

The Role of Contextual Ontologies in Enterprise Modeling

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Abstract—Information sharing and exchange, rather than information processing, is what characterizes information technology in the 21st century. Ontologies, as shared common understanding, gain increasing attention, as they appear as the most promising solution to enable information sharing both at a semantic level and in a machine-processable way. Domain Ontology-based modeling has been exploited to provide shareability and information exchange among diversified, heterogeneous applications of enterprises.

Contextual ontologies are “an explicit specification of contextual conceptualization”. That is: ontology is characterized by concepts that have multiple representations and they may exist in several contexts. Hence, contextual ontologies are a set of concepts and relationships, which are seen from different perspectives. Contextualization is to allow for ontologies to be partitioned according to their contexts.

The need for contextual ontologies in enterprise modeling has become crucial due to the nature of today's competitive market. Information resources in enterprise is distributed and diversified and is in need to be shared and communicated locally through the intranet and globally through the internet. This paper discusses the roles that ontologies play in an enterprise modeling, and how ontologies assist in building a conceptual model in order to provide communicative and interoperable information systems. The issue of enterprise modeling based on contextual domain ontology is also investigated, and a framework is proposed for an enterprise model that consists of various applications.

Keywords—Contextual ontologies, Enterprise model, domain ontology.

I. INTRODUCTION

AN *enterprise model* is defined by [8] as: “a computational representation of the structure, activities, processes, information, resources, people, behavior, goals, and constraints of a business, government, or other enterprise.” An enterprise model provides the language used to explicitly define an enterprise. Moreover, it should be built to aim at an agile enterprise. Agility is the ability to monitor market demand continuously; to provide new products and services quickly; and respond to new technologies and new business methods quickly. Ontology-based modeling has become widely used in many scientific and commercial

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disciplines. Ontology-based models have become the backbone for many applications namely: e-commerce, intelligent integration information, database design and integration, and in new emerging fields namely the Semantic Web and pervasive computing. Ontology is commonly defined as: an explicit specification of conceptualization. Ontology, however, is *characterized as a hybrid of taxonomy and an axiomatic theory*. It is in the sense that taxonomy is used for terms and glosses organized [8] into *subsumed hierarchical relations*. An axiomatic theory deals with formal system with clear rules and semantics.

Domain ontology [6] of an enterprise is a representation of the entities and relations existing within a particular domain of reality such as accounting, enterprise resource planning, marketing, etc. Domain ontology of an enterprise will provide the following:-

- A controlled, structured vocabulary to annotate data in order to make it more easily searchable by human beings and processable by computers.
- ‘Task’ or ‘Application’ Ontology: runs, uses, exploit domain ontology. Examples of application ontologism in an enterprise are accounting systems, marketing and finance... etc.
- Common understanding between the sub-domains in the enterprise.

Contextual ontologies are ontologies that are characterized by concepts that may have several representations and they may exist in several contexts. Contextual concepts are useful to specify concepts according to the role they play in the enterprise.

II. ONTOLOGY-BASED ENTREPRISE MODELING

Ontologies are classified as top level ontologies, domain ontologies, and application ontologies [6]. Application ontologies explain concepts which are specific to a particular domain and tasks. In this research we believe that an enterprise is modeled according to the different applications that are prevalent in the enterprise namely enterprise resource planning (ERP's), client management systems (CMS)...etc. Hence, the domain information of an application in the enterprise will enable building a model based on the concepts and relationships of such applications. The formalization of a business model, however, will provide the conceptual foundation for new methods and computer-based tools for such diverse fields as management-level business model

design, business strategy & Information Technology/Information Systems alignment.

In brief, we aim at applying ontologies to the concept of business models. The approach will remove eventually existing ambiguities and will allow the use of the reasoning capabilities of an ontology based upon a logic language to check the consistency and satisfiability of the business model.

III. DOMAIN CONTEXTUAL ONTOLOGY IN AN ENTERPRISE

To achieve common understanding and to allow for better communications we should have knowledge of what purposes the things are intended for, by whom, when and where, of how the things are related to one another and to environment, etc. Shortly, it is necessary to know about contexts in which the things appear, have appeared, and/or will be appeared. Context is commonly used to specify and interpret meanings in several disciplines, such as formal logic, knowledge representation and reasoning, pragmatics, sociolinguistics, organizational theory, sociology, cognitive psychology, etc. An approach that combines an ontology with its context is proposed by [1], [3], and [4]. Misunderstanding can be avoided if the context is explicitly defined. The resulting structure is called contextual ontology. Contextual ontologies need to be expressed in a language that is machine processable. In the following section, we propose a formal technique based on description logic(DLs) to formally express an enterprise model.

IV. FORMALIZATION OF CONTEXTUAL ONTOLOGY-DESCRIPTION LOGIC APPROACH

For the purpose of our research on contextual multiple context ontologies, we adopt the term contextual ontology to emphasize the importance of context in first, solving the multiple representation problem and second, providing a better visibility and access to ontological information elements (concepts, roles, individuals). The term contextual ontology is used as well to indicate that the ontology we deal with is context dependent. Therefore, a contextual ontology consists of two key words context and ontology. To meet the contextual ontologies' requirements, we propose the notion of contextual concepts. Contextual concepts are basically derived from atomic concepts by using a set of non-contextual and/or contextual constructors. To formally define a contextual concept, we propose adding a new constructor known as projection to the syntax given in Definition 1. This projection constructor is expressed in Definition 3. Definition 4 gives the new contextual interpretation of concepts.

