A Knowledge Base Guided Approach for Process Modeling in Complex Business Domain

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Abstract: The business process analysis requires an in-depth knowledge of factors such as the activities carried out; the actors involved; the domain or business context in which the activities are performed; the internal company structure; the current regulatory framework. This involves the employment and the collaboration of different professionals, such as business experts, domain experts and legal experts, along with a considerable effort in terms of time and resources. For the purpose of an efficient and effective management of business processes, it is also important to ensure the compliance with the company context and the flexibility with regard to changes that may occur within the company or at the legislative level. This paper shows a methodological and architectural approach guided by a knowledge base that describes the application domain. It is populated iteratively with the information extracted from the analysis of documents, regulations and requirements. The knowledge base is then used by the process designer as a guide for business process modelling and management.

1 INTRODUCTION

Business process modelling and management is a discipline that aims to increase the efficiency and effectiveness of the activities carried out in the companies. Indeed, it analyses the processes, which is the company way of working, and identifies, by comparison with the best practices in the same context, the strengths and the weaknesses. It follows a business process reorganization and reengineering.

The analysis of business processes requires an in-depth knowledge of some aspects such as the activities carried out in the company; the actors involved; the domain or business context in which the activities are performed; the internal company structure; the current regulatory framework. This implies the interaction and the collaboration of different professionals, such as business experts, domain experts and legal experts, along with a considerable effort in terms of time, about 60% of the total time spent to manage the processes (Herbst and Karagiannis, 1999).

For the purpose of an efficient and effective business process management, it is also important to ensure compliance with the company context and flexibility with regard to changes that may occur within the company or at legislative level.

As reported verbatim in (Sadiq and Governatori, 2015) “The ever-increasing obligations of regulatory compliance are presenting a new breed of challenges for organizations across several industry sectors. Aligning control objectives that stem from regulations and legislation with business objectives devised for improved business performance is a foremost challenge”. Indeed, a prompt response to changes and the compliance with the company context could be the reason of improvement in the competitive position compared to other companies in the same sector.

In view of these consideration, there is the need of methods and technologies able to facilitate and speed up the acquisition phase of the information related to the company context, identify and model business processes and ensure the process compliance with the company operational context, even in the faces of changes.

Most of such business information, about 85% (Blumberg and Atre, 2003), is stored in an unstructured way, in text documents and the amount of available unstructured sources is continuously growing. But how these sources can be used for defining and modelling business processes?

In this paper we propose a methodological and architectural solution that falls in research

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disciplines such as knowledge management (Tiwana, 2000), process mining (Van Der Aalst, 2011) and business process management. It is based on an approach guided by a knowledge base realized by the help of domain and legal experts. This knowledge base describes the entire company domain in the form of concepts and relationships among them. The idea is to populate, iteratively, the knowledge base with the information extracted from unstructured sources, and to use the knowledge base for business process modelling, ensuring the compliance with the company context and facilitating the process adaptation to changes.

The purpose is to make the process design experts as autonomous as possible during business process management phases.

The paper is organized as follows. In Section 2 we describe the background of this research work. Section 3 shows how the literature faces problems similar to those analysed here. Section 4 describes the methodology and the phases that characterize it. Section 5 shows the approach from the architectural point of view and of the components that characterize it. Finally, Section 6 includes some conclusions.

2 BACKGROUND

The contribution described in this paper represents a continuation of the research work (Caione et al., 2015a) which results in a methodological and architectural solution able of managing the entire business process life cycle in complex business domain, from process modelling to process running on an automatically generated web application prototype.

