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Business Functions Ontology and its Application in Semantic Business Process Modelling

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Abstract

Current business process modelling tools support neither restricting names nor using ontologies to describe process artefacts. This lack results in creating non-consistent process models which are difficult to understand, compare, evaluate and re-use, etc. Within this article we argue that the Business Functions Ontology (BFO) developed within the SUPER project may be effectively used while modelling processes as a mean for annotating them and thus help to avoid some of the above mentioned problems. We show the BFO structure as well as an example of its practical application within a tool for business process development.

Keywords

Semantic Business Process Modelling, Business Function, Business Vocabulary, Ontology.

INTRODUCTION

Business process modelling is the first phase of the Business Process Management (BPM) lifecycle. The main goal of the business process modelling is to produce a business process model depicting and describing the activities that contribute to the production of good or delivery of service taking place in an enterprise. Then, the developed process model needs to be linked to the existing IT infrastructure in order to be executed. This linkage is usually done by the IT department.

One of the main problems in business process modelling is the freedom that the business analysts have to name and describe process artefacts. Current business process modelling tools support neither restricting names nor using ontologies to describe process artefacts. Examples of wrong naming approaches are the following: use of the same term with a different meaning (homonym); use of different terms for the same concept (synonym); use of inappropriate expressions. In addition, different definitions of the same term may be used by various business analysts i.e. process creators. This leads to several problems. One of them is that the modelled business process is fully understandable only to its creator. Furthermore, if multiple roles are involved in the process modelling, they often use terms at different abstraction levels what results in non-consistent process models that are difficult to compare. In addition, if one would like to translate a business process model into another language, for instance from English to German, more problems would appear. Some terms are recognized as synonyms and the proper meaning of homonyms cannot be identified. Also, subtle differences in wording are very hard to translate.

Other problems appear when the modelled business process is passed to another phase within the lifecycle. Business experts and IT experts do not speak the same language, do not share the same concepts of processes, or use the same tools. In consequence, the implementation of the process does not necessarily meet the expectation of business experts. It is so because either the IT department does not understand what should be implemented or the business experts model something that cannot be done using the available IT infrastructure.

In order for enterprises to benefit from business process modelling efforts, business analysts require better support in creating process models. Some of the above mentioned problems could be avoided if a controlled vocabulary recommendation mechanism would be available within the modelling tools. This would enable business analysts and IT experts to achieve consistency in naming of business process artefacts when modelling

a process and thus also improve the understandability of the business process model during the implementation phase. However, current business process modelling tools provide only little guidance to the user and, thus, resemble a scratchboard rather than a technical approach. If any guidance is provided at all, it is on a purely syntactical level which does not account for business semantics.

One of the initiatives to support business analysts with predefined set of knowledge during the modelling phase is the Semantic Business Process Management (SBPM) (Hepp et al. 2005) concept developed within the SUPER project[1]. SBPM aims at automation of the business process management life cycle with use of semantics and Semantic Web services technology. The key issue to fulfil this aim is to provide an adequate machine-processable representation of both process structure (control- and dataflow) and the process content description. The process content relates to the enterprise and its environment and therefore must rely on a proper and unambiguous organization description represented in a machine-understandable manner. As the main parts of the process model are activities, therefore, the main ontology needed for description of processes should describe functions performed within an enterprise. It should provide a common, widely acceptable foundation for structuring and defining business functions. This ontology together with the ontologies modelling other parts of an enterprise, i.e. business resources ontology, roles ontology, organizational ontology, strategy ontology, goals and policies ontology, provides complete description of the organizational process space.

The main aim of this paper is to show the Business Functions Ontology (BFO) developed within the SUPER project and how it may be used to annotate processes. We argue that BFO derived based on careful studies of current approaches and classification used by ERP systems may become a commonly accepted terminology to name functions and activities that may be used by business analysts to describe a process. In addition, we show how we can support business process modellers more actively and create high-quality business process models using intuitive and self-explained approaches.

