

Organisational Ontology Framework for Semantic Business Process Management

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Abstract. The field of Semantic Business Process Management (SBPM) has refuelled interest in using ontologies for the representation of the static and dynamic aspects of an enterprise and value chains. Putting the SBPM vision into practice, however, requires a consistent and operational network of ontologies reflecting the various spheres of enterprise structures and operations. Consistent means that the ontologies are based on compatible paradigms, have a compatible degree of detail, and include at least partial sets of alignment relations which allow data interoperability. Operational means that the ontology specifications are available in a single, current ontology formalism for which scalable repositories, reasoning support, APIs, and tools are available. In this paper, we describe a set of ontologies for SBPM that follows the mentioned requirements, and compare our work with the related efforts.

Keywords: ontology, Business Process Management, enterprise description, organisation framework

1 Introduction

Although BPM used together with SOA is believed to provide a complex approach to manage business processes in an enterprise, currently it offers only little support for automation of the BPM lifecycle. It is especially visible when it comes to the difficulties in smooth and automatic transition from one phase to another.

Various attempts were undertaken to provide a holistic view of the process space and achieve a higher level of automation in the BPM lifecycle. One of the most advanced initiatives in this area is the concept of Semantic Business Process Management (SBPM) developed in the SUPER project [1] taking advantage of the Semantic Web technologies (ontologies and reasoning mechanisms).

In order to fulfil its aims, SBPM needs a semantic representation of various artefacts used within all of the phases of business process management. Therefore, apart from the semantic description of the process flow (control structure), the process content description is also required. The process content relates to the enterprise and its environment. Thus, putting the SBPM vision into practice requires a consistent and operational network of ontologies reflecting the various spheres of enterprise structures and operations. Consistent means that the ontologies are based on compatible paradigms, have a compatible degree of detail, and include at least partial sets of alignment relations which allow data interoperability. Operational means that the ontology specifications are available in a single, current ontology formalism for which scalable repositories, reasoning support, APIs, and tools are available.

The goal of this paper is to present the notion of the consistent and operational set of organisational ontologies aiming at providing vocabulary and constraints for describing the environment in which processes are carried out from the organisations perspective. In order to fulfil its aims, the article is structured as follows. First, the related work in the area of process artefacts representation is shortly discussed. In the following section the description of a consistent organisational ontology stack is given along with an application of the organisational ontologies within a domain-specific use case scenario. In Section 4 we conclude our work with a comparison between our work and related approaches and provide arguments in favour of our contribution.

2 Related work

The process content depends on organisation and its characteristics. Many researchers focused on development of models or ontologies cataloguing an appropriate scope of information on companies that should be considered when describing organizations or their processes e.g. [2][3]. For instance [2] highlighted that a process model should provide information on what is going to be done (i.e. functionality), who is going to do it (i.e. actors), when and where it will be done (i.e. location and time), how and why it will be done (i.e. means and motivation), as well as who depends on the results that are to be achieved (i.e. dependencies with other processes). Further on, the authors distinguished four different perspectives on the process, namely: functional, behavioural, organisational and informational. These perspectives underlie separate yet interrelated representations for analyzing and presenting processes.

The mentioned initiatives focused not only on the scope of information to be considered but also on its representation. Within the last few years there have been numerous initiatives attempting to capture the process-related and also organisation-related information in a machine-friendly manner. Most of them focused on possible application of semantics, as ontologies are perceived as a good way to capture the domain and its relations [4, 5, 10, 15]. These initiatives differ, when it comes to the scope of the process description they intend to cover, the level of details of the ontology created, as well as the formalism used.

One of the earliest initiatives was the TOVE project [6] that aimed at development of a set of integrated ontologies for modelling all kinds of enterprises (i.e. commercial and public ones) [4]. TOVE Common Sense Model of Enterprise included three

levels: reference model with typical business functions (finance, sales, distribution, and administration), generic model (with such concepts as time, causality, space, etc.), and concept model (e.g. role, property). However, the granularity of developed ontologies may be perceived inconsistent what hampers their potential application..

