SABUMO: Towards a collaborative and semantic framework for knowledge sharing

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A B S T R A C T

Knowledge is one the most valuable assets in todays companies. Artificial Intelligence (AI) techniques aim to represent the knowledge in a way that can be applied to solving complex problems or supporting decision making processes. During the last years the semantic web techniques have supported the share of knowledge by means of ontologies. Ontologies have been used for both annotating resources and rea soning. Business Process Management is one of the specific fields in which the use of ontologies has been widely applied. This paper presents SABUMO, a framework based on ontologies that allows experts to represent and share their knowledge with other experts by means of shared and controlled vocabularies. The framework also allows the execution of business processes represented by experts. The execution of this knowledge does not require the installation of complex AI programs. Initial results of the evaluation setup show promising results both in usability and recommendation.

1. Introduction

In a Knowledge Society, knowledge must present a tacit structure for sustainable advantage (Sharma, Ng, Dharmawirya, & Samuel, 2010). The power of knowledge is a very important resource for pre serving valuable heritage, learning new things, solving problems, creating core competences, and initiating new situations for both individuals and organizations today and in the future (Liao, 2003). In this scenario, knowledge workers perform their duties in knowl edge intensive organizations (Soto Acosta, Casado Lumbreras, & Cabezas Isla, 2010), with a high interest in keeping the actual knowl edge and expanding it via innovation (O'Sullivan & Dooley, 2010).

Knowledge management is a field that has been addressed by researchers from many different angles, but industry, too, has reacted with a large variety of specialized tools for different approaches (Rus & Lindvall, 2002). According to Jeon, Kim, and Koh (2011), knowledge management emerges as the core manage ment of paradigm future survival strategy of the 21st century. There are two main strategies in knowledge management (Jahn & Nielsen, 2011): personalization and codification. While personalization fo cuses on people and provides possibilities to share their knowledge (person to person), the codification strategy focuses on documents and provides possibilities to write down and store information and for others to access it (people to documents to people).

Knowledge codification can be defined as a software and human agent driven process by which organizations extract, transform, and store knowledge for codification and embodiment in organiza tional routines (Datta & Acar, 2010). Knowledge codification pre sents several limitations as depicted in Michailova and Gupta (2005) that, in many cases, influence the ultimate goal of knowl edge management knowledge sharing.

Semantic technologies have impacted in the last few years on knowledge codification and knowledge management, presenting a solution to knowledge codification. Semantic technologies and more precisely, ontologies provide us with organization, communi cation and reusability (Blanco, Lasheras, Fernandez Medina, Valencia Garcia, & Toval, 2011). This paper presents a framework for Semantic Anotation and BUsiness processes MOdelling (SABUMO), based on semantic technologies, that allows experts to represent and share their knowledge with other experts by means of shared and controlled vocabularies. The framework also permits the execution of business processes represented by experts. Moreover, SABUMO enables the execution of these processes through its own platform in an easy and scalable way.

The remainder of this paper is organized as follows. Section 2 reviews the state of the art related to technologies and processes present in SABUMO. Section 3 describes the architecture of the solution. Section 4 shows the results of the validation conducted. Finally Section 5 presents the conclusions and the future research.

2. Related work

This section presents relevant works related to the technologies applied in SABUMO. First business process modelling techniques and trends are described. Second, the relevant literature about

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semantic technologies is outlined and, finally, semantic annotation trends are depicted.

2.1. Business process modelling

The roots of process modelling can be traced back to the early 20th century as a tool for organizational design (Mendling, Reijers, & van der Aalst, 2010). A business process model captures ele ments, typically in some graphical form, such as the activities that constitute the business process; the performers of these activities; the time, location, and modus of their execution; and the informa tion that is processed (Giaglis, 2001). In plain words, according to Fernandez Fernandez et al. (2010), business process modelling is a group of techniques that allow modelling those business aspects necessary for correct performance of the business process applications.

Many organizations have, over time, built repositories of busi ness process models that serve as a knowledge base for their ongo ing Business Process Management (BPM) efforts (Dijkman, Dumas, van Dongen, Kaarik, & Mendling, 2011) and these companies de sign and maintain several thousand process models (Reijers & Medling, 2011). Business process modelling is, thus, widely used within and across organizations as a method to increase awareness and knowledge of business processes (Recker, Indulska, Rosemann, & Green, 2010). Not in vain do business process modelling and its automation improve the performance of business activities and en ables enterprise wide monitoring and coordination (Nikolaidou, Anagnostopoulos, & Tsalgatidou, 2001).

There are many grammars available on the market for business process modelling purposes. The type of grammar to be used for process modelling is an important managerial decision (Rosemann, 2006). Not in vain, according to Recker et al. (2010), is the decision for a particular process modelling grammar associated with sub stantial investments in tool purchases, training, conventions and methodologies. The type of grammar used for modelling defines the language and its grammatical rules that can be used to articu late and communicate details about the real world domain and, thus, determines the outcomes of the modelling process (Siau & Rossi, 2011). There are panopoly of process modelling grammars including WS BPEL, YAWL and Business Process Modelling Notation (BPMN), to cite just some of the most relevant. However, business process modelling tools on the market today are mostly "one person tools" and, in the main, do not support an efficient re use of process models, resulting in dissatisfaction of business users with current IT implementations (Koschmider, Song, & Reijers, 2010). On the other hand, according to Recker et al. (2010), Recker and Rosemann (2010), there are several ontological deficiencies of process modelling in practice. In this scenario, semantic technolo gies are expected to provide an added value to the conventional business process modelling grammars in terms of expressiveness and reuse.