First it is important to consider and know the operational context in which the company takes place in order to proceed with the definition of the activities and business processes. To this end it is essential a strong interaction between different professionals. Because of a different cultural background, they should use a common dictionary to allow the knowledge sharing and transfer. In this regard, in (Guido et al., 2015) the authors suggest some guidelines addressed to legal experts in order to schematize the texts of laws and regulations and to simplify the understanding to the process design experts who will model the processes in accordance with the existing laws. The output of the guidelines is a set of schemes that could provide support for domain knowledge base modelling. The knowledge base is actually the result of a careful analysis of the operational context, the detection of the main concepts that characterize it along with the identification, reuse and merge of one or more existing knowledge bases able to describe the entire reference domain. In (Paiano et al., 2015) the authors propose a knowledge model structured into two ontological levels:

- *Enterprise Domain Ontologies* (EDO) that "model the entities (i.e., human resources, tasks, processes, objectives, etc.) that represent the organizational environment from a general perspective. Because of their general purpose, these ontologies have been defined extending and combining ontologies (i.e. reference ontologies) already existing at the state of the art";
- *Application Domain Ontologies* (ADO) that "model domain specific concepts and they support the classification of entities represented through the EDO. The regulations represent a typical example of ADO because they are application specific".

This model is useful during the design phase of new business processes compliant with the reference domain and during the management of expected and/or unexpected events.

With regard to the definition and management of business processes, in the literature there are several workflow management systems that support the business and IT expert during the process planning, execution and management. A survey is given in (Caione et al., 2015b) in which the authors describe five open source workflow management systems:

- Intalio BPMS (*www.intalio.com*);
- BonitaSoft (*http://it.bonitasoft.com*);
- jBPM (*www.jbpm.org*);
- Activiti BPMN 2.0 (*www.activiti.org*);
- Camunda (*www.camunda.com*)

These solutions are compared on the basis of eight key aspects:

- process editor oriented to business and/or IT experts;
- APIs availability for business and/or IT experts;
- connectors availability;
- BPMN 2.0 compliance;
- fast prototyping;
- prototyped application customization;
- process monitoring;
- engine source code customization.

Particular attention is paid to the requirements of extending the solution in order to allow the integration and the interaction with the domain knowledge base.

From the analysis and the obtained results, jBPM has proved to be the most suitable system from the point of view of the requirement fulfilment.

The processes are modelled using the standard Business Process Model Notation (BPMN) also available in version 2.0 (OMG, 2011). It includes four categories of elements necessary for the design of a process:

- flow Objects (Activities, Events and Gateways), swimlanes (Pools and Lanes);
- artifacts (e.g. Data Objects, Text Annotations or Groups);
- connecting objects (Sequence Flows, Message Flows and Associations).

Typically, a process design reflects the analysis of the operating context and of the company requirement that is carried out through interviews, meetings, etc., then transcribed into text form, along with the understanding of structured and unstructured documents.

The methodological and architectural approach described in this paper, shows the use of these guidelines, knowledge bases and tools. We have also done a scouting on the state of art of software solutions able to map the information contained in unstructured documents with the concepts of a previously modelled knowledge base, the tool named *OwlExporter* was identified (Witte et al., 2010).

It is an extension of the General Architecture for Text Engineering (GATE) framework (Bontcheva et al., 2004). It includes support for the semantic language Ontology Web Language – Description Logic (OWL-DL), the automatic population of a knowledge base and the integration of information taken from Natural Language Processing (NLP) in order to make a more accurate reasoning.

Being the tool dependent on a specific knowledge base, for the purposes of this work it will have to be extended and customized for the specific reference domain in order to better support the process designers in the business process modelling phase.

3 RELATED WORKS

Recently there is a considerable attention to the identification and generation of process models from content written in natural language.

An interesting solution is described in (Friedrich et al., 2011). In the paper the authors present an automatic approach for the generation of process designs according to the BPMN standard and starting from texts written in natural language. Verbatim, they "combine an extensive set of tools from natural language processing (NLP) in an innovative way and augment it with an anaphora resolution mechanism". The approach involves three steps:

- *Sentence Level Analysis*, through which it is possible to extract actors and actions (verb + object) and connect the actors to the actions;
- *Text Level Analysis*, through which it is possible to analyse the sentences taking into account their mutual relationships. The end result is the creation of flows of activities describing how the activities interact with each other;
- *Process Model Generation*, the information extracted in the previous steps and stored in a template are transformed into processes according to the BPMN standard.

Another solution, validated on a case study in the archaeological field, is described in (Viorica Epure et al., 2015). It is called *TextProcessMiner* and consists of the generation and analysis of process activity logs starting from text documents in an attempt to define the process instance model. The solution is "fully unsupervised and uses natural language processing techniques with a focus on the verb semantics" and is divided into three components:

- *TextCleaner*, “responsible for cleaning the methodology section and preparing the text which will be mined”;
- *ActivityMiner*, “responsible for mining the activities from the text”;
- *ActivityRelationshipMiner*, “responsible for mining the relationships between the activities, thus discovering the process instance”.

Lastly, we quote the paper (Brandão et al., 2015) where the authors propose a solution able to solve the problem of subjectivity related to the business expert vision. It also facilitates the process management, the reuse, the maintenance and the understanding. The idea is to automatically identify particular elements in business processes through the analysis of the process event log. Within the business process models, as defined by the authors, "elements can be scattered (repeated) within different processes, making it difficult to handle changes, analyze process for improvements, or check crosscutting impacts". These elements are called aspects.

Some of the above mentioned solutions use knowledge bases to define a set of useful rules in order to analyse natural language texts. In this paper,

the knowledge base plays a crucial role since it describes the entire reference domain in terms of concepts and relationships and it is integrated into the business process management system to support the business expert and the process designer during the modelling, the reuse and the maintenance phases of processes. Therefore, the option of automatically populating the knowledge base from the information contained in analysis and requirement documents could support the business experts and process designers, reducing their knowledge gap and the time spent in the analysis of the operational context.

An attempt similar to that described in this paper, though with different aims and tools, is shown in (Rashwan et al., 2013) which illustrates an automatic requirement classification system, based on support vector machines. It automatically categorizes requirement sentences into different Non-Functional Requirements knowledge base concepts.

4 METHODOLOGY

The methodology adopted in this work consists of three main phases that can be summarized as follows:

- knowledge acquisition about the company domain. The output of this phase is a knowledge base that summarizes the context in the form of concepts and semantic relationships among them;
- information mapping, which aims to automatically populate the knowledge base, defined in the previous step, through the information contained in the analysis, regulatory and business requirement documents;
- business process modelling, the final result of which is the BPMN representation of the business processes modelled by the process designer through the information contained in the populated knowledge base.

In the following we describe in detail these phases.

4.1 Knowledge Acquisition about Company Domain

In recent years, the use of knowledge bases has seen a strong increase as a result of the spread of semantic information systems. The design of these systems is an activity demanding from the standpoint of time and human resources. This led to the definition of methodologies with the attempt to standardize the construction of knowledge bases and to achieve a result in a common semantic language, in order to ensure the knowledge base sharing and reuse even in different domains.

There are numerous methods in the literature for the creation and the management of knowledge bases, among them Methontology (Fernández-López et al., 1997), Skeletal Methodology (Uschold and King, 1995), Grüninger and Fox (1995), to name but a few. They provide a valuable support to knowledge engineers and carefully describe the steps to be followed during the phases of modelling, implementation and maintenance of the knowledge bases.

Our approach inherits what realized in (Paiano et al., 2015). The authors chose the methodology of Grüninger and Fox, both because it is based on a complete existing technique, Methontology, which describes the entire knowledge base creation life cycle, both because it extends this methodology and focuses on the creation of knowledge bases from the the information related to the application domain.

Added to this is the importance of the research and the reuse of existing knowledge bases or parts of them as additional support for the knowledge engineer.

We combine the above mentioned work with some helpful guidelines with the attempt of schematizing complex domains such as those that provide laws and regulations (Guido et al., 2015).

The end result is an abstract representation of the application domain in a standard semantic language. This representation organizes the company knowledge in both ADO and EDO levels, briefly described in the Background section.

Although there are tools that can semi-automatically generate knowledge bases starting from textual documents such as Ontogen (Fortuna et al., 2007), Text2Onto (Philipp and Völker, 2005), etc. For our purposes, they are not sufficiently accurate to describe complex domains such as business and regulatory ones. Therefore, from our point of view, it is preferable that the construction of such knowledge bases is guided by domain experts, legal experts and business experts.

4.2 Mapping of the Information Written in Natural Language

The implemented knowledge base, in order to be helpful during the business process modelling phase, should also contain the actual data extracted from the analysis documents, regulatory and requirement texts written in natural language.

Having built a solid knowledge base, it is possible to use tools that, starting from documents

written in natural language, instantiate the concepts of the knowledge base. Among the tools we name OwlExporter (Witte et al., 2010).

The main characteristics of this tool are:

- instance creation, using the entities contained in the text;
- creation of the relations between concepts, using the information and relationships in the text;
- coreference chains creation, leveraging the concept of equality for the same entities that are positioned in different parts of the text.

We have extended and customized this tool with the idea of modelling business processes in complex domains.

To this end, the pipeline and the source code have been modified in order to overcome a limitation which did not allow the processing of complex texts.

Subsequently we have defined a lookup list of entities and some JAPE transducers, that are files containing some rules to further identify patterns/entities from the text and to generate annotations that will have to be matched with the concepts and properties defined in the knowledge base.

The benefit of automatically populating a knowledge base from text, is to have a categorization of the information contained in the documents on the basis of the concepts modelled in the knowledge base and, therefore, the possibility to make queries and inference in order to extract implicit knowledge.

Furthermore, taking advantage of the concepts and instances contained in the knowledge base, it is possible to enrich the model comparing the information present in text documents with the instances of the knowledge base.

4.3 Business Process Modelling

Since we have on the one hand a knowledge base that schematises the application domain in terms of concepts, instances and semantic relationships, and on the other a business process management system, the business expert and the process design are facilitated in the design of the business activities. More to the point, the interaction with the knowledge base allows to fill the gap of the knowledge expert in terms of the application domain, speeds the information retrieval and facilitates the adjustment of the processes if changes happen in the application domain.

Our approach organises the business process modelling into two main phases, as shown in Figure 1, *Planning Time* and *Design Time*.

In order to have a greater understanding of these phases, it is good to define the concept of sub-process template and the motivations of its use. It is a block of BPMN elements, or a portion of process that can not be executed by workflow engines, but can be composed with other elements or portions to derive executable business processes.

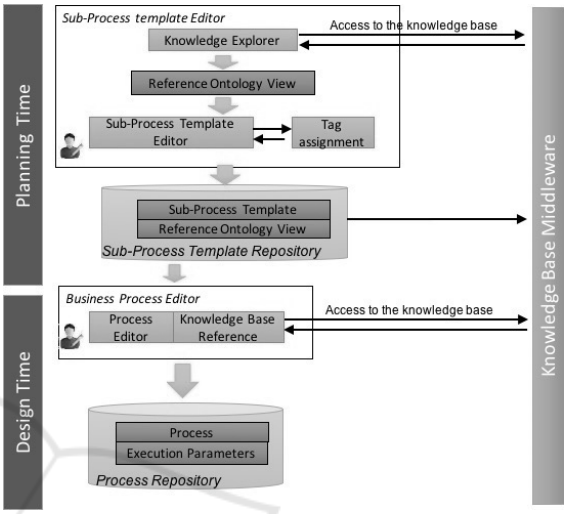

Figure 1: Business Process Modelling - Planning Time and Design Time.

Planning Time - In this phase the process designer uses an editor called *Business Process Editor* to model the sub-process templates in BPMN standard notation.

The editor allows the process designer to query the domain knowledge base through an interface named *Knowledge Base (KB) Explorer*. The interaction is useful to semantically characterize the sub-process template elements, establishing a semantic relationship between the elements of the sub-process templates and the knowledge base concepts; to get some suggestions about the design (the names of the process tasks, the input and output parameters, etc.); to facilitate the management of domain changes.

Design Time - In this phase the process designer models the business processes that can be executed within the workflow engines. To this end it may use the previously defined templates, connecting them according to three possible options:

- sequential adding: the connection in sequence of the activities that constitute the sub-process templates used;
- parallel adding: the connection in parallel of the activities that constitute the sub-process templates. This can be done using the parallel

gateway of the BPMN notation;
- conditional adding: connection with branching of the sub-process template activity flow. This is applicable using all of the BPMN gateway types.

It is clear that the events and the redundant tasks must be eliminated or merged.

At the end of the process composition and modelling, the business designer must enter the execution parameters, inputs and outputs to the tasks, in order to make the processes executable. The integration of such information may be done querying the knowledge base.

The business model thus obtained is stored in two different ways: in a format executable by workflow engines (*.bpmn extension*); in a semantic format so that it is sent to the knowledge base and stored in it (*.owl extension*).

This makes easier to ensure the compliance of the processes modelled with respect to the application domain. A change in the domain, results in a change in the knowledge base and, as a consequence to a notification to the process designer who will have to adapt the processes on which the change has impact.

5 ARCHITECTURAL SOLUTION

The proposed architectural solution (Figure 2) includes three main components.

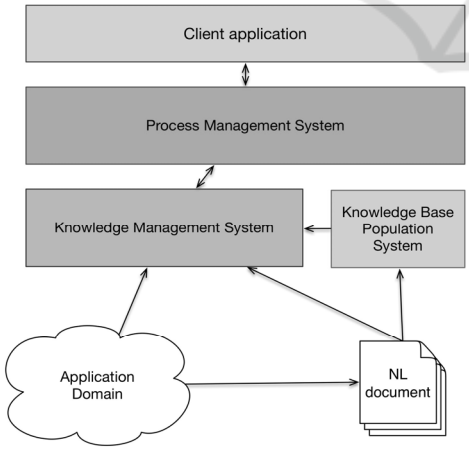

Figure 2: Architectural solution.

- *Knowledge Management System.* It is responsible for the management of the domain knowledge base. It stores the concepts and the semantic relationships and allows to make inferences and queries. The access to the knowledge base is realized, on the client side, using the interface *KB Explorer*. The process designer can start a search for concepts entering free text or keywords. The interaction occurs through Representational State Transfer (REST) and Simple Object Access Protocol (SOAP) calls.
- *Knowledge Base Population System.* It is responsible for the knowledge base population with the information contained in unstructured documents. It customizes and extends the *OwlExporter* tool for the specific domain and is based on GATE NLP framework that allows to work with the knowledge bases using integrated models.
  The system is characterized by two knowledge bases. The first models the concepts and the relationships relevant for the particular domain. The second knowledge base is a basic NLP knowledge model independent from the domain that contains the concepts commonly used in language engineering, such as Document, Sentence, Noun, Predicate, etc.
- *Process Management System.* It is responsible for the business process modelling through the composition of sub-process templates and it is responsible for the entire management of the modelled processes using the features offered by the *Knowledge Management System*. The *Business Process System* extends the jBPM modelling editor for the features of sub-process template definition, composition, saving of the executable processes in a standard format and in a format compatible with the knowledge base, access to read and insert information to and in the knowledge and management of domain changes.

5.1 Process Management System

In this section we describe in more detail the main modules that constitute the core component of the architecture, the *Process Management System*.

The component conforms with the business 1 *Knowledge Management System* component manages the domain knowledge base, result of the knowledge acquisition about company domain phase of the methodology. The *Knowledge Base Population System* component allows the mapping of the information written in natural language phase of the methodology in order to automatically populate the knowledge base with instances extracted from documents.

Architectural details for the these two components are provided in the papers (Paiano et al., 2015) and (Witte et al., 2010), respectively.

5.1.1 Knowledge Base Explorer

The *KB Explorer* module allows the interaction with the knowledge base and the collection of the concepts contained in it. The designer can retrieve the concepts stored in the knowledge base by performing one of the following search methods: by free text; by keywords; by concepts related to the results of a previous search.

This tool is integrated into the *Business Process Editor* and can be used:

- to insert one or more references to the knowledge base concepts, when creating a sub-process template or a process;
- to characterize a specific BPMN element of the model with one or more knowledge base concepts, during the design of a process;
- to insert the input and output parameters connected to the knowledge base concepts, during the concretization of the process.

The concepts used in the models can assume different states:

- active, when the concept is valid and can be used to semantically describe an entire process or an element of it;
- deleted, when the concept has been removed from the knowledge base;
- replaced, when the concept has been modified in the knowledge base because of some domain changes.

The change in status is indicated by events from the knowledge base.

5.1.2 Business Process Editor

The *Business Process Editor* is a standalone application extending the Eclipse-based editor of jBPM.

The necessity to update the source code is dictated by the following features:

- creating a new model, that is a process or a sub-process template. The wizard, then, allows the process designer to use the *KB Explorer* in order to select the concepts that will characterize the design.
- opening an existing model to view it and/or to make changes in it. The user can also update the concepts of the model.
- modelling of a business process. In this activity the process designer uses the tools, the graphic elements, the palette and the properties of the jBPM Eclipse-based editor. However, extensions are needed to allow the process designer to connect the process elements with the concepts extracted from the knowledge base and to insert the task execution parameters.
- saving the model. The model is saved in a format executable by the jBPM workflow engine and it can be exported in the corresponding semantic representation. This semantic file is sent to the knowledge base, transparently to the designer.
- management of changes in the application domain. The process designer can check for changes in the knowledge base, can see the changed concepts and, then, he can update the respective templates and/or processes.
- execution parameters entry. They are parameters functional to execute a process. The definition of the input and output parameters, through the knowledge base, is obtained by invoking the *KB Explorer* module.
- process recomposer. This is a useful feature for events for the management of which is not possible to identify a perfectly compatible process. After the selection of an event, the system suggests to the user a list of processes and/or sub-process templates semantically related to the event. The user can select one or more processes and/or sub-process templates among those proposed in order to insert and connect them into the process that will handle the event.

6 CONCLUSIONS AND FUTURE WORKS

This paper presents a methodological and architectural approach for business process modelling, starting from the analysis and the requirements of complex application domains.

Compared to the related works, where business processes are obtained from documents written in natural language, here a domain knowledge base plays a central role in the business process modelling phase. Indeed, it summarizes in terms of concepts and relationships the application context and it is integrated into a business process management system. In this way the process designer can proceed with the design of business processes autonomously, without the need to interact with domain and legal experts but with the possibility to extract the required information from the knowledge base.

Moreover, the use of an automatic knowledge base populating system from text, constantly

enriches this model and simplifies the reading and the understanding of analysis and requirement documents along with of more generally texts describing the application domain.

Interesting is the possibility to define some business-process templates that could be reused and merged during the final process modelling phase. These templates could be also semantically characterized, tagging them and their elements with the concepts of the knowledge base.

Finally, it is important to emphasize the flexibility of the system with respect to the domain, and consequently knowledge base, changes. The proposed system, in effect, notifies to the process designers the occurrence of such events and the processes on which these events may have impact.

In the future it is expected to increase the level of the system automation through the iterative use of the system itself. We plan also to show some examples and usage scenarios of the methodology and the system on which to make evaluations and comparisons of the obtained results with those arising from the employ of a traditional approach, that is without the use of a knowledge base, but with the iterative interaction with the domain, legal and business experts.

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