Semantic Technology in Business Process Modeling and Analysis. Part 2: Domain Patterns and (Semantic) Process Model Elicitation

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Abstract: Conceptual modeling in Business Process Management (BPM) is one of the core research areas of Information Systems (IS). A variety of different strategies for modeling support and model analysis exists such as syntax-based auto-completion features, recommendation techniques, correctness and compliance checking, abstraction and matching, semantic and domain patterns, or AI-based planning approaches. These mechanisms increasingly gain attention in the BPM and conceptual modeling community. Due to the great variety of techniques and use cases of modeling support systems, research is scattered amongst different sub-communities of the large BPM and conceptual modeling communities and a common ground for discussion and research is not yet established. In order to bring together researchers working on different aspects of modeling support systems, the new working group *Semantic Technologies in Business Process Management* (SEMTECHBPM) has been established, which is associated with the EMISA, a sub-group of the GERMAN INFORMATICS SOCIETY (GI).

The article at hand presents the second part of our overview article presenting first results of the SEMTECHBPM working group in outlining different existing research streams engaged with semantic technologies in business process modeling and -analysis. Although we discussed all aspects in the working group and also invited non-members to contribute their knowledge prior to writing this article, we make no claim that the overview provided with this article is well-balanced or exhaustive. Rather, it should serve as a starting point to foster the collaboration between researchers engaged with semantic technologies in BPM and to promote their results. We are open to comments and welcome researchers who want to participate in the SEMTECHBPM working group.

In the second part of the article, we focus on the extraction and usage of domain patterns and (semantic) process model elicitation techniques.

1 State of the Art of Semantic Technology (Part 2)

1.1 Semantic and Domain Patterns

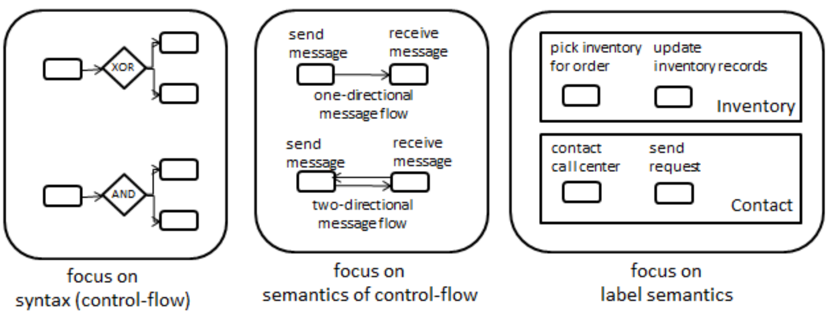
Patterns may serve as a basis for semantic modeling support and analysis. Whereas semantic patterns, for example, consist of a combination of control flow constructs to implement a specific behavior, domain patterns may specify the procedures or resources typically used in processes of a particular domain. This section provides the essential background on (business process) patterns and presents approaches that identify related patterns. Some of the approaches explicitly use semantic technologies to help identify the patterns, while others use other techniques to accomplish a semantic processing of the pattern-relevant data.

In general, patterns have long proven to be effective concerning their ability to preserve existing knowledge, to abstract from concrete problems, and to foster communication between participants [**?**]. The use of patterns is very common in fields such as Software Engineering (patterns in this field are grounded by (software) design patterns). In the field of Business Process Management patterns constitute a rather unstructured research area due to a missing consistent definition of the term business process pattern (BPP). Due to this lack, also a systematic comparison of patterns is hampered (e.g., see the findings in [**?**]).

A variety of patterns can be found in literature. Particularly, patterns investigating the recurring syntactic structure or behavior of process models have attracted high attention. A popular representative of this category are workflow control flow patterns [**?**], which describe syntactic relationships between process activities. For instance, the *Parallel Split* pattern describes the divergence of a branch into two or more parallel branches each of which executed concurrently (see left hand side of Figure **??** for an example).