The REA enterprise ontology [7] is based on elements of the REA (Resource-Event-Actor) model [8]. The REA concepts and definitions are applied to the collaborative space between enterprises where the market exchange among trading partners occurs. Although REA is considered one of the most promising business domain ontologies, it is criticized for the lack of clarity and inconsistency e.g. [9].

The main aim of the e3-value project [10] was to propose the methodology to help in eliciting, analyzing, and evaluating e-commerce ideas. Therefore, the e3-value ontology was introduced as a tool to help explaining the concepts used to represent e-commerce ideas. The ontology provides concepts for describing economic exchange among partners. Other e3-value extensions like e3forces, e3competences should be of particular attention as they intend to model more advanced organisational aspects.

Enterprise Ontology (EO) [5] is a collection of terms and definitions relevant to business enterprises. It was developed as part of the Enterprise Project, with the aim to provide a framework for enterprise modeling. 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, iv) terms relating to marketing and sales and v) terms used to define the terms of the ontology together with terms related to time. It was first completed in natural language format and then ported to Ontolingua [5].

Although significant effort was already committed to the creation of business and enterprise ontologies and the mentioned initiatives may provide an inspiration and foundation for developing organisational ontologies, to the best of our knowledge, there is no commonly accepted model that could be reused in various domains.

3 Ontology framework

The semantic process representation required by SBPM may be divided into three main groups, namely; process, organisational and domain-specific ontologies. Process ontologies [14] are created in order to describe the structure of a process, whereas organizational ontologies provide a description of artefacts, actors etc. that are utilised or involved in the process. The domain ontologies provide the additional information specific to an organisation from a given domain.

The organisational ontologies, this paper focuses on, aim at providing vocabulary and constraints for describing the environment in which processes are carried out from the organisations' perspective. Following [15], the organisational ontologies provide a basic vocabulary and structure for describing organisations, business goals and resources, define common types of divisions, roles and tasks, and define common types of business resources. Thus, the organisational ontologies layer provides a high level view on the organisation and process-related space and may be logically divided into a few subontologies, each of them describing different part of this space:

1. **Organisational Structure Ontology (OSO)** focusing on organisational structure (hierarchy) of a company. It is designed as an upper level ontology and provides main structure and relations aiming at achieving domain independency.
2. **Organisational Units Ontology (OUO)** providing specification of typical units that may be found in a company. Along with Business Functions, Business Roles and Business Resources Ontologies, it provides extensions to OSO.
3. **Business Roles Ontology (BROnt)** representing roles in the organisation e.g. Designer, Process Modeller, IT Expert, CEO.
4. **Business Functions Ontology (BFO)** provides hierarchy of different functions that may be carried out within the company. It is supposed to enable vendor and domain independent classification of company processes and process fragments providing abstraction over single tasks constituting processes.
5. **Business Resources Ontology (BRO)** describing resources spent when carrying out certain processes or that may be results of certain task in a process.
6. **Business Goals Ontology (BGO)** modelling a hierarchy of business goals and provides a set of relations between them to enable goal-based reasoning.

In next sections of this paper each of the ontologies being a part of the organisational layer is presented. Due to the different character and status of the ontologies in question there is a difference in the level of details given while presenting them. They all have been modelled using WSML [25] in its Flight variant as the representation language.

3.1 Organisational Structure Ontology and Organizational Units Ontology

An organisational structure is defined as a hierarchy of an organisation showing how its elements work together in order to achieve organisation's goals. Following [17] the organisation structure encompasses: departments, employees, their responsibilities, resources etc. as well as relations among them.

The Organisational Structure Ontology (OSO) focuses on organisation hierarchy. The OSO structure benefited from already described models [4], [5], [12], [13] and [18]. The main distinguished concepts are: organisation, legal and non-legal entity, organisational unit, business function, person, skills, role and organisational position as well as resource (for exact definitions please refer to [16]).

It was designed as an upper level ontology providing the main domain-independent structure and relations. The structure of OSO makes it easy to be imported by other ontologies constituting the organisation ontology. And so Business Roles Ontology refers to the Role concept, Business Functions Ontology refers to the Business Function concept, Resource Ontology refers to the Resource, and finally Organisational Units Ontology refers to the Organisational Unit concept. OSO enables full description of an organisational structure and in addition links the mentioned organisational ontologies.