The article is structured as follows. First, the BFO is presented. In the following section, we delve into the sources based on which the BFO was created. Further, we show how the BFO can be applied within the business process modelling phase. The article concludes with some final remarks.

BUSINESS FUNCTIONS ONTOLOGY

BFO[2] has been developed in order to provide basics for structuring and defining generic business functions in enterprises and thus to enable a more thorough access to organizational aspects within the modelling and analysis phase. BFO may be also used for classification of processes or process fragments when discovering process fragments for the needs of autocompletion (Markovic 2008). For the needs of the BFO, a business function was defined as “a functional area of an enterprise”. The exemplary functions which are in accordance with this definition are e.g. Human Resources Management, Sales Management, etc.

The discussed ontology consists of two parallel structures: the *Function* and *ActivityOrStep* structures. The Function structure gathers top-level concepts which reflect the broadly recognizable business functions within most of enterprises. *ActivityOrStep* structure is designed at far more detailed level of abstraction. The concepts from both structures are mutually linked by transitive *isSubPhaseOf* attribute of each of top level *ActivityOrStep* concepts. The suitability of established connections is ensured by constraining axioms.

The final version of the *Function* tree consists of 40 concepts, 14 of them are top-level ones and the rest is grouped as their sub-concepts. The top level concepts name coherent and autonomous areas of functionalities. Some of the top level concepts, such as e.g. *FinanceManagement*, are further divided into sub-functionalities. Figure 1 presents the current *Function* structure of the BFO.

The *ActivityOrStep* structure supplements the *Function* structure. Consequently, it contains most of the ontology concepts (about 920), grouped as sub-concepts of 33 top-level concepts. The *isSubPhaseOf* attribute connection determines which concept from the *Function* structure is complemented by a particular group of activities. The attribute is inherited by sub-concepts within the *ActivityOrStep* tree, therefore assigning the function to a given activity is equivalent to assignment of this function to all the concepts of the activity’s sub-tree.

[1] www.ip-super.org
[2] The Business Functions Ontology can be found at http://www.ip-super.org/ontologies

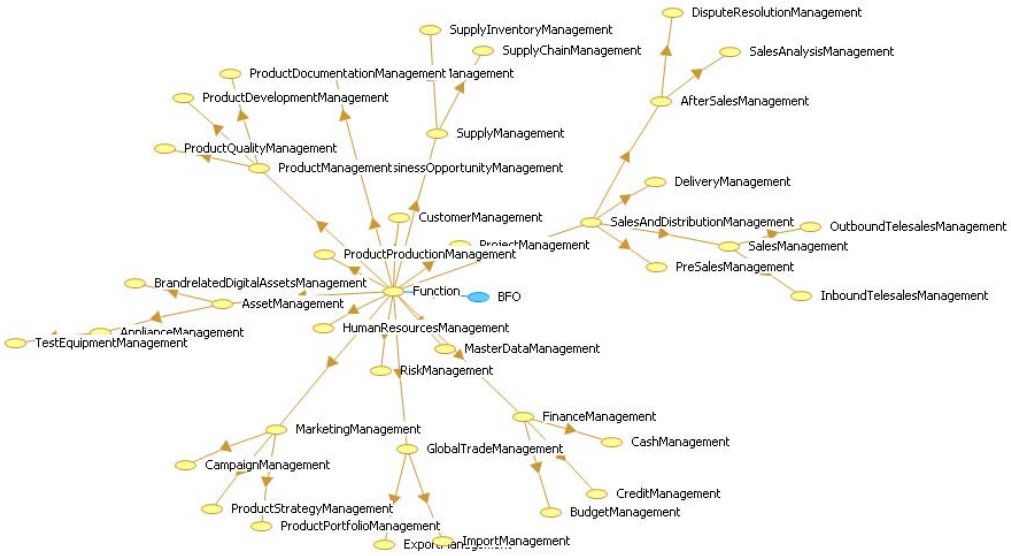

Figure 1. Business Functions Ontology – Function structure

The current version of BFO is to answer the following competency questions:

- *What are the main functional areas of the enterprise?*
- *How can the areas be further divided?*
- *What activities does the X-business function include?*
- *What kind of business function is an X- business sub-function?*

We decided to use the ontology as a knowledge representation technique as to overcome the conflicts mentioned in the introduction that may occur between various actors. The developed information model expressed using ontology ensures that business analysts use a standard mean to describe attributes of processes, tasks as well as functions. Simultaneously, it ensures that within the next phase of the BPM also IT experts use the right mean to express the information about the services and therefore facilitates matching between various phases of BPM lifecycle.