In the following, we are particularly interested in patterns being useful for semantic technologies and patterns, which can be identified using semantic technologies. This are patterns that deal with process element labels or patterns facilitating to identify a recurring behavior of process model semantics (i.e., patterns that help to ensure compliance in busi-

Figure 1: Focus of Different Types of Workflow Patterns



Approach	Authors
Semantics of process activities	
Investigation of the repetition of business functions when designing a process model	Thom, Reichert and Iochpe [?]
Enforcing quality requirements through the application of process quality patterns	Foerster, Engels and Schattkowsky [?]
Identification of a question answering-pattern enabling automatically responding to questions	Hao et al. [?]
Methodology for analysis of weaknesses in semantically analyzable business process models	Becker et al. [?]
Semantics of process activity labels	
Description of pattern to model the recurring behavior in inventories	Fern [?]
Proposal of patterns for health services management projects	Stephenson and Bandara [?]
Description of recurring element labels of particular application domains	Koschmider and Reijers [?]

Table 1: Overview on Process Model Design Patterns Focusing on the Process Model Semantics

ness process modeling). While the latter category has been widely discussed in Part 1 [?] of this article (see Chapter 2.3), this section is dedicated to the description of the first category of patterns. This category has been only rarely addressed in the literature (compared to compliance patterns or workflow patterns).

The right hand side and the middle part of Figure **??** illustrate patterns investigating process element labels using semantic technologies. Patterns, which address the semantics of labels (see right hand side of this figure) use semantic technologies in order to identify the content of process element labels without considering the control-flow. This means that a process model that has syntactical bottlenecks (e.g., a faulty usage of element constructs) might be appropriate with respect to patterns considering the label semantics. Exemplary, the Inventory pattern subsumes all process element labels that are involved in inventory management e.g., activities for managing reserves on the inventory, for managing adjustments to the inventory, and for managing the expected inventory. Process patterns, which identify the business functions that frequently occur in a process model such as decision making are described by a further type of patterns. For instance, the two-directional message flow pattern describes the business function of message exchange between activities that are bi-directionally connected.

Table **??** summarizes approaches, which are either related to patterns identifying the business function of process activities or the content of process element labels.

1.1.1 Pattern Elicitation

Only few approaches can be found, which (semi-)automatically identify business process patterns. Usually, this task is creative and manual work.

Compliance patterns can systematically be obtained by studying legal documents or internal guidelines. From these documents, it is possible to define anti-patterns (i.e. patterns that should *not* occur in a model) [?, ?]. Less common are approaches such as [?] where patterns define what *should* happen in a compliant process.

Systematic approaches for finding patterns need to process the element labels of activity nodes. SMIRNOV et al. [?] describe an algorithm where relations between actions in a process model are learned. These relations – called action patterns by SMIRNOV et al. – refer to co-occurrence and ordering relations between model elements.

KOSCHMIDER and REIJERS [?] use natural language processing techniques for extracting high-level patterns for generic activities (such as “inventory” or “invoicing”) from business process models.

While both [?] and [?] concentrate on the action verbs and the objects in a business process model, BÖGL et al. [?] aim to detect a variety of semantic roles (such as a role “source” and “direction”) from an activity label. This is achieved by regarding semantic text patterns.

By analyzing a number of models, it is possible to identify stereotyped sequences of actions that are common for a family of processes. It has to be noted that this idea is not specific for the analysis of business process models. Representing typical courses of action as scripts is well researched in the area of text understanding. For the purpose of business process modeling, the theory of scripts has been exploited by LEIGH and RETHANS [?] who generated stereotypes of common purchasing processes by interviewing experts. PEYLO [?] also follows the idea of scripts. He suggests an ontology-based approach to document a typical course of action. Those approaches perfectly fit our notion of a process model pattern, even if no graph-based business process models are involved.

In addition to the already mentioned approaches for identifying business process patterns manually or by using an algorithm, RODRÍGUEZ et al. [?] describe a crowd-based process for finding patterns.

1.1.2 Using Patterns

Semantic business process patterns can be used in various ways. At first, the pattern names provide a common vocabulary which enables business process analysts to discuss the processes on a higher level of abstraction. Second, the patterns are helpful for education and training. Business process modelers can profit from experiences of others who have documented well-working solutions to common modeling problems.

As already discussed in the first part of our article, patterns and anti-patterns can be applied for checking the compliance of a model [?, ?] and – more generally – for improving the quality of the models [?].