In turn, in case of the Organisational Units Ontology, an organisational unit is defined as any recognized association of people in the context of an enterprise. Following [17], it may be a corporation, a division, a department, a group or a team as well as a committee, task force, or a class [13].

As we decided to follow the OMG definition of Organisational Units [13], all units are divided into temporary and permanent ones. Temporary units are entities, that are created in order to carry out a task, project etc. They exist in an organisational structure only as long as a task is carried out. Permanent Units included in the structure are common for many organisations and were selected as a result of analysis of different organisational structures of existing companies as well as SAP Solution Maps [20]. A variety of existing departments as well as naming standards, forced us to use some simplification. In consequence, the developed ontology includes only the most common organisational departments in a production enterprise. Therefore, in order to describe some highly specific organisational units of e.g. security company, additional concepts need to be defined.

3.2 Business Roles Ontology

A business role is defined a set of expected behaviours, prerogatives and obligations featured by an actor [12]. The Business Roles Ontology provides a common meaning of concepts related to roles featured by organisational members. Each actor may play more than one role and these roles may change depending on the context.

The BRO was designed with an aim to provide a domain-independent, yet comprehensive, set of concepts, that would allow for description of roles in the organisation microenvironment i.e. both the inside structure of an organisation and its close surroundings. The proposed ontology allows to model both internal and external interactions and consists of 37 concepts. The fundamental concept for the ontology is a BusinessRole. The next level of the model splits up into three concepts. Two of them being specialized BusinessRole: InternalRole and ExternalRole. The third one – InternalRoleType – provides the possibility to extend the description of any InternalRole. ExternalRole concept represents any BusinessRole that characterizes an agent from the outside of the organisation (e.g. BusinessPartnerRole further divided into IntermediaryRole and ProcurerRole). The assumption about ExternalRoles is that they are not disjoint. In contrast to ExternalRole, InternalRole is defined as BusinessRole that characterizes an agent from within the organisation (e.g. CustomerServiceRole). Any two InternalRoles are not mutually exclusive.

The current version of the Business Roles Ontology is supposed to answer the following exemplary competency questions: what role(s) does an actor or a group of actors play in the organisation? How many roles are featured by an actor or a group? Are there other actors with the same or similar role? What are the main and additional roles? Are the roles internal or external? Are there any specific (expanding) features characterizing a given role?

3.3 Business Functions Ontology

A business function is understood as a functional area of an enterprise e.g. Sales Management, Risk Management, Customer Management. The Business Functions Ontology (BFO) aims at standardizing meaning of business concepts and thus provides a common vocabulary for business functions within enterprises [18]. It was

designed as a reference ontology, therefore, provides structure of business functions that are common for every company, regardless of the domain it operates in. It acts like an upper ontology for enterprise specific functional ontologies. It is supposed to be a starting point for further development of the business functions and should be extended with domain-specific functions.

Concepts included in the BFO as well as its structure are a result of analysis of existing ERP systems and abstracting over the SAP Business Maps [20]. While designing the BFO, the main goal was to provide as much information as possible and at the same time keep the ontology industry-independent.

BFO consists of two main structures [18], namely: Function and ActivityOrStep. The structure *Function* is the high level view on the functional side of the enterprise. It is specialised by such concepts as e.g.: *Customer Management*, *Marketing Management* and *Sales Management*. The Function structure contains only 40 concepts, 14 of them are top level, and the rest is grouped as their sub-concepts. The top level concepts name coherent and in some degree autonomous areas of functionalities. In addition, some of the top concepts such as e.g. FinanceManagement, are divided into sub-functionalities.

The *ActivityOrStep* structure supplements the Function structure and presents a more detailed view on the performed functions. An activity is understood as a unit of work identified within the business process e.g. UpdateSalesOrder. ActivityOrStep structure was designed at far more detailed level of abstraction and contains 920 concepts grouped as sub-concepts of 33 top-level concepts. Function and ActivityOrStep structures are connected via a transitive *isSubPhaseOf* attribute of each of top level concepts from ActivityOrStep sub-structure which determines which concept from Function structure is complemented by particular group of activities and steps. Appropriate axioms ensure the correctness of the specified relations.