By modelling certain functions as classes in a Semantic Web language, we can classify them into hierarchies and model additional relations that exist between various concepts. Moreover, the ontological representation of the information is expressive and machine-understandable and can be automatically processed. One of the advantages of using a semantic description language is that one can use machine reasoning in particular class subsumption to bridge different levels of abstraction (as mentioned in the following section) that occur when specifying properties of a process or task. In addition, the ontology is a concise and complete representation technique, flexible and easy to understand. Although machine reasoning is sometimes perceived as not so efficient, the state-of-the-art reasoners are proved to be both efficient and effective (Bishop and Fischer, 2008).

KNOWLEDGE SOURCES USED TO DEVELOP THE BFO

The purpose of the BFO is to provide a common foundation for structuring and defining business functions. Therefore, while creating the ontology we took inspiration from previous initiatives in this area. The best sources to guide the conceptualization process and modelling decisions turned out to be the currently existing approaches to formalize the process space (REA, TOVE and Context-based Enterprise Ontology). To obtain a source of different types of functions and activities we took advantage of the classification used by ERP systems on the example of the SAP Business Maps.

A concise description of the related work taken into account during the conceptualization phase of the ontology development is presented within this section. First, a short overview of the ontology in the area of business functions is discussed, and then the ERP system being an inspiration to the developed ontology is presented. While presenting each of these approaches we also mention the differences and similarities between them and the developed BFO.

Enterprise ontologies

This subsection presents the most important initiatives in the field of business and enterprise ontology modelling. For more detailed description of initiatives in this area please see (Filipowska et al. 2007).

The REA (Resource-Event-Actor) enterprise ontology is based on elements of the early REA model (McCarthy 1982) containing only the concepts of resources, events and agents. The theoretical background of REA comes from the field of microeconomics. All REA concepts and definitions are applied to the collaborative space between enterprises where market exchange occurs among two or more trading partners (Geerts and McCarthy 2000). In REA Enterprise Information Systems the economic activities of enterprises (thus business functions and activities) are represented as a top-down decomposition with three layers: the enterprise scripts, processes and low-level tasks. In this case a business function is not perceived as a subject of separate ontology or domain, but it is embodied into comprehensive REA ontology.

Another work in the field of business ontologies is the TOVE initiative (Fox 1992). The goal of the TOVE project was to develop a set of integrated ontologies for modelling of both commercial and public enterprises. The authors aimed at the creation of shared representation of an enterprise, definition of the semantics and symbols which depict defined concepts along with implementation of the semantics in a set of axioms in order to provide automatic deduction capabilities. In later works of the authors some additional aspects like quality (Kim and Fox 1994), organizations integration (Fox and Gruninger 1994), costs of actions and resources (Tham et al. 1994) were also identified. As a result of works conducted in the TOVE project, two foundational ontologies (Activity, Resource) and four business ontologies (Organization, Product and Requirements, ISO9000 Quality, Activity-based Costing) were developed. We find the granularity of respective ontologies inconsistent, what makes them inoperable to use. In this case also a business function is not perceived as a subject of separate ontology or domain, but it was embodied into comprehensive business ontology.

Another initiative close to our work is the Core Enterprise Ontology (CEO) being an upper level ontology defining enterprise concepts proposed by Bertolazzi et al. In this approach, a specific enterprise ontology is built starting from CEO and proceeding top-down in the refinement and decomposition hierarchies.