2.2. Semantic web technologies

Durguin and Sherif (2008) portrays the semantic web as the future web where computer software agents can carry out sophisticated tasks for users. Semantic Technologies, based on ontologies (Fensel, 2002), provide a common framework that enables data integration, sharing and reuse from multiple sources. Ontologies (Fensel, 2002), are the technological cornerstones of the Semantic Technologies, because they provide structured vocabularies that describe a formal specification of a shared con ceptualization. Ontologies were developed in the field of Artificial Intelligence to facilitate knowledge sharing and reuse (Fensel, van Harmelen, Horrocks, McGuinness, & Patel Schneider, 2001). An ontology can be defined as "a formal and explicit specification of a shared conceptualization" (Studer, Benjamins, & Fensel, 1998). Ontologies provide a common vocabulary for a domain and define, with different levels of formality, the meaning of the terms and the relations between them. Knowledge in ontologies is mainly formalized using five kinds of components: classes, rela tions, functions, axioms and instances (Gruber, 1993). Languages such as Resource Description Framework (RDF) and Ontology Web Language (OWL) have been developed. These languages allow for the description of web resources, and for the represen tation of knowledge that will enable applications to use resources more intelligently (Horrocks, 2008). The Semantic Web consists of several hierarchical layers, where the Ontology layer, in form of the OWL Web Ontology Language (recommended by the W3C), is currently the highest layer of sufficient maturity (Lukasiewicz & Straccia, 2008).

According to Ding (2010), semantic web is fast moving in a multidisciplinary way. Thus, Breslin, O'Sullivan, Passant, and Vasil iu (2010) state that industry has begun to watch developments with interest and a number of large companies have started to experiment with Semantic technologies to ascertain if these new technologies can be leveraged to add more value for their custom ers or internally within the company, while there are already sev eral offers of vendors of Semantic solutions on the market. As a consequence, semantic web applications cover a wide range of do mains including tourism (e.g. Garcia Crespo, Lopez Cuadrado, Colomo Palacios, Gonzalez Carrasco, & Ruiz Mezcua, 2011), customer relationship management (e.g. Garcia Crespo, Colomo Palacios, Gomez Berbis, & Ruiz Mezcua, 2010), research and devel opment activities (Colomo Palacios, Garcia Crespo, Soto Acosta, Ruano Mayoral, & Jimenez Lopez, 2010), human development (e.g. Fernandez Breis, Castellanos Nieves, & Valencia Garcia, 2009; Soto Acosta et al. (2010)), eGovernment (e.g. Alvarez Sabucedo, Anido Rifon, Corradini, Polzonetti, & Re, 2010), health domain (e.g. Garcia Sanchez, Fernandez Breis, Valencia Garcia, Gomez, & Martinez Bejar, 2008), multimedia (e.g. Paniagua Martin, Garcia Crespo, Colomo Palacios, & Ruiz Mezcua, 2011), manufacturing (e.g. Garcia Crespo, Ruiz Mezcua, Lopez Cuadrado, & Gomez Berbis, 2010), financial (e.g. Rodriguez Gonzalez, Garcia Crespo, Colomo Palacios, Guildris Iglesias, & Gomez Berbis, 2011) or media (e.g. Garcia, Perdrix, Gil, & Oliva, 2008) to cite just some of the most relevant cases.

The application of semantic technologies has been considered from various angles for process modelling (La Rosa et al., 2011). In this scenario, the work of Hepp, Leymann, Domingue, Wahler, and Fensel (2005) proposed the concept of Semantic Business Pro cess Management (SBPM) a cornerstone of the integration of semantic technologies and BPM. The primary idea of SBPM is to combine BPM technology with semantic web services technology so that stakeholders in both the business world and the IT world can query and manipulate business processes by traversing the space bidirectionally without a great deal of manual effort (Kim & Suh, 2010). Following this line there are some relevant works de voted to this area including Thomas and Fellmann (2007), SEMPA by Heinrich, Bewernik, Henneberger, Krammer, and Lautenbacher (2008) or more recently APROMORE (La Rosa et al., 2011). In the case of SABUMO, the effects of semantics and its intrinsic expres siveness are augmented by the application of collaborative annotation.

2.3. Semantic annotation

Semantic web annotations go beyond familiar textual annota tions about the content of the documents; they formally identify concepts and relations between concepts in documents, and the annotations are intended primarily for use by machines (Uren et al., 2006). In this scenario, the current focus of semantic web research is on recasting the Web by providing methods to add semantics to data, manually or automatically, thereby moving the Web toward easier machine processing (Benjamins et al., 2008). Annotation tools may fall into several types: manual, semi automatic or automatic. Recent and relevant efforts have been directed at facilitating semantic annotation tools in scenarios like multi ontology annotation (e.g. Gomez Berbis, Colomo Palacios, Lopez Cuadrado, Gonzalez Carrasco, & Garcia Crespo (2011), collaborative annotation (Moscato, Di Martino, Venticinque, & Martone, 2009) or multimedia annotation (Haslhofer, Jochum, King, Sadilek, & Schellner, 2009)).

3. SABUMO: an approach to knowledge sharing based on semantics and collaboration

This section describes the SABUMO concept from a description of its operation, to the underlying ontologies that supports the framework and a deep description of the framework architecture.

To date, the literature has reported the definition of business processes by means of classical tools. As mentioned in the previous section, some approaches have dealt with the collaborative aspects of Business Process Management. However, these approaches do not cover execution of the process and the reuse of the knowledge generated for other peers. SABUMO mixes the benefits of the collaborative business process definition with the possibility of executing such business processes and of obtaining feedback from other users of the system.

3.1. SABUMO operation

Prior to describing the ontologies and the architecture of the system it is necessary to understand the operation model. The operation model is mainly based on defining and annotating business processes, executing the business processes and the rating of these business processes by other users. Fig. 1 depicts the operation model of SABUMO. Although the previous approach (Ruiz Mezcua, Garcia Crespo, Lopez Cuadrado, & Gonzalez Carrasco, 2011) was able to represent and execute many processes, it lacked the possibility of collaboration between users, since the definition of the business process was offline. Extending the old framework to online collaboration for defining business process implies three main challenges: representing the users involved in the business process; using common vocabularies for allowing the understanding between different users: and providing remarkable feedback to users, about the business processes. Each of these aspects is addressed below.