The current version of the Business Functions Ontology 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? Within which functions the given activity or step is performed?

3.4 Business Goals Ontology

In our work we define business goal as *the state of the enterprise that an action, or a given set of actions, is intended to achieve* [24]. The Business Goals Ontology provides a standard set of properties and relations used in modelling a hierarchy of organisational business goals and enables formal verification of goal specifications.

Depending on the time horizon, business goals may be classified as operational or strategic. A strategic goal tends to be longer term and defined qualitatively rather than quantitatively. An operational goal is a short-term contribution to a strategic goal and provides the basis for measuring the progress toward meeting strategic goals.

Goals may be quantitative or qualitative. Quantitative goals are specified in a way allowing devising (measuring) the state of the goal by comparing values stated in the goal that express desired state of the world and the actual state. Qualitative goals are using textual descriptions of the desired state, and verification of the state of the goal

requires human judgement. Quantitative goals need to have measures and threshold values defined, qualitative goals do not have to have such properties provided.

Business goal can have a more detailed *description*, it has an assigned *measure* for controlling the progress, *deadline* for completion and *priority*. In addition, as we can only control what we can measure [19], we assign a *Measure* to each quantitative goal. Each *Measure* has a defined *Unit*. *Measure* has a *Current Value* in the observed moment and a *Desired Value* which should be reached by a goal.

An important notion to keep in mind when talking about goals is time – goals have to be achieved in a certain time period (deadline). Goals can have priorities, which allow us to order the goal set according to their importance. Prioritization focuses attention on key areas, while allowing the modeler to describe goals which are currently perceived as less important or out of scope. Analysts can choose to show only those goals that are in scope. The goal hierarchy approach thus makes clear the effects of scoping decisions, and allows trade-offs to be evaluated.

Business goal models usually contain a hierarchy of an organisation's business goals according to which the processes in the organisation are designed. The higher level goals are refined into more specific goals through AND or OR-decomposition, where the goals are decomposed into alternative subgoals (OR) or combinations of subgoals that must be satisfied (AND). The relation *subgoal_of* together with the constructs for AND/OR goal decomposition is used when creating the goal hierarchy. The relation *subgoal_of* is transitive, non-reflexive and anti-symmetric. An *atomic goal* is a goal that can not be further divided into subgoals.

Additional goal influencing relation types can exist. A support relationship between goals g_1 and g_2 suggests that achievement of goal g_2 assists achievement of goal g_1 ; however achievement of goal g_2 is not a necessary condition for achievement of goal g_1 , or else goal g_2 would be a successor goal of goal g_1 . On the other hand, a hinders relationship between goals g_1 and g_2 suggests that achievement of goal g_1 negatively influences achievement of goal g_2 . Relations supports and hinders are transitive, non-reflexive and anti-symmetric. Goals can also conflict with each other - if a goal g_1 hinders a goal of higher priority g_2 , goals g_1 and g_2 are in conflict.

Introducing formalized business goal models enables new possibilities in process analysis [24]. For example the following queries can be executed using the business goals ontology: Show me all processes that support a specific goal. Show me the goal that is supported by the specific process. Show me all goals that are not completely specified. Filter goals on the basis of a given deadline and/or priority. Show me all goals that have no business process linked. Show me all processes that do not support any goal (gap analysis). Show me all processes that hinder the achievement of a specific goal. Show me all conflicting/redundant goals.

3.5 Business Resource Ontology

When formalizing knowledge about the business process space of an organisation, we also need a mean for describing the tangible and abstract resources that are relevant in the respective operations. For example, we need to know which tools are required for a particular production step. Therefore, we propose a *Business Resources Ontology*, which defines the core abstractions for resources, and associated notions of access,

ownership, and consumption. This ontology can be imported and refined in more specific domain ontologies that define common types of business resources for specific domains, e.g. such things, e.g. *WeldingStation* or *GalvanizationVessel*.

We reuse the definition by Uschold et al, saying that a resource is „something that can be used or consumed in an activity“ [5, p. 41], as the most mature and conceptually clean specification of resources. Since being a resource is a role of an object and not a subtype of an object, the SUPER Resources Ontology does not contain a concept *resource*, but a relationship *requiresAsResource*.