Another inspiration comes from the Enterprise Ontology (EO) developed by Uschold et al. EO is a collection of terms and definitions relevant to business enterprises (Uschold et al. 1998). It was developed as part of the Enterprise Project, with the aim to provide a framework for enterprise modelling. EO is divided into five parts: i) terms related to processes and planning, ii) terms related to organisational structure, iii) terms related to high-level planning for an enterprise, iv) terms relating to marketing and sales of goods and services and v) terms used to define the terms of the ontology together with a few terms related to time. It offers comparable levels of details, however, as it was first only informally modelled in a natural language format and only afterwards ported to the semi-formal Ontolingua, its efficient application is hampered.

In 2007, Mauri Leppänen (Leppänen 2007) suggested a contextual approach to ontology development in order to gain high flexibility of the enterprise ontology. A context involves seven domains: purpose, actor, action, object, facility, location, and time. Created context-based enterprise ontology provides a unified view of an enterprise as an aggregation of contexts. This ontology can be specialized into task ontologies or domain ontologies to meet particular needs of enterprises, and still maintain connections of the specialized things to their contexts. Within this approach a business function is defined as an action domain that "comprises all those concepts and constructs that refer to deeds or events in a context" (Leppänen 2007). It scopes from the highly abstract work such as strategic planning to physical execution of step-by-step procedure with detailed routines.

The abovementioned initiatives provided an inspiration and foundation for developing the BFO. The structure of REA and Context-based Enterprise Ontology is the closest to our vision, yet it does not separate vocabulary from business process structure, what we are trying to introduce. BFO follows the understanding of business functions presented in Context-based Enterprise Ontology. However, BFO in contrast to the presented initiatives is much more focused and concentrates only on one part of the information space needed to describe the functional decomposition of coarse-grained business functions to fine-granular activities, i.e. the functional perspective of business processes (Weske 2007). The other parts of the information space are covered by other ontologies (Filipowska et al. 2007) developed within the SUPER project. As a consequence, the BFO reflects its domain in a very detailed manner providing a few layers of details and often dozens of sub-concepts which have one or even none equivalents in other knowledge models. BFO is supposed to be one of the reference ontologies used while developing enterprise-specific functional ontologies. Therefore, our intention is not to provide all means needed for defining activities on a very detailed level (as done in (Leppänen 2007)).

In this context it is worth to notice that the BFO model seems to fit into REA's three-layer architecture, not duplicating any of those layers but rather constituting the fourth one. The BFO concepts are more general than the low-level layer which in the case of REA resembles the process tasks concepts but they are also different than the REA's middle layer concepts. The middle layer of the REA model is to describe any given economic process as a kind of resource exchange.

ERP system categorization - SAP Business Maps

As already mentioned we decided to use SAP Business Maps[3] as an example of ERP system categorization to obtain content for the BFO.

The SAP Business Maps provide information on core processes and functions of an enterprise. They were developed based on several decades of experience gained by SAP consultants. The SAP Business Maps are comprehensive and generic, therefore, may be viewed as a kind of reference model for business processes, both industry-specific and cross industry. Their creation allowed increasing ability of companies to compete, strengthen their relationships with partners, and help enterprises to become more customer-oriented by organizational improvements.

There are two main types of Business Maps, each providing different perspective of the organizations' processes, namely:

- Solution Maps - well-defined tools that outline the scope of an organization's business. The Solution Maps also show how various processes are covered, including the processes that SAP and its partners support. Solution Maps are divided into two levels: an Overview and Business Blueprint.
- Business Scenario Maps - a collection of industry-specific and cross-industry process blueprints. They explain state-of-the-art business processes and, in addition, define the activities, roles, system interfaces, as well as the business documents required for inter-enterprise collaboration.

The above mentioned types sum up to a total of about 410 main documents.

Both types of business maps are diversified when it comes to their scope. This results in distinguishing the following map categories:

- Cross-Industry Business Maps,
- Industry-Specific Business Maps,
- Infrastructure and Services Maps.

It is essential to take into account that SAP Business Maps were designed in order to depict and concentrate on how business may create value for their customers and at the same time how SAP components may support business processes. They are, therefore, the resource containing large amount of semi-structured knowledge on many important as well as irrelevant in our case aspects of an enterprise and its processes. The SAP Business Maps can be viewed, customized, and further developed with the use of dedicated SAP tools.