First of all, we can distinguish three types of users involved in the business process definition, namely Business Process Modellers (BPModellers), Business Process Experts (BPExperts) and Business Process Executers (BPExecuters). They are defined as follows:

1. *BPModellers*. They are the users who model the business processes. Their responsibility consists of defining the business process through a knowledge editor. They can define one or more business processes, labelling each business process with domain ontologies. The annotation of a business process is twofold: on the one hand, the annotation of the business process as a whole and, on the other, the annotation of each element of the business process representation. The annotation of each business process and each element allows intelligent searches.
2. *BPExperts*. They are the users who have the knowledge and the necessary experience in the domain in which the business processes is modelled. Their responsibility lies in the assessment of the business processes defined by the BPModellers. BPExperts can rate the business process and its components in order to provide feedback to the BPModellers. The proposed framework includes social tools in order to enable the active collaboration between modellers and experts.
3. *BPExecuters*. They represent the stakeholders who need executing a business process in order to obtain a result. As stakeholders of the business process, BPExecuters have knowledge about the domain. Their responsibility is to search for a business process according to a number of requirements. Once they have found a business process that copes with their expectations, BPExecuters can execute the business process and obtain a result. During the execution they can rate each action of the business process and, at the end of the execution, they can rate the business process as a whole. BPExecuters can also act as BPModellers or BPExperts.

Once the users have been defined, the second aspect is related to collaboration. To improve the collaboration between users, the inclusion of Web 2.0 techniques seemed to be a good approach. However it is not enough, because the third aim of the framework is to take advantage of the feedback of each user. For this reason,

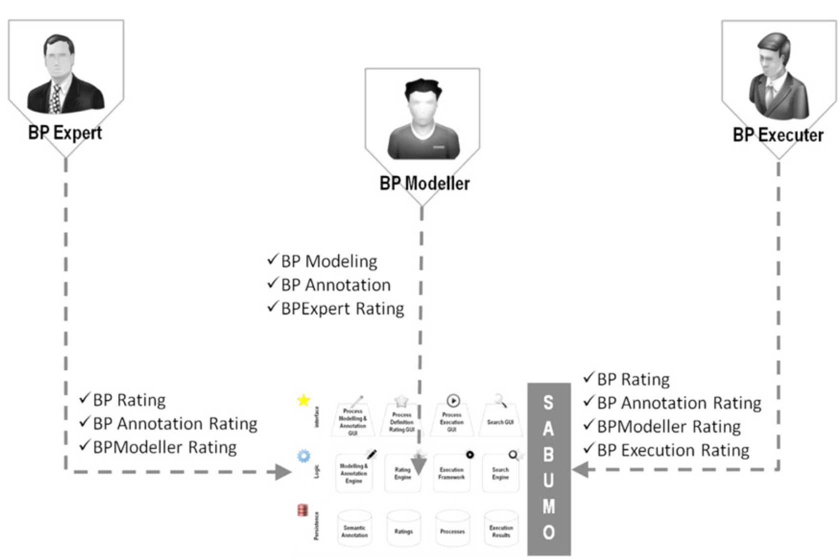

Fig. 1. SABUMO operation model.

besides the application of social techniques, it is necessary to include two elements: semantic annotations and ratings. Semantic annotation of processes and elements allows the description of each with vocabularies shared by all users, and ratings allow a concrete measure of the quality of the business process.

Based on the experience presented in Gomez Berbis et al. (2011), the annotation based on domain ontologies eases the annotation process because the concepts are well established. It also enhances the searches, because all users know the keywords and the relations between the concepts of the ontologies allow intelligent searches. Thus, BPModellers can select one or more domain ontologies for each business process and associate each element of the business process with one or more concepts of those ontologies. Furthermore, all users can search business processes using the concepts of the domain ontologies. This supposes a unified vocabulary for searching and annotating purposes.

Finally, the feedback is represented by means of ratings. Each user can rate the business processes on a Likert scale (0 10). Thus, BPExperts can rate a business process based on their experience and BPExecuters can rate the business process based on the results obtained. Additionally each user is rated by the other users. In this way, BPModellers are rated by BPExecuters and BPExperts. BPExecuters are rated by BPModellers and BPExperts according to the quality of feedback provided by the former. BPExperts are rated by BPModellers and BPExecuters according to the utility of the knowledge provided by the former.

The rating of processes and users is calculated as the weighted mean of the rating provided by another user and the current rating of that user (see Eq. (1)). Thus, ratings of most rated users are more important than ratings provided by less rated users

$$W_{mean} = \frac{\sum_{i=1}^{n} User\ Rating_i * Rate_{object}}{\sum_{i=1}^{n} User\ Rating_i} \quad (1)$$

As shown, the business processes can be defined, rated and executed in SABUMO. In this way, the proposed framework allows for the complete lifecycle of the business process, from its definition to its execution and continuous improvement. The improvement of the business process can be achieved by the analysis of the ratings provided by other users. It is also noticeable that during the process definition a BPModeller can receive feedback from other users.

3.2. Ontology definition: users, ratings and annotations

SABUMO's framework is based on the ontology presented in Garcia Crespo, Ruiz Mezcua, et al. (2010) and extended by Garcia Crespo, Ruiz Mezcua, Lopez Cuadrado, and Gonzalez Carrasco (2011). Fig. 2 depicts the main concepts of the ontology designed for SABUMO. As mentioned in the operation model, the evolution from the previous approaches to the new one requires the representation of the different users involved in the business process and the inclusion of annotations and ratings. These new concepts are:

- *Business Process User* (*BPUser*). BPUser is a person who interacts with the system. This concept is specialized by:
  - *BPModeller*. A modeller is the person who defines a business process by means of the web interface. A modeller can create one or several business process, and each business process comprises a set of elements, as described in Fig. 2. As mentioned in the operation model, a BPModeller can rate other users and other business processes with their respective elements.
  - *BPExpert*. Experts are people who have knowledge relative to a concrete business area. They can provide modellers with advice relative to their expertise area, in order to improve the quality of the business process. They can also rate processes and objects in order to provide a measure of their quality. BPExperts also rates BPModellers according to the quality of their business processes.
  - *BPExecuter*. The executer is a person who executes a business process, obtaining a concrete result. The executer can search for processes according to the concepts of the domain ontologies as well as the rating provided by other users. Finally, they can rate business processes and other users.
- *Rate*. As commented in the operation model, the collaboration is not only obtained by means of the social environment included in the tool. The rating provides the possibility of measuring the quality of the business process as well as its accuracy and adaptation to the given problem. In a lower detail, each object (situation, action, decision...) can be rated according to the point of view of executers, experts and other modellers. Users can also be rated by other users according to the level of agreement with their ratings of business processes. The properties of a rate object are:
  - *comment*. This is a text property containing the comment of the user who rates.
  - *rating*. This is a float value representing the rating provided by the user using a Likert scale (0 10).

The rest of the elements of the model were presented in previous works (Garcia Crespo, Ruiz Mezcua, et al., 2011):

- *Action*: an action is a task to be performed in a business process. One action can be executed by one person or by a software agent.
- *Situation*: a situation is a step in the business process in which it is necessary to execute an action and make a decision about the next step to take. Since one action can be executed in different situations, one situation has an action related and each action can be related to several situations.
- *Context*: a context represents a concrete status of the environment of the business process. Let us suppose the action "contact mobile provider". This action is related to a situation: the stock of mobile phones is under a threshold (i.e. 100 units). But this situation can occur under different conditions. For example, in sales periods we can contact with Provider A because it is faster than others and, in regular periods, we can contact with Provider B because it is the cheapest one. Thus, the process definition includes the definition of the different context in which the process can be executed.
- *Decision*: a decision represents a rule applicable in a concrete situation in order to decide what the next action in the business process is.

Apart from that, two new properties have been included in each element of the ontology:

- *Rating*. It represents the mentioned weighted mean of the ratings provided by the other users, taking into account the individual rating of each user. This property is calculated by Eq. (1), defined in the operation model.
- *Annotation*. It represents the relationship between the concept and one or more concepts of other domain ontologies.

Thus, the old ontology has been extended to the new requirements of SABUMO. The system architecture is described below.

3.3. SABUMO reasoning

As mentioned in the operation model, SABUMO provides the possibility of executing the business process defined in the same

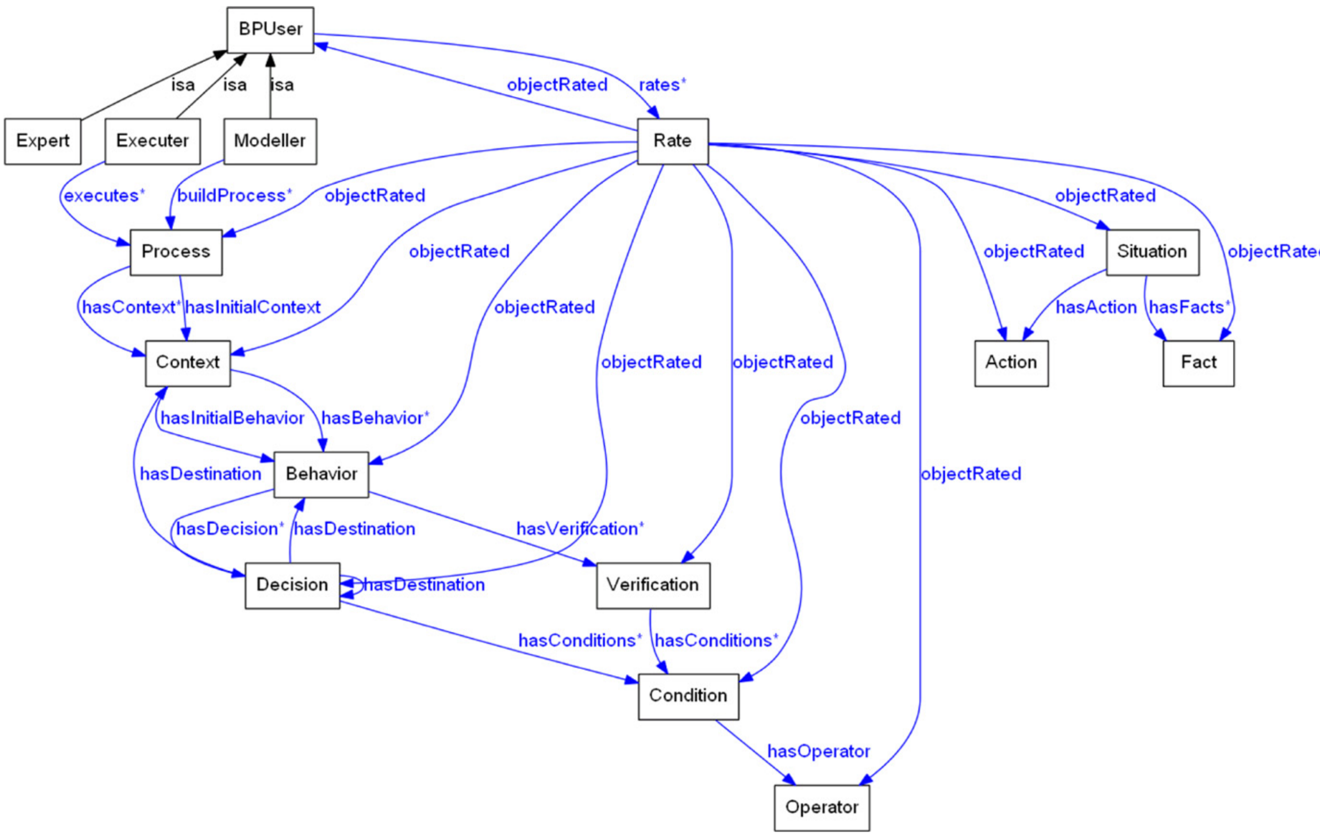

Fig. 2. SABUMO ontology.

environment. Prior to the execution of the business process, the searching process allows the BPExecuter a suitable business process for their interests. This searching process is enriched by the rules and axioms of the domain ontologies. It allows the location of related and approximated terms based on the initial search.

Once the business process has been found, the reasoning process is based on the interpretation of the process defined by BPModellers. Each situation is translated into a concrete action whose results are evaluated with the decisions associated to the situation. These decisions are translated into a number of if then rules that are evaluated by the inference engine of SABUMO in order to determine the next situation of the process (Ruiz Mezcua et al., 2011). New features have been defined for the inference engine in order to allow the rating of the situations and the results of the business processes according to the restrictions described in the operation model. In this way, after the execution of an action, the BPExecuter can rate it.

3.4. SABUMO architecture

The architecture of SABUMO is based on a well established framework which allows the semantic definition of business processes (Ruiz Mezcua et al., 2011). As shown, the original ontology has been extended according to a new operation model based on the collaboration between a number of people related to business processes from several domains. The main elements of the architecture are defined below. Fig. 3 depicts the elements of the proposed architecture. These are described in the next subsections.

3.4.1. Interface

One of the weaknesses of the previous approach (Ruiz Mezcua et al., 2011) was related to the web environment. This work was based on the web execution of the business processes. However, the definition of the business processes was based on a desktop application. It could be useful in scenarios with no Internet connection. However, the natural way of defining web based business processes is by means of a web based environment. This web based environment combines the elements required for the definition of each business process based on the representation ontology. Thus, each BPModeller can create as much business processes as he or she needs. While the BPModeller is creating a defining process, he or she can label the process and each of their elements (contexts, situations or decisions) by means of domain ontologies. BPExperts can help BPModellers by rating the business process and their elements.

Due to the new requirements identified, an administrator interface allows the definition of ontologies to be used for labelling both users and business processes. This administrator interface also allows the management of the web site.

A third element of the web environment is the execution GUI. The defined business processes are based on the execution of actions based on web interaction with BPExecuters. For this reason, once a business process is defined, it can be published in a production environment. The production environment is accessible to all the users, who can rate each situation during the execution of the process. Thus, on the one hand, BPModellers define the business process, labelling both the process and actions and, on the other, BPExecuters execute the business process rating, both the process and the actions. This allows the problems to be identified and provides the necessary feedback for the continuous improvement of the process.

As shown, there are three different user profiles, each with a specific role, but all of them involved in the creation, execution and improvement of the business process. The proposed framework provides specific elements in order to ease the work of each type of user. Interface contains the four modules described below:

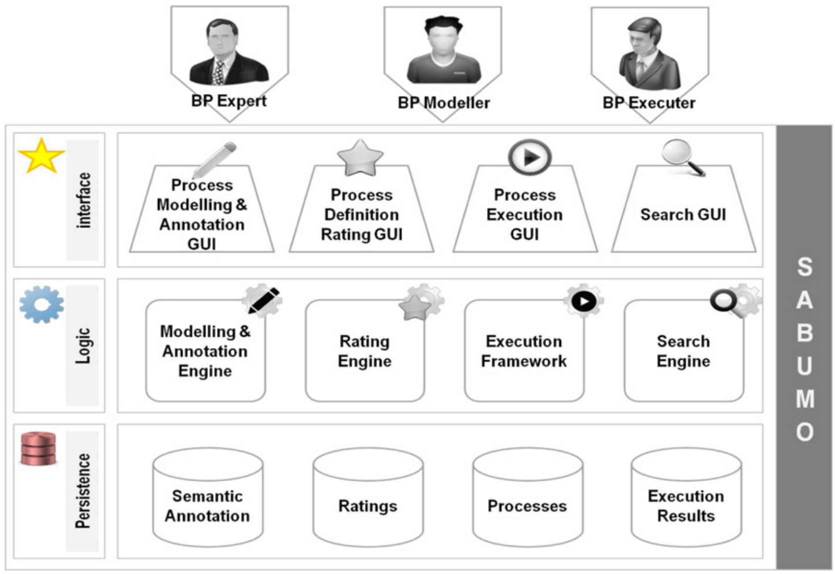

Fig. 3. Framework architecture.

- *Process Modelling and Annotation GUI.* The process modelling and annotation GUI allows the definition of the business pro cesses based on the above mentioned ontology. Once the busi ness process has been created, the process and its elements can be annotated using the domain of domain ontologies. The inter face allows BPModelleres for the easy annotation of the pro cesses and their elements.
- *Process Definition Rating GUI.* Once the business process has been defined by the BPModellers, it can rated by one or more BPEx perts. Using the GUI rating, the BPExperts can access processes and their annotations and rate them separately. According to the rating of the experts, the BPModellers can make decisions about the business process and can also rate the suggestion received in order to identify the most accurate BPExperts.
- *Process Execution GUI.* This element of the framework is respon sible for the execution of the business processes defined by the BPModellers. This element is based on the inference engine pre sented in Ruiz Mezcua et al. (2011). During the execution of the process, BPExecuters can rate the process as a whole or each element of the process (situations, decisions, results, ...) in order to provide feedback to BPModellers. Thus, BPModellers can make decisions based on the rating provided by BPExecut ers and BPExperts.
- *Search GUI.* This engine searches for business processes and users based on the semantic annotation of each. Thus, each user (BPModellers, BPExperts or BPExecuters) is labelled according to the concepts of domain ontologies. Each business process is also labelled with the domain ontologies to which it is related. Then, BPModellers can search for BPExperts related to the busi ness process in which they are working. They can also search for other business processes or elements in order to reuse ideas or feedback. BPExperts can search for business processes related to their expertise area or even other BPExperts in order to share information. BPExecuters can search for business processes according to their requirements, along with BPExperts and BPModellers, to contact them for collaboration.

3.4.2. Logic

Under the interface, the logic layer provides the engines which allow the operation of the framework as a whole.

The annotation engine is based on OWL ontologies. On the one hand, the ontology of business processes extended with the users ontology and, on the other, the domain ontologies which allow the annotation of business processes and users. Thanks to the interaction of these ontologies, all elements are inter related and it allows the intelligent search of them.

The rating engine allows the rating of business processes as a whole, of independent elements of business processes, and of users. This engine automatically updates the rating of each ele ment using (1) described in the operation model.

Once the business processes have been defined and labelled, they can be upgraded to the production environment. This produc tion environment is based on that presented in Ruiz Mezcua et al. (2011). The rating engine has been adapted in order to allow the rating of the execution of the business process. Thus, the user can rate the business process and its elements while it is under execution. The advantages of the execution framework are clear: the execution is integrated with the rest of the framework and is web accessible. Both BPModellers and BPExperts can work to gether to improve the business process.

The search engine allows the searching of elements based on the concepts of the domain ontologies. The search is based on both annotations and ratings, using SPARQL and rules as underlying technology. SABUMO allows the search based on concepts of the domain ontologies, including the option of establishing a threshold in the rating. For example, the user can search for BPExperts in machining processes rated with more than 3 points. In this way, users can identify who are the best rated BPExperts, BPModellers or BPExecuters in order to contact them or access their business processes. On the other hand, the best business processes can be identified through the ratings.

3.4.3. Persistence layer

The persistence layer provides the logic layer with permanent storage of data for the process definition, annotations, ratings and the execution of business processes. The business processes and the domain ontologies are represented and stored in OWL for mat, while the annotations and the rating system mix the OWL storage and a conventional database system in order to improve the system performance. This hybrid approach is based on the fact that the results of the process execution are stored in database sys tems. Hence, the database of annotations and ratings links the OWL storage with the database system.

4. Validation

4.1. Experiment design

The validation has been carried out based on the business processes defined in Garcia Crespo, Lopez Cuadrado, et al. (2011). This work presents a complete case study composed of five different sales processes in the Telco domain: faxes, telephones, DSL, mobile phones and an all together solution. For our purposes, these processes have been divided into four different business processes (Fixed Line Phone, DSL, Cell Phone and Combined Solution). Three BPModellers modelled these business processes using SABUMO. Thus, each BPModeller has modelled four business processes. After that, all BPModellers rated the process definition of such business processes. Once this step is completed, a total of 12 business processes together with their ratings were available in SABUMO for testing purposes.

The main objective of this validation is to compare SABUMO search results with results provided by a set of experts from the Telco domain. To do so, two experts were selected in order to provide a process recommendations based on the requirements of the users. The other side of the comparison was formed by a set of tasks performed by a group of 10 BPExecuters. The task consisted of the search for and execution of three business processes suitable for their particular needs in the Telco domain. All subjects provided feedback about their experience using SABUMO. Research design is depicted in Fig. 4.

The interactions of BPExecuters with SABUMO are as follows. BPExecuters, using SABUMO, searched for three business processes according to their interests that were coded in questionnaires in order to be used later by Experts. Secondly, once they had found a suitable business process, they executed it in order to obtain a recommendation. BPUsers were asked to rate the execution of the business process in order to rate the process as it is (not the result). This value is useful for determining the level of agreement of the user with the actions defined in the business process. At the end of the process, they rated the result obtained in order to provide feedback about the business process executed. In short, every subject acted as BPExecuter and by means of a questionnaire rated four factors related to SABUMO: Search experience, Search results, Execution experience and Execution results. This rating was a Likert scale, whose descriptors were as follows:

- 0 Very bad.
- 1 Bad.
- 2 Regular.
- 3 Somewhat good.
- 4 Good
- 5 Very good

Data collection was conducted through a questionnaire that obtained information from both users and experts. The field work of the survey was conducted by the authors. All questionnaires were filled out by subjects and experts with the assistance of at least one researcher. Questionnaires were answered on printed copies and subsequently coded in the statistical analysis tool GNU R.

Taking into account that some of the components (e.g. Modelling) had already been tested Ruiz Mezcua et al. (2011) with notable results. This research design aims to test SABUMO as a whole, including the new features of the system, which are focused on the importance of social rating, the execution framework along with semantic annotation and search features. Thus, a testing of the output of the system from a BPExecuter point of view was considered convenient.

4.2. Sample

The sample consisted of three groups of subjects. For business processes definition, three experts of the telecommunications area were selected to play the role of BPModellers. They were in charge of the definition of a business process along with the rating of the process of the peers. This first group of subjects was formed by three male experts with an average age of 39.9 years, all of them working in Telco companies for more than 10 years and with experience in Business Process Management.

The second group of subjects played the role of BPExecuters. The group consisted of a set of 10 subjects, three women and seven men. All subjects were Masters students with an average age of 25.6 years. In order to guarantee that subjects had sufficient knowledge about the functional domain, they were selected from those who purchase Telco products regularly.

Finally, the third group of subjects was formed by a set of experts that performed the recommendation of business processes according to BPExecuters requirements. This last group consisted

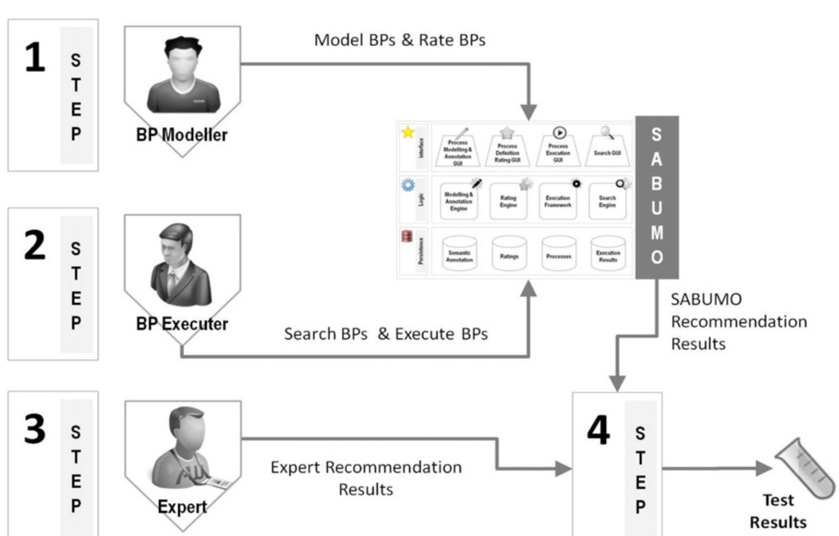

Fig. 4. Experimentation scheme.

of two male experts working in the telecommunications sector for more than 10 years with an average age of 43.2 years.

4.3. Results

Table 1 shows the results obtained from the validation of SABUMO with respect to BPExecuter feedback on Search experience, Search results, Execution experience and Execution results. Results show that, in general, features are well considered. The highest average is for Execution experience (4.37) while the lowest is Search Experience (3.77). With respect to standard deviation all scores are below 1 (Search experience: 0.90; Search results: 0.81; Execution experience: 0.67; Execution results: 0.96) which means that, taking into account that the rating was performed using a scale with a total of six values, the level of agreement in considerably high. To analyze whether differences among variables analyzed existed, the ANOVA analysis was used. ANOVA provides a statistical test of whether or not the means of several groups are all equal. The aim of this test is to find out if authors extended their answers to all issues assessed in SABUMO. Results show that there are significant differences between groups ($F(119) = 2.775$, $p < .05$) and, thus, users performed their assessments of all factors with a different criterion, producing an independent evaluation of these factors.

Table 2 shows the comparison between the results provided by SABUMO and the suggestion of the expert. In order to measure the accuracy of SAMUMO suggestions, Precision measure was calculated. Precision and Recall (not used in this study) can be seen as extended versions of accuracy metric. This metric computes the fraction of instances correct from the returned. In this case, Precision is taken as a synonym of fidelity. According to results, the Precision of SABUMO in the recommendations is 86.67%.

However, a deeper look at results show that most of the inexact suggestions falls in a BP of the same category of the BP suggested by SABUMO. If we consider valid all recommendations that fall in the same product family, then the Precision of SABUMO is 96.67%. It is noticeable that all cases in which a given BPExecuter provides a low rating to search results, such results does not corresponds with the expert proposal. In other words, it is probable that we can encounter here a bad annotation or too few ratings from the BP itself or its annotation.

4.4. Discussion

Results show promising values relatives to the assessment of SABUMO in four relevant aspects. Firstly the search experience has been rated with a mean value of 3.77. It is a good result, taking into account that the search interface is based on the selection of keywords from a set of domain ontologies. This search method can be less intuitive than others (e.g. faceted search), but it allows more accuracy in search definition with respect of a given domain. In future works it is aimed to deal with the improvement of the search definition interface. In any case, authors believe that the rating is more than acceptable.

Secondly, the overall assessment of the Search results factor is 4.2. As remarked in the previous section, the cases in which search results were different from expert suggestions were rated with less punctuation. It is important to notice that BPExecuters were not aware of the suggestions of the expert, and this difference in the results did not affect the punctuation provided by BPExecuters.

With respect to the functionality provided by the business process, the punctuation reaches 4.37 points. This outstanding result is grounded on the good definition made by BPModellers who provided a number of good business processes along with a set of useful ratings. Apart from that, it also indicates that SABUMO is powerful enough to define useful business processes in an accurate way.

Results obtained from the business processes execution were rated with 4.03 points in average. It shows that, although the

Table 1
Score of the search functionality.

BPExecuter	Search definition	Search score	Execution	Result
1	4	5	4	3
1	4	3	3	2
1	3	2	4	2
2	3	4	4	5
2	3	4	4	5
2	3	3	3	4
3	4	5	5	3
3	4	4	5	4
3	4	5	4	4
4	5	4	5	3
4	5	3	4	3
4	5	4	5	4
5	4	5	5	5
5	4	5	4	4
5	4	5	5	5
6	5	5	5	5
6	5	4	5	5
6	5	3	3	2
7	4	4	5	4
7	3	4	4	4
7	4	4	5	4
8	2	5	4	4
8	2	4	4	5
8	2	4	5	5
9	4	4	5	4
9	4	5	5	5
9	4	4	5	4
10	3	5	4	4
10	4	5	4	5
10	3	5	4	5
Mean	3.77	4.2	4.37	4.03

Table 2
SABUMO and expert suggestions of business processes.

BPExecuter	Searched product	SABUMO suggestion	Expert suggestion
1	All	BP11	BP11
1	DSL	BP4	BP5
1	Phones	BP11	BP2
2	All	BP12	BP12
2	DSL	BP5	BP5
2	Mobile	BP7	BP7
3	DSL	BP5	BP5
3	Mobile	BP7	BP7
3	Phones	BP3	BP3
4	All	BP10	BP10
4	Mobile	BP9	BP8
4	Mobile	BP8	BP8
5	All	BP12	BP12
5	DSL	BP4	BP4
5	Mobile	BP9	BP9
6	DSL	BP6	BP6
6	Mobile	BP8	BP8
6	Phones	BP2	BP3
7	DSL	BP6	BP6
7	Mobile	BP7	BP7
7	Phones	BP1	BP1
8	ALL	BP11	BP11
8	DSL	BP4	BP4
8	Phones	BP2	BP2
9	DSL	BP6	BP6
9	Mobile	BP9	BP9
9	Phones	BP2	BP2
10	All	BP12	BP12
10	DSL	BP4	BP4
10	Mobile	BP8	BP8

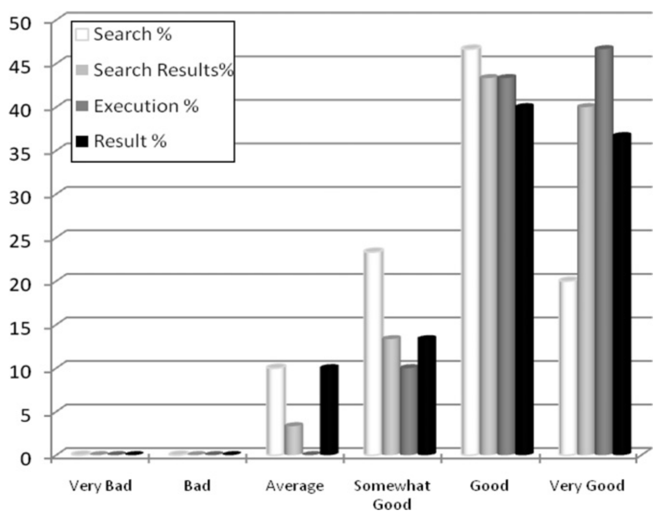

Fig. 5. Distribution of valorations.

business processes were suitable for the users, they do not agree with the results of the business processes in the same level.

Fig. 5 depicts the distribution of the punctuations for each category. The figure shows how the higher values are the most used by the users. The execution is the aspect better evaluated. The majority of the ratings fall between 4 and 5, showing the wide acceptance of SABUMO among BPExecuters.

With respect to Precision values, the results are more than promising. Previous works regarding recommender systems (Garcia Crespo, Colomo Palacios, et al., 2010, 2011) presented notable values, but in the case of SABUMO, these results have improved in remarkably. However, it is important to note that there are many limitations in the case of SABUMO that other efforts do not present. In the first place, the limited sample available in the test set. In the second, the limited scope of the functional environment of the testing environment. A final limitation comes from the implications of the use of certain technologies (e.g. Natural Language Processing) not present in SABUMO in the Precision of recommendations.

It is important to note that many of the results of SABUMO depend on the ability, knowledge and implication of BPModellers in business processes modelling and rating. But, in many cases, it is not easy to find good modellers. To fight against this shortage, SABUMO offers the possibility of rating their work among peers or even of using assessments from BPModellers and BPExperts. This new feature, not present in previous literature, implements a 360° assessment and enables a continuous improvement slant in business process modelling. Thus, taking into account ratings, BPModellers are able to improve their BP definitions and to compete to be the most valued among the community. Following the path drawn by Erol et al. (2010) and Bruno et al. (2011), this approach, present in many social web killer applications, can be considered as one of the main contributions of SABUMO.

5. Conclusions and future work

As mentioned in Sharma et al. (2010), nowadays in a Knowledge Society, knowledge must present a tacit structure for sustainable advantage for companies. In accordance with the literature referenced, the knowledge workers perform their duties in knowledge intensive organizations, trying to keep current knowledge and to innovate to expand it. Finally, knowledge management, both for personalization and codification, emerges as the core management of paradigm future survival strategy of the 21st century.

In this scenario, several technologies and approaches have been developed by industry and researchers to increase the performance and the productivity of the companies. In this sense, Artificial Intelligence (AI) techniques aims to represent the knowledge in a way that can be applied to solving complex problems or to supporting decision making processes.

Taking into account these conditions, this paper presents a framework for Semantic Annotation and Business Processes Modelling, based on semantic technologies, that allows experts to represent and to share their knowledge with other experts by means of shared and controlled vocabularies. The suitability of the technologies used in this research has been demonstrated in Section 2. The main components of the SABUMO framework, Business process modelling and Semantic Web technologies, have been adopted by several authors to model those business aspects necessary for a correct performance of the business process applications and to increase the expressiveness and reuse of the grammars associated. The framework also permits the execution of the business processes represented by the experts. Moreover, SABUMO enables the execution of these processes using its own platform in an easy and scalable way. Therefore, the proposed framework allows the complete lifecycle of the business process, from its definition to its execution and continuous improvement.

Initial results of the evaluation setup show promising results both in usability and recommendation results. The tests performed have analyzed the assessment of SABUMO in four relevant aspects. In all the cases, the authors have discussed the feasibility of the research, taking into account the acceptance of SABUMO among the different users involved, and gathering their feedback by means of ratings.

The implications of the inclusion of the social collaboration between the stakeholders of business process provide a wide number of lines for future research. First, the authors analyze the possibilities of enhancing the inference process in order to use the ratings provided by BPExecuters and BPExperts to dynamically change the priority of the decisions during the execution of the business process. Secondly, since business processes and their components are labelled using domain ontologies and rated by other users, the authors are studying the intelligent suggestion of components based on the annotations associated to a business process: for example, given an action of a business process, the decisions related to this action can be automatically suggested on the basis of the annotations, providing the highest rated decisions semantically related to that action. This will allow the continuous adaptation of the business process to the real perspective of the stakeholders.

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