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ABSTRACT:

In the last decade, ontologies as shared common vocabulary played a major role in many AI applications and information integration for heterogeneous, distributed systems. The problems of integrating and developing information systems and databases in heterogeneous, distributed environment have been translated in the technical perspectives as system's interoperability. Ontologies, however, are foreseen to play a key role in resolving partially the semantic conflicts and differences that exist among systems. Domain ontologies, however, are constructed by capturing a set of concepts and their links according to various criteria such as the abstraction paradigm, the granularity scale, interest of user communities, and the perception of the ontology developer. Thus, different applications of the same domain end up having several representations of the same real world phenomenon. Multi-representation ontology is an ontology (or ontologies) that characterizes ontological concept by a variable set of properties (static and dynamic) or attributes in several contexts and/ or in several scales of granularity. This paper introduces the formalism used for defining the paradigm of multi-representation ontology and shows the manifestation of this paradigm with Enterprise Information Systems.

Keywords:

Ontologies, Enterprise Information Systems, Multi-representation, Modal Description Logics.

INTRODUCTION:

Ontologies are still a puzzle for some decision makers; whereas for others it is a silver bullet. First, establishing an adequate communication media among various user communities and different departments can always be possible through a shared common vocabulary [Usch96]. Thus, an informal ontology for a specific domain of interest can be used for communication in the human level. Second, ontologies can be expressed formally in machine processable language (e.g. OIL, DAML+OIL, RDF, OWL, etc.), which allow for querying and drawing conclusions from heterogeneous information sources. Third, ontological concepts are reusable within an application as well the domain of interest. Hence, as in the object-oriented technology, by reuse, quality intends to increase meanwhile cost will decrease. Fourth, ontologies will bring together the concrete conceptualization and the reasoning capabilities. Although taxonomies offer hierarchical description for related concepts, ontologies extend this notion by providing intensive logical reasoning facilities. Fifth, most enterprises have a fairly dynamic environment and consequently information entities and relationships (taxonomies) are apt to change. Ontologies, however, can provide formalism (e.g. description logic) and a multi-representation based approach to cope with such dynamism.

A real world entity is unique but it can have several representations [Bens03] due to various interests, purposes, or perspectives. The notion of context is used as form of views to deal with concepts from different perspectives. The multi-representation ontologies [Ara04], hereafter contextual ontologies, are defined to take into account the notion of context or point of view during the abstraction mechanism.

Ontologies can be considered an essential element to growth, competition, and challenges among enterprises. Therefore, adapting ontology to meet the enterprise technical and business needs such as reusability, interoperability, and shareability becomes important. In particular, the issue of improving Enterprise Information Systems (EIS) includes providing a global enterprise view over EIS with data integration initiative combined with interoperability and reusability services.

In this paper, we are arguing that the use of multi-representation ontology as a common description for EIS conceptualization based on system specification gives the systems the ability to be reusable and interoperable. In fact, we intend to define a common framework of an ontology driven enterprise information systems that will pinpoint the advantages and shortcomings of unaware or unplanned procedure of *ontologizing* enterprise's information systems. On one hand, we present formalism describing the paradigm of multi-representation ontology. On the other hand, we show the application of this paradigm to the EISMO (Enterprise Information System Multi-representation ontology) project and its relevance for answering the motivating enterprise needs. Three main goals can be identified for EISMO project including global understanding over EIS, information systems interoperability (intra-inter), and reusability.

The paper is organized as follows. Section 2, we informally present contextual ontology and its application to Enterprise Information Systems. We also discuss the interoperation problem along with motivating requirements for the proposed contribution to the multi-representation criteria. Section 3 presents formalism to describe contextual ontology. Section 4 gives an overview of the ongoing project EISMO with a framework based on the proposed contextual ontology. In section 5, we conclude the paper by a set of suggestions for future work.