Recently, on top of the SAP Business Maps the SAP Business Maps Ontology was developed offering a common schema for all entities named throughout all Business Maps. Instances of respective entities were generated in the form of separate ontology importing the schema ontology. Several sources provided input to the development process of the Business Map Ontology. On the one hand information material on the SAP Solution Composer[4] gave a rough overview of the major concepts and their meanings. On the other hand, and even more important, the Business Maps as such were analysed on an instance level. Due to the high degree of flexibility the Solution Composer offers in terms of editing options often merely a close look at the delivered Business Maps to clarify the meaning of a concept and its relations. As almost all Business Maps elements may be interrelated with each other only analysing the delivered instances revealed which interconnections were regarded as meaningful by the Business Maps creators and thus have to be integrated into a 'common understanding' of the domain of discourse. Thus, the developed ontology has to be understood as a conceptualisation of the Business Maps in their current state. By virtue of the evolutionary process of map refinement further releases of the Business Maps may contain concepts and relations which are not considered in the ontology presented in the following.

BFO used SAP Business Maps (not SAP Business Maps Ontology as it was developed shortly after BFO) as a primary source of information. Extraction of terms from the SAP Business Maps corpus resulted in 34086 terms. This large set however, was characterized by a huge number of redundancies as well as close synonymy or high level terms similarity. As the terms set was extracted without preserving any structure, the process of abstracting over Business Maps comprised a number of tasks: textual-form terms organization and removal of errors; normalization of terms; identification of concepts' context; removal of redundancies; atomization and splitting of conjunctions; identification of domain terms and exclusion of non-business-function-related terminology; integration and normalization of terminology from other knowledge sources; conceptualization; iterative restructuring, structure adjustment and concepts matching. The final ontology was obtained as a result of all the

[3] http://www.sap.com/solutions/businessmaps/index.epx
[4] http://www.sap.com/solutions/businessmaps/composer/index.epx

above mentioned tasks. After performing all preparatory tasks, a reduction in a number of terms was achieved. The potential concepts were further filtered with regard to intended granularities on different levels of abstraction.

Table 1 represents relations between SAP Business Maps Ontology and BFO. It should be highlighted that in this case one cannot use the term "mapping" between these two structures. Mapping assumes the simple subsumption relation between any two concepts and deals always with a given set of concepts limited to one on at least one side of the mapping relation. In Table 1 we point the thematic areas (sets of concepts) rather than observing strictly any single concept. Consequently, it has to be taken into account that some major changes to the SAP Business Maps were introduced before including them into the BFO structure (as mentioned in the already presented list of the development tasks).

Table 1. BFO and SAP Business Maps Ontology - Corresponding Groups of Concepts.

Source	Terms group	BFO sub-tree	Comment
SAP Business Maps	Scenario Group	Function	
SAP Business Maps	Value Chain Element	Function	Supplementary
SAP Business Maps	Business Process	Function	Supplementary
Managerial Literature		Function	Initial structure
Management Handbooks		Function	Initial structure
Other		Function	Analysis of exemplary enterprises
SAP Business Maps	Activities	ActivityOrStep	Main source
SAP Business Maps	Process Steps	ActivityOrStep	Additional source (not fully processed)
SAP Business Maps	Process	ActivityOrStep	Additional source (not fully processed)

From Table 1 one can see that the *ActivityOrStep* structure was created on the basis of three groups of terms. The entities within those groups (2817 Activities; 6720 ProcessSteps; 8925 Processes) were selected as candidate terms for lower level vocabulary based on the careful scrutinize and expert evaluation. After removal of defects of the entry Business Maps terms set the number of potential concepts in those groups was reduced to more than 3000 terms.

The *Function* structure as shown in the Table 1 is composed of concepts that reflect mainly the Scenario Group entities from the SAP Business Maps integrated with knowledge from a number of other knowledge sources (handbooks, literature overview, other research results) and combined with the ontology developers' analysis results done on the basis of exemplary enterprises and their functional organization layer.