Reuse of previously defined patterns (i.e. model fragments) does not only help to build better models, it can also be helpful for creating models faster. For this purpose, THOM et al. [?, ?] extended a modeling tool such that certain patterns can be directly inserted into a model. While in their approach the patterns are included in the modeling tool, more advanced scenarios allow for storing commonly occurring process fragments in a repository [?]. Using such a repository, can allow indexing patterns, linking between patterns, searching for patterns and social collaboration such as adding comments to documented patterns [?].

All these techniques allow to suggest model fragments to be included into a model. However, patterns can also be used for recommendations of single activities (see for example [?]) and for auto-completion of process models [?]. A detailed discussion of such recommender techniques can be found in [?].

1.2 Semantic Process Model Elicitation

The scope of this section are approaches that use semantic technologies to discover models from various input sources as well as to automatically construct, abstract, maintain, improve, enrich and translate models.

Semantic Process Mining denotes the extension of process mining techniques using semantic technology. In this area, DE MEDEIROS et al. [?] propose to shift the analysis of log files from the syntactic level (considering labels in the log files) to the semantic level using ontologies in order to accomplish a more accurate and robust analysis. The authors present core building blocks of such a technique and demonstrate the feasibility using the ProM framework. The practical application of Semantic Process Mining in an industrial application is demonstrated by INGVALDSEN and GULLA [?]. The authors discuss the industrial benefits and challenges of their Semantic Process Mining approach. They also describe how to make use of ontologies and annotated log files in conjunction with data mining technologies to enable a more flexible generation of process model views. This can be used to present the discovered models in business terms at various level of detail. The approach has been implemented in the process mining tool EVS (Enterprise Visualisation Suite) and applied to ERP systems such as SAP. Finally, BAIER and MENDLING develop an approach to bridge abstraction layers in Process Mining [?]. The authors tackle the problem of automatically associating the events from a log with the activities from a process model. One of the core challenges in this context is that events from logs are typically more fine-granular than activities. To solve this problem, they use domain knowledge extracted from existing process documentation.

Another form of process model discovery is *process discovery from text*. Early works in this area addressed the extraction of models from requirement specifications. For example, KOP et al. [?] developed a tool to support the extraction of behavior models from requirements texts. The approach makes use of various techniques for Natural Language Processing such as word tagging and sentence analysis. Further approaches also focus on process mining from specific sorts of text. For example, GONCALVES, SANTORO and BAIAO [?] extract workflow models from group stories using text mining and natural language interpretation. Also, discovering process models by parsing business policies has been proposed and demonstrated by WANG, ZHAO and ZHANG [?]. In contrast to the approaches introduced so far, there are approaches to model discovery that are more versatile regarding the form of input. For example, GHOSE, KOLIADIS and CHUENG [?] develop a framework and prototype for rapid process discovery called R-BPD. In a mixed-imitative setting, the tool can be used to extract process models from diverse sources such as text, web-content or other models such as sequence diagrams. In order to resolve naming and abstraction conflicts, an enterprise ontology is used. The extracted models serve as a basis

Approach	**Authors**
Semantic Process Mining	
Core building blocks of semantic process mining tools	de Medeiros et al. [**?**]
Industrial application of semantic process mining	Ingvaldsen and Gulla [**?**]
Bridging abstraction layers in process mining	Baier and Mendling [**?**]
Process discovery from text	
Tool supported extraction of behavior models	Kop et al. [**?**]
Process discovery from model and text artefacts	Ghose, Koliadis and Chueng [**?**]
Business process mining from group stories	Goncalves, Santoro and Baiao [**?**]
Discovering process models from business policies	Wang, Zhao and Zhang [**?**]
Process model generation from natural language text	Friedrich, Mendling and Puhlmann [**?**]
Extraction and reconstruction of enterprise models	Sanchez, Reyes and Villalobos [**?**]
Planning-based process model construction	
Automated model construction: A logic based approach	Krishnan [**?**]
SEMPA – an approach for business process model planning	Heinrich et al. [**?**]
Automated planning of context-aware process models	Heinrich and Schoen [**?**]
Process model abstraction	
A semantic approach for process model abstraction	Smirnov, Reijers and Weske [**?**]
Techniques for generating model names	Leopold et al. [**?**]
Value-chain discovery from business process models	Boubaker et al. [**?**]
Process maintenance and improvement	
Resolution of compliance violation using planning	Awad, Smirnov and Weske [**?**]
Business processes contextualisation via context analysis	de la Vara et al. [**?**]
Continuous planning for business process adaptivity	Marrella and Mecella [**?**]
Revising process models through inductive learning	Maggi et al. [**?**]
Process optimization using formalized patterns	Niedermann, Radeschuetz and Mitschang [**?**]
Process model enrichment	
Towards the Automated annotation of process models	Leopold et al. [**?**]
Automatic service derivation from model repositories	Leopold, Pittke and Mendling [**?**]
Process model translation	
Transformation of use cases into activity diagrams	Yue, Briand and Labiche [**?**]
Use cases to process specifications in BPMN	Sinha and Paradkar [**?**]
Automatic business process model translation with BPMT	Batoulis et al. [**?**]