This may be surprising but is a consequence of the fact that being a resource actually *relates* an object to an activity. In WSML syntax, this relation can be specified as follows: **relation** requiresAsResource (**ofType** Activity, **ofType** Object, **ofType** TypeOfPropertyRight, **ofType** _boolean); where:

- requiresAsResources means that the execution of the given Activity requires access in the form of the specified TypeOfPropertyRight to the specified Object;
- Activity is a subconcept of the ActivityOrStep concept from the Business Function Ontology (i.e. bfo#ActivityOrStep);
- Object is the explicitly identified or anonymous object needed. The characteristics of the object are specified by the respective class of object;
- TypeOfPropertyRight is the type of property right that is needed to specify what type of access is needed on that resource. For example, we may want to specify whether the object is modified, transformed, or even destroyed when serving as a resource, or whether it is just temporarily used. Economic theory and law uses the notion of property rights for distinguishing such types of access to a good. We use the four core distinctions from Property Rights theory. When we want to check whether a particular resource is available, we need a mean to specify what types of property rights are assigned to the entity who wants to use the respective object. This can be done best using a ternary relation hasPropertyRightOnObject (ofType Entity, ofType Object, ofType TypeOfPropertyRight);
- the boolean attribute indicates whether using the resource for the given activity consumes the resource or does not consume it. This is an important distinction, since some resources are lasting (e.g. documents, machinery) while others are consumed in the usage (e.g. coal, fuel).

Since we have no concepts for resources, the characteristics of an object serving as a resource must be reflected by the definition of the object and not its resource role. The following competency questions describe the scope of this subontology: which resources/types of resources exist in an enterprise? Which resources are required for a particular task? Which individual or legal entity has property rights on a particular resource? Does the regular usage of a given resource consume this resource?

3.6 Use Case Study

This section provides an example of application of organisational ontologies within the SUPER project based on a Digital Asset Management use case scenario in the telecommunications domain. The aim of this scenario is the provision of digital content to end users. The service provider, based on a customer query on the digital content specifying also the type of digital rights license the user is interested in,

searches for the relevant digital content by several content providers. The search results are then presented to the user, who selects the content he wants to preview or purchase.

Telco ontologies used in this scenario were created to extend the organisational ontologies and provide domain specific concepts which are supplementary to the basic domain-independent concepts, while following the design principles provided by the organisational ontology layer. Further details on the development of telco ontologies within the SUPER project are provided in [22].

In the following, we provide some example queries which demonstrate the usage of our ontology framework within the use case scenario. The queries are expressed using WSML-Flight logical expressions, where boldfaced keywords refer to keywords in the WSML language.

Query 1. Show me all business goals with high priority:
 ?goal[bgo#hasPriority **hasValue** high] **memberOf**
 bgo#BusinessGoal

Query 2. Show me all business goals in conflict with the goal *ImproveServices*:
 bgo#hinders (?g, *ImproveServices*) **and**
 bgo#priority_lt(?g, *ImproveServices*)

The following example demonstrates how we use our integrated view on the process space to query different process perspectives:

Query 3. Show me all processes which have Business Function related to ‘Fulfilment’ and use system ‘CRM’ as the Business Resource:
 ?process [bpo#hasBusinessFunction **hasValue** ?bf **and**
 bpo#hasBusinessResource **hasValue** ?bres] **memberOf**
 bpo#Process **and** ?bf **memberOf** telbfo#Fulfilment **and**
 ?bres **memberOf** telbro#CRM

Notice that *bpo* refers to the previously mentioned process ontology. Symbols *telbfo* and *telbro* denote the telco domain specific extensions of the Business Functions Ontology and Business Resource Ontology, respectively.

Query 4. Within which functions the activity *ValidateOrder* is performed?
 ?function[telbfo#isSubPhaseOf **hasValue** *ValidateOrder*]
memberOf telbfo#BusinessFunction

Note that in answering this query we utilize the transitivity axiom of the *isSubPhaseOf* relation.