Figure 2 gives a presentation of correspondence of granularity level between specified parts of the SAP Business Maps versus BFO. The figure provides only a general visualization. This means that not all elements were necessarily transformed from SAP Business Maps into indicated places in the BFO hierarchy and target BFO areas might contain a limited number of additional concepts of other origin.

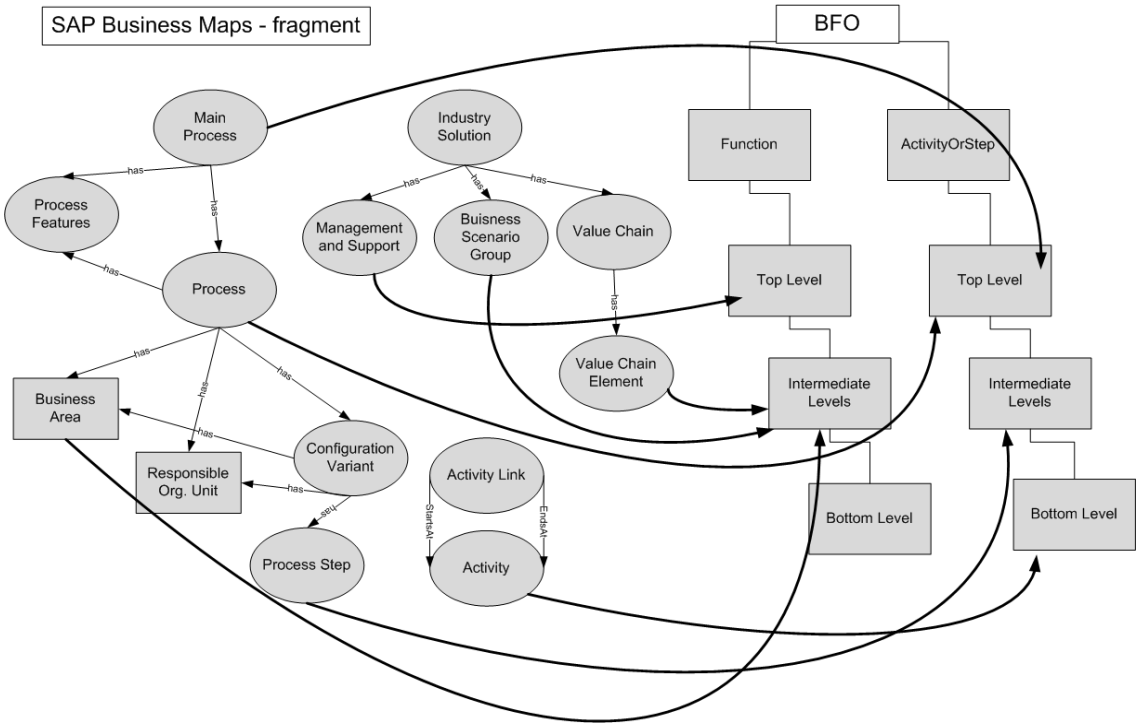

Figure 2: Granularity correspondence between BFO and SAP Business Maps structures

As it can be seen in Figure 2 the grouping and fine-tuning of entities represented by different parts of the SAP Business Maps ontology has been quite complicated especially taking into account that the intermediate and bottom levels in both structures of BFO are internally multi-level layers. In order to achieve the best effects and make it possible to handle this amount of entities, a special web system for collaborative ontology concepts alignment was created and deployed. The use of the system resulted in a swift pace of the carried work combined with high quality of the achieved outcomes.

APPLICATION IN SEMANTIC BUSINESS PROCESS MODELING

Current business process modelling tools support neither restricting names nor using ontologies to describe process artefacts. Our approach incorporates ontology-based different matchmaking functionalities which are required to bridge the gap between the business process model and the semantic world, in order to allow for description of a graphical business process model with BFO instances.