Table 2: Range of Semantic Process Model Elicitation Approaches

for further refinement by the human expert. Similarly, SANCHEZ, REYES and VILLALOBOS [**?**] focus on the extraction and reconstruction of (existing) enterprise models using information from multiple sources such as information systems, databases and previously existing models. Although semantic technologies are not explicitly addressed, the approach makes use of a domain metamodel serving as a knowledge representation backbone which helps querying and analyzing the contents. Finally, research focuses on generating complete process models out of natural language descriptions. For example, FRIEDRICH, MENDLING and PUHLMANN [**?**] automatically generate BPMN models from natural language text. The authors combine existing tools from Natural Language Processing and extend them with an anaphora resolution mechanism.

Departing form the discovery of models where semantic technology is used somewhere behind the scenes, the field of *planning-based process model construction* uses semantic technologies and knowledge representation at its very core. An early work in this area is the automated model construction using a logic-based approach as proposed by KRISH-

NAN [?]. More recent approaches combine logic, knowledge representation, planning and graph processing techniques to provide sophisticated tools and techniques. With SEMPA, an algorithm for the automated planning of process models has been devised by HEINRICH et al. [?]. Making the planning context-aware has subsequently been investigated by HEINRICH and SCHOEN [?].

Once the process model is discovered or is constructed using semantics-enabled approaches, it may not be on the right level ob abstraction yet. Here, *process model abstraction* is applicable. When abstracting a process model, it is challenging to combine activities into high-level tasks in a way that approximates how a human would solve this problem. In this regard, SMIRNOV, REIJERS and WESKE [?] developed an approach that exploits semantic information within a process model to decide on which activities belong to each other. Similarly challenging is to find a name for the newly created, more abstract model. To tackle this problem, LEOPOLD et al. [?] developed a technique for generating model names. Another approach presented by BOUBAKER et al. [?] creates more abstract value-chains from business process models expressed using BPMN. The value-chains are represented using concepts of the REA-ontology. The transformation is implemented with the help of a Business Rules engine.

Following its creation, a process model is subject to *process maintenance and improvement*. Regarding maintenance, a major issue is to keep business processes compliant with regulations, especially if a huge number of such models exist. To ease the task of ensuring compliance, AWAD, SMIRNOV and WESKE [?] develop a planning-based technique for resolving compliance violations in business process models. They address violations of execution ordering compliance rules using background knowledge in the form of violation patterns in conjunction with algorithms to detect and resolve them. Another form of background knowledge is used by DE LA VARA et al. [?] in the form of context analysis models. Originating from Requirements Engineering, such models are created to support the context-specific adaptation of business process models. Process model adaptation is also addressed by MARRELLA and MECELLA [?]. They propose a technique to automatically cope with unexpected changes preventing process execution. The technique is capable of modifying only those parts of the process that need to be changed or adapted and keeping other parts stable. It is based on continuous planning using the Planning Domain Definition Language as well as SmartPM, a formalism for declarative modeling.

Regarding improvements, it is challenging to include all relevant data sources and to detect improvement choices. To support this process, NIEDERMANN, RADESCHUETZ and MITSCHANG [?] develop a deep Business Optimization Platform addressing these challenges by integrating data from various sources in a data warehouse and applying (amongst others) graph analysis and matching techniques to detect applicable patterns for process optimization. Another direction of research is to revise process models through inductive learning as proposed by MAGGI et al. [?]. The approach improves models by automatically revising them to be in line with practice throughout their lifetime using a non-monotonic inductive learning system. In doing so, it aims to minimally revise business process models. The authors also argue that business process revision offers significant advantages over business process discovery.