A. Contextual constructors

Definition 1. Syntax of contextual concept terms Let s_1, \dots, s_m be a set of context names. Contextual concept terms C can be formed according to the following syntax:

$C \rightarrow (C)[S]$ (contextual restriction)
 $S \rightarrow$ list of context names

The definition of non-contextual concepts remains always possible. Such concepts will exist in all contexts with a single

representation. The semantics of a noncontextual language is extended with the contextual notion as per Definition 1.

Definition 2. Semantics of contextual concept terms The semantics of the contextual part of the language is given by a contextual interpretation defined in a context j over S . A contextual interpretation $I = (I_0, I_1, \dots, I_j, \dots, I_t)$ is a t -tuple indexed by the contexts $\{1, \dots, t\}$ where each I_j is a (non-contextual) interpretation (Δ^1, \cdot^{I_j}) , which consists of an interpretation domain Δ^1 , and an interpretation function \cdot^{I_j} . The interpretation function \cdot^{I_j} maps each atomic concept $A \in C$ onto a subset $A^{I_j} \subseteq \Delta^1$ and each role name $R \in R$ onto a subset $R^{I_j} \subseteq \Delta^1 \times \Delta^1$. The extension of \cdot^{I_j} to arbitrary concepts is inductively defined as follows:

$$\begin{aligned} \perp^{I_j} &= \Phi \\ \top^{I_j} &= \Delta^{I_j} \\ (C \parallel D)^{I_j} &= C^{I_j} \parallel D^{I_j} \\ (C \cap D)^{I_j} &= C^{I_j} \cap D^{I_j} \\ (\exists R.C)^{I_j} &= \{x \in \Delta^1 \mid \exists y : (x, y) \in R^{I_j} \text{ and } y \in C^{I_j}\} \\ (\forall R.C)^{I_j} &= \{x \in \Delta^1 \mid \forall y : (x, y) \in R^{I_j} \rightarrow y \in C^{I_j}\} \\ (\leq n R)^{I_j} &= \{x \in \Delta^1 \mid \|\{y \mid (x, y) \in R^{I_j}\}\| \leq n\} \\ (\geq n R)^{I_j} &= \{x \in \Delta^1 \mid \|\{y \mid (x, y) \in R^{I_j}\}\| \geq n\} \\ ((C) ([S]))^{I_j} &= C^{I_j} \text{ if } j \in S \\ ((C) ([S]))^{I_j} &= \Phi \text{ otherwise} \end{aligned}$$

B. Examples

The following suggests some concept definitions in multiple contexts.

Example 1. An employee is defined in context s_1 as anyone who has an employee number and in context s_2 as anyone who works for a company.

$$\text{Employee} = (\exists \text{EmployeeNumber.Number})[s_1] \parallel (\exists \text{WorksFor.Company})[s_2]$$

Example 2. In context s_1 a student is a person who is enrolled in at least one course, while in s_2 a student is a person who has an id-card.

$$\text{Student} = \text{Person} \cap ((\exists \text{EnrolledIn.Course})[s_1] \parallel (\exists \text{Has.StudentIDCard})[s_2])$$

Example 3. In context s_1 a married man is a man who has exactly one wife, while in s_2 he may have up to 4 wives and in s_3 he may have an unlimited number of wives.

$$\text{MarriedMan} = \text{Man} \cap \exists \text{wife.Woman} \parallel ((\leq 1 \text{wife})[s_1] \parallel (\leq 4 \text{wife})[s_2] \parallel (\top)[s_3])$$

The expression $(\top)[s]$ is interpreted as the whole domain Δ^1 in s_3 , which expresses the absence of number constraint on wife in s_3 .

C. Algebraic manipulations

It is straightforward to prove the following equivalences

$$\begin{aligned} C[s] \sqcup D[s] &= (C \sqcup D)[s] \\ C[s] \cap D[s] &= (C \cap D)[s] \\ \exists R.(C[s]) &= (\exists R.C)[s] \\ C[s] &= C \cap \top[s] \end{aligned}$$

For negations and universal quantifiers the rules are slightly more complex. In fact we have

$$\begin{aligned} (\neg C)[s] &= \neg C \cap \top[s] = \neg(C[s]) \cap \top[s] \\ \neg(C[s]) &= \top[\check{s}] \sqcup (\neg C)[s] \\ (\forall R.C)[s] &= (\forall R.C[s]) \cap \top[s] \\ \forall R.(C[s]) &= (\forall R.C)[s] \sqcup \forall R.\perp \end{aligned}$$

where \check{s} is the complement of the set of contexts s . These equivalences can thus be used to shift the projection operator inside or outside expressions.

V. CONCLUSION

A model of an enterprise lies at the heart of information infrastructure. Various methods and techniques are used to build a conceptual model that covers the process as well as the information of an enterprise. The combination of context and ontology makes the problem of semantic heterogeneity more plausible notably when multi-represented phenomena are considered. Contextual ontologies incorporate logic and reasoning aiming at coordination and unambiguous, shared understanding among systems.

The main contribution of this paper is the definition of a framework for contextual ontologies in building an enterprise model. The pair-up of context and ontology allowed semantics capturing of local ontologies. Since single global ontology is not possible due to many factors, therefore we treated multiple ontologies as context dependent ontologies. Hence, interpretation of concepts is done according to context (s) where they occur. In this respect, we devised a contextual description logics language that includes context in its constructs.

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