Utilizing the BFO, the matchmaking functionalities address the problem of deriving a list of proposals for a selected model element that a user has chosen for semantic refinement, based on the previously specified business function for a process or previous task in a process. To solve this problem, we use a combination of different text and name matching methods and process diagram context information. The utilization of the diagram context information of the selected model elements and the BFO knowledge helps to match the model fragments with BFO elements. Therefore, we can derive a list of element proposal using BFO elements which are already specified in the process model.

For instance, let us assume that a modeller has already created an activity “Create contract offer” which is linked to the BFO concept *CreateContractOffer*. Based on this information we can derive the process context and know that he wants to model a business process for *ContractProcessing*, as this is the parent concept of *CreateContractOffer*. Now, using the *ContractProcessing* concept of the BFO, the system knows which subsconcepts (e.g. *UpdateContract*, *ReviseContract*, etc.) are available for this function. Hence, once a modeller starts creating new activities, our recommendation engine provides him with a list of valid names based on the BFO concept hierarchy. Figure 3 sketches the user interface of our prototype. Furthermore, the BFO is linked to the Business Resources Ontology (Filipowska et al. 2007) through the relation *requiresAsResource*, which relates a process activity and a business resource required for performing that activity. We utilize this link to propose a usage of appropriate resources for the selected process activity. Figure 3 shows that the concept *CreateContractOffer* (process activity) of the BFO requires as resource the concept *ContractOffer* of the Business Resource Ontology. Therefore, the resource *ContractOffer* is suggested to the modeller.

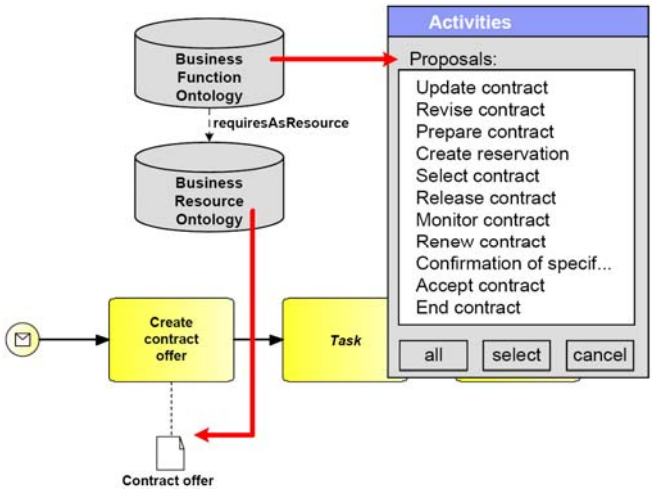

Figure 3: Recommendation engine using the Business Function Ontology

The matching can lead to even better results when using name matching functionalities, where we use a combination of heuristic comparison methods on the strings of characters, well-known string distance metrics (Cohen et al. 2003, Chapman et al. 2005), and matching methods considering synonyms and homonyms. The work concerning name-based matchmaking is related to schema matching efforts. A survey of (Rahm and Bernstein 2001) presents a nice overview of this research area. However, the fundamental difference is that schema matching tries to map between two formalized schemas (e.g. defined in XML), whereas the matching problem addressed in this paper is to find appropriate BFO elements given a free-text name entered by the user and context information derived from the process model, concerning the selected element. Nevertheless, the name matching tasks are similar for the two approaches. A comparison of (Cohen et al. 2003) describes different string distance metrics, some of which are utilized for name matching tasks in this work. Therefore, these established, general approaches for name matching tasks are reused to some extent and are enhanced with new (context-related) matching functionalities.

Using such matchmaking functionalities the engine can reduce the list of possible activities. Figure 4 continues the given example. Once a modeller starts typing the letters *re* for naming the process activity, the system will only suggest all concepts related to the string *re* which are subconcepts of *ContractProcessing* (cf. Figure 4, right).

