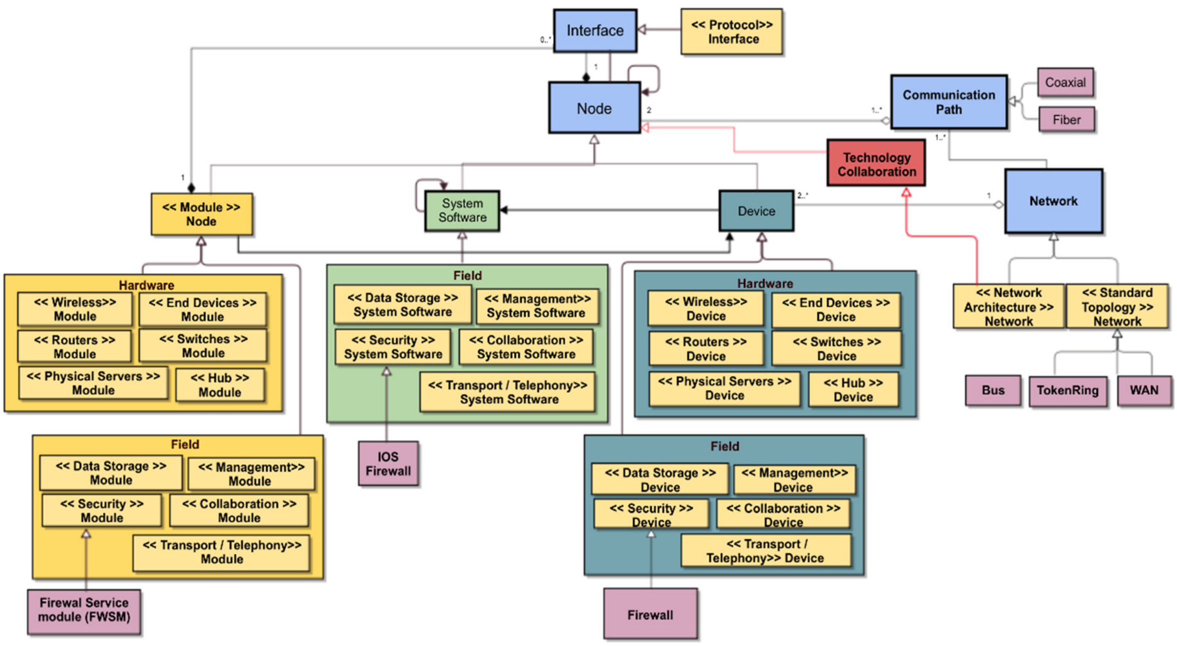

Figure 2: Proposed Network-ArchiMate metamodel.

approach is applicable. It has also shown some ways of improvement, such as the introduction of additional specifications (e.g. a color code) in the ArchiMate language in order to keep trace of the original network class, this information being lost in the transformation proposed. However, no conclusion can be drawn from this experiment at the level of soundness and usefulness of our approach in a real-world context and further validation work is deemed as necessary to consider our approach as valid.

Regarding future work, we first need to experiment our approach on a wider and real world case. Then, it is necessary to assess with users the relevance of the approach especially at the level of the soundness of the EA models obtained compared to the initial network models, as well as their usefulness as a starting point to design complete EA models.

ACKNOWLEDGEMENTS

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Towards Modeling Adaptation Services for Large-Scale Distributed Systems with Abstract State Machines

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Keywords: Formal Modeling, Abstract State Machines, Large-Scale Distributed Systems, Adaptation, Smart City.

Abstract: The evolution of Large-Scale Distributed Systems favored the development of solutions for smart cities. Such systems face a high-level of uncertainty as they consist of a large number of sensors, processing centers, and services deployed along a wide geographical area. Bringing together different resources poses increased complexity as well as communication efforts, and introduces a large set of possible failures and challenges of continuously growing computational and storage expectations. In such a frame, the role of the adaptation components is vital for ensuring availability, reliability, and robustness. This paper introduces a formal approach for modeling and verifying the properties and behavior of the adaptation framework addressing the case of a system failure. We formalize the behavior and the collaboration mechanisms between agents of the system with the aid of Abstract State Machines and employ the ASMETA toolset for simulating and analyzing properties of the model.

1 INTRODUCTION

Large-scale distributed systems (LDS) have appeared as a solution to the continuously expanding computing and storage demands. Services offered through such architectures bring an increased value to the end client, but there are still many open questions posed by issues like heterogeneity, network failures, and random behavior of components. Recovering from failures and ensuring a high availability of the system requires reliable monitoring and adaptation techniques.

One of the biggest beneficiaries of LDS are the applications for smart cities, which connect and allow the communication of a huge number of sensors spread along a wide radius. Such systems cover various aspects like traffic surveillance, infrastructure and environment, and aim to ease and improve the quality of life of inhabitants. These solutions are characterized by the same properties as well as failures and availability issues as any LDS. Therefore, the adaptation component plays a key role in enacting adaptation plans to bring the system to a normal execution mode.

The goal and contribution of this paper is to integrate the formal modeling capabilities of the Abstract State Machines (ASMs) for defining and validating an adaptation solution for LDS. Our project promotes a service-oriented approach to heterogeneous, distributed computing that enables on-the-fly run-time adaptation of the running system based on the replacement of sets of employed services by alternative solutions. For this we develop an advanced architecture and an execution model by envisioning and adapting a wide spectrum of adaptation means such as re-allocation, service replacement, change of process plan, etc.

The remainder of the paper is structured as follows. Section 2 provides an overview of the system and its architecture, followed by a description of the structure of the adaptation framework in Section 3. Essential concepts related to the Abstract State Machine formal methods as well as the formal specification of the adaptation framework are detailed in Section 4. Related work is discussed in Section 5, after which conclusions are drawn in Section 6.

2 SYSTEM OVERVIEW

The evolution of distributed systems, Internet of Things (IoT) and network capabilities played an important role in the adoption of ubiquitous solutions for smart cities. Widely distributed sensors for traffic,

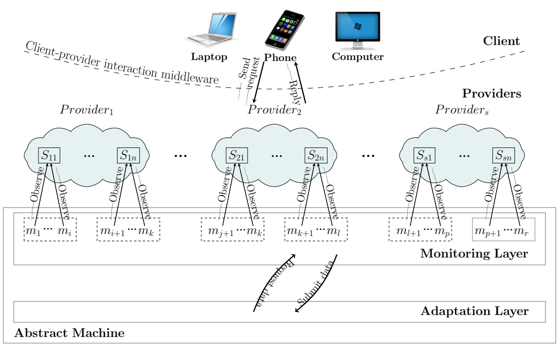

Figure 1: Architecture of the LDS system.

pollution, energy efficiency and environment continuously collect data that are integrated in various applications. The aim is to sustainably develop cities and improve the quality of life of the the inhabitants.

One of the main areas of interest is provisioning of traffic services, where centrally-controlled traffic sensors regulate the flow of traffic through the city in response to demand. The benefits of such a smart traffic management application also empowers people to take informed decisions, and prevent severe traffic congestion due to overcrowded areas. In a smart city network, traffic sensors provide real time data related to the percentage of road occupancy, the number or traffic participants, just to name a few. Such sensors are distributed along an LDS and the data they provide can be integrated with activity patterns extracted from smart gadgets for building a knowledge base for a traffic application.

The organization of the solution reflects the structure of LDS, where nodes refer to sensors and services are offered by various providers. Such systems are characterized by heterogeneity, unavailability, instability, network and node failures. Problems occurring at component level are propagated to the whole solution, making it hard to identify the source. We emphasize the role of the adaptation framework for ensuring availability of the system and propose a formal model for the solution. Figure 1 illustrates the architecture of the LDS system for a smart traffic application.

2.1 System Architecture

The envisioned solution proposes distributed middleware components containing different units responsible for specific tasks: service integration, process optimization, communication handler. The core makes use of ASMs for expressing the specification of the other components and foresees a three-layered abstract machine model addressing normal processing, monitoring and adaptation. The organization, as illustrated in Figure 1, is rooted in three parts: the client side where different users request services from providers, the side of the providers where sensors are deployed and an abstract machine containing the monitoring and adaptation layers for the resources of the providers. The interaction of the clients with the service providers is based on a solution defined by (Bósa et al., 2015), where the client-cloud interaction middleware processes the requests and ensures the delivery of services to the end user.

The processes of the monitors and adapters are highly interconnected and interdependent, enabling the system to perform reconfiguration plans whenever any of the traffic sensors faces a problem. The monitors are responsible for collecting data, aggregating it into meaningful information and communicating observations about abnormal executions to the adaptation framework. The latter deals with recovering from anomalous situations, logging them, and finding the best remedy to restore the LDS to normal running mode. Diagnosis is strongly correlated with the high-level interpretation of collected data.

The adoption of LDS demands a deep understanding of the underlying infrastructure, its running mechanisms and uncertainties, as services may become unavailable or change, or network problems may impact negatively on the reliability and performance of the distributed system (Grozev and Buyya, 2014). Delivery of reliable services requires a continuous evaluation of the system state and adaptation in case of abnormal execution. Therefore primarily, two aspects are considered: resilience and fault tolerance. With respect to resilience the project targets system architectures that guarantee that a LDS keep running and producing desired results, even if some services become unavailable, change or break down. With respect to fault tolerance the project targets assessment methods that permit the detection of failure situations and adaptive repair mechanisms. Therefore for LDS, adaptability is a valuable and an almost inevitable process.

3 ORGANIZATION OF THE ADAPTATION FRAMEWORK

As aforementioned in section 2, the architecture and execution model are enhanced to capture dynamic adaptation of a LDS to changing environmental circumstances. The Adaptation Engine aims to perpetually react to the input measurements and notifications from the monitoring component and maintain its resiliency to gracefully handle and adapt to new contexts varying from network traffic fluctuations to un-

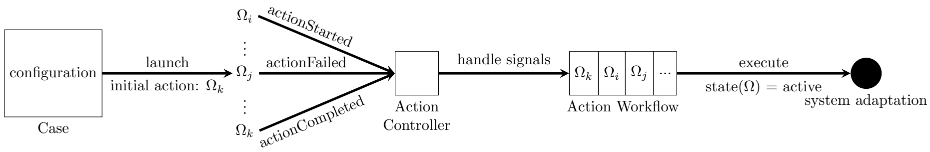

Figure 2: Overview specification of the Adaptation Manager.

availability of different system components. Its main measures consist in reacting to and evaluating the data collected and assessed by the monitoring components in regards to the detected faults within the system, employing the repair of the encountered problem under presumably optimal performance and adjusting the solution to higher levels of quality compliance.

Standardized repair actions for on-the-fly changes in reaction to identified critical situations are defined and will be employed on demand. This will result in a catalog of possible adaptive collaboration patterns, each supported by a set of subsequent adaptation tools and components. Such repair patterns can be the replacement of a component service by an equivalent one or the change of location for a service, up to the replacement of larger parts of the LDS, i.e. a set of services involved, by a completely different, alternative solution.

These steps in the adaptation process highlight the two major components that make up the Adaptation Engine as an inner component of the abstract machine included in the middleware: solution exploration, identification and maintenance carried out by the Case Manager, and solution management and enactment processed by the Action Manager. Each constituent component runs with well delimited responsibilities and areas of inference and control. The current paper focuses on the second part of adaptation, the Action Manager.

In the envisioned framework, any adaptation solution is configured and stored in the repository as a workflow schema detailing the actions and underlying transition dependencies needed to restore the system to a normal execution mode.

An action is an autonomous entity (e.g. a software module) which has the power to act or cause a single update to the system. Its autonomy implies that its processes are neither controlled by other actions, nor are they controlled by the environment. The power of such autonomous and self-aware actions lies in their ability to deal with unpredictable, dynamically changing, heterogeneous environments while relying fully on existing solutions for LDS adaptability. Given the situation of replacing one service with another, one such action would encompass finding a suitable matching service to replace the problematic one (by accessing the capabilities of an existing tool) or dynamically reconfigure the service calls to the new in use service.

The action's instantiation and execution are handled by linked ActionController loaded based on the defined contract for that particular action. The actions' ordering and dependency on other actions is handled by means of notification/signaling, where every action state change would imply for the parent ActionController to broadcast the associated notification. Figure 2 depicts the overall structure of the adaptation process once the problem is mapped to previous encountered problems and the attached solution is carried out based on its configuration.

Therefore, the adaptation system consists of a finite set of autonomous, interacting Action Controllers that intercept and assess all the raised notifications triggered by actions' execution or failure. The assessment implies either enacting and executing its corresponding action, or ignoring the notification as it is not of interest in the given solution configuration. Having Action Controllers to monitor and handle the interaction between the actions of a solution, it emphasizes new properties of the actions being defined in terms of needed input, concrete implementation and resulting output. More importantly, the underlining actions can be easily reused or substituted by enabling the possibility to add or remove any given number of actions without the need to update the current actions.

The model's underlining observer/controller architecture is one realization of the feedback loop principle (Brun et al., 2009): the executing adaptation is observed by its registered controllers, which in turn, based on the reported observations and broadcast notifications, affect the system towards the remediation of the reported problem/failure. An environmental change resulted from the execution of an adaptation action triggers a reaction within the system that causes, in return, a configuration-based chain of subsequent changes. These loops guide the system behavior and dynamics for the adaptation to succeed in reaching the intended goals.

In order to better understand the intrinsic problems that the framework can face, we focused our attention on building ground models in terms of ASMs. Based on them we can validate the specifications and verify if they fulfill desired properties as safety and liveness.

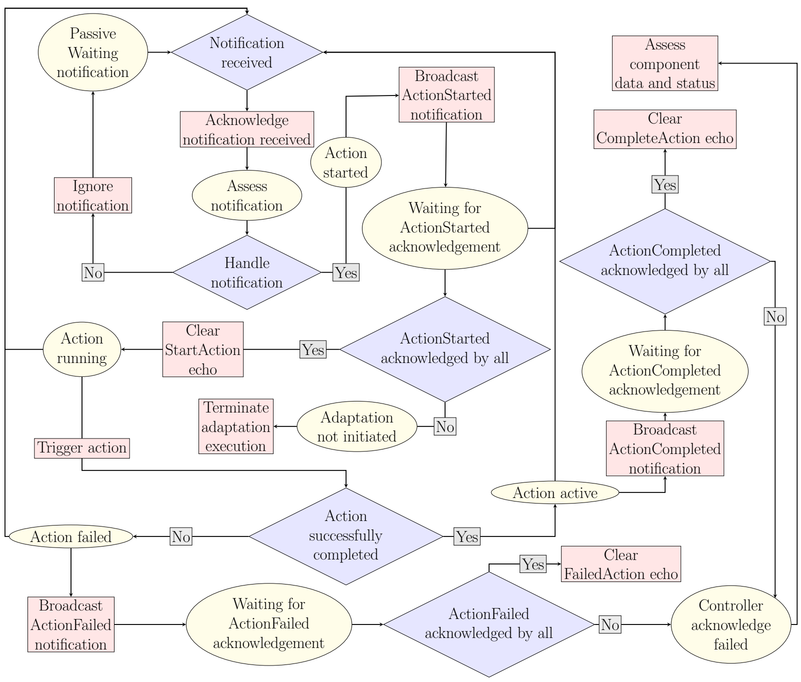

Figure 3: Control ASM for the Action Controller agent.

4 FORMAL SPECIFICATION OF THE SYSTEM

4.1 Background on ASM Theory

According to (Kossak and Mashkoor, 2016), ASMs stood out as a high-quality software engineering method for behavioral and architectural system design and analysis. By further considering the assistance of the model through the expressiveness of the specification, the software development process, its coherence and the scalability in industrial applications (Kossak and Mashkoor, 2016) we adopted the ASM method.

The specification of an ASM consists of a finite set of *transition rules* of the type: **if** *Condition* **then** *Updates* (Börger and Stark, 2003), where an *Update* consists of a finite set of assignment $f(t_1, ..., t_n) := t$. As ASMs allow synchronous parallelism execution, two machines might try to change a location with two different values, triggering an inconsistency. In this case the execution throws an error.

Rules consist of different control structures that reflect parallelism (`par`), sequentiality (`seq`), causality (`if...then`) and inclusion to different domains (`in`). With the `forall` expression, a machine can enforce concurrent execution of a rule R for every element x that satisfies a condition φ: `forall` x `with` φ `do` R. Non-determinism is expressed through the `choose` rule: `choose` x `with` φ `do` R.

Definition 1. *A* control state ASM *is an ASM built on the following rules : any control state i verifies at most one true guard,* $cond_k$*, triggering, thus,* $rule_k$ *and moving from state i to state* s_k*. In case no guard is fulfilled, the machine does not perform any action.*

In the design phase of software development, ASM technique permits transforming the requirements from natural language to ground models, and further to control state diagrams, that are easier to formalize. ASMETA [1] toolset for simulating, validating and model-checking ASM models, permits elaborating the models with the aid of the AsmetaL language, which is able to capture specific ASM control structures and functions. The models are further simulated and validated for inconsistencies. The tool permits also automatic review of the model for properties like conciseness or faultiness or for design issues. In the verification stage, properties like reachability, safety and liveness are defined and checked.

4.2 ASM Specification

Based on the overall specification of the adaptation framework mentioned in Section 3, we define the specific states and transitions of the adaptation processes, with emphasis on the management and enactment of

[1] http://asmeta.sourceforge.net/

adaptation actions. The model contains ActionController ASM agents, each of which carrying out its own execution. The ground model illustrated in Figure 3 details the behavior of an ActionController in relation to the received and broadcast notifications. The ActionController can pass through several states by various rules and guards.

At initialization, the ActionController is in the *Passive, Waiting notification* state. This initial state is reached again either when the associated action's execution and acknowledgment by all the other controllers are fulfilled or when the received notification is not bound to influence the ActionController in question. This is a clear indication of the continuous character of the adaptation process which takes place in the background of service execution.

Once a notification arises, the ActionController acknowledges the received notification in disregard of the actual sender, after which it moves to the *Assess notification* state. The rule responsible for acknowledging a notification is captured in Listing 1.

```
rule r_AcknowledgeNotificationReceived($c in Controller,$broadcaster in Controller) =
  if (controller_state($c) = NOTIFICATION_RECEIVED) then
    seq
      controller_state($c) := ASSESS_NOTIFICATION
      par
        acknowledged_controllers($broadcaster) := acknowledged_controllers(
                $broadcaster) + 1
        r_HandleNotification[$c]
      endpar
    endseq
  endif
```

Listing 1: Acknowledge notification ASM rule.

Handling the received notification implies to broadcast first the notification that the action execution is bound to start, as captured in Listing 2.

```
rule r_BroadcastNotification($c in Controller, $n in Notification) =
  forall ($neighbor in Controller) then
    if (not(id($c) = id($neighbor))
      seq
        acknowledged_controllers($c) := 1
        par
          controller_state($c) := WAITING_FOR_ACKNOWLEDGEMENT
          AcknowledgeNotificationReceived[$neighbor, $c]
        endpar
      endseq
    endif
  endforall
```

Listing 2: Broadcast notification ASM rule.