Query 5. Show me all processes that support the business goal *IncreaseRevenue*:

Here we first need to find which business goals support the goal *IncreaseRevenue*:
 telbgo#supports(?g, *IncreaseRevenue*)

where symbol *telbgo* represents the telco domain extension of the Business Goals Ontology. In order to answer our query we need to find processes which are annotated with the supporting business goal *g*:

?process [bpo#hasBusinessGoal **hasValue** g] **memberOf**
 bpo#Process

Querying of organisational ontologies has been successfully utilized in various scenarios within the use case, such as: decision making support, reuse of business artefacts in process modelling and process redesign, see [23, 24, 26] for more details.

4 Discussion and conclusions

In this section we compare the organisational ontologies presented in this article with the previous attempts in this area taking into account the defined criteria, namely: comprehensiveness, consistency and operational aspects (see Table 1).

Approach	Comprehensiveness		Consistency	Operational aspects	
	Domain covered	Easy Extensible	Comparable level of details	Ontology language used	Scalable reasoner etc. availability
TOVE	Generic enterprise model (Conceptualizations of: agents, roles, positions, goals, communication, authority, commitment thus it models an organisational structure, activities and management.)	-	-	FOL representation	+/-
REA	Creation of transfer of economic value. The core concepts are: Resource, Event, and Actor.	-	-	None commonly accepted	-
e3-value	Identifying exchange of value objects between the business actors. The basic concepts in e3-value are actors, value objects, value ports, value interfaces, value activities and value exchanges.	+/-	+/-	MODEL description logic language	+/-
Enterprise Ontology	Organisational structure, activities and management. Four subject areas are distinguished: activities and planning, organisation, strategy, marketing	+/-	+	Informal (text) and semi-formal (Ontolingua)	-
SUPER	Organisation context with main focus on functions, goals, organisation structure, roles, resources.	+	+	WSML	+

Table 1. Comparison of the approaches

The approaches have usually different focus and the domain covered is not always comparable. While the TOVE and EO projects focus on providing generic enterprise model, REA and e3 value focus more on creation and transfer of economic value, our approach aims at describing organisation context relevant for the needs of business process modelling. The already developed ontologies cover often a substantial area of knowledge, however their usefulness is sometimes limited as the modelled parts of information space are defined on the different level of details and are sometimes

inconsistent. In addition, only few initiatives define alignments between various ontologies constituting the set. For instance in TOVE project, three distinguished layers were designed at an inconsistent level of details (inconsistent granularity) and in case of REA the terminology for constructs is criticized for the lack of clarity [9]. The set of ontologies proposed for the needs of SUPER has been aligned and constitutes a consistent and coherent stack, as we have shown earlier in this paper.

In addition, the proposed approaches are rather domain-independent and general in essence, thus in order to improve their usability they should be considerably extended with a domain-specific vocabulary what sometimes is impossible as only few of them were designed bearing in mind further extension. In opposition to these approaches, our ontology stack was designed with the aim to achieve domain-independence as well as allow for easy extensions and usage of domain and industry specific ontologies within the framework as presented in the previous section.

Moreover, the lack of the formal version (expressed using one of the ontology languages) hampers practical application of some of the already defined ontologies (e.g. EO). Even if the ontology are presented in a more formal way (e.g. TOVE), very often the results are not serialized in any contemporarily recognized ontology language standard for which an efficient reasoner exists. In our case, usage of WSML formalism allows for application of a very good operational infrastructure. E.g. the currently available version of WSML2Reasoner uses the IRIS reasoner as a back-end reasoning engine. [21] reports that the functionality and performance of IRIS compare favourably with similar systems.

In this paper we have presented an organisational ontology framework for SBPM which integrates different views of an enterprise. Our ontology framework is designed with consistent level of detail and represented using a current ontology language for which scalable reasoners, repositories and tools are available. The framework has been successfully applied to a use case scenario in the telecommunication domain. By fulfilling the identified criteria to a greater extent in comparison to other approaches, the proposed organisational ontology framework has a great opportunity to become a useful and flexible tool to be applied in real world cases within different domains. With semantic annotation of business processes using organisational ontologies we also enable new types of business process verification and validation techniques.

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