INFORMAL PRESENTATION OF CONTEXTUAL ONTOLOGIES:

Several technical solutions have been proposed to cope with the problem of heterogeneity whether in the system physical level, syntactical, or semantic level. Semantic heterogeneity is classified as: heterogeneity of concepts, heterogeneity of concept structures, and heterogeneity of object instances. Although ontologies are foreseen to play a key role in partially resolving the semantic conflicts and differences that exist among systems, they still require further research work. Along this line of research, we strongly feel that combining the two paradigms context and ontology may support the aspect of semantic interoperation in both the local and the global view.

EIS motivation and requirements (from semantic point of view)

Enterprise Information Systems (EIS) represent a set of crucial systems used for managing enterprise and establishing its business. EIS are growing continuously with high demand of efficiency and information quality. In addition, EIS are evolving with enterprise business and challenges to bring new functionality through wide range of accessibility portals. The perspective of improving EIS includes providing a global enterprise view over EIS with data integration initiative combined with interoperability and reusability services. Indeed, many EIS are developed independently based on specification with a mono-representation of the domain of interest. They offer separately, a low potential for providing global querying and knowledge sharing ability. A closer look at existing EIS has led us to identify some facts and needs:

- Many systems have overlapping models, which makes reusability being not only limited to tools but also it includes conceptual reusable models, implementation packages, and physical resources (DB, CICS transaction, etc.).

- There are needs to explicitly describe all EIS components for all systems in a company by providing a general view enabled by the conceptualization mechanism.

- There are crucial needs to improve the modeling of EIS by defining a common framework of Information Systems; as well as a common core platform for integration, sharing, and cooperating EIS.

- EIS accessibility is changing with enterprise business and market challenges considering merging, information and knowledge sharing with partners and web-based systems. This wide portal of accessibility aggravates the problematic of semantic interoperability initially unresolved.

- There is a lack of transparency and cooperation between existing systems within the same enterprise [Rifa02]. Therefore, there is a need for a common knowledge base over all EIS's.

Based on the previous facts about EIS's, we may strongly argue that using the multi-representation ontology as a common description for EIS conceptualization (based on system specification) may give systems the ability to be reusable and interoperable along with a global query answering service.

Motivating example:

Example.1: Let us consider two Information Systems used in an enterprise: PMIS (Project Management Information System) and HRIS (Human Resource Information System). The UML models, defined in Figure.1 and Figure.2, represent the mono-representation of each system. These systems contain concepts having the same identifier and the same meaning, such as Manager in PMIS and Manager in HRIS, or concepts are different but have the same component, structure and semantically
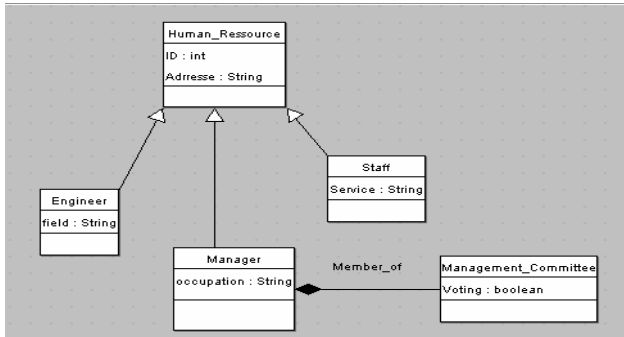
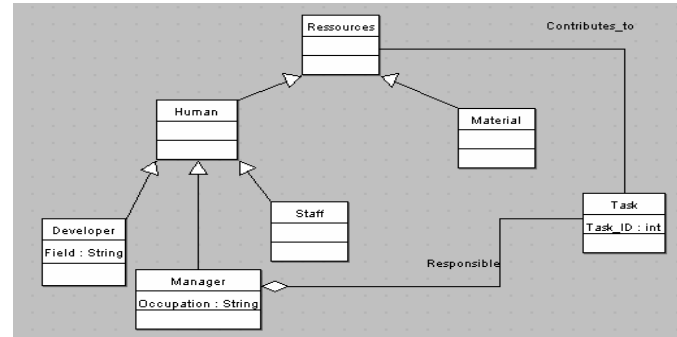**Figure.1: a side of UML model for HRIS**   **Figure.2: a side of UML model for PMIS**

similar, such as Engineer in PMIS and Developer in HRIS. In this case we can identify that the concepts manger, engineer, etc. are multi-represented in these systems.