The controller must act on executing the underlying action only once the notification is acknowledged by all neighboring ActionControllers which were instantiated as part of the same adaptation session. Depending on the output of the executed action, one notification will be broadcast signaling the success or failure of this particular system update. As there is no linked track of the ActionControllers' order to execution, if at least one ActionController does not acknowledge any of the sent notifications, the adaptation is abruptly terminated and the component data and status are assessed and logged accordingly. The rule responsible for triggering the associated adaptation action is captured partially in Listing 3.

```
rule r_TriggerAction($c in Controller) =
  seq
    while (controller_state($c) = RUNNING_ACTION)
      wait
    if (action_completed($c))
      par
        r_BroadcastNotification[$c, ACTION_COMPLETED]
        r_AwaitAcknowledgement[$c]
        if (acknowledged_controllers($n) = numberOfControllers)
          par
            r_ClearNotificationEcho[$c]
            controller_state($c) := WAITING_NOTIFICATION
          endpar
        else
          par
            controller_state($c) := CONTROLLER_ACKNOW_FAILED
                AssessDataAndStatus
          endpar
        endif
      endpar
    else
      par
        BroadcastNotification[$c, ACTION_FAILED]
        ...
```

Listing 3: Trigger action ASM rule.

4.3 Validation of the Model

The validation for the current state of our work deals only with the separate processes for each agent. It focuses on checking the work ow and the transitions from different states. AsmetaV tool permits validation of specific scenarios defined with the aid of the Avalla language presented by (Carioni et al., 2008). Scenarios resemble the unit tests performed during the software testing development phase. They capture execution flows given specific values to functions of the system.

One of the problems we identified during the validation phase was that the Avalla language does not support working with infinite domains. Therefore, we needed to consider that each ActionController remembers only one Notification instance. Other inconsistency errors detected at simulation time led to design changes or restrictions.

More than one system failure can be reported in a short time frame. Therefore, the failure recovery part is done in a sequential mode because, although the case/reconfiguration plan is locked while it's associated solution is executed, a parallel execution of simultaneous adaptations may try to update system parts or components with different values at the same time. We leave as a future work the elaboration of transaction specific operations, which would permit triggering simultaneously multiple adaptions within the system. This could be supported by annotating the case with extensive knowledge on the area of inference in the system of each case, which would later on be considered in the retrieval phase of the process.

5 RELATED WORK

Research in software adaptation ranges from the development of generic architectural frameworks to specific middleware using component frameworks and reflective technologies for specialized domains. Mechanisms proposed include: DA by generic interceptors (Sadjani, 2004), which do not modify a component's behavior, but intercept messages between components; DA with aspect-orientation (Yang, 2002); parametric adaptation (Pellegrini., 2003) or dynamic reconfiguration by means of adjusting or fine-tuning predefined parameters in software entities; dynamic linking of components (Escoffier and Hall, 2007); and model-driven development (Zhang and Cheng, 2006).

However, while existing techniques offer a wide range of options to achieve different degrees of DA, questions related to the identification and soundness of a given adaptation model are still open. Formal methods grant clearer definitions and precision for the adaptation framework. Our project focuses on how to extend and build on this previous research while specifying and validating LDS specific requirements like on-the-fly reaction to change, loss or addition of resources. We consulted the area of formal methods and chose the ASM technique proposed and exemplified in various industrial examples by (Börger and Stark, 2003).

Modeling LDS has been addressed in several cloud and grid related projects. The ASM technique contributed to the description of the job management and service execution in (Bianchi et al., 2013). Specification of grids in terms of ASMs have been proposed also by (Németh and Sunderam, 2002), where the authors focused on expressing differences between grid and traditional distributed systems.

6 CONCLUSIONS

The current paper proposes an approach for achieving a reliable adaptation solution for LDS. By employing the ASM formal method we analyze the properties of the model and identify reasoning flaws. The knowledge scheme presented in the paper supports adaptation related processes and is reflected in the model. We analyzed the model with the aid of the AsmetaV tool and validated the reliability of some of our models when executing an adaptation solution.

In the future steps of our work we aim to enhance the models and express their properties in terms of CTL logic, which is supported by the Asmeta toolset. By these means, faults and drawbacks of the proposal can be identified and corrected.

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Some Issues in the Re-Engineering of Business Processes and Models by Using Intelligent Security Tools

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Keywords: Re-Engineering, Cyber-Attack, Security Systems, Expert System.

Abstract: Even though integrating IT (Information Technology) and business leads to more profits and increased effectiveness, this is often accompanied by information security risks because many current businesses are carried out via the Internet. Re-engineering business processes and re-designing business models may improve the resistance of enterprises to information security threats and risks. In this case nevertheless, the software application (and portal) developers should take into account the pitfalls of the latest technologies. The usage of intelligent tools that are realizing system security auditing and are recommending (supported by especially constructed expert systems) corresponding actions, may be valuable for both business executives and software developers. Hence, a new paradigm is needed, reflecting the concepts of secure application development and communication between all participants and stakeholders involved in the application development process.

1 INTRODUCTION

IT (Information Technology) usefully supports business processes, by helping increase the business capitalization, by facilitating process automations as well as the remote business management and financial transactions, and so on. For this reason, it is not surprising that methods that support the IT-driven re-engineering of business processes, are becoming increasingly popular. Hence, the terms "business process", "functional modeling", "information modeling", "re-engineering", and so on, are included in the lexicon of managers of all levels. In parallel with this, we observe the appearance of more and more computerized methods and tools for business process analysis. In addition, with changing the business paradigm, we can observe corresponding changes in business interfaces, and currently this is mainly reflected in web-portals - for some types of companies, web-portals are becoming the main tool for doing business.

However, for doing successful businesses via Internet and using of web-portals it is necessary to take into account the risks from cyber threats that can make any information system and web-application more sensitive and vulnerable for the cyber attacks.

A special impact of cyber threats is its affection to the financial balance items. Currently, cyber threats and risks have become complex and sophisticated for detection. The permanent development of information technologies and close dependence of companies and people themselves led to escalation of cyber security threats at all levels of business.

Let us look at some statistics. According to the results of the General Data Protection Regulation (GDPR) (Blackmer, W.S., 2016) researches in Britain, "One in five firms was in the past 12 months under cyber-attacks. The results indicate that 63% of businesses are reliant on IT providers to resolve issues after an attack, compared with just 12% of banks and financial institutions and 2% of police and law enforcement organizations". By the words of Adam Marshall, executive director of BCC, "The firms need to be proactive about protecting themselves from cyber-attacks". He said that they should be able to comply with GDPR starting from May, 25 in 2018 (Report "The Global State of Information Security, Survey 2017").

According to the report "The Global State of Information Security, Survey 2017" for 2016 year the number of confirmed incidents in the field of information security all over the world in 2016 have been increased to 48 percent and amounted to 42.8 million. It means that in average 117,339 attempts of unauthorized access happen every day. To prevent these incidents, companies use the following methods of information security and information technology tools: 48% of IT services are delivered through the cloud, 23% plan to invest in artificial intelligence and machine learning this year, 55% collaborate with the extern partners to improve security and reduce risks.

In spite of the efforts that companies make for protection from the cyber threats the new kinds and elements of cyber attacks appear every day and it is almost impossible to prevent the risks from all kind of cyber threats.

Therefore, for providing enough security level of computer and information systems the companies should be interested in the regular information security active auditing. This process often accompanies the checking and control of the security systems of enterprises but it is usually expensive by finance, time and human resources consuming.

The automation of the information security audit procedure and the process for detection of new forms of cyber threats require the creation and development of new paradigms in the re-engineering of business processes and models.

In the current paper, we motivate the claim that the whole process of information and computer security management can be improved and facilitated, by using intelligent tools in the business process re-engineering. The remaining of the paper is organized as follows: In Sub-Section 2.1, we describe how technological developments may influence the appearance of security gaps in web-applications; In Sub-Section 2.2, we consider the main types of attacks as classified by the Open Web Application Security Project (OWASP) Community, and we discuss how they can be discovered and processed by vulnerability scanners, the special tools for detection of vulnerabilities in web-applications. Section 3 addresses the creation of an adapted framework for process re-engineering, by using intelligent tools. Finally, Section 4 contains the conclusions.

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2 WEB APPLICATIONS: TECHNOLOGY DEVELOPMENT, ATTACKS AND DETECTION OF CYBER VULNERABILITIES

2.1 Influence of Technology Development to Security Gaps in Applications

The main channel of penetration the cyber threats are websites and web portals of organizations. There is an evolution of web portals that have been dramatically influenced to the business processes of companies. On the one hand, there is a progress - is greater openness to consumers, the establishment of new and strong links with them and other companies. The companies are increasing the speed of decision-making based on the "fast" information, which dramatically increases the productivity of business tools. On the other hand, the "integration” of the web component to the business interface leads to increasing the information security risks of the business itself. So, bank secrets, confidentiality of information of various people become violated.

The development of web technologies has undoubtedly many advantages but we shouldn’t forget about the pitfalls.

Nowadays the technology level of web 1.0 is not in use because it allowed only reading the information. The technology level web 2.0 ("read-write") gives the opportunity to share the content with other web users. The development of web 3.0 technologies (semantic executing web) has the possibility of pulling the information from various sources but the company may not know about this. The world is talking about the development of web 4.0 that focuses on the Internet of Things and we don’t know still how it may influence to the business in terms of security.

This phenomenon can be called as unintended violation of the company security with the components of randomness and unpredictability. This is not always the actions of insiders. But, the crimes related to the actions of "insiders" are more costly for the company than the incidents in which "outsiders" are guilty. Nevertheless, many companies have not yet implemented a program to counter threats from "insiders", and, accordingly, such companies are not ready to prevent and identify internal threats, as well as properly respond to them.

The problem of security of websites is complex, so the security system should be comprehensive. In this regard, simple security systems are no longer able to identify all threats of the website operations and applications, and it is necessary to use the intelligent tools like expert systems, intelligent vulnerability scanners, and so on.

2.2 Attack Vectors vs Vulnerability Scanners

There is an international non-profit organization focused on analyzing and improving software security: the Open Web Application Security Project (OWASP) Community. OWASP has created a list of 10 most dangerous attack vectors to web-based applications, called: OWASP, the TOP-10. It focuses on the most dangerous vulnerabilities that can cost a lot of money, from undetermining the goodwill, up to loss of business (D. Wichers, 2013).

According to D. Wichers we can classify the following vectors of attacks and distinguishes their peculiar properties:

- [V1] Injection
- [V2] Broken Authentication and Session Management
- [V3] Cross-Site Scripting (XSS)
- [V4] Insecure Direct Object References
- [V5] Security Misconfiguration
- [V6] Sensitive Data Exposure
- [V7] Missing Function Level Access Control
- [V8] Cross-site Request Forgery
- [V9] Using Components with Known Vulnerabilities
- [V10] Invalidated Redirect and Forwards

If attack vector V1 Injection (the most famous among them is SQL Injection) can be consider as the specific category of exploits and well detected by vulnerability scanners. The vector V2 (Broken Authentication and Session Management) may not be automatically identified by the most of vulnerability scanners. For example, the user's password which is stored in plain text in the database (the good practice, however, is using the hash instead of that). An automated web vulnerability scanner can never know how user credentials are stored in the backend of the target system. An expert can only check it. Nevertheless, some of the security issues are relate with V2, which can be detect by scanners automatically. For example, session IDs posted in URL or in the cookie or the sending of user credentials through an unencrypted connection.

Attack vector V3 (Cross-Site Scripting (XSS)) is relate to the kind of technical vulnerabilities, which can be reveal by security scanner. There are several types of XSS including persistent and DOM XSS, and for the best identifying of this type of attack the scanner should support the detection of DOM XSS (Su Z. and Wassermann G., 2006; Johns M., 2006).

The most vulnerability scanners have the problems with identification of V4 attack vector (Insecure Direct Object References) because it relates to the logical security issue in targeted system. The support of human (security expert) is usually necessary. The V4 refers to the security issues where some resources with limited access are not secure properly and can be available for anyone. For example, when user of a targeted system has access to some sensitive information, which must not be available for him. To avoid this problem the system must check the role and privilege of the user before giving him access. Scanner cannot identify whether current user should have access to some URL or not. Only a human who is familiar with a business process of a targeted system can determine the correct role and privileges for every users (Reis C.et el., 2006).

The V5 (Security Misconfiguration) category of vulnerabilities is resulted in misconfiguration at the server during the initial setup of server, framework and etc.

Here the following types of vulnerabilities can been analyzed.

- Unnecessary network services, namely, turn of unnecessary services such as FTP, DNS and SMTP. The scanner can identify whether service is launched or not, but the human must determine the necessity of service and use the actions - setup service correctly or shut it down.

- Out of Date Software. For example, if the system has built, using the old versions of some framework, which contains well-known security holes, the scanner will alert about that. The scanner also can identify the programming language of the framework such as PHP, NET and etc., version of the framework and name of the framework like WordPress, Drupal, etc.

- Security Settings of Development framework. System can been launched in producing the developer's options. For example, the debugging may been enabled, and some functionality may be disabled to speed up the development process.

The attack vector V6 (Sensitive Data Exposure) are may analyze via prism of the next case. Most of the web pages do not protect important data such as the bank cards and other user data for authentication. Hackers may steal or modify such unprotected data are to be used for their own purposes. The simplest example - the transfer of data over HTTP. The fact that data transmitted over HTTP protocol being not encrypted, and the passage of data through the person's computer to the server, all data will be transferred from a router or a home office router, ISP router, the router on the channel, hosting provider's data center router and so on. At each of these nodes of hidden malware can exist, for example, sniffer program that reads all the traffic and sends to the attacker, who can view the personal data and credit card data. Such data shall be transmit only over HTTPS, which is be read as the corresponding inscription in the address bar of your browser.

The vulnerability V7 (Missing Function Level Access Control) concerns the issues of the lack of availability of proper access to the requested object. The most web applications check the access rights before displaying the data in the User Interface. But, web applications must do the control checks for an access on the server when requesting any method. After all, there are still a lot of support service requests, which often sent in the background asynchronously using AJAX technology. If the query parameters are not sufficiently carefully checked, the hackers will be forge a request to access the data without proper authorization.

- Default Accounts and Passwords. Weak passwords may be detect by brute force, which uses special dictionaries, or default password that comes from the vendor is not change to new one.

To understand how vulnerability scanner analyzes the attack vector V8 (Cross-site Request Forgery - CSRF or XSRF) we should consider the mechanism of this attack implementation. Firstly, the CSRF/XSRF attack vector allows an attacker to perform actions on behalf of the victim on the server without additional checking and testing. For example, in a payment system to transfer funds to another account, for instance, there is a web page of the form:

bank.com/transfer.asp?operation_amount=4400 &account=558246557 where "operation_amount" is the amount of money to transfer and "operation_account" is account number, where money must been sent.

If the victim visits a site created by the attacker, an attacker sends a request to the page mentioned above of the payment system. As a result, the money goes to the account of the attacker, then, are likely to been quickly converted to Bitcoin, or translated into another irrevocable payment system where money cannot be returned. It is assumed that the victim should have been pre-authenticate to the payment system and must be opened an active session (for example, payment system page is open in another browser tab).

For understanding V9 type of vulnerability (Using Components with Known as vulnerabilities) we consider the following. Often, web-applications have written by using special libraries and frameworks, which are supply by third parties. In the most cases, these components are made by open sources, which means that anyone can have access to the code (see and use), he can study the source code for vulnerabilities and can find them including the finding the errors in the code. In addition, often vulnerabilities are found in the low levels system components, such as database server, web-server, and finally in the operating system components up to its core. It is important to use the latest versions of the components and monitor for known vulnerabilities appearing on famous sites (like securityfocus.com).

The attack vector V10 (Invalidated Redirect and Forwards) works with the problems of redirection. Web-based applications frequently redirect the user from one page to another. In this process may be improperly verifiable parameters that indicate the final destination of the redirect page, which can be discover. Without proper checks, an attacker can use these pages to redirect the victim to a fake website that, may have very similar or indistinguishable interface, but can steal credentials, sensitive private data and etc. This type of vulnerability, as well as many others listed above, is a type of incoming data validation errors (input validation).

The vulnerabilities mentioned above can met very often and the methods of their identifying and alerting for vulnerability scanners become very critical. We can notice that the most of the attacks depend on human detection and the adding of the intelligent components to the scanner's logic may become the beneficial element in security analysis.

The above types of attacks can be eliminated only by intelligent security systems that are combined with some types of vulnerability scanners (Nurmyshev S, et el., 2016).

3 THE ADAPTED FRAMEWORK FOR RE-ENGINEERING PROCESS BY USING INTELLIGENT TOOLS

3.1 Re-engineering of Business Process and Business Model in the Context of Security Issues

The concept of reengineering has various definitions. For us, the definition is that reengineering is a cardinal reorganization and redesign of business processes and organizational structures.

It is undeniable that every organization now uses IT management in one or another perspective. The strategic goal of IT is to promote management, to respond to the dynamics of the market, to create, maintain and increase the competitive advantage. The main component of the IT management system in the organization is the information security subsystem (Threat management), which must be supported technically, legally and operatively, relying primarily on the use of artificial intelligence systems, which today significantly influent to the decision-making of executive management.

The subsystem of information security today rely on artificial intelligence systems, such as intelligent information retrieval systems, expert systems, calculation and logical systems, hybrid expert systems.

The development of new paradigm in re-engineering process may include the IT strategies with the security issues processing. In this case it is very important to reorganize the staff of the enterprise with involving the information security experts and knowledge base of intelligent tools (Expert System, for example).

From the existing 12 principles of organization of business processes, an expert system for information security in the process of reengineering can influence the following:

1. Decentralization of responsibility (vertical compression of business processes) when the executors are make the independent decisions in cases, which they traditionally had to turn to management;

2. Adoption of management decisions and rationalization of horizontal links between units. This makes it possible to coordinate highly effective.

3. Culture of the problem solution - minimization of coordination in the course of the process execution by reducing external contacts.

4. In the new process, all the processing is performed by one specialist, equipped with an information expert system that provides decision making and access to all the necessary data and tools. Now, in most cases (more than 90% of queries), one specialist provides the solution to the problem, in difficult cases he addresses the expert.

The business model with elements of information security should affect to the business process. It must contain the following:

1. Uses a business-oriented approach
2. Can be used regardless of an enterprise's size or the information security framework it has in place
3. Focuses on people and processes in addition to technology.
4. Is independent of any particular technology and is applicable across all industries, countries, and regulatory and legal systems.
5. Includes traditional information security, as well as links to privacy, risk, physical security and compliance.
6. Enables information security professionals to align the security program with business objectives by helping to widen the view to the enterprise.

3.2 The Adapted Framework

When developing business models, it is necessary to involve specialists of two types - professionals in the field of the reconstructed business and developers of information systems. The experience of reengineering shows that a truly successful and innovative introduction of information technologies is a unique and creative process: managers of companies and technologists, getting acquainted with the methods of information technology, make discoveries about the possibilities of their use in their business. At the same time, the creation of high-quality information systems requires the participation of professionals in the field of information technology. There is a problem of finding a common language. The solution to this problem is in the integration of such modern technologies as knowledge engineering, object-oriented programming, situational technologies, simulation of processes and active graphics. This trend is currently observed in the development of methodologies and tools for business process reengineering. A great contribution to finding common points of contact is given by methods of knowledge engineering, with the help of which it is possible to directly represent in models poorly formalized knowledge of managers about business processes, in particular, about working procedures. In addition, the task is to quickly develop applications and create an intelligent end-user interface with complex tools for analyzing models.