Process model enrichment denotes performing operations on existing models aiming at an extension of the models content or the derivation of additional useful information e.g. to use, extend or implement the model. In this direction, LEOPOLD et al. [?] propose an approach for automatic process model annotation with elements of an activity taxonomy. The approach builds on the corpus-based method of second-order similarity, different similarity functions and a Markov Logic formalization of the annotation problem. The automated semantic annotations may be consumed by other tools and techniques e.g. to improve retrieval, content-analysis or matching of process models. An example of an approach deriving additional information from process models is the automatic service derivation from business process model repositories developed by LEOPOLD, PITTKE and MENDLING [?]. The technique reduces the amount of manual work in the context of service derivation by automatically deriving service candidates from business process model repositories. The approach leverages semantic technology for deriving ranked lists of service candidates. It may be used for enabling business and IT managers alike to quickly spot reuse potential in their company, to improve Business/IT alignment or to prioritize IT support based on relative importance of a business operation.

Finally, *process model translation* deals with transforming a model from one (modeling) language to another. Regarding the translation from UML Use Cases to UML Activity Diagrams, YUE, BRIAND and LABICHE propose an automated approach [?]. The implementation makes use of transformation rules as well as libraries for linguistic text processing. A similar but semi-automated approach that also aims at translating between Use Cases and Activity Diagram is developed by SINHA and PARADKAR [?]. The authors additionally put more emphasis on synchronizing between the two types of models and enforcing consistency. They also use natural language processing that is packaged by the authors in the form of a linguistic analysis engine for natural language use case description. Finally, in regard to the translation of the natural language labels contained in process models, BATOULIS et al. have developed an automated translation tool called BPMT [?]. It builds upon the machine translation system Moses and extends it with word and translation disambiguation considering the context of the domain. This is done to successfully process the compact and special language fragments typically found in business process models.

2 Conclusion

In the second part of the paper, we focused on approaches making use of semantic technologies in the area of domain patterns and (semantic) process model elicitation. What we again see in these areas is that a wide range of semantic technologies and techniques is in use.

However, regarding domain patterns, only a few approaches can be found being able to (semi-)automatically identify business process patterns. Regarding the application of patterns, most of the tools we are aware of provide little flexibility regarding the granularity of reuse (e.g. parts from a pattern, complete pattern or combination of patterns integrated via a planning approach) and reuse strategy (e.g. recommending strategies). What is more, they are often tailored to specific pattern collections. Hence, approaches that more closely integrate (automatic) detection of patterns with pattern management and reuse in a single approach may be subject to future research.

Also, approaches that more closely integrate (automatic) detection of patterns with pattern management and reuse in a single approach may be subject to ongoing research.

Regarding (semantic) process model elicitation approaches, we see that semantic technologies in the area of Natural Language Processing are widely used. A recommendation for the research community would be to make the adaptations and adjustments to general purpose NLP tools reusable by packaging or providing them in a form that fosters reuse (e.g. via web services). In regard to other semantic technologies originating from the Artificial Intelligence community, such as planning approaches, no single tool or technique is dominating. Hence an opportunity for future research would be – in line with our observations from the first part of the article – to create a catalog of such tools and techniques describing their use, prospects and limitations in a BPM-related setting.

Finally, in regard to the knowledge representations used, we observe that the majority of approaches use non-standard representation languages and tools. Further, we notice that current approaches rarely use existing bodies of normative and (at least partially) formalized knowledge, such as the Process Classification Framework, the MIT Process Handbook, the Enterprise Ontology, or industry-related Frameworks, such as ITIL and SCOR. In addition, some knowledge representations such as pattern catalogs developed as part of research papers are either not accessible at all or not accessible in a machine processable form. Hence, it would be beneficial for further research and progress within the BPM field to update and curate standardized collections of knowledge and to make them easily available to the research community using standardized languages such as XML or OWL as well as lightweight interfaces for invocation such as web services.

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