Each system using one of these models offers separately a low potential for providing global querying and knowledge sharing ability. For example, it will not be possible to answer queries with global visibility such as: What are the roles that a manager plays in a company?

Contextual ontology approach

Making ontologies accessible to large user communities with *diversified perspectives* is another direction of research that requires attention. Formal ontology representation becomes very essential to satisfy the needs of ontology users. At the present, concepts are expressed formally as single representation, in the sense that the representation language is characterized by defining a unique concept and its properties as a fixed data set. In this paper we investigate the multi-representation problem of ontologies where a concept is seen from different perspectives. For instance, if an ontology user is only interested in information about the same concept from different contexts or points of view, then there will be no possibility to retrieve such information based on mono-representation. As a matter of fact, the multi-representation phenomenon becomes normative rather than exceptional if interoperations among systems are sought. Multiple representations over a common space can arise in different ways such as different properties and/or different taxonomies. In brief, the multiple representations are rooted to the abstraction mechanism where several conceptualizations are associated with the same object due to several other factors such as viewpoints, contexts, special interest, etc. Hence, multi-representations can be defined as:

Multi-representation ontology is a set of context-dependent ontologies (contextual ontologies), in the sense that a set of ontologies is put together without being integrated for the purpose of global representation. Hence, contextual ontology is an ontology that is kept locally, but inter-related with other ontologies through a mapping relation between concepts.

Our approach is aiming at describing formal contextual ontologies to support several applications that are associated with several representations of the same real world entities. Our basic idea is to treat such monotonous systems as local views, where they preserve their local semantics, but we develop coordination schemes and formalism that allow for communication among locally independent systems.

The approach we propose can be scalable and extensible to support querying and accessing information from several points of views. A formalism based on modal description logics is proposed in the following section of this paper. In specific, a contextual description logic language based on the $\mathcal{ALCN}$, augmented by modal operators, is suggested to support the phenomenon of multi-representation.

Indexing

For the first thought, we can define a stamping mechanism that helps our approach to label the components of each ontology with operators and constructors. The usefulness of such technique consists on resolving the ambiguity while importing a concept from another ontology. Informally speaking, it is a simple labeling technique where each concept is known (identified) by the context that it belongs to. **Example.2:** (C1:S1, C1:S1 ⊔ C2:S2 , etc.)

Nevertheless, this solution is limited by the fact of being unable to provide by itself a global view over contextual ontology. Indeed, indexing and cataloguing is totally different from contextualizing ontology, it does not offer any relation between similar multi-represented concepts of two ontologies.

Coordinating contextual ontology:

The second issue concerning the multi-representation ontology is the potential to define the contextual and semantical relationship between contextual ontologies. In other words, how can we define the bridges that relay a context to another using a cross mapping between a set of contextual ontologies?

The need of mapping between context-dependent ontology is identified by the requirements of the multi-representation approach such as:

- Defining or identifying a relation between ontologies (concept, roles, and instances) is very important to extract semantically similar based information that may exist between two contexts. These relations are useful to asset the multi-representation ontology to extract knowledge from many contextual ontologies.

- The essential requirements of multi-representation ontology include the possibility of having a powerful global answering capability. This goal cannot be reached without identifying a set of relations between concepts existing in different contexts.

- We need to identify the semantic similarity between concepts existing in the ontologies, this semantic similarity will be expressed by a mapping rule [Borg02] such as: identical, subsumption, inclusion, etc.

- For small ontology these rules can be identified manually, but it gets more complicated with real scale ontology where a matching algorithm can be useful to reduce the complexity of this task.

Example.3: let's refer to the *Example.1*, I_1= "*John Smith*" is an instance of Manager in the system S_1, the ontology can offer the knowledge corresponding to I_1 in the system, but with a rule R_{12} identifying that: a Manager in S_1 is similar to a Manager in S_2. The system can deduce a new knowledge, which is important from the global point of view; thus we can infer that I_1 is a member of Management_committee.