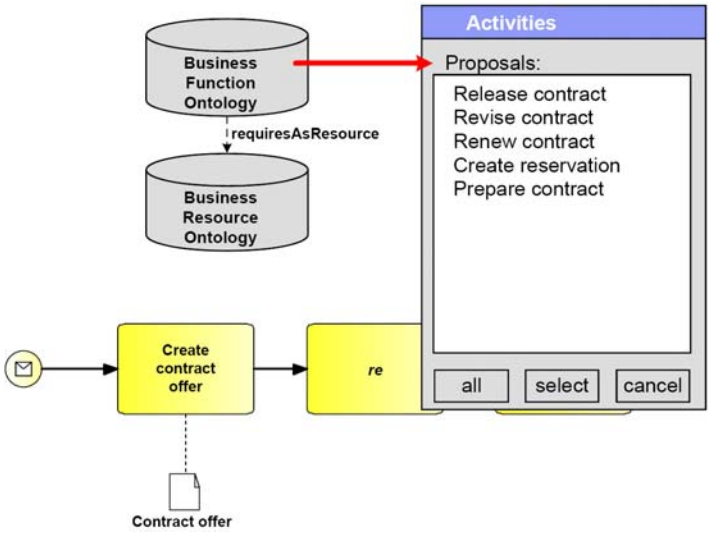

Figure 4: Name matching functionality

The description above provides remarks about the User Interface. One should however remember that in the background as a result of modelling the ontological description of a process is created (the listing below presents only a part of such a description created).

```
wsmlVariant _"http://www.wsmo.org/wsml/wsml-syntax/wsml-flight"
namespace { _"http://www.ip-super.org/ontologies/ContractProcessing#",
     wsmostudio _"http://www.wsmostudio.org#",
     bpmo _"http://www.ip-super.org/ontologies/BPMO/20070529#",
     upo _"http://www.ip-super.org/ontologies/UPO/20070529#",
     bfo _"http://www.ip-super.org/ontologies/BFO/20070731#",
     bront _"http://www.ip-super.org/ontologies/BROnt/20070801#",
     bro _"http://www.ip-super.org/ontologies/BRO#",
}

ontology _"http://www.ip-super.org/ontologies/ContractProcessing#"
 // (…)

instance ContractProcessingProcess memberOf bpmo#Process
     bpmo#hasName hasValue "ContractProcessingProcess"
     bpmo#hasBusinessFunction hasValue bfo#ContractProcessing
     bpmo#hasWorkflow hasValue ContractProcessingWorkflow
     bpmo#hasBusinessGoal hasValue goals#contractProcessed

instance CreateContractOffer memberOf bpmo#Task
       bpmo#hasHomeProcess hasValue ProductDeliveryProcess

// (…)
```

BFO concepts (the *Function* structure) are also used for annotating complete process models, parts of them (process fragments) or best practices (process patterns). This helps the modellers in retrieving (discovering) existing process models which can be re-used in their design. In our example, the modeller can query for all process models and best practices in the *ContractProcessing* function, in order to re-use and/or adapt previous work. With such support, process modellers are able to create higher quality models in less time. An even more advanced way of supporting the modellers can be realized through the autocompletion mechanism, where the modeller receives suggestions from the modelling tool regarding the subsequent process activities or process fragments to be added in the model, based on the part already modelled.

CONCLUSIONS AND FUTURE WORK

This article elaborates on the Business Functions Ontology, modelling the functional perspective of an enterprise. BFO was developed bearing in mind experience of developers of previous terminologies for description of processes as well as SAP Business Maps. We have shown how BFO concepts may be used for consistent naming of process activities and suggesting appropriate resources in process modelling, which leads to more readable, consistent and higher quality process models. We also present how BFO may be used for the description of processes, what would enable business analysts to e.g. re-use already modelled process artefacts or benefit from the autocompletion mechanism suggesting functions that may complete the process being modelled. Our current work focuses on the full integration of our concepts within the SAP Research “Maestro for BPMN” process modelling tool. In general, it is not easy to measure the quality of business process models as they usually reflect the perspective of one person and are based on individual thoughts and feelings. Nevertheless, in (Becker et al. 2003) the authors have developed the “Guidelines for Business Process Modelling” which are the basis for our evaluation. We plan to conduct a case study using the “Maestro for BPMN” tool and complement this by using surveys.

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