For productive interaction between the stakeholders of re-engineering processes it is necessary to create the understandable language. This language may be based on the special framework and patterns (Atymtayeva L., et al., 2015)

For storing the patterns for business process, security and software patterns, IT processes and so on may be built the special repository that can become the knowledge base for the expert system and serve as intelligent tool for selection of the right re-engineering methods and models (Atymtayeva L., et al., 2015).

If the business model contains the secure applications there is a problem for communication between security experts and software developers (Atymtayeva L., et al., 2015). The repository and patterns that are included to the framework may be the good base for development of stable business processes and intelligent tools in this case can serve as a good solution for decision-making process.

For example the adapted framework for secure applications development in the paper of Atymtayeva L., et al., 2015 shows how to organize communication process between the stakeholders – security experts and software developers. However, here it is necessary of adding one more “actor” which can be responsible for giving possible solutions and analyzing the results. It is expert system (intelligent system) which can take into account the possible threats and pitfalls of the process (Figure 1).

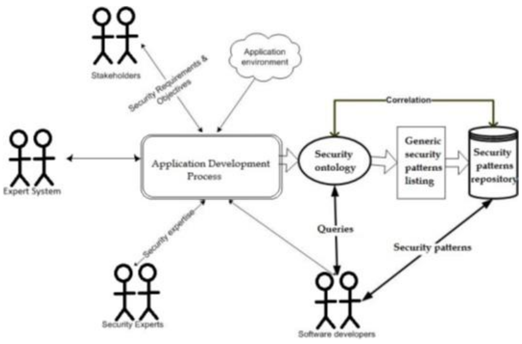

Figure 1: The adapted framework for secure application development with adding the intelligent tools

In this connection, the issue of an expert in the reengineering complex becomes particularly important. The carried out developments allow to confirm: the expert complex of reengineering can be created on the basis of software products available on the market. But not with every type of software you can carry out reengineering, but only with innovative ones.

In this case, the tasks of reengineering are similar to the tasks of innovation: the development of innovations to ensure the competitiveness of products and ultimately the survival of the enterprise.

4 CONCLUSION

Summarizing the paper, we claim that even though integrating IT into businesses leads to more profits and increased effectiveness, this is also accompanied by increased information security risks because many current businesses are carried out via the Internet. We claim as well that business process re-engineering can improve the resistance to cyber security threats and risks. However, in this case software application developers should take into account the pitfalls of the latest technologies. Not only business owners but also software developers and security specialists could benefit from using intelligent tools in auditing system security and making decisions on the base of corresponding recommendations. New paradigms are needed, reflecting the concepts that concern the secure application development and communication between all participants and stakeholders involved in the application development process.

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Integration of Augmented Reality Technologies in Process Modeling
The Augmentation of Real World Scenarios With the KMDL

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Keywords: Augmented Reality, Process Modeling, Knowledge Modeling Description Language, KMDL, Tacit Knowledge Transfer Visualization, Cyber-Physical Market Visualization, Process Simulation Visualization, Simulation Process Building, Industry 4.0, CPS, CPPS, Internet of Things.

Abstract: The integration of powerful technologies in traditional domains realizes promising potentials but mostly rises complexity and shrinks comprehensibility of underlying processes. With the aim to rise comprehensibility of non-transparent processes, a process modeling language has been transfered in 3-D and prepared to augment the real world. Definitions for a methodological proceeding have been created and were mapped to a software tool. Three scenarios then have been realized as demonstration and proof the working of drawn AR integrations. Focusing non-transparent processes, scenarios visualize tacit knowledge transfers (1), complex coordination mechanisms (2) and process simulations (3) in the domain of cyber-physical production systems.

1 INTRODUCTION

Once, new technologies are integrated in existing processes, new potentials can be established. As one takes the integration of Internet of Things technologies in traditional production systems, there can be realized customized productions and flexible, fast changing production processes based on further feedback loops between cyber-physical systems (Gronau et al., 2016a). With this, new coordination efforts among them require much more complex processes, with time-dependent system states and numerous data transfers. Since, all of them are hard to comprehend for non-experts and the current processing is hard to categorize correctly, those further are referred to as non-transparent processes. Although not limited to the domain of cyber-physical production systems, this domain is very suitable for the selection of non-transparent processes.

Since 2-D modeling approaches can be extended easily with a third dimension, new AR technologies bring in potential to increase the comprehensibility of those non-transparent processes in using available dimensions and located existing 2-D models within the real world. Hence, the following research question will be focused within this paper: "How can non-transparent processes be visualized with help of AR technologies?" This includes the process of modeling. Because of the interplay of the real world, augmented world and the more or less paper based 2-D world of common process models, lots of potentials can be realized during all process modeling phases. This paper intends not to collect an all-embracing collection of potentials rather than drawing a first way of structuring. Although several options can be realized to use three dimensions of the AR technology, the following focuses only on a spacial placement.

The research approach is intended to be design-oriented as Peffers proposes (Peffers et al., 2006) and (Peffers et al., 2007), such that the paper is structured as follows: A second section presents underlying concepts, the third sections derives objectives for an integration of augmented reality in process modeling. The fourth section provides the design, followed by its demonstration and evaluation. A final section concludes the paper.

2 UNDERLYING CONCEPTS

Starting with the selection of a modeling approach in the first subsection, the application center for industry 4.0 is identified as a promising environment for non-transparent processes since participating systems provide separate knowledge bases. Further, approaches such as the cyber-physical market require numerous non-transparent coordination efforts and provide a fruitful environment for process simulations and coordination approach benchmarks. In a last subsection, available AR technologies are discussed.

2.1 Process Modeling Areas

Since non-transparent processes shall be focused on the base of separate knowledge bases and complex conversations within Internet of Things similar structures, the following concentrates on knowledge modeling methods.

An overview of existing modeling methods and a comparison of their ability to represent knowledge can be found by (Remus, 2002, p. 216f.). Here, ARIS, INCOME, PROMOTE, WORKWARE, EULE2 and FORWISS are only some representatives. Hereunder, (Gronau and Maasdorp, 2016,) identify the Knowledge Modeling Description Language (short: KMDL) as only representative to overcome lacks in visualizations and analyses through the combination of several views (process view, activity view and communication view). Focusing on the even broader context of organizational, behavior-oriented, informational and knowledge-oriented perspectives, (Sultanow et al., 2012,) identify the KMDL to be inferior in the comparison of twelve common modeling approaches as well.

Being developed iteratively and being applied in numerous projects, the KMDL has been developed and optimized over more then ten years. An evolution of the KMDL can be found in (Gronau, 2012) and currently, the development of the version 3.0 is in progress (Gronau et al., 2016b). The KMDL has proven its benefits in numerous application areas such as software engineering, product development, quality assurance and investment good sales. It provides a fully developed research method which can be found in Figure 1 and is described by (Gronau, 2009, p. 386) in detail.

With its strengths in visualization, the KMDL seems attractive for augmenting the reality. To the best of our knowledge, so far an augmentation of the real world with spacial correct positioned process models has not been realized yet. A prototype of an AR collaborative process modeling tool augments the real world with BPMN process models, which are augmented only w.r.t. inner model relations (Poppe et al., 2011). Eichhorn et al. presented geometric 3-D Figure models in a virtual space and created statistical insights from those (Eichhorn et al., 2009).

Hence, the current paper builds on the wide spread KMDL version 2.2 (Gronau and Maasdorp, 2016,).

With its intention to focus on the generation of knowledge following (Nonaka and Takeuchi, 1995), the KMDL enables the modeling of tacit knowledge bases, single or numerous knowledge transfers, the socializing of several conversion partners in complex control flows and their time-dependent development. Since all can be identified as non-transparent processes, the KMDL seems attractive for the scenario design in section 4.3.

2.2 Application Center for Industry 4.0

Since the physical meaning of classical production components can be enhanced by a virtual representation, these can be considered as cyber-physical systems (short: CPS), providing more or less distinctive characteristics in abilities to perceive its environment via sensors, to interact with its environment via actuators, process data via processors and communicate via communicators (Gronau et al., 2016a). Equipped with memory, each CPS can build individual knowledge bases and can hold time-dependent states.

A cyber-physical production system (short: CPPS) integrates several CPS with the purpose to realize productions. For this, huge communication efforts are necessary and complex coordination mechanisms are required. As one of many, a cyber-physical market can realize this coordination analogous to real market mechanisms (Grum et al., 2016) such as each CPS is considered as market participant and has to negotiate with its environment before tasks are realized.

The Application Center for Industry 4.0 (short: ACI4.0) is build as CPPS, containing several types of CPS. *Machines* are surrounded by computer displays and can visualize different kind of production steps. *Conveyors* connect machines and transport workpieces. A *workpiece* is a small box surrounded by displays such that its current production state can be visualized. Next to the conveyors, *robots* or *humans* are placed, that are part of the production process. All of them are considered to be a CPS providing more or less distinctive characteristics within a cyber-physical market. Hence, the ACI4.0 is a fruitful environment for tacit knowledge transfers, process simulations and coordination efforts, which are all non-transparent processes. In section 4.3, the scenario design will therefore be based on the ACI4.0.

2.3 Available AR Technologies

As augmented reality (short: AR), the paper follows the definition of (Azuma, 1997), who identifies AR as a variation of virtual environments, which allows users to perceive the real world, superimposed and

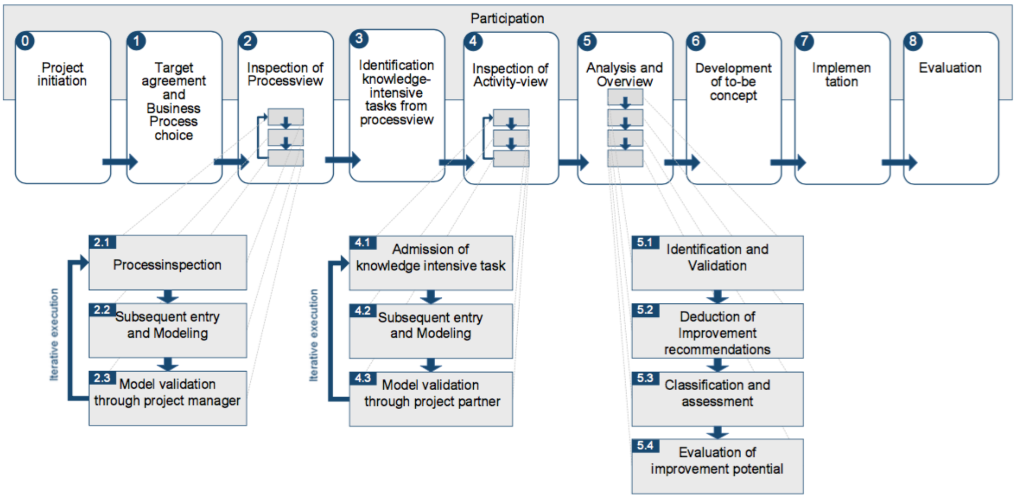

Figure 1: KMDL procedural model.

composited virtual objects such that users have impression those worlds would coexist. Therefore, AR systems have the following characteristics:

- a real world and a virtual world is combined;
- an interaction with both worlds is possible in real time;
- objects are registered in 3-D.

Following (Schart and Tschanz, 2015), the visualization can be realized with help of screen displays, mobile devices (handhelds), head-up displays, head-mounted displays and contact lenses. Here, head-mounted displays (HMD) were focused because of the intention to quickly hand over the visualization technique from person to person and do not limit their interaction via hands during the production process.

HDM gadgets are available as optical see-through HMD and closed-view HMD. While the first variant lets the user see the real world directly, the second variant does not allow any direct contact with the real world. Each brings individual advantages and (Jannick et al., 1994) discusses tradeoffs. The following focused optical see-through HMD with the intention to choose the most realistic system. Here, *Google Glass*, the Epson *Moverio BT-200* and the Microsoft *HoloLens* were compared with respect to the following criteria: price, processor performance, battery runtime, RAM, field of vision size, display solution, usability and availability. Here, the AR glasses from Epson were selected since other products did not provide a handheld control unit.

The Epson *Moverio BT-200* is available for about EUR 700 and provides two miniature projectors which are placed on each glasses side piece. The projection surface is positioned within the field of view and transparent, such that it is possible to perceive both, the real world and projected world directly. Being equipped with a dual core processor (1300Mhz) and one gigabyte RAM, the AR component is sufficient for first augmentation purposes. A GPS module beside software computer vision components can be used for the placement of the AR glasses within space.

3 OBJECTIVES OF AN AUGMENTED REALITY INTEGRATION IN PROCESS MODELING

Since a modeling language shall augment the real world, objectives of three domains have been identified: The modeling language itself, the context for the modeling language as well as the augmentation technique.

Aiming to prepare the KMDL for the purpose to augment the real world, the following set of requirements has to be considered:

- the augmentation has to build up on an existing version of the KMDL;
- existing shapes have to be mapped to 3-D;
- the augmentation has to be included within the methodological approach of the KMDL;
- the augmentation of the KMDL has to go along with the extension of the corresponding modeling software, which is *Modelangelo*[1];

[1] http://www.kmdl.de/en/node/46

- time-dependent visualizations have to be considered, since process models can change on an abstract level and the content of modeled items can change as well on a concrete level;
- fast time-dependent visualizations have to be slowed down so that the human perception is able to deal with.

With respect to the scenario creation, the following objectives have been identified:

- a real world tacit knowledge transfer has to be visualized;
- the communication of heavily complex processes has to be visualized;
- the simulation of processes has to be visualized;
- all three, the *activity view*, *process view* and *communication view* shall be visualizable;
- process modeling phases shall be supported.

Focusing on the hardware selection, the following criteria were relevant additionally to AR technique inherent requirements such as the positioning within an area, performance issues, etc.:

- AR glasses shall be used within closed rooms;
- AR glasses shall be used within the outdoor area;
- AR glasses shall cost less than Euro 1.000;
- AR glasses shall bring programming libraries for free and ideally open source;
- AR glasses shall realize free movements;
- AR glasses shall consider real physics so that obstacles cover shapes in the background;
- AR techniques shall be used on base of common cameras, so that persons who currently do not wear AR glasses can see the augmented world on a projector;
- AR glasses shall realize interactions with the augmented world.

Each identified objective of those three domains has been relevant for the augmentation of non-transparent processes and serves as input for the following sections.

4 DESIGN OF AN AUGMENTED REALITY INTEGRATION IN PROCESS MODELING

The design of AR integration in process modeling is presented with help of four subsections. For the first, the KMDL is augmented, then the method is expanded. Afterwards, three scenarios are built and finally, software tooling issues are designed.

4.1 Augmenting the KMDL

On base of existing shapes of the KMDL as it was selected in section 2.1, items were mapped to three dimensions, which were required by the scenarios and can be seen in the modelings of subsection 4.3. Those items were constructed with Autodesk *Fusion360* and can be found in Figure 2.

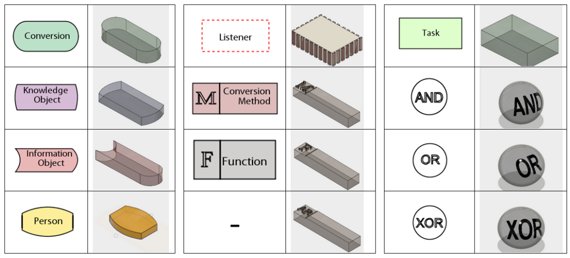

Figure 2: Mapping of existing KMDL shapes to three dimensions.

Here, mostly simple extrusions and colored glass materials were used because of their transparent characteristics in the augmentation.

Since those shapes shall be located within the real world, the following new attributes have to be brought in the KMDL:

A set of *origin coordinates in x-, y- and z-axis* define the global point of origin within space. A set of *coordinates in x-, y- and z-axis* with respect to a point of origin locates the center of any body within space. Initially, the global point of origin is selected but those coordinates can consider the position of other bodies as a relative point of origin as well, such that easy spacial movements are possible. A set of *size in x-, y- and z-axis* manages the spacial requirements and is ideally automatically adjusted in relation to other bodies' sizes. A set of *rotation in x-, y- and z-axis* can assure the optimal angle with respect to a person wearing AR glasses, such that bodies and texts can be identified easily. Since each item can hold a 3-D model, a *filepath* to this model and a checkbox for the standard *KMDL shape visualization* and a checkbox for the *3-D model visualization* shall switch them on or off.

For the modeling, only a single shape has been introduced, which looks similar to the shape of the *conversion method* but holds an "AR" on it. This shape indicates a proper prepared AR perspective and saves previously mentioned 3-D information. Since the same knowledge conversion can be visualized in different views, the modeling can hold several of them.

All together, those extensions are the basis for the augmentation of the real world with process modeling languages.

4.2 Expansion of the Methodological Appraoch

Faced with a well described procedural model of the KMDL as can be seen in Figure 1, the following describes the integration of AR technology. For this, the numbers within the Figure serve as orientation.

Phases from the *project initiation* (phase 0) until phase 2.1 can be realized as usual.

The modeling (phase 2.2) can be enriched by 3-D information as was required in section 4.1, can be simplified with help of a *ground plan* and *sketch plan* as is described in section 4.4, and is visualized as can be seen in Figures 10 and 11.

The *model validation* (phase 2.3) can be enriched with the spacial observation within those plans as well as with a look on the augmented reality as it is described in subsection 5.3.

Phases from the *identification of knowledge intensive tasks* (phase 3) until phase 4.1 can be realized as usual.

Analogous to modeling and validation steps before, 3-D information can enrich the activity modeling with help of a *ground plan* and *sketch plan* as is described in section 4.4, and is visualized as can be seen in Figures 6 and 7 as well as in Figures 8 and 9.

The *model validation* (phase 4.3) can be enriched with the spacial observation within those plans as well as with a look on the augmented reality as it is described in subsection 5.1 and 5.2.

The work of analysts can be enriched by the impression of the collection of created plans and real world augmentations (phase 5).

Phases 6-8 can be enriched in AR visualizations of a static to-be concept and non-static simulation visualizations as they can be seen in all three scenarios. Hence, is- and planned-to-be comparisons can be realized, the working of an implementation can be tested. Further, comparisons of planned-to-be and realized-to-be can be realized.

All together, those methodological expansions serve as guideline and show how to integrate AR technology in the process modeling. The following was realized considering those extensions and demonstrates its working.

4.3 Integration of AR Technology

The integration of AR technology in process modeling shall be visualized with help of three scenarios. All can be located within the ACI4.0, which was described in section 2.2.

A laser manipulation scenario shall visualize the tacit knowledge transfer in complex, multi-interaction partner settings. As can be seen in Figure 3, a situation has been designed within the CPM, wherein a robot manipulates a workpiece with a laser cutter. The workpiece stands on top of a conveyor and is observed by a human worker. The worker's task is to control the production progress and interfere when necessary. For this, basic knowledge in laser manipulation and the experience gained from former production is considered as tacit knowledge.

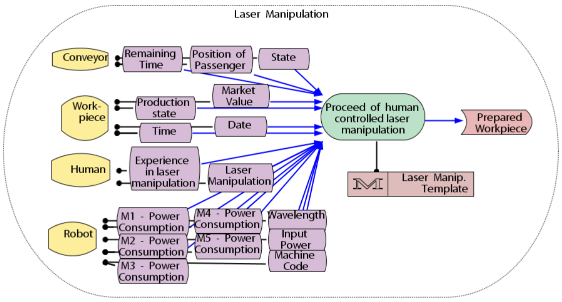

Figure 3: Current activity view of the laser manipulation task (laser manipulation scenario).

A negotiation scenario shall visualize the complex interplay of numerous CPS during a negotiation within the CPM following (Grum et al., 2016). Here, four CPS socialize and update themselves with price value, amount and duration information.

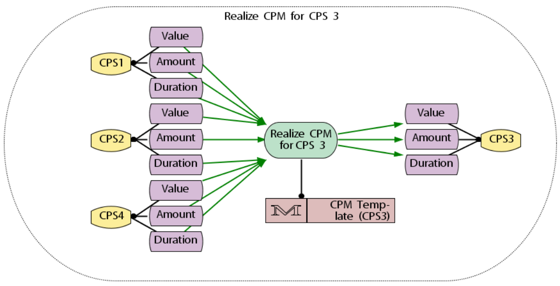

Figure 4: Current activity view of the negotiation task from CPS3 (negotiation scenario).

A process variation scenario shall focus process variations during process simulations within CPPS. As becomes clear in Figure 5, a selected workpiece can be produced following alternative process options. Either, a closely situated robot is used for human controlled laser manipulation (see scenario 1), or robots are used that are located in greater distances so that the workpiece requires further transport steps to reach the robot. Place holder tasks showing "..." visualize the idea that neither the entire production process of the workpiece nor all process options are visualized in this Figure.

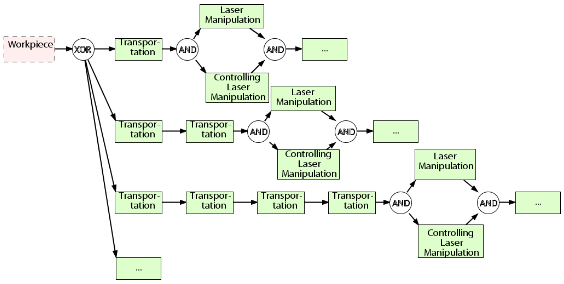

Figure 5: Simplified current process model of a workpiece within a CPPS simulation (process variation scenario).

Since more than one workpiece is produced within CPPS simultaneously, this Figure only shows a very limited insight in the current process simulation model.

All together, those three scenarios serve as fruitful context to integrate AR technology with the purpose to visualize non-transparent processes.

4.4 Extending the Modelangelo Modeling Tool

With help of a modeling tool called *Modelangelo*, the following software design supports the integration of AR in process modeling, as it was designed in section 4.2.

In section 4.1 identified attributes are introduced in the properties space of *Modelangelo*.

Beside the normal modeling environment, two further modeling surfaces are introduced, that simplify the model enrichment with required 3-D information. Those take existing model information and transfer them in a *sketch plan* and a *ground plan*. Here, the modeling is not realized w.r.t. the reading direction from left to right (see Figure 3-5), but locates existing shapes within space per drag and drop. Figure 6 and Figure 7 visualize this difference w.r.t. the laser manipulation scenario. Before the positioning of items within space, white rectangles have been used to model realistic dimensions and distances easily. Then, items were placed and resized.

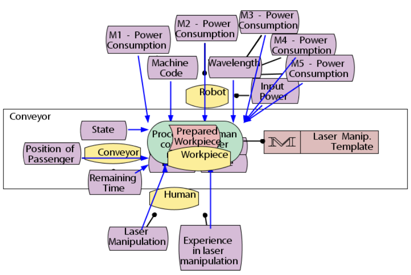

Figure 6: Ground plan of the laser manipulation scenario.

Having a detailed look on Figure 7, shape overlaps can be identified because of the spatial arrangement.

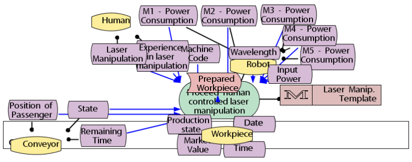

Figure 7: Sketch plan of the laser manipulation scenario.

The creation of the ground plan and sketch plan of the negotiation scenario was realized similarly to the positioning of the laser manipulation scenario and can be found in Figure 8 and Figure 9.

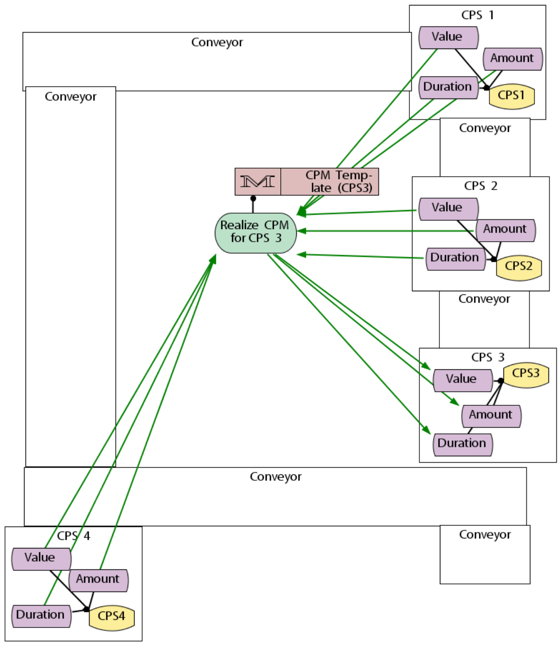

Figure 8: Ground plan of the negotiation scenario.

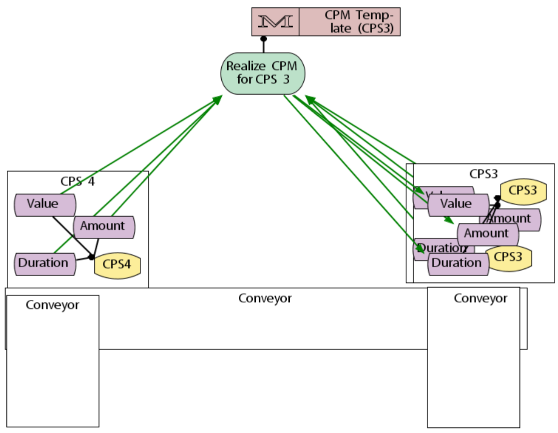

Figure 9: Sketch plan of the negotiation scenario.

Further, a *KMDL Augmentor* is introduced, that translates existing KMDL models to the selected AR glasses (Epson *Moverio BT-200*), such that models can be visualized easily. For this, the *Vuforia* framework has been chosen. KMDL models that lay on the department servers serve as interface and can be augmented easily.

Further, the *KMDL Augmentor* can be connected via interfaces, such that models can visualize time dynamics. Then, real world sensory data e.g. coming from the ACI4.0 or connected simulation frameworks can be displayed. Since tasks can hold repetitive machine components, three-dimensional visualizations can be attached directly to modeling items and optionally displayed by activating the *3-D model visualization*. Hence, quickly huge production settings can be build. Figure 10 and Figure 11 visualize this by indicating task elements displaying its three-dimensional components in blue.

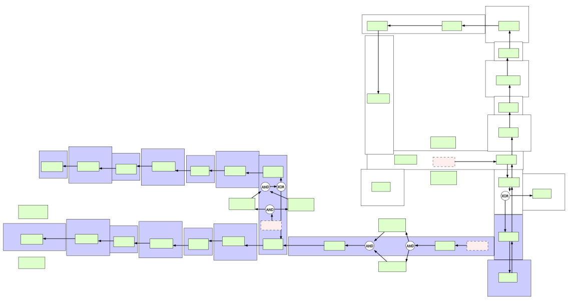

Figure 10: Current ground plan of the process variation scenario.

Similar to Figure 7 and 9, task overlaps can be found in Figure 11 because of the spatial arrangement.

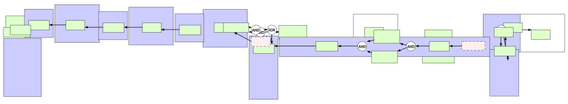

Figure 11: Current sketch plan of the process variation scenario.

A zoomed version of those Figures considering correct denominations can be found in the appendix.

All together, those software extensions help to locate model items easily per drag and drop in real spacial dimensions, transfer existing 2-D process models on AR glasses and help to connect further simulation frameworks.

5 DEMONSTRATION

The following subsections show the realization of selected scenarios with help of the *Vuforia* Developer Libary and the *Moverio BT-200*. Full videos are available at following links and complete the here presented screenshots. Videos have been cut with *PowerDirector* of CyberLink.

5.1 Scenario 1

The positioning of knowledge modeling entities, such as the KMDL proposes, can be seen in Figure 12. As the robot manipulates the workpiece, the conveyor holds the workpiece and pauses the movement of its rolls. Observed by a human worker currently wearing the AR glasses, the worker's experience is considered in the externalization as well. So, a controlled laser manipulation can be realized.

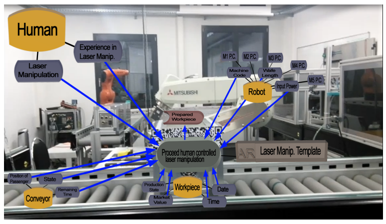

Figure 12: A potential look through AR glasses on the augmented KMDL modeling (using Epson Moverio BT-200).

The prepared "AR Manipulation Template" can be seen in Figure 13. As the human worker observes transparently arranged knowledge objects, a more detailed view can be realized because of a manual activation of a virtual button by a cyber-physical contact with the worker's real hand. This is the way, a well-grounded decision to interrupt the observed laser manipulation can be found. Since this decision has to be realized continuously, relevant knowledge modeling entities update in the video, of course.

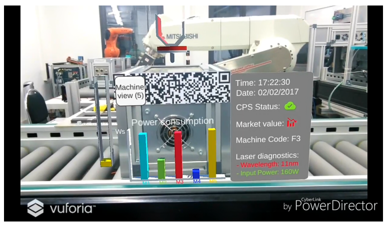

Figure 13: A look through AR glasses on the AR laser manipulation template (using Epson Moverio BT-200).

The corresponding video is available at https://mediaup.uni-potsdam.de/Play/7230.

5.2 Scenario 2

The positioning of knowledge modeling entities of the negotiation scenario, can be seen in Figure 14. Since available CPS are communicating via the CPM and are exchanging value, amount and duration information, green arrows indicate a socialization.

As relevant knowledge modeling entities are not required within the "AR CPM Template of CPS3", Figure 15 visualizes the conversion on a minimal base. The CPM is visualized by the red planet. Since

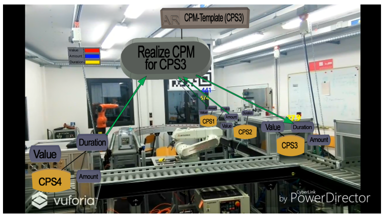

Figure 14: A potential look through AR glasses on the augmented KMDL modeling (using Epson Moverio BT-200).

the communication direction changes over time, the video shows bidirectional and changing communication partners, of course.

The corresponding video is available at https://mediaup.uni-potsdam.de/Play/7231.

Figure 15: A look through AR glasses on the AR CPM template of CPS3 (using Epson Moverio BT-200).

5.3 Scenario 3

Figure 16 shows the positioning of knowledge modeling entities of the process variation scenario. Here, a process view is realized considering tasks, logical operators and current control flows. Since not only real world elements can be augmented, here, the focus lays on the virtual extension of the physically available production setting within the ACI4.0.

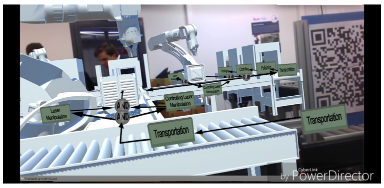

Figure 16: A potential look through AR glasses on the current KMDL simulation setting (using a common camera).

The simulation can be nicely regarded as knowledge modeling entities are not visualized (Figure 17). Hence, the video shows the simulated production of numerous workpieces on the left next to real, physical productions on the right.

The corresponding video is available at https://mediaup.uni-potsdam.de/Play/7232.

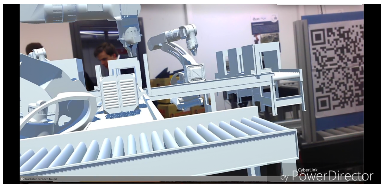

Figure 17: A look through AR glasses on the current simulation setting (using a common camera).

6 EVALUATION

Considering the presented demonstration, the objectives identified in section 3 could be met with respect to three objective groups.

Objectives of the KMDL augmentation have been met as follows: Time-dependent visualizations have been considered in all three scenarios. Since a trigger such as an information exchange started a visualization, the speed of that visualizations was adjusted on base of the human perception. Since the concrete content of the scenarios (scenario 1 and 2) and the abstract process models (scenario 3) changed, all time-dependent objectives were met. Building up on the model items of KMDL (version 2.2) and extending its shapes with a third dimension, the first two objectives were considered as well. The extension of *Modelangelo* has been met with the integration of the ground and sketch plan, the identified set of properties as well as the integration with the selected AR framework.

Objectives of the scenario selection have been met as follows: An activity view has been realized in the laser manipulation scenario, a communication view has been realized in the negotiation scenario. A process view has been realized in scenario three. Hence, all objectives have been met.

Objectives of the hardware selection have been met as follows: All three scenarios have been realized within a closed room with help of the computer vision technique of the *Vuforia* framework. For this, three QR codes have been placed within the production setting, so that each scenario has been identified easily. The objective to move freely was met but has to be limited: The identification was only possible when the QR code was detected by the camera system. Hence, the degree of freedom was limited and dependent on the size, position and viewing angle of the QR code relative to the AR glasses. Hence, the design of each scenario was optimized w.r.t. the position of the intended QR code relation. Although an outdoor arena has not been part of any scenario, one can proceed on the assumption that all three scenarios would have worked there with the aid of the QR code as well. Further, a GPS signal could have been used additionally so that greater movements were possible. With about Euro 700, the price objective was met by the selection of the Epson *Moverio BT-200*. The performance was acceptable although the hardware was not powerful enough to carry all three scenarios within one common application. Each scenario has had to be realized as separate application. Since the room was not scanned and 3-D modeled by the AR system, augmentations did not consider physical obstacles so that the objective to consider real world physics has to be limited. Augmented parts, which should not be visible because of real world elements, were visualized although. Hence, the design of each scenario was optimized w.r.t. the position of the intended QR code. Interactions with the augmented world were possible on behalf of the camera system of the AR glasses. The results of a look through a common camera (scenario 3) were very good so that further parties will be able to enjoy a persons perspective on a display.

7 CONCLUSIONS

In this paper, an integration of AR technologies in process modeling has been drawn and realized on behalf of the KMDL. Main contributions and scientific novelties are the following: A modeling language has been prepared for augmenting the real world. This includes the building of three-dimensional shapes of the KMDL, the identification of required shape properties and the definition of AR required modeling techniques such as the ground and sketch plan. An expansion of an methodological approach for augmentations has been drawn. On that base, three non-transparent process scenarios have been designed on behalf of the KMDL and brought to a time dynamic realization. With this, the drawn integration could have been applied and proven. Hence, the research question was answered and the following potentials are suitable next steps:

The realization of an outdoor scenario was attractive in order to get insights about the precision of augmentations. Further, the comparison of AR glasses of the same price level was attractive as well as the comparison with more powerful AR glasses. Still promising is the deepening of the AR integration in process modeling phases such as the bidirectional interplay of modeling within the augmented world and the two dimensional process model world. For example a process model could be created while standing on a real world position and dropping model items. Further, process optimizations could be realized within the augmented world in grabbing and moving certain process steps. Here, a systematic research considering all modeling phases as shown in Figure 1 was attractive. In presented approaches, given three dimensions were interpreted as spacial dimensions but the use of further meanings can rise comprehensibility as well. Considering further dimensions in created scenarios, those can be tested quantitatively through surveys that shall identify a rise in comprehension.

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tional Conference on Design Science in Information Systems and Technology (DESRIST)*, 24(3):83–106.

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APPENDIX

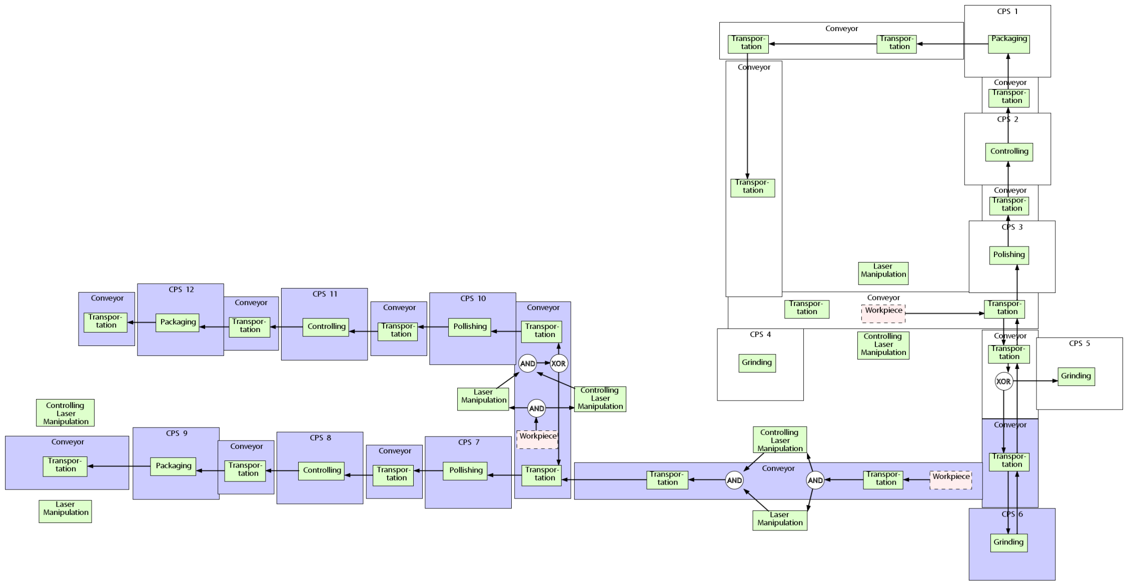

Figure 18: Zoomed current ground plan of the process variation scenario.

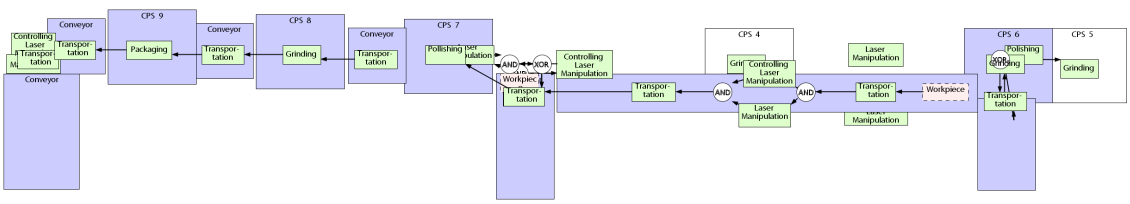

Figure 19: Zoomed current sketch plan of the process variation scenario.

Usability Assessment of Drone Technology With Regard to Land Border Security

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Keywords: Usability, Drone Technology, Land Border Security.

Abstract: Some years ago, it would have been amazing to see a drone flying and behaving ‘on its own’, not knowing whether it is distantly navigated by a human or it is somehow autonomic. Currently we observe that: (i) Youngsters can easily buy toy drones and navigate them distantly; (ii) Military drones realize sophisticated operations in dangerous environments. This indicates for impressive advances in the technologies underlying drone developments, and that is all about ICT – Information and Communication Technology: current ICT is often embedded in services and/or devices. It is ICT that brings together hardware, software, and net-ware features, to enable useful solutions in different domains, such as aviation. As it concerns particularly drones, they represent complex devices comprising mechanical and ICT ‘components’. Current drones can be piloted remotely. Further, being equipped with video cameras, they can provide fast access to images (and/or real-time videos) from a range of locations. Finally, advanced solar power supplies make it possible for drones to stay up for a very long time. Hence, this all makes current drone technology societally relevant. At the same time, many questions have not yet been answered (even though technology developed) – several of those questions are: Is current drone technology indeed reliable if used in critical (rescue) operations? How is the human navigating a drone responsible for what the drone would do? Who is responsible in the case of autonomic drones? Are current software platforms running on drones powerful enough to cover all possible situations that may pop up in the sky? To answer those and other related questions, it is necessary to ‘step in the shoes’ of a particular application domain since those issues are domain-specific – an answer concerning one domain is not necessarily valid for another domain. Hence, inspired by another paper in the current proceedings, we focus on land border security. We therefore aim at studying the usability of drone technology, with regard to the mentioned domain. For this reason, we firstly discuss drone technology in general and then we analyze its usability in land border security. This analysis is a contribution of the current position paper and inspiration for further research featuring the development of advanced context-aware drone platforms.

1 INTRODUCTION

Some years ago, it would have been amazing to see a drone flying and behaving ‘on its own’, not knowing whether it is distantly navigated by a human or it is somehow autonomic. Currently we observe that: (i) Youngsters can easily buy toy drones and navigate them distantly; (ii) Military drones realize sophisticated operations in dangerous environments (IoTDI, 2017). This indicates for impressive advances in the technologies underlying drone developments, and that is all about ICT – Information and Communication Technology: current ICT is often embedded in services and/or devices (AWARENESS, 2008). It is ICT that brings together hardware, software, and net-ware features, to enable useful solutions in different domains, such as aviation. As it concerns particularly drones, they represent complex devices comprising mechanical and ICT ‘components’. Current drones can be piloted remotely. Further, being equipped with video cameras, they can provide fast access to images (and/or real-time videos) from a range of locations. Finally, advanced solar power facilities make it possible for drones to stay up for a very long time (Gavrailov, 2014). Hence, this all makes current drone technology societally relevant. At the same time, we argue that many questions have not yet been answered (even though technology has developed) – several of those questions are: Is current drone technology indeed reliable if used in critical (rescue) operations? How is the human navigating a drone responsible for what the drone would do? Who is responsible in the case of autonomic drones? Are current software platforms running on drones powerful enough to cover all possible situations that may pop up in the sky? To answer those and other related questions, it is necessary to 'step in the shoes' of a particular application domain since those issues are domain-specific – an answer concerning one domain is not necessarily valid also for another domain (IoTDI, 2017). Hence, inspired by another paper published in the current proceedings (Shishkov et al., 2017), we focus particularly on land border security (FRONTEX, 2017). We therefore aim at studying the usability of drone technology, with regard to the mentioned domain. For this reason, we firstly discuss drone technology in general and then we analyze its usability in land border security. This represents the contribution of the current position paper and an inspiration for further research featuring the development of advanced context-aware drone platforms.

As for current drones, they are unmanned aircraft often operated distantly (but it is also possible that drones are to some extent autonomic), as mentioned before. Drones come in different sizes and shapes – from microUAVs that can be held in the palm of one's hand to large airships that rival the size of traditional piloted craft (Gavrailov, 2014). As already mentioned, drones are empowered by mechanical, software, hardware, and net-ware components, and are designed to: primarily collect data (in the context of diverse tasks), trigger some actuators, and so on. Depending on their main function, drones can be designed based on different aircraft styles, such as: fixed wing, rotary-wing, tilt-rotor, ducted fan, and so on. Drones may be piloted remotely (as mentioned already) and are often equipped with video cameras.

Drones are partially used in military operations, rescue actions, and so on. Nevertheless, there is insufficient justification to date on the real value and reliability of drone technology, for example, in the area of security (Drent at al., 2014).

For this reason, the usability analysis presented in the current paper, is considered actual.

The remaining of the paper is organized as follows: We firstly introduce and discuss drone technology, taking a black-box perspective towards drones: stressing on the functionality of drones with respect to their environment (Section 2) and then taking a white-box perspective with regard to a drone, analyzing its internal components, processes, and rules (Section 3). Then, in Section 4, we analyze the usability of drone technology especially in land border security, featuring particular relevant strengths of this technology. Finally, we present the conclusions in Section 5.

As for Section 2 and Section 3, they are backed by the following references:

- Adams and Friedland, 2011;
- American Red Cross, 2015;
- Bravo and Leiras, 2015;
- Drent et al., 2014;
- European Emergency Number Association 2015;
- Gavrailov, 2014;
- Guerra and McNerney, 2015;
- ICARUS, 2012;
- Lachar and Maroney, 2012;
- OCHA - UN, 2014;
- SenseFly, 2016;
- Tanzi et al., 2016.

2 DRONE-TECHNOLOGY

In introducing and discussing drone technology, we start from a more abstract view and move to a more concrete view. This we do in order to keep good traceability to concepts, such that comparison with and/or alignment to other technologies is possible.

2.1 Conceptual View

Essentially, drones are devices themselves and in order to be able to function, they need distant command and satellite navigation. Hence, there are interactions: (i) between a ground control station and a drone; (ii) between a drone and a satellite. This points to a conceptual entity-to-entity model featuring collaborations with three types of entities, namely: drone, satellite, and ground control station, as illustrated in Figure 1:

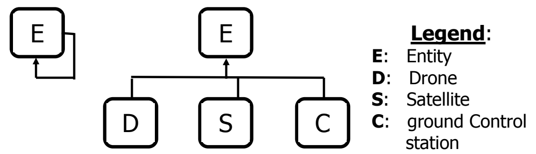

Figure 1: Drone technology – conceptual model.

As it is seen from the figure (left), there are entity types and one entity can interact with another entity; as it is also seen from the figure (right), there are three entity sub-types, namely: DRONE, SATELLITE, and GROUND CONTROL STATION. This is a simplified view on drone technology and performance; still, since only essential concepts are reflected in the presented model, it is possible to add further elaborations, staying considtent with it.

In the following sub-section, we will take a technology-specific view on the above.

2.2 Technology-Specific View

Even though the technology-specific view on drone functioning is to be consistent with the conceptual view, there are more technical and operational details that are to be considered in such a technology perspective. A partial technology-specific view on drone functioning is depicted in Figure 2:

Figure 2: Drone technology – technical view.

As it is seen from the figure and as also suggested by the conceptual model: there are three layers, namely ground control stations ('stations', for short), drones, and satellites. Further, drones are capable of operating (flying) with certain autonomy; nevertheless, there is always human decision-making and responsibility behind – this is conveyed through the stations (there is a bi-directional communication between the station and the drone: the drone receiving instructions (commands) from the station and the station receiving (processed) information from the drone). Still, the commands delivered from the station are not enough for allowing the drone to operate adequately since for this the drone would need precise navigation – this is provided through corresponding (GNSS) satellites; satellites are also used sometimes for facilitating the communication between the drone and the station (or the communication with third parties). With regard to this, the following technologies are important as relevant to the operation of drones:

- Data-link (up-link and down-link of data in real-time) – in order for this to be secure and protected against jamming, encryption is needed;
- The aircraft proximity warning "Sense and Avoid" systems;
  - This including approved automatic detection and avoidance equipment to be used as a mitigation means in case the drone-pilot cannot avoid C2-linkloss during Extended Visual Line of Sight (EVLOS) and Beyond Visual Line of Sight (BVLOS);
- Automatic flight control systems (and guidance);
- Navigation equipment (Inertial/GPS);
- Redundancy in critical location tracking systems such as GPS and location reporting systems;
- Sensor technology, such as Weather Sensors, for example, installed depending on the weight category of the particular drone.

Since functionally, two issues are essential when 'using' a drone, namely: (i) its collecting data from the environment; (ii) its streaming back data to the station, the *payload* concept is important – it is about determining the type of data the drone can collectit; *streaming back* data is important as well and this is done via the C2 (Communication and Control) link.

All this concerns sensor technology and data-streaming technology. The products diversity related to the mentioned technologies justifies the design of various drones, in terms of size and weight (including very small ones).

As mentioned already, those issues (and other related issues, such as the quality and the requirements for the sensor pack) are domain-specific.

2.3 Classification of Drone Platforms

There are different drones for a wide range of applications with different sizes. Drones can be classified in many ways: Use (civil vs military), Lift (fixed-wing vs multi-rotors), MTOW (maximum take-off weight), and so on. For a conceptual approach, a good way is to look at drone's performance, so it becomes easier to understand the underlying capabilities. We claim that drones could be usefully classified based on their size and payload since those are essential features from a functional point of view. For this reason, we are considering a US classification that reflects those features:

- Hand-launched, lightweight, low payload, multi-rotor drones, weighing less than 25 kg and flying at altitudes under 300 m. – they can handle localized imaging and be used for mapping with light payload;
- Long endurance reconnaissance and surveillance, fixed wing drones, weighing between 21 kg. and

50 kg., and flying at altitude under 3500 m. above ground level AGL - they can handle wide-area imaging and be used for mapping with light payload;
- Long endurance, large payload drones, weighing up to 1320 kg. and flying at altitudes under 8000 m. mean sea level MSL - they can handle localized imaging and be used for mapping with heavy payload;
- Heavy lift helicopter drones, often weighing more than 1320 kg. – they can be used for transportation of people and fly to remote locations;
- Long endurance, high altitude reconnaissance and surveillance drones, weighing more than 1320 kg. and having approximately the same size (and similar capabilities) as traditional manned aircraft – they can be used for wide-area searches.

All those platform choices concern corresponding platform characteristics and application needs, and often considering the trade-offs between the two is necessary, as depicted in Figure 3:

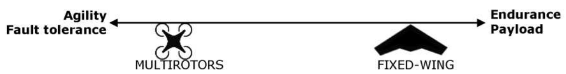

Figure 3: Trade-off between platforms and applications.

3 MAKING DRONES OPERATIONAL

Based on the functional (black-box) view on drone technology, as outlined in the previous section, we are presenting in the current section an operational (white-box) view on that, staying mainly focused on the payload aspects (that concern data capturing) and the software driving the drone, while abstracting from other engineering concerns, such as mechanics, motor, energy consumption, and so on.

Still in addressing payload and software, we are to keep in mind the particular drone mission that in turn relates to the aerial drone platform of choice. As an example: Fixed-wing platforms would be appropriate for scanning vast areas and/or for realizing long range flights, while rotor-drone platforms would be appropriate when situation-awareness is needed, featuring small areas and/or a specific target. Hence, taking this into account, we consider in the remaining of the current section payload and software as essential with regard to the operation of a drone.

3.1 Payload

While platforms dictate the drone's ability to access certain environments, its payload often determines the type of data it can collect. Remote sensors like Electro-Optical (EO) and Infrared (IR) (EO/IR) cameras can help establishing situation-awareness while communications relay payloads can be used to broadcast wireless frequencies wherever the drone travels. Other sensors are used in scanning the ground nevertheless – those are called Mapping (M) Sensors. In the remaining of this sub-section, we briefly consider EO/IR sensors and M sensors.

1. **EO/IR sensors** are the workhorses of drone-based sensing technology. These sensors provide the most commonly used data collected from drone platforms. We can consider in particular:
   - EO Sensors, mainly used for day operations; those sensors are relatively cheap and widely available; they include video cameras and high-definition photography equipment.
   - IR Sensors are excellent for night operations; those sensors detect the heat signatures of various objects; this is particularly useful for locating intruders at night and in large, open environments.
   - Dual EO/IR Sensors (combined into a dual package) can be used for both day and night operations.
2. **M sensors** scan the ground and create 2D or 3D maps of the surrounding area. Much drone-based mapping is currently geo-referenced, allowing it to be easily transposed onto existing geographical information systems (GIS):
   - LiDAR: capable of creating highly detailed topographical maps and 3D maps of border areas, useful in specifying maps of high precision.
   - Synthetic Aperture Radar (SAR): capable of providing detailed imagery of the ground day or night through cloud, fog, and smoke; also capable of detecting metal and other material.

Further, we consider **communication relay payloads** that allow drones to act as mobile communication stations, beaming Wi-Fi Internet, cellular service, radio, and other important signals to security personnel.

Hence, given their ability to quickly reach high altitudes (and hover in place for a prolonged perios – this is particularly valid for rotary-wing drone platforms), drones provide ideal stopgap solutions when communication infrastructure is unavailable.

3.2 Software

Drones need to be paired with sophisticated software – this is to improve the (data) link between the drone and its operator, but also to facilitate the streamline sharing of drone-collected data with other stakeholders. Such data can be utilized by mapping software products featuring maps and GIS – Geographic information Systems.

As for the requirements that concern drone software, they would inevitably relate to the typical drone environment – often aligned with military structures. This assumes considering three layers as follows:

- The bottom (executive) layer concerns the flight management and navigation. Therefore, the corresponding software support would be responsible for maintaining a controlled flight, often performed by an on-board autopilot. To this layer we can add also payload control systems harvesting data from the environment, such as sensors and radars.
- The tactical layer concerns the station (see Figure 2) where all the information about position, heading, speed etc. is ‘crunched’ with the mission important information from the payload and all is presented on the displays of the operators.
- The top (strategic) layer receives full real-time picture from all deployed drones and available infrastructure, for the superiors in order to make proper decisions.

4 USABILITY IN BORDER SECURITY

We refer to an application scenario featuring land border security (LBS, 2012), which is considered in another paper from the current proceedings (Shishkov et al., 2017). The scenario reflects the security protection of a land border segment equipped with wired border fence. There is no border crossing point in the considered area; this means that the security goal is to prevent any border crossings. Still, even though such a border segment could be secured professionally, it is physically impossible for border police officers to be anytime anywhere to react upon violations, if counting on traditional equipment (Shishkov and Mitrakos, 2016).

This leads to several important DEMANDS whose consideration would bring in useful results:

1. Effective monitoring of the large area around the wired fence, limited not only to the very close proximity to the fence itself;
2. Situation analysis capturing both problematic spots (for example: a crowd passing illegally) and available resources (for example: border police officers and vehicles);
3. Rescuing a border police officer (or another person) in trouble (for example: because of weather conditions).

Hence, those identified demands are basis for our analyzing the relevant strengths of drone technology.

In this regard, drones are claimed to present an attractive proposition mainly due to their providing unique viewing angles at low altitudes, something impossible to be achieved either by manned aircraft or by fixed cameras. For example, drones, flying over a border fence, are in a position to view much more that a fixed camera can, and cover a much vaster area than a human can physically cover while patrolling.

Further, drone technology is highly deployable. Drones, particularly small models, can be launched in a variety of environments without the need for a runway – this makes drone technology useful at the border where terrains are often difficult to handle.

Therefore, we consider drone technology as having good potential to usefully support border security. At the same time, we observe the need for corresponding control because as it was discussed already, drones may be autonomic to some extent and/or they may be navigated from distance – both cases assume risk of situational mis-interpretaion, in our view. Hence, establishing control should mainly be about the adequacy of task formulations and the validity of situation perception. On such a basis and taking into account the capabilities of the particular drone, it would be possible to actually involve drone(s) in particular operations at the border.

If this would be successful, then drones could indeed releave officers from some of their most dangerous duties (for example: rescuing a border police officer or another person who is in trouble). In this, a drone (representing an unmanned device) would deliver specific types of actions that can contribute to a smart and better decision making process, especially as it concerns disaster management (also in the border security context):

- Informer: A drone would often be capable of geting more information from the accident spotm which in turn would allow for a smart decision-making to be delivered accordingly.
- Helper: In some situations, a drone would be capable of delivering medication(s) and/or equipment needed in approaching an accident.

Finally, such solutions, if delivered through drones, would be cost-efficient, especially if compared to man-run helicopter actions. Also, a drone could do times more as monitoring, compared to what fixed cameras and physical persons could accomplish.

At the same time, there are particular limitations of drone-driven solutions, such as the risk of mis-interpretation of visual information as well as the flight risks in situations of strong wind / turbulence and or icing.

Summarizing the Strengths of Drone Technology

Based on our considering drone technology in Section 2 and Section 3, and inspired by the border security demands and related discussion (see above), we summarize the strengths of drone technology, particularly with regard to land border security. In doing this, we take into account that border protection uses a series of strategies, some more effective than others, to monitor huge strips of (rugged) terrain along the border: In some situations, it is needed to involve more border police officers in the protection of the border; In other situations, it would be enough to just better maintain and reinforce the fences (if any), barriers, access roads, and so on; In yet other situations, the deployment of specialized technology would be considered necessary, such that advanced monitoring can be realized (this may include high towers or radar, camera equipment, and so on) (LBS, 2012).

Hence, we identify strengths of drone technology, especially related to the **`monitoring`** challenge. Currently, *fixed towers* are used, which include radar as well as day and night cameras (mounted on a series of towers along the border). The radar and cameras transmit data to the border control center, where border police officers determine an appropriate course of action accordingly. Nevertheless, the limitations of such fixed static equipment are obvious. A wisely chosen drone platform can meet targetted demands in this regard, providing also augmentation of the existing systems via data transfer, surveillance, agility and additional flexibility over the mentioned static technologies (a surveillance would be much more effective from an aerial point of view); this would relieve personnel from missions, as well.

Further, drones can step into aviation shoes concerning aviation services for **`border surveillance and goods delivery`**, due to cost effectiveness. With regard to surveillance, drones are capable of carrying platforms for radar and long-distance cameras. With regard to goods, delivery, it is possible, depending on the drone platform of choice and corresponding weight limitations (initial testings of such deliveries have already been completed and there is an ongoing certification for them).

5 CONCLUSIONS

Aerial drones feature promising new technological solutions relevant to many aspects of our lives, security included (and in particular – land border security). At the land border, drones are capable of complementing traditional manned activities (such as patrolling, monitoring, conducting rescue operations, and so on), by helping to ensure that those activities are conducted safer, faster, and more efficiently. In particular:

- Drones are capable of providing a border police officer with situation-awareness – they can help locate intruders, perform structural analysis of damaged facilities (for example: a border fence facility) over large distances, and deliver needed supplies and equipment.
- Drones are capable of assisting with mapping and corresponding planning.
- Drones are capable of approaching dangerous zones where the safety of border police officers would be endangered.

Still, we claim that drones would be capable of being so useful only if drone roles and tasks are adequately specified not only from the engineering perspective but also from the domain perspective:

- Engineers should make sure that the user requirements are realistic with regard to the technical possibilities and related limitations of the drone platform of choice;
- Security experts should make sure that the tasks assigned to drones are complementing (rather than conflicting) with regard to the tasks fulfilled by border police officers and also that corresponding performance indicators are used, such that the information captured (by drones) as well as its interpretation are justified.

Those are the conclusions drawn in the current position paper in which we have analyzed the usability of drone technology with regard to a particular application domain (namely: land border security), inspired by a high-level study of drone technology and the consideration of the mentioned domain and a related application scenario.

A limitation of our work is that it is too high-level and insufficiently concrete as it concerns enterprise / software specifications (Shishkov, 2017) related to the enabling of drone usage at the land border. This will be the main focus of our further research.

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POSTERS

Encouraging Business Flexibility by Improved Context Descriptions

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Abstract: Business-driven software architectures are emerging and gaining importance for many industries. As software-intensive solutions continue to be more complex and operate in rapidly changing environments, there is a pressure for increased business flexibility realized by more efficient software architecture mechanisms to keep up with the necessary speed of change. We investigate how improved context descriptions could be implemented in software components, and support important software development practices like business modeling and requirement engineering. This paper proposes context descriptions as an architectural support for improving the connection between business flexibility and software components. We provide initial results regarding software architectural mechanisms which can support context descriptions as well as the context description's support for business-driven software architecture, and the business flexibility demanded by the business ecosystems.

1 INTRODUCTION

Business requirements are shaped by collaboration and continuous knowledge creation (Nonaka, 1994) between stakeholders, who are driven by intents while acting in business ecosystems. The business requirements and the speed of implementing them become the dominant concern for Software Intensive Product Development (SIPD) (Bharadwaj et al., 2013) companies and forces these companies to reach new levels of agility and orchestration of digital resources.

For SIPD, this challenge translates into creating efficient software architectures which support business flexibility in order to adapt existing business models or support new business models as a response to changes in the business ecosystems. Software components are often expensive to re-use and maintain in new or multiple business models due to a lot of business logic connecting various components while functions are hard-wired to certain business environments. Components cannot be re-coded every time a business model changes. Therefore, new software architectures need to support the complete lifecycle of connecting business models to software components with an efficient support for changeability.

This paper focuses on supporting business flexibility by using specific context descriptions. The aim is to transform these context descriptions into executable containers which could be used to support the needed business flexibility. The remaining part of the paper is structured as follows: Section 2 presents background and related work, Section 3 and 4 provide information about how the ideas have been used by practitioners, and Section 5 concludes the paper.

2 BACKGROUND AND RELATED WORK

Business architecture flexibility focuses on business trade-offs that need to be quickly resolved and how they impact both function layers and realization layers. Depending on the estimated future value for relevant stakeholders (Khurum et al., 2013), the business architecture flexibility allows for agile changes to the realization layer. Availability and flexibility are recognized as important aspects in high uncertain business environments (Richter et al., 2010).

The transition to service driven economy has given the birth to Industrial Product-Service Systems (Meier et al., 2010) with the focus on lifecycle-integration of products and services. New possibilities for capturing value as well as for "on-demand lock/un-lock" of business value options are possible with the digital delivery of software and value. This requires the software components to support new levels of flexibility for option-locking support, including governance.

Several significant contributions have been made in decomposing value for software products (Kang et al., 1990) or describing industrial context in software engineering (Petersen and Wohlin, 2009). Castro et al. focused on bridging the gap between the software systems and their operational environment using i* modeling framework (Castro et al., 2002) leveraging on goal based modeling. Goal based modeling of requirements and agent-based software engineering are common approaches to capture the requirements on software components, e.g. KAOS, MAS, and TAO (Silva et al., 2003). However, in practice these frameworks still lacks usability (Dalpiaz et al., 2016) in which industry can effectively and efficiently industrialize these practices and develop efficient software architecture.

Creating software components that can be orchestrated and bring value to the relevant stakeholders in business ecosystems and timely respond to frequent changes remains the main challenge. This is partly addressed by Software product lines (Bosch, 2009) and industrial Product-Service systems (Meier et al., 2010) which focused on changeability (Richter et al., 2010), as ways to create flexible, adaptable and efficient component-based software architectures.

Supporting business flexibility requires support for agile business policies and business rules (Business Rules Group, 2003) which are used to govern how an enterprise does its business (OMG, 2014). It is desired to have a common governance structure and a standardized way of handling the business rules. Rosca et al. have contributed valuable knowledge in the area of common governance of business rules (Rosca et al., 2002; Rosca et al., 1997). However, we use to the more declarative nature of the business rules (Business Rules Group, 2003).

To fully support business flexibility, we need to better understand and define the business context. Modeling context is also critical for developing context-aware software systems (Brun et al., 2009). Baldauf et al. (Baldauf et al., 2007) summarized context-aware systems including methods to achieve context-awareness, e.g. resource discovery, sensing, context model, context processing, hierarchical context data. Despite several similarities, context-aware software systems focus on dynamically discoverable services rather than dynamically changing business opportunities. This paper builds upon the definition provided by Baldauf et al. (Baldauf et al., 2007) and introduces context description and context frame as concepts for achieving context-aware business architectures.

By composition, context descriptions can be used to create efficient re-usable descriptions that can be used not only in business requirements but also in business rules. The context description is what gives a context frame a scope (boundary) and defines a meaning (semantics). In this paper, we propose the context frame as a fundamental building block in new software business architectures to create self-adaptive software components that can understand, negotiate and adapt to a business context.

3 CASE CONTEXT

In today's implementations of business support systems, business rules are configured in different places of the system, and in different formats. This makes it hard to have a common view of what is defined, and to execute the same logic in different parts of systems, without re-implementing the rules.

Since humans are defining the business rules, these rules are usually ambiguous. Visual and logical support to verify the correctness of the defined business rules are desired. Parts of the business rules could be made executable in order to make the operation of the business more efficient and effective. The process of translating business rules to executable business rules is error-prone due to human interpretation. Sharma et al. (Sharma et al., 2014) have proposed a method to find business rules in requirements documents. This is a good start but most business rules are not about the information system it selves but rather about the business the information system shall support.

It is desired to use a software algorithm to translate business rules into executable business rules. A way to execute business rules is to use a common rule engine for all the components in a business support system. This approach might not be desired or possible. Instead, the possibility to express executable business rules in a different software language, which could be distributed to the different components in a business support system, might be an option. Contrary to many proposed solutions, we believe that a business rule could be triggered by several different events. This makes the use of a simple event-condition-action architecture not suitable for the problem at hand.

Together with Ericsson we have performed a proof-of-concept to investigate if it is possible to support visual and logical verification of business rules, and to generate executable business rules. We have chosen to investigate a limited part of an enterprise's business rules. The business rules we have chosen to study are targeting support for value propositions, based on different business models. The business rules are based on following five parts of the Osterwalder canvas (Osterwalder and Pigneur, 2010): customer type, customer relationship, channels, revenue streams, and a specific area of the value propositions.

4 PROOF OF CONCEPT

Since a business model is supported by a set of legal contracts ,we started to derive the business rules from these type of contracts. Some of the information in a legal contract is not meaningful to translate into a business rule which should be executed in software, e.g. which country laws should be used to solve a dispute. Many times the nature of the language used in legal contracts requires human interpretation. However, the majority of the terms and conditions in a legal contract can be translated into meaningful business rules which could be implemented in software.

We have implemented machine learning pipelines which make it possible to conduct visual and logical verification of business rules, and generate executable business rules. This process can be regarded as the creation of a context frame. We have added different types of functionality which is regarded as needed when handling business rules. Missing data is handled as a wild card, i.e. all values are true. Continuous values have a defined boundary and there are no value gaps in the data. Since a human is defining the business rules, entering all possible combinations by hand is not an option. A meta-data file is used to describe the nature of the features.

In order for the solution to exist in an event-driven environment, the extracted business rule was extended with the events it is intended for. We have added the possibility to use two classification columns. These classification columns respectively represents eligible objects and the allowed actions on the business rules. The idea is borrowed from the gaming industry where a specific context gives the character the possibilities to, for example find specific treasures and stipulates how these treasures can be handled. The combination of event, eligibility and action makes it possible to mimic a business process.

There is a strong demand on the possibility to separate the design from the execution and the need for governance of the business rules throughout their life-cycle. This demand is in-line with TMForum's eTOM (TMForum, 2015). The design is supported by the possibility to, visually and logically, validate the correctness of the business rules before they are put in execution. The execution is supported by the possibility to logically validate the correctness of the business rules before they are put in operation, and to deploy and operate the executable business rules as a context frame. The governance views are supported by the fact that the executable business rules can be handle as immutable artifacts.

The pipe-lines are considered as a proof of concept, and as such is regarded as successful by the four practitioners involved in its evaluation. Three of them are system architects and one is a business support system expert. The pipe-lines make it possible to, visually and logically, validate the correctness of the business rules before they are put in production. Generating executable code representing the model of the business rules, makes it possible to execute the same model in different components without the need of re-implementation. This might improve the coherence of the business rules in a business support system. It was concluded that this way of supporting business processes can support the business models of the business support system it selves, as well as the business models of the enterprises which are running their business with the help of the business support system.

There are several improvements to the pipe-lines which should be considered. The precision of feature value has to be configurable feature by feature, and with different values for the maximum limit and minimum limit. The executable code representing the model of the business rules should support additional languages, for example Java^{TM}. The ability to extract information from the legal contracts must be improved. We will investigate how we can leverage on the research made in the area of common governance of business rules (Rosca et al., 2002; Rosca et al., 1997). During the proof-of-concept we elaborated with the logical visualization of the deployed business rules. We plan to investigate if a graph database can support the needed deployment capabilities regarding visualization and semantics.

There are no real-time requirements on the transformation from business rules to executable business rules. Since the data set will vary in the number of used feature columns and since each feature has its own characteristic, the use of a typed-language is not ideal. Based on this, Python fulfills the requirements as a suitable implementation language for the problem at hand.

5 CONCLUSIONS AND FURTHER WORK

This vision paper illustrates the potential benefits with introducing context descriptions and context frames to support business flexibility. The implementation makes it possible to, visually and logically, validate the correctness of the business rules before they are put in production. The possibility to generate executable code representing the model of the business rules, makes it possible to execute the same model in different components without the need of reimplementation. However, the PoC does not include support for business requirements and the software architecture mechanisms supporting the context frame are very basic.

Together with Ericsson we plan to improve the solution in order to make it useful in a business support system offering. This includes the improvements discussed in this section and in Section 4.

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Market Share Research Using Conjoint Analysis on Digital Cameras

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Keywords: Market, Conjoint, Share.

Abstract: This research conducts conjoint analysis market research study on a branded digital camera using programing R. The aim is to predict market share (strictly share of preference as the model doesn't take into account distribution or promotional effects). In conjoint analysis, customers are shown a variety of possible products (or services) and asked to say which they prefer. By analyzing the preferences against the specification of the products shown statistically, the underlying preferences can be worked out, so that preference for products that were not tested can be evaluated (see conjoint design) to produce a conjoint analysis model to explore different sets of preferences across the market as a whole. Using these preference values (utilities or part-worths) from the conjoint research, a market model on customers' preferences can be created based on what drives customers' decisions. This allows businesses to model and test different product and service options to evaluate likely market preferences and potential share, revenue and profit, all based on what customers really value. In this project, a share of preference model is developed to improve the offering to customers and estimate their effect on share to find out which options give the best return on investment.

1 INTRODUCTION

This research conducts conjoint analysis market research study on a branded digital camera using programing R. The aim is to predict market share (strictly share of preference as the model doesn't take into account distribution or promotional effects). In conjoint analysis, customers are shown a variety of possible products (or services) and asked to say which they prefer. By analyzing the preferences against the specification of the products shown statistically, the underlying preferences can be worked out, so that preference for products that were not tested can be evaluated (see conjoint design) to produce a conjoint analysis model to explore different sets of preferences across the market as a whole. Using these preference values (utilities or part-worths) from the conjoint research, a market model on customers' preferences can be created based on what drives customers' decisions. This allows businesses to model and test different product and service options to evaluate likely market preferences and potential share, revenue and profit, all based on what customers really value. In this project, a share of preference model is developed to improve the offering to customers and estimate their effect on share to find out which options give the best return on investment.

2 CONJOINT DESIGN

A product or service area is described in terms of a number of attributes. Based on the knowledge the product category, product features and product attributes, one design can be deployed by working with the product manager in order to know what parameters should be used. Attributes that affect customers' preference most significantly are price, zoom, image quality, LCD screen size, and battery life, which are all put into the model. This digital camera study can be applied to any consumer product because of the process would be exactly the same.

A digital camera may have attributes of zoom, screen size, brand, price and so on. Each attribute can then be broken down into a number of levels. For instance, levels for zoom may be 4x optical, or 7x optical. Using experimental design the attributes have been used to develop 16 different types of camera (the choice objects). For the sake of simplicity, the attribute with a larger magnitude is denoted as +1 while the smaller one is -1. (See Appendix 1).

However, it is hard to determine which feature has the greatest impact on customers' preferences, and what will the market share of a product with certain features be. To answer this research question, the following survey is conducted.

Since the analysis comes from the company's point of view, some combination does not make sense for a company and therefore can be eliminated. (For example, it is impossible for a company to sell goods that have the best attribute with a lower price. This means that the combination of -1,1,1,1,1 is impossible and therefore it is not under the concern).

Participant would be shown a set of products, prototypes, mock-ups, or pictures created from a combination of levels from all or some of the constituent attributes and asked to choose from, rank or rate the products. Each example is similar enough that consumers will see them as close substitutes, but a unique combination of product features is made up for a clear preference. The cameras were then organized into 120 groups for customers to choose from. (16*15/2) each pair of camera composes a question in the survey looks like the table below.

	Digital Camera A	Digital Camera B
Price	$ 185	$ 225
Zoom	4x optical	7x optical
Image Quality	12.1 meg	14.2 meg
LCD Screen Size	2.3 in	3.1 in
Battery Life	125 photos	300 photos

Which digital camera would you ***mostd likely*** to buy

Digital Camera A Digital Camera B

Which camera a consumer would buy at the end of day? What would the survey look like? To answer above question, a comparison of a pair of cameras is conducted to 200 responders like above.

For this model we had to simplify so that it fits on the page. The data are made up and do not reflect any real life situation.

3 DATA COLLECTION

Data for conjoint analysis are most commonly gathered through a market research survey, although conjoint analysis can also be applied to a carefully designed configurator or data from an appropriately design test market experiment. Market research rules of thumb apply with regard to statistical sample size and accuracy when designing conjoint analysis interviews. The length of the research questionnaire depends on the number of attributes to be assessed and the method of conjoint analysis in use.

A typical Adaptive Conjoint questionnaire with 20-25 attributes may take more than 30 minutes to complete. Choice based conjoint, by using a smaller profile set distributed across the sample as a whole may be completed in less than 15 minutes. Choice exercises may be displayed as a store front type layout or in some other simulated shopping environment.

200 people completed the survey, each made 120 choices. Then the total number of choices is 24,000.

An Excel spreadsheet is presented below with the choice frequencies for each camera and each person. Here is a peak of choices. An ordinal assumption is made regarding the dependent variables:

Participant	Camera1	Camera2	Camera3	Camera4	Camera5
1	15	9	14	6	12
2	13	12	14	8	14
3	13	11	12	12	10
4	14	13	6	5	13

4 ANALYSIS

Consumer psychologists have found that statistical models such as dummy variable regression or ANOVA very useful in conjoint analysis for multi-attribute alternatives.

The task addressed is to model, fit, and if successful, to predict the choices among alternatives. Several abbreviations are used in the model, and they are listed below:

DV = Choice frequency (sum across all people). Dependent variable, this is the sum of all frequencies across all people. For example, on camera 1, the sum of all frequencies across all people, the value is 2146.

IV's= Product attributes. Independent variable, this is the Product attributes as Price, Zoom, Image Quality, LCD Screen Size, Battery Life.

The Results is a simplified regression model that helps predict the odds for consumer to choose a specific product.

To evaluate the relative impact of all attributes, we use the regression equation in R:

```
RegModel <- lm(ChoiceFrequency ~
Price+Zoom+Image.Quality+LCD.Screen.Siz
e+Battery.Life)
```

Predicted Frequency =

$$= 1500 - 347*Attribute1 + 257.7*Attribute2 + 321*Attribute3 + 121*Attribute4 + 283.1*Attribute5.$$

	Coefficients	Standard Errors	tStat
Intercept	1,500.00	5.05	297.17
Price	-347.00	5.05	-68.75
Zoom	257.75	5.05	51.06
Img. Quality	321.38	5.05	63.67
LCD Scr. Size	121.00	5.05	23.97
Battery Life	283.13	5.05	56.09

R-squared =0.99, F-stat=3021

5 MODEL RESULT

People like to look for price, but not like to compromise price for zoom. It means people like to pay more for higher zoom. The results can be summarized into two points.

1. All product features were considered by people when they choose cameras.
2. If there is no major surprises, they preferred:
   - Lower prices (negative coefficient)
   - Large zooms (positive coefficient)
   - Higher image quality (positive coefficient)
   - Larger LCD screens (positive coefficient)
   - Longer battery life (positive coefficient)

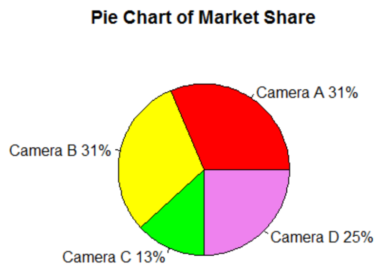
But price and image quality are most critical since they have the highest coefficients in the model.

How do we use model results in the future marketing? We can use this result to predict the market share in the future. Here is an example:

Camera A:	185	7x zoom	12.1 mg	3.1 in LCD	300 photo battery
Camera B:	225	7x zoom	14.2 mg	3.1 in LCD	300 photo battery
Camera C:	225	7x zoom	12.1 mg	3.1 in LCD	125 photo battery
Camera D:	185	4x zoom	14.2 mg	3.1 in LCD	125 photo battery

If I want to introduce camera D, what would be the market share be, comparing to other 3 competitors?

Using the model for the matrix of the example to calculate the predicted frequencies, and look at the proportions, and the proportion tells us the relative preferences and shares of digital cameras in the market.



6 DISCUSSION

Share in a market model is known as "Share of Preference". This is the expected share if customers knew all the information and all the products had the same level of distribution. If prices and costs are known, the model can be extended to include revenue and profit potential.

Models can have extra parameters to take external effects into account, so providing models that are more closely related to reality reflects the real market. A further element missing from this simple model is the ability to look at different subgroups and segments to see if a range of products could do better than a single product in the market. Market models are very valuable tools in the process of strategic analysis.

Note that the ratings must reflect what your customers perceive the position to be. Often customers' perceptions do not reflect reality and so changing the ratings on the attributes may be more about communication than changing the actual delivery. Often we find that simple service features such as delivery, availability of help, keeping promises and so on can have greater psychological effects on customers, therefore have more significant market effects than changing price or specific product features. Market modeling, also known as a market simulation, is one of the key strengths of Conjoint Analysis.

There are other types of market models for other types of trade-off research such as Pricing Research or Brand-Price Trade Off Research. Models are a major benefit of trade-off studies over other forms of quantitative market research.

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APPENDIX

Attributes	Description	Level 1 (-1)	Level2 (+1)
Price	The price indicates the amount you would pay for the camera in your local shop.	$ 185	$ 225
Zoom	This is how much the camera can offer a 'close up' of what you are looking at. A greater zoom indicates you can get a better 'close up' image.	4x optical	7x optical
Image Q/ty	This is how detailed the picture is when stored by the camera. A higher image quality indicates you can print a larger version of the photo.	12.1 meg	14.2 meg
LCD Scr. Size	This is the size of the LCD display on the back of the camera. A larger LCD offers a better preview of you photo when you take it.	2.3 in	3.1 in
Battery Life	This is how many photos the camera can take before it needs to have the battery re-charged.	125 photos	300 photos

Impact of Agility on the Business IT Alignment

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Keywords: Business IT Alignment, Agility, IT Agility, Business Agility.

Abstract: A strategic alignment with a strictly constant rhythm assumes stability. There are several factors that influence this stability. The strategic alignment must be evolutionary, long-term, and dynamic in spite of those factors. In our case we opted for the agility. Agility has a global impact on the internal and external environment of an organization. Agility concerns the future of the organization/company. It is this concept which became a standard for business models since the rhythm of the change in companies accelerates. The current article reflects this idea, by describing the nature of the relation between the factor of agility and the strategic alignment in the determination of various types of agility. Furthermore, we try to establish in this article if an aligned system can stay so, by transforming the company into an agile one. A transformation on all the levels of abstraction is going to maintain the alignment on the long term and will give an added value, and a way the changes can be detected in reality and be gradually integrated within the framework of the strategic alignment.

1 INTRODUCTION

Over the years, particularly during the last two decades, there has been a fast technological advancement which has changed the way in which firms behave. They need to try to get the excellence and remain competitive in a world that is stimulated by the same advancement in Information Technology (IT). A key success factor for a successful business in a dynamic business environment is an effective and efficient IT strategy capable of supporting the strategies and processes (Henderson and Venkatraman, 1993). A situation has therefore arisen, asking for a strategic integration of trades with the IT. It is because of this that most current agencies are trying to implement IT governance with the model's support variables, in order to be able to reach one of the ultimate objectives, namely the alignment between business strategy and IT.

If this alignment is inadequate, the enterprise processes would not take full advantage of the technological means invested (Henderson and Venkatraman, 1993). In effect, the changes often influence the organization in its entirety, concerning the business processes in the information system.

However, it is important for organizations if they aim at staying competitive, to respond quickly and flexibly to anticipated changes. In previous studies and research, it was observed that the strategic alignment is affected by several factors, to cite only a few of them: communication between IT and strategy, the sharing of knowledge between IT and strategy, the flexibility of environment, the agility of the system, the ambiguity, and so on. For this study, we have put the emphasis on agility due to some reasons which will be mentioned further on in the current article. In a chaotic environment in which markets are emerging, evolve and die, one of the main success determinants of a company is agility, the ability to remain flexible in the face of new developments, continuously adjusting the strategic company direction and developing innovative ways of creating value. The competitive environment has significantly evolved over the past few years. Companies should adapt fast to unpredictable changes.

However, recent research also indicates that organizations can fall into a trap where the inflexible rigidity may impede or delay the ability of an organization to respond to environmental changes (Benbya and McKelvey, 2006) (Tallon and Pinsonneault, 2011).

It is challenging for any business to anticipate changes and adapt quicker and more effectively. What is underlying with regard to agility is: change.

Therefore this article has developed an adequate response to the following question: : "How can long-term dynamics be facilitated through strategic alignment, by detecting change, assuming business agility?" For this, we have established that an aligned system is to be able to move to the challenges of change. For this, the system is to allow transformations while keeping the alignment of information systems with the business process.

The remaining of the paper is organized as follows: Section 2 will present a state-of-the-art analysis. Section 3 will consider relevant approaches. Section 4 presents an analytical discussion. Section 5 concludes the article.

2 LITERATURE

2.1 Agility

We define agility concerning an organization /company as a set of processes which allow the organization to detect changes in the internal and external environment, respond effectively in a timely and efficient manner, and learn from previous experience to improve the organizational skills.

2.2 Business IT Alignment

Since the beginning of the nineties, the business alignment with IT was becoming an issue for increasing organizational performance and has received much attention in literature for example: (Thevenet, 2009). The business IT Alignment relates to the alignment between the company and the IT strategies, and between the organizational information systems and infrastructure (Henderson and Venkatraman, 1993). It is defined as "the extent to which the framework of the mission, objectives and plans of support, and are supported by, the mission of the organization, objectives and plans" (Hirschheim and Sabherwal, 2001). This alignment creates an integrated organization where each function, unit, and person are centred on the organization and its competitiveness.

2.3 Relationship Between Business IT Alignment and Agility

Chung et al. (2003) find a strong correlation between the agility of the IT infrastructure and the strategic Business IT alignment. They conclude that IT must be closely aligned with the organizational strategy with a view on the computer infrastructure to be able to facilitate the agility of the company. This close alignment means that the IT infrastructure must be flexible, because the agility of the IT infrastructure enables the company to develop new processes and applications quickly, which allows the agility of the company.

If there would be a proper relationship between the strategic company alignment and the enterprise agility, those two would impact one another and give an added value that is the nature of the relationship between them.

Previous research shows that knowledge sharing facilitates the business-IT collaboration and this makes it easier for businesses to detect changes before deciding to a common line for the best way to react (Barki and Pinsonneault, 2005; Tallon and Pinsonneault, 2011).

The resulting alignment between IT and the enterprise strategy can activate the agility since essential changes in the strategy can be easily communicated to IT managers. In this way, the path of dependencies and routines provided by the alignment can allow to increase the adaptability and innovation (Zahra and George, 2002).

Resources for business process integration and concerning vicinity with regard to the locus of change mean that, in addition to facilitating the alignment, firms are more likely to be agile to respond to change (Tallon, 2008).

If it is proved that the use of environmental assessment allows an alignment, it can be assumed that it will also allow the organization to be more flexible while working effectively (Tallon and Pinsonneault, 2011; Obitz et al., 2009) and to anticipate the changes to come in order to be ready for them. The agility is perceived as a result or an advantage of alignment (Tallon and Pinsonneault, 2011).

2.4 Enterprise Architecture and Agility

The architecture of enterprise is defined as the whole of the primitive and of descriptive artefacts which constitute a knowledge base of the company (Zachman, 2005).

Moreover, a survey conducted by Infosys in 2009 shows that the key objective of an enterprise architecture is the Business IT alignment.

Type of Agility

Agility can be incorporated in each layer of the architecture of the organization / enterprise or in the enterprise as a whole. The main challenge for the achievement of agility is to obtain the alignment through the different layers and components of the enterprise architecture. We have tried to define each type of agility by report to the whole layer of the enterprise architecture.

Strategic / Business Agility which encompasses: business architecture as well as the process.

- The ability of an enterprise to develop and exploit it's inter and intra-organizational capabilities.

Operational / IT Agility which includes: functional architecture, and application technique. Reconfiguring or replacing your information technology systems when new marketplace realities change the way you have to do business.

Agility is analysed in the perspective of structural design within the enterprise architecture as a whole and in the different layers of the enterprise architecture.

3 STUDIES OF APPROACHES

In literature, several approaches are relevant to the problem of the business IT alignment (Couto et al., 2015; Engelsman et al., 2011; Doumi et al., 2013). Without taking into account the business agility, other researchers (Tallon and Pinsonneault, 2011; Wirattanapornkul, 2012) have determined the relationship between the agility and the alignment and in concluding that the agility is perceived as a result of the alignment. Others (Lemrabet, 2012) have developed service-oriented approaches that focus on business process management and service-orientation with the strategic alignment, by making the business agile.

This part is intended to define a multi-dimensional grid, which encompasses all the approaches which speak of the set of strategic alignment and agility which are refined by the criteria of a general definition "A company is called agile when its operational components work together in synergy and in addition: if one happens to have a system that **anticipates and detects the change in order to allow the integration and reactivity**". Anticipation, detection of change, and the reactivity, have two sub-levels: level of abstraction and the nature of the reactivity to determine the impact of agility on the strategic alignment.

3.1 Analytical Grid

According to the analytical grid, Tallon and Pinsonneault (2011) have made a comprehensive study on how strategic alignment would have a positive or negative impact on agility, "Agility is perceived as a result or benefit of alignment".

Oosterhout (2010) has designed a model that anticipates what could happen and thus detect changes internal or external that can disrupt the system. Further, Oosterhout considers this extensively as factor which will thus concern the changes in the system.

Agility and strategic alignment can be measured together to see whether their co-habitation is what it is necessary for the architecture of the company or not.

Detection of change should be considered explicitly as well as its impact on all levels of the model, and we consider several criteria for that. First of all, information on changes is to be collected. Secondly these changes are to be analysed in the framework of the enterprise information system. Thirdly, the agility under the influence of IT is to be evaluated with respect to the strategy of the company. Fourthly, the design changes are to be validated as it concerns the changes collected.

4 DISCUSSION

It is assumed that a system is aligned when each level of the architecture is in correspondence with the various levels of abstraction. Agility can give us an added value for this system and thus we can consider agility to be a level of maturity for the alignment, a model which will thus make the system aligned and agile any by measuring the agility, we can establish that.

What would be the impact of agility on an aligned system? Perhaps an evolution? In this section we quote essential points concerning the possibility of transforming an agile business, knowing that its system is still aligned and dynamic. The alignment is the connection between the entities. When there is a change it is the whole system that is affected. We argue that change is rarely considered as a concept in itself. It is therefore seldom represented.

In effect, it is difficult to reason on a concept if it is not clearly formalized.

When there is a change environmental factors which affect the aligned system, the first thing that must be done to change it is the strategy of the company which has its turn determine the key objectives which must be consistent with the objectives regarding the IT.

<table>
<tr><th colspan="2">Approach / Criteria</th><th>Rabab Imach et al., 2012</th><th>Tallon and P.P, 2011</th><th>Oosterhout et al., 2007</th><th>Bonnet 2009</th><th>Bradley et al., 2011</th></tr>
<tr><td colspan="2">Anticipate</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td></tr>
<tr><td rowspan="3">Detect of change</td><td>Yes/NO</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>No</td></tr>
<tr><td>Types of uncertainty</td><td>Implementation the strategic standby</td><td>NaN</td><td>Factor of change establish</td><td>NaN</td><td>NaN</td></tr>
<tr><td>Nature of uncertainty</td><td>Change intern and external.
These changes are analyzed in the Urbanization IT</td><td>NaN</td><td>Identification of six factors of change between change internal and external</td><td>Nan</td><td>Nan</td></tr>
<tr><td rowspan="2">Correction action</td><td>Level</td><td>All the level abstract to project POIRE</td><td>NaN</td><td>Between Business and IT</td><td>NaN</td><td>Enterprise Architecture (All of the level)</td></tr>
<tr><td>Nature</td><td>The necessary adjustments are implemented at each level identified for each dimension of the project POIRE
Process of continuous improvement</td><td>NaN</td><td>BAN-NEED-BAR-Readiness-BAG-GAP</td><td>NaN</td><td>Impact maturity EA in an assign-ment business IT for an agile enterprise</td></tr>
</table>

Therefore, for an agile transformation one must arrive to take the best decisions, as quickly as possible as well remaining aligned.

The firms are more likely to be agile to respond to change. In addition, a flexible system can keep a scalable enterprise in the long term.

In summary, the world is facing a new change paradigm and it is necessary to mobilize the human capital of enterprises to respond to adequately.

The business of tomorrow will be agile. It will be aligned as well: there will be a symmetry between the promise made to collaborators and to clients. It will mutate in passing from a stable state to an unstable state, since there is no solution defined on the transformations that must be integrated.

When there is a harmonization between several entities and each entity has its relations and its links, it is largely difficult to modify a relationship that is in relationship with another relationship. Therefore, it is largely difficult to manage an entity that is in relationship with another from the strategic level to the operational level (no matter if this goes bottom up or top down). Then, when agility is back, this dependency can pose a problem, beyond what concerns the transformation itself. Hence, agility will change the strategy that in turn will change the process which in turn will change the IT.

5 CONCLUSION AND FUTURE WORK

In conclusion, we consider it not so useful to have an approach that just enforces transformation towards agility. We are more interested in agility as quality of something else – with regard to "things", which have matured in the sense of becoming more agile over time. From a practical point of view, it is also important that we can even measure this. Given that, companies are more likely to be agile to respond to change, especially in the long run.

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A Policy-Based Dynamic Adaptation System for Service Composition

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Keywords: Service Orchestration, Adaptation, Quality-of-Service (QoS), WS-Policy.

Abstract: As web services are distributed and autonomous applications that live in dynamic environments, any unexpected change to a service such as a QoS parameter degradation, could potentially lead to faults in the composition. Therefore, these parameters need to be identified and controlled during execution. In this paper, we present an architecture that features a plan for monitoring the orchestration processes during execution. This architecture concerns the dynamic adaptation with regard to services composition. The architecture is based on QoS requirements and adaptation strategies expressed with WS-Policy. We illustrate our proposal by means of an example related to a bookstore orchestration process.

1 INTRODUCTION

Web Services (WS) have become a universal technology for the integration of distributed and heterogeneous applications over the Internet (Charfi and Mezini, 2004). Their modeling simplifies the business application development and interoperation (Tsalgatidou and Pilioura, 2002). Services come in two flavors: simple services and composite ones (Papazoglou and Van den Heuvel, 2003). WS composition consists of combining and coordinating a set of services with the aim to achieve a functionality that cannot be achieved by a single WS. An orchestration process represents a form of composition in which the various services can be efficiently organized through a flow to execute a business process. The orchestration must be dynamic, flexible, and adaptable to meet changing business needs (Peltz, 2003). The BPEL (Business Process Execution Language) allows designers to orchestrate individual services, in order to construct higher level business processes, the orchestration specification is expressed in an XML-based language, and it is deployed in a BPEL execution engine (Margaris, 2015). The services involved in a composition have different QoS (Quality-of-Service) criteria.

However, in dynamic environments such as Internet, they may be subject to unexpected malfunctions. Inconsistencies can occur when calling a partner service and performing one of the composition activities, for instance, while an incorrect response arrives or the service is unavailable, and so on. This leads to a deviation from QoS parameters.

Therefore, we assume that the aspects of QoS should be monitored and analyzed at run time, in order to determine if the process meets the defined criteria and requirements.

In this paper, we present a system that allows the monitoring and the dynamic adaptation of services participating in an orchestration, by analyzing aspects of QoS. Our system is composed of two main levels: the monitoring level and the adaptation one. Each of these two levels contains a set of components that interact with each other to ensure a proper functioning of business processes. The first level serves essentially to observe and to detect the QoS deviations of composition processes during the WS execution. It should be able to understand if a given service does not meet certain QoS conditions and requirements. These requirements are generally specified and validated during the design phase. The second level will be used in our system, when a failure has been detected. The adaptation process must be able to identify the type of problem and to adjust it dynamically.

The remainder of this paper is structured as follows. Section 2 presents related work. In Section 3, we present a system on adaptation of business process composition. In Section 4, we give an example to illustrate our proposal. Finally, Section 5 concludes the paper and discusses future work.

2 RELATED WORK

The need to identify and evaluate the quality parameters of service orchestration is an open question receiving attention by many researchers.

In (Erradi et al., 2006), the authors propose a policy-based middleware, called MASC (Manageable and Adaptive Service Compositions) for monitoring WS compositions and dynamically adapting them to various execution changes. However, the adaptation actions that relate to the substitution of services must be dynamically chosen to determine the appropriate alternative service. In the approach, these actions are taken in real time, during the execution phase.

VieDAME (Vienna Dynamic Adaptation and Monitoring Environment for WS-BPEL) (Moser et al., 2008) introduces a mechanism for a dynamic service adaptation of BPEL processes and monitoring QoS attributes. Each service in a BPEL process can be marked as replaceable. Each service and all of its alternative services' endpoints are stored in the VieDAME service repository. A replacement policy can be selected to control which of the available service alternatives will be used. Yet, in this work the authors do not handle the case of updated service repository. This requires a selection again of possible alternative services.

CEVICHE (Complex Event processIng for Context-adaptive processes in pervasive and Heterogeneous Environments) (Hermosillo et al., 2010) is a framework that supports a dynamic business process adaptation, by combining Complex Event Processing (CEP) and Aspect-Oriented Programming (AOP). The information about the processes, contextual environment, business rules, adaptation conditions and alternative services, is saved in an XML file. However, this framework must be referred to a services registry to take account of changes in alternative services.

In (Berkane et al., 2012) the authors propose a pattern-based architecture for designing an adaptation system of business process. However, in this work the adaptation system is specified in the functional layer where the equivalent WS is defined before the process execution.

In our work, the equivalent service is selected during the execution phase.

3 PROPOSED ARCHITECTURE FOR ADAPTING BUSINESS PROCESS ORCHESTRATION

In Figure 1, we present the architecture of our system which allows the dynamic adaptation of WS orchestrations. The orchestration process presents the various services that can be composed efficiently through a flow, in order to execute a business process. The service orchestration is presented in a well-defined language to express the different stages of the composition process. In our work, we choose to use the BPEL language for the

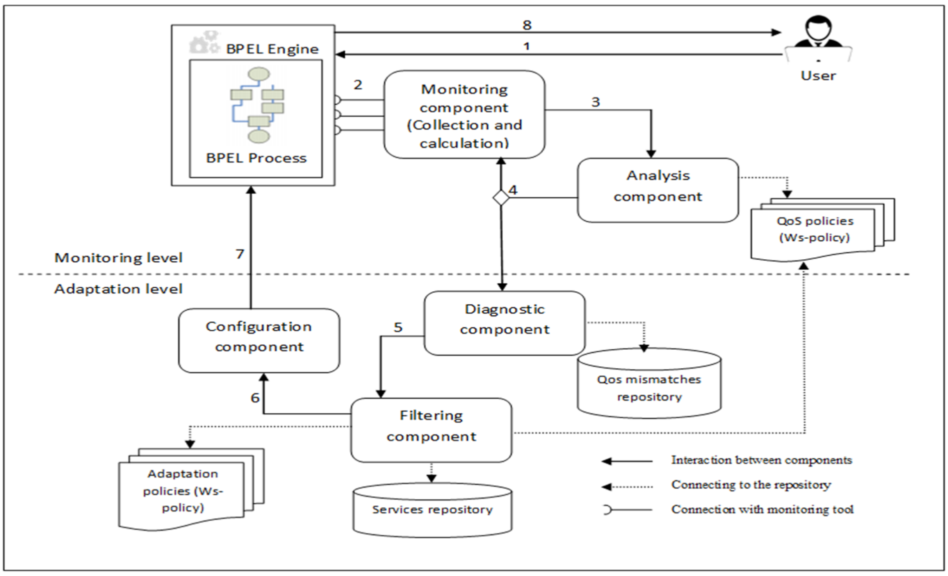

Figure 1: Proposed adaptation architecture.

definition of process models in the form of service orchestrations. BPEL provides an inherent extensibility mechanism at the process and activity level. The orchestration process allows to control the collaboration between services, but unfortunately it does not provide a means to control QoS attributes. Our system focuses on monitoring the different services' orchestration process activities that run in the BPEL engine, then adapting the composition, if it does not meet the requirements set. This system breaks down into two levels: the first level encompasses two components responsible for monitoring and analysis of the composition operation and the second one includes three components that provide a solution for dynamically adapting the composition of services. In the following we present the components of our architecture which is modularized into five distinct components working in cooperation to achieve dynamic adaptation issues.

3.1 Monitoring Component

This component is responsible for providing information about the execution state of the orchestration in the BPEL Engine. It has two parts: the first part is the extraction and collection of QoS values from monitoring tools and the second one aims to calculate the QoS parameters collected in the previous part. After computing the QoS values, the monitoring service sends these parameters to the analysis component for the evaluation.

3.2 Analysis Component

This component is responsible for verifying and evaluating the information collected by the monitoring component to determine the case of an inequality QoS values. It is based on a set of policies expressed with WS-Policy that represents a repository containing the necessary values of QoS that must be verified during the execution of the services. WS-Policy is an extensible model that we can adapt in any system case. In our work, we adopt the QoS policy model suggested in (Mezni et al., 2014), in which a QoS parameter is presented as : <assertion> including attributes <name>, <value> and <unit> which contain other child parameters.

3.3 Diagnostic Component

It is the system responsible for identifying the type of deviation according to the faulty QoS types sent by the analysis component. It interacts with a repository that contains the deviation types of these parameters. Then, it selects the mismatch type, and sends it to the filtering component. The mismatches repository also serves to record the different faulty QoS parameter data. This support can be provided in the specification of the compositions during the design phase.

3.4 Filtering Component

This component's role is to recover the type of deviation sent by the diagnostic component and to select the appropriate configuration action. We provide the adaptation policies (Mezni et al., 2014) and the services repository that allows one to dynamically select the service equivalent to the chosen adaptation action. We use WS-Policy to specify the set of events and actions for each type of event. We adopt the extension AWS-Policy (Autonomic Web Service Policy) presented in (Mezni et al., 2014), in which a model of adaptation policies is described. It contains the actions that can be performed in the case of a detected event, described in an <EventAssertion> element. An adaptation plan can consist of a set of adaptation actions described in an <ActionAssertion> element. However, we will not introduce the name of alternative WS in adaptation policies. The filtering component is responsible for dynamically selecting WS equivalent to the adaptation process.

3.5 Configuration Component

The configuration component is responsible for retrieving the information sent by the filtering component, by applying the necessary changes to the system. It presents a final step in the adaptation process. After the adaptation of the orchestration process, the monitoring system takes the control of the interactions following the composition process with the partner services.

4 EXAMPLE

To provide illustration with regard to our proposed architecture, we take a simple example of a bookstore process (Chan and Bishop, 2009). The process includes a series of activities allowing users to buy books online. The system begins by authenticating the user. After that, the system invokes the "ResultSorting" WS to present the existing catalogues. Then, the user can browse the catalogues for making a search. (S)he can select items and add them to a (ShoppingCart). The process will run two spots in parallel: one to find the provider of the chosen books; the other one to calculate the price. After that, an order will be generated.

We present an example of the ”ResultSorting” service’s QoS policy. Figure 2 shows the QoS requirements for the “ResultSorting” WS.

```
<wsp:Policy  xmlns:wsp="schemas.xmlsoap.org/ws/2004/09/policy"
xmlns:qosp="garnize:8080/schema/qospolicy"
name="ResultSortingService"
operation="ResultSorting" scope="QOS" location="provider">
<wsp:ExactlyOne>
<wsp:All>
<qosp:All name="performance">
<qosp:All name="responsetime">
<qosp:Assertion name="executiontime" value="1300" unit="ms"/>
<qosp:Assertion name="latency" value="1000" unit="ms"/>
</qosp:All>
<qosp:Assertion name="throughput" value="15" unit="mb"/>
</qosp:All>
<qosp:All>
<qosp:Assertion name="availability" value="70" unit="mb"/>
</qosp:All>
<qosp:All>
<qosp:Assertion name="reliability" value="50"/>
</qosp:All>
<qosp:All>
<qosp:Assertion name="successability" value="85"/>
</qosp:All>
</wsp:All>
</wsp:ExactlyOne>
</wsp:Policy>
```

Figure 2: ResultSorting QoS policy.

The filtering service uses the adaptive policies declared in the repository to determine the possible configuration action for this situation. Figure 3 features an example of QoS adaptation policies, used for the bookstore process.

```
<wsp:Policy  xmlns:wsp="schemas.xmlsoap.org/ws/2004/09/policy"
xmlns:qosp="garnize:8080/schema/qospolicy" name = "adaptationset">
<wsp:ExactlyOne >
<wsp:All>
<qosp:All>
<qosp:All  name ="Event">
<qosp:All >
<qosp:AssertionEvent  name ="timeout"/>
<qosp:AssertionEvent  name ="unavailability"/>
</qosp:All >
</qosp:All >
<qosp:All  name ="Plan">
<qosp:AssertionPlan  name ="substitute"/>
</qosp:All >
</qosp:All>
<qosp:All>
<qosp:All  name ="Event">
<qosp:AssertionEvent  name ="unreliability"/>
</qosp:All>
<qosp:All  name ="Plan">
<qosp:AssertionPlan  name ="reexecute"/>
</qosp:All>
</qosp:All>
</wsp:All>
</wsp:ExactlyOne>
</wsp:Policy>
```

Figure 3: Adaptation policy for the bookstore process.

5 CONCLUSION

In this paper, we have presented a policy-based architecture to dynamically monitor and adapt the QoS parameters of orchestration processes. This architecture is divided into two levels: (a) the monitoring level, which consists of two components, namely the monitoring component and the analysis one; (b) the adaptation level containing three components, namely the diagnostic component, filtering component, and configuration component. We used WS-Policy for expressing QoS requirements and to also express adaptation policies. As future work, we intend to present a method for developing and checking QoS policies during the design phase, and to evaluate our proposal with a more complex case study.

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Software Development Process Supported by Business Process Modeling
An Experience Report

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Keywords: Software Development Process, Business Process Modeling.

Abstract: Understanding businesses and how they work can help software engineers build systems that really meet the corresponding business goals. For instance, methods such as the Rational Unified Process (RUP) include activities to model a business before eliciting requirements. However, during our software development practice in academic and "real-life" projects, we found problems using these artefacts with stakeholders. Here we present our experience on integrating BPMN (Business Process Modeling and Notation) diagrams with RUP, aiming to improve the elicitation of software requirements. These diagrams appeared to be easier to understand by stakeholders. The current paper discusses the challenges we faced in using RUP and the way in which we integrate conceptual maps and BPMN into the process. In addition, we illustrate the changes using models that reflect real project implementations realized by using this approach.

1 INTRODUCTION

Nowadays, software is a key element in business strategies and processes. Very often organizations request new software aiming to improve their business or contribute to their goals. Understanding the business and how it works can help software engineers to build systems that will really meet the expectations.

In the Universidad de los Llanos (Unillanos)[1], we have used RUP in academic and "real life" software development projects. It is used not only in courses related to software engineering but also in development projects aimed to the university and other affiliated institutions. Faculty members and students are usually involved in these projects trying to apply the concepts and models described in the theory into real settings. However, after our experience in several projects between 2010 and 2017, we have integrated Business Process Models, i.e., BPMN diagrams (OMG, 2011), into the RUP activities to improve the business understanding by stakeholders and developers.

This paper presents our experience using BPMN diagrams to support activities for eliciting and specifying software requirements. Here we present some of the challenges we faces trying to use RUP to understand business processes, and obtain agreements on the corresponding software requirements. We present our integration of BPMN and RUP and discuss some lessons learned in multiple academic and "real-life" software development projects.

The rest of this paper is organized as follows: Section 2 describes our experience on several software development projects and how we integrated BPMN in this context. Section 3 presents the modifications we made to RUP to integrate BPMN and Section 4 concludes the paper.

2 ELICITING REQUIREMENTS FOR BUSINESS APPLICATIONS

Developing software to support business processes implies an understanding of these processes. For instance, the method we used, the RUP - Rational Unified Process -, includes activities to model the business processes before eliciting the software requirements.

Eliciting requirements using RUP. In RUP, business processes are analyzed using diverse artifacts:

[1] The Universidad de los Llanos (Unillanos) is the biggest public university in the eastern plains in Colombia

(1) Each process is depicted using a BUCM - Business Use-Case Model, i.e., by a circle and a set of relationships to the diverse actors that participate. (2) The activities in each process are specified using an AD- Activity Diagram, i.e., a flowchart-like model that represents the steps that comprise the process (Jacobson et al., 1999). Finally, (3) Additional information is specified in a glossary and a set of textual descriptions and specifications.

Challenges using RUP. Although there are some books and guides describing how to elicit requirements based on the models representing the processes in RUP, we faced multiple challenges.

Using the glossary: our software engineers had problems to write correctly the terms in the glossary. Some times they wrote incorrect definitions or assumed incorrectly that two terms were equivalent. The problems were aggravated by users that refused to read and correct glossaries with a large number of terms.

Using the BUCMs: software engineers and stakeholders had problems to review the BUCMs. These models represent processes as use-cases without specifying an ordering of the tasks, inputs and outputs neither the people that perform the tasks. Many times the stakeholders approved a BUCM because they represented steps in the process without noting missing tasks or missing participants.

Using the ADs: finally, activity diagrams cannot represent some elements important in the processes such as escalations and deadlines. Software engineers and stakeholders were able to use ADs to discuss on the typical case of the process but failed to represent there the exceptional flows.

Additionally, we found problems trying to create a single set of models representing the business processes. In many projects the stakeholders were sure of the steps in the current process but not of the steps in the process they want. In addition, we had to deal with constant changes on the stakeholders, the domain's experts, the involved legal regulations and/or the software requirements. Many times, the models combined elements of the current process with one or more of the desired processes. It was hard, when a change in a regulation or stakeholder occurred, to determine which elements must be modified. Moreover, some stakeholders did not receive well the ideas and recommendations of the software engineers because they believed that the software engineers did not understand the process because of these models.

Related Work. There are other methods and modeling notations aimed to represent business process. For instance, the BPMN - Business Process Modeling and Notation - is an OMG standard for "bridging the gap between process design and implementation". Although business modeling can be done independently of the software development, it is clear that each process can benefit from the other.

There are studies that show a misalignment between the software applications and the business processes of many organizations (Przybylek, 2014). These studies describe, as a main reason, the lack of methodology and rigor to determine the software requirements from the business goals. Other studies (Sedelmaier and Landes, 2014) (Monsalve et al., 2012) have shown the benefits of determining requirements based on the modeling of the business processes that the software aims to support. Thereby, we can find tools integrating business and software modeling such as IBM Rational and Visual Paradigm.

3 OUR PROPOSAL

To overcome the mentioned problems we integrated conceptual maps and BPMN diagrams into the Requirements activities of the RUP.

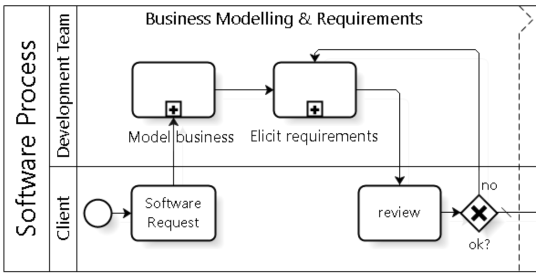

Figure 1: Changed requirements activities.

Figure 1 shows the process starting when a client requests a new software. Then, the project team model the business and elicit the requirements. The requirement specifications are later reviewed with the client. If the client agrees, the process follows to other phases such as analysis, design and implementation (out of the scope of this paper).

3.1 Model Business

The main changes we made on the *Business Modeling* sub-process were the artifacts produced, showed in Figure 2. We complemented the glossary with a conceptual map, and replaced the BUCM and AD by an AS-IS business process model. In addition, once they are built, the conceptual map and the business process models are reviewed and modified directly with the client.

Conceptual map: A *conceptual map* is a technique to graphically represent the knowledge. The project

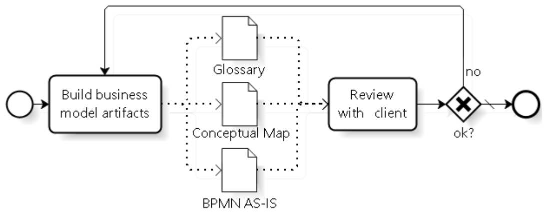

Figure 2: Model business sub-process.

team constructs a first version showing the concepts and the relations between them such as they are understood. Then, using a whiteboard the map is reviewed and modified with the domain experts. The purpose of this graphical artifact is to facilitate the concepts review between the development team and the client, and, in this way, contribute to an adequate communication in the project, as a result of talking in the same terms.

BPMN AS-IS: The *BPMN AS-IS* represents the current business processes. Developers create an initial version of this artifact, showing the processes such as they have understood, then they review and adjust the models with the help of domain experts, using markers on the whiteboard where developers presented the models.

3.2 Elicit Requirements

In our proposal, the *Requirements* sub-process (detailed in Figure 3) starts with the activity of building a *BPMN TO-BE* model representing the intended process, for which the software will be build.

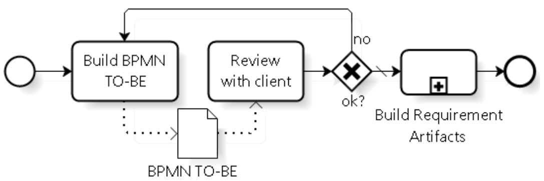

Figure 3: Elicit requirements sub-process.

When it is approved, the designed process is used to define the scope and the requirements of the software in the showed *Build Req.Artifacts* sub-process.

BPMN TO-BE: The *BPMN TO-BE* model represents the intended process. It is created from a first version presented by the development team, which incorporate software to automate or support users in some of their tasks, then, based on the diverse software alternatives that may improve the process, analyzing the implications on the organization, which technologies can be used, and the time and costs that the development may imply, the stakeholders decide which is the most appropriate. The decisions are registered on a whiteboard where the domain experts make changes directly in the BPMN.

Other requirement artifacts: Once the TO-BE process has been defined, the requirements discipline continues as proposed by RUP. The software engineers build use cases, scenarios and mockups based on the TO-BE process defined before.

3.3 Madiba Example

Here we illustrate the application of our process.

Madiba is software that support the conciliation process in Colombia. The conciliation is a legal act provided by Colombian law for citizens aimed to resolve conflicts with the help of a neutral third party, before going to court. This is a project widely documented, whose terms are rare and very particular of a legal business domain. After receiving from the client whole piles of documents, the software team elaborated a glossary and an initial conceptual map to graphically represent the knowledge that they have achieved so far. In a jointly elaboration with the client, we obtained a concise graphical artifact showing the main domain concepts and their relations; and consequently we could assure a correct definition of them in the glossary.

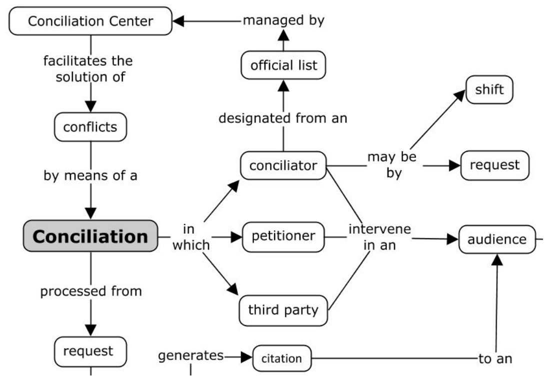

Figure 4: Madiba Conceptual Map fragment.

Conceptual map. One excerpt of the conceptual map is in Figure 4; it abstracts dozens of documents to show that a *Conciliation Center* facilitates the solution of conflicts by means of a *conciliation* in which a *petitioner*, a *third party* and a *conciliator* intervene in an *audience*. The *conciliator* is designated from an official list managed by the center and may be designated by *shift* or *request*.

Business Process AS-IS. Once the elaboration of the conceptual map was going on, the software development team presented a first version of the conciliation process AS IS . Then jointly completed with the client, using the whiteboard, we obtained a BPMN modeling the conciliation. Figure 5 is an excerpt showing the conciliator designation by shift.

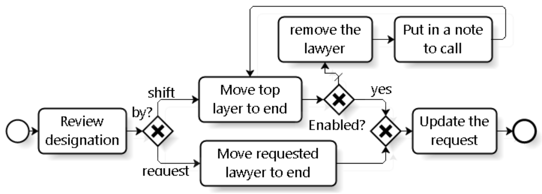

Figure 5: Madiba BPMN AS-IS, Request phase fragment.

After reviewing the kind of designation, if it was by shift, the top lawyer on the list must be moved to the end, next, validate if he is enabled and update the request with him. By the contrary, the lawyer must be removed from the official list, take note to call him after, and repeat the cycle until get an enabled lawyer. If the conciliator was selected by the petitioner, after removed from the request is updated. The whole business process was elaborated jointly with the client using the whiteboard with markers on it. This guaranteed representing the business in the way and the terms the client do and use.

Business Process TO-BE. Once approved the *AS-IS Process* model the development team transformed it into a *TO-BE Process* incorporating the software to be build. As a result, the request phase fragment, showed up, is transformed to a simple software supported task: *designate conciliator* in Figure 6 that shows an excerpt of the TO-BE process for the Madiba project.

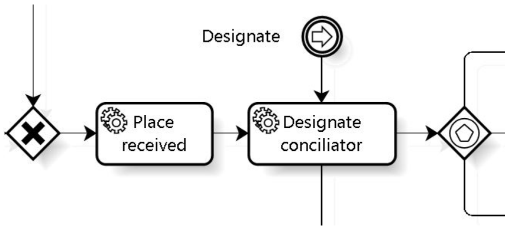

Figure 6: Madiba BPMN TO-BE, Request phase cut.

Again, this activity was realized jointly with the client (the lawyer group), and as a result, before elicit requirements, it was possible to take decisions that involve organizational, technical, financial and time issues. As an example, the next activity after designate conciliator is to announce that to the lawyer. In this example, the client decided to use the major available technologies (i.e. SMS, e-mail and whatsapp messages) to realize this ad in the way showed in Figure 7

The *conciliator* receives a message asking her/him be a conciliator for a case (i.e., the *designation* message). He can accept by sending his availability (i.e., the *schedule availability* task), or can decline by sending a justification (i.e., the *decline* task). The resulting requirements specifications were faithful to the need and decisions made by the client, and they are easily verifiable in the TO-BE process.

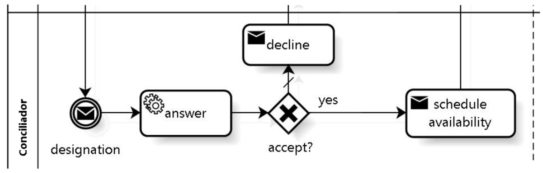

Figure 7: Madiba BPMN TO-BE, Request phase cut.

4 CONCLUSIONS

We found that BPMN help us to elicit the requirements, because the stakeholders were able to discuss and propose changes to the artifacts, to the scope and the requirements of the software.

Our current and future work is focused on (1) implementation of traceability between the high level artifacts depicted here towards the code, to facilitate the software evolution and requirements change management. (2) Research on ways to manage BPMN artifacts (linked with use cases and code) as software assets with which a software product line strategy can be implemented.

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AUTHOR INDEX

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