MULTI-REPRESENTATION FORMALISM:

The use of DLs formalism can specify ontologies in machine understandable format and can provide reasoning services [Ohlb99]. Despite the fact that DLs are very expressive and machine processable, but there are still several research problems that encounter the use of DLs, such as the multiplicity of representations and dynamism of information and their propagation of change. Such problems have direct impact on extending and exploiting further the existing families of DLs, as well as the well-known modal logics.

Nevertheless, multi-representation ontology (MURO) provides a wider support to access heterogeneous information sources by various applications in a domain; the logic formalism can provide different behavior to express contextual ontology. Three different approaches can be identified:

- DL based approach (extension of DL): it consists of applying the DL formalism with an extension to support the definition of many ontologies and the relations between them.

- Modal Logics approach (propositional logics): the contextual ontology can be expressed with modal logics whereby propositions are used to identify ontology's components and relations through Kripkie's structure.

- Modal DL approach (hybrid): it is a hybrid approach consisting on taking the trump from the previous ones. In our work, we chose to study this approach because it ties together the expressiveness of DL and the decidability over worlds of interest with modal logics.

In modal logic, the semantics of expressions or formula is defined in terms of the truth of things in different *worlds* or contexts. This contrasts with classical description logic, where things are just true or false, and not true in one context and false in another. Modal logics distinguish **modes** of truth. For the generalized modal logic, modes of truth are explained by referring to (abstract) worlds, namely: truth in **all** (accessible) worlds, truth in **this** world, and truth in **some** (accessible) world.

Description Logics:

Description logics (DLs) are a family of object-centered knowledge representation formalism that has been used for many Information Systems (IS) applications (DB integration) and Intelligence Artificial (IA) applications (intelligent agents). Recently, it gets more attention since it has been chosen as the basic formalism for semantic web ontology and the language OWL (Ontology Web Language).
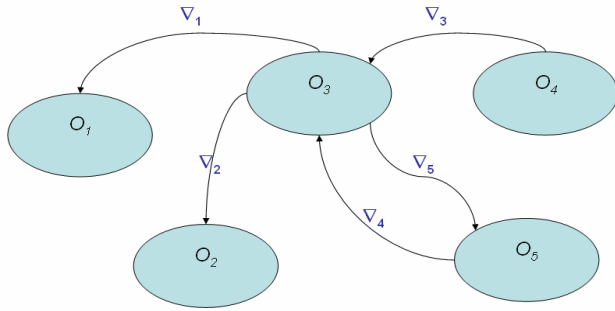
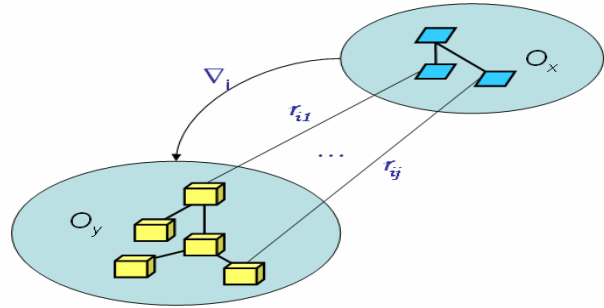**Figure.3: Labeled oriented graph representing Kripke's structure.**

Figure.4: Accessibility relation between worlds or contextual ontologies.

The basic elements of a concept language are concepts, roles and objects [Baad03]. A concept is a class that is used to describe a set of objects with common properties. Roles are used to describe binary relationships between objects. Indeed, Description Logics view the world as being populated by individuals that can be grouped into classes, and that can be related to each other by binary relationships. A specific DL language (such as $\mathcal{ALC}$, $\mathcal{ALCN}$, $\mathcal{ALCNH}$, etc.) provides a set of constructors and operators for building more complex concepts and roles. A DL language distinguishes between two types of collection:

T-Box (Terminological Box): which is a collection of subsumption assertions specifying the terminology used to describe some application domain; it is similar to an IS schema.

A-Box (Assertion Box): which is a collection of assertions about individuals describe some state of worlds; it is similar to a database of facts in an IS.

A DL knowledge base $\mathcal{K}$ is a pair $<\mathcal{T},\mathcal{A}>$ where $\mathcal{T}$ is a terminology (T-Box) and $\mathcal{A}$ is an A-Box. Our research will focus on the reduced DL language $\mathcal{ALCN}$, an extension for a more sophisticated language such as $\mathcal{SHIQ}$ with Modal Logics, it is foreseen as improving the expressivity of the approach.

Modal Description Logics:

Modal logic [Wolt98] is a propositional logic based language. It can also be used as a set description language. It defines a set of worlds and the relations existing between these worlds. The minimal description language, $\mathcal{ALC}$, including full negation and disjunction, i.e. propositional calculus, is a notational variant of the propositional multi-modal logic $\mathcal{K}_{(m)}$.

Therefore, the description logic $\mathcal{ALC}$ corresponds exactly to the multi-modal logic *Km,* even though their origins are completely different. One can simply combine a description language with a suitable modal language. Thus, Modal DL is a language combining a DL language and modal logic operators without the propositional logic. Informally, a concept corresponds to a propositional formula, and it is interpreted as the set *of possible world* over which the formula holds. The existential and universal quantifiers correspond to the possibility and necessity operators over different accessibility relations: $\Box_r C$ is interpreted as the set of *all the possible world* such that in every *r*-accessible world *C* holds; $\Diamond_r C$ is interpreted as the set of *all the possible world* such that in some *r*-accessible world *C* holds.

The modal $\mathcal{ALCN}_{M}$ (Modal $\mathcal{ALCN}$) language is used in this approach due to the fact that it is satisfiable (consistency check).

Syntax and semantics of $\mathcal{ALCNM}$:

The syntax of MDL $\mathcal{ALCN}_{M}$ consists of the classical $\mathcal{ALCN}$ constructs and the modal operators $\Box_r$ and $\Diamond_r$ known respectively as necessity and possibility operators.

The formal semantics of $\mathcal{ALCN}_{M}$ language are interpreted by: (i) the conventional $\mathcal{ALC}$ *interpretation* (description logics) with Tarski's model where an interpretation is a pair I = $(\Delta^I, .^I)$, such that the set Δ^I is the interpretation domain and $.^I$ is the interpretation function that maps every concept to a subset of Δ^I and every role to a subset of Δ^I x Δ^I. (ii) Kripke's structure stating what the necessary relations between worlds are and what the formulas are necessarily holding in some worlds. It

defines where concepts are interpreted with respect to a set of worlds or contexts denoted by W. If |W| = 1 then our interpretation becomes the classical interpretation of Tarski-Model described in (i) above.

Having a set of contexts or worlds $W = \{ w_1, \ldots, w_n \}$, our model of interpretation of concepts will require a Kripke's structure $<W, \nabla_r, I(w)>$, where ∇_r denotes a set of accessibility binary relations between contexts and *I(w)* is the interpretation over W.

Syntax	Semantic
$\Box_r C$ Necessity operator	$(\Box_i C)^{I(w)} = \{x \in (\Box C)^{I(w)} \quad iif \quad \forall v \nabla w, x \in C^{I(w)} \}$
$\Diamond_r C$ Possibility operator	$(\Diamond_i C)^{I(w)} = \{x \in (\Diamond C)^{I(w)} \ iff \ \exists v \nabla w, x \in C^{I(w)} \}$

A model of $\mathcal{ALCN_M}$ based on a frame $F = <W, \nabla_0, \nabla_1, \ldots>$, is a pair $\mathcal{M} = <\mathcal{F}, \mathcal{I}>$ in which I is a function association with each $w \in W$ a structure

$$I(w) = < \Delta^{I(w)}, R_0^{I(w)}, \ldots, C_0^{I(w)}, \ldots, a_0^{I(w)}, \ldots >$$

$\Delta^{I(w)}$ an interpretation domain in context $w \in W$

$R_i^{I(w)}$ set of roles that are interpreted in context w

$C_i^{I(w)}$ set of concepts that are interpreted in context w

$a_i^{I(w)}$ set of objects that are interpreted in world w

Adaptation of MDL ($\mathcal{ALCN_M}$) to multi-representation ontology

The following parameters are used as a design guide to describe the modal extension of the $\mathcal{ALCN}$ language and its adaptation for multi-representation ontology:

- **Set of worlds:** A world is an ordinary model of the pure description language [Wolt98]. It consists of domains in which the concepts, roles names, and objects names of the description component are interpreted. In our approach, each world represents a contextual ontology.

- **Operators:** the $\mathcal{ALCN_M}$ language offers operators which include $\mathcal{ALCN}$ general operators such as cardinality restriction, universal and *existential* quantification, etc. and modal logics necessity operator and possibility operator respectively $\Box_i$ and $\Diamond_i$. Modal operators are applied in front of concepts to form complex ones (i.e. $\Diamond_i C$). The number of modal operators corresponds to the number of accessibility relations identified between the worlds or ontologies. Modal operators can be applied to different kinds of well-formed expressions of the description language.

- **Structure:** All the languages defined by contextual ontologies are interpreted with the help of the possible ontology semantics in which the accessibility relations between ontologies treat the modal operators. The set of accessibility relations defines the Kripke's structure; which is in our approach a labeled directed graph see Figure.3. The accessibility relations define a set of bridge rules that enables one to express the semantic similarity or correspondence between each world's components Figure.4. These rules have been studied in the literature with Schema mapping [Rifa03], ontology Mapping [Doan02], or articulation between ontologies [Mitra00].

- **Arbitrary domain**: When connecting worlds, that are ordinary models of the pure description logics language (contextual ontologies), by accessibility relations, we face the problem of connecting their objects. We have to distinguish between three types of domains; those with constant, expanding, and varying domains. In a constant domain, we have $\Delta^{I(v)} = \Delta^{I(w)}$ for all $v, w \in W$. In models with expanding domains $\Delta^{I(v)} \subseteq \Delta^{I(w)}$ whenever $v \nabla_i w$ for some *i*. In our approach, the worlds are just arbitrary domain, depending on bridge rules of the accessibility relations.

  For example, we can consider a restriction for some ontologies the increasing domain assumption with assumption bridge rules. Given two contexts s and t and the context t is accessible from context s. We apply the increasing domain assumption where we have $\Delta^{I(s)} \subseteq \Delta^{I(t)}$. In this case, accessible means that there are $n \geq 1$ contexts $s_1, \ldots s_n$ such that $s = s_1$ and $t = s_n$ for all $i: 1 \leq i \leq n$, there exists contextual modality such that $(s_i, s_{i+1}) \in \nabla_k$. The advantage of this model is that the domain elements that have been introduced in s can also be referred to in all contexts that are accessible from s.

- **Finite domain:** In our approach modal description logics is used for defining multi-representation ontology which is a specification of conceptualization [Gru93]. The real world knowledge that we are capturing in its conceptualization is a finite domain. For example: when the domain consists of employees of a company, then certainly we should assume it to be finite.

- **Rigid designators:** In our approach we consider that we have rigid designator characteristics concerning objects. Indeed, when we talk about an object in *all the worlds* we will always refer to the same one. For example: when the knowledge base is talking about employees of a company, name *John Smith* should denote the same person no matter what world we consider.

In this paper, we are not concerned with finding out whether there exist algorithms for checking satisfiability for the proposed model $\mathcal{M}=<\mathcal{F},I>$. The issue of satisfiability and algorithm complexity in description logics with modal operators has been studied by [Wolt98] for several important classes of models including $\mathcal{ALC}$.

Revisited examples:

Let's consider the *Example.1*, we assume that an ontological representation has been associated with each system and we need to define in the HRIS a new concept *Management-committee-member*. This concept is defined based on combining (importing) information from PMIS. A *Management-committee-member* is every *manager* in HRIS and every *engineer* in HRIS having a management responsibility according to PMIS.

According to multi-representation ontology paradigm, we can define for each contextual ontology the relevant concepts used by the system. Let us index the concepts of HRIS with *h* and concepts of PMIS by *p* to avoid any ambiguity.

We will consider the ontology of HRIS O_h with the definition of the following concepts:

$$h : Employee \subseteq T$$
$$h : Engineer \subseteq h : Employee$$
$$h : Manager \subseteq h : Employee$$

The ontology of PMIS O_p includes the concepts:

$$p : Project \subseteq T$$
$$p : Ressource \subseteq T$$
$$p : Manager \subseteq p : Ressource$$

These ontologies have been contextualized by defining an accessibility relation (∇i) including a set of bridges between their concepts. The relation $\nabla_i = \{r_{i1}, r_{i2},...\}$ contains the bridge rule r_{ij} attesting that $h : Employee \supseteq p : Manager$.

The definition of *Management-committee-member* can be considered using the accessibility relation between the context ontologies O_p and O_h as following:

$$h : Manag\_committe\_member \doteq h : Manager \cup (h : Engineer \cap \Box_i \, p{:}Manager)$$

The operator $\Box_i$ applied to the concept *p:Manager* relays the objects of *p:Manager* in O_p by necessity through the accessibility relation ∇i being a subset $(\supseteq)$ of the concept *h:Employee* for O_h .

Related work

The notions of context and multi-representation have been studied in the literature, in many fields. In AI context appeared as means of partitioning knowledge [Theo01], into manageable sets, or it has been used as logical constructs, and recently as contextual reasoning.

In particular, a theoretical framework and a concrete language for contextualized local ontology were proposed by [Bouq03]. In this research work, the notions of contexts and ontologies are combined. The approach considers autonomous representation and management of local ontologies [Bena02]. The OWL language is extended with respect to its syntax and semantics to meet the requirements of contextualized ontology. The new C-OWL language is augmented with rules (or as they are called *bridge rules*) that allow for relating (syntactically and semantically) concepts, roles, and individuals of different ontologies.

In addition, authors in [Borg02] studied formal semantics of distributed description logics and distributed first order logics to provide coordination among a set of distributed information systems. In this approach, they argue that there will be no single global view, but correspondence between objects in the local domains should be furnished through directed import feature and mapping using bridge rules. They also show that it is possible to translate distributed description logics (DDLs) reasoning to description logics (DLs) reasoning.

In software development and software engineering, the notion of viewpoints has been used to support the actual development process of complex systems. In this respect, a viewpoint is defined as a locally managed object or an agent, which encapsulates partial knowledge about the system and its domain. An approach was proposed by [Fink92] in which a framework was devised to describe complex systems based on viewpoints. The framework is independent from any specific development methodology and actively encourages multiple representations in software development.

TOWARDS MULTI-REPRESENTATIONAL ONTOLOGICAL APPROACH FOR EIS (EISMO PROJECT)

EISMO (Enterprise's Information System Multi-representation Ontology) is a software engineering project, which is dedicated to describe a rich conceptual model based on ontologies. Hence, the ontology will be commonly used by several systems and applications within the enterprise. It defines a high level of conceptualization for Enterprise Information Systems by using context-dependent ontologies. Sharing the same concept among several applications enforces the multiple-representation paradigm. Consequently, we need to represent each concept with different roles, attributes, and instances. In terms of implementation, the architecture combines ontological conceptualization of EIS and J2EE platform as an implementation framework for reusability and interoperability, a prototype of EISMO is being implemented.

The goals of the ***EISMO*** project can be classified as it follows:

- First, we aim at exploiting the formalism presented in section 3 to deal with the multi-representation problem in the context of EIS.
- Second, a case study that includes scenario use and query processing to validate the proposed conceptual model and to explore its impact on re-usability and shareability of information in the enterprise [Rifa03], [Rifa02].
- Third, it provides global understanding over EIS to support communication and global query answering.
- Fourth, it aims at achieving information systems interoperability (intra-inter), communication between systems, and reusability.

The detailed description of the EISMO project is beyond the scope of this paper.

CONCLUSION:

Ontology-based approaches have been accepted as a very promising solution to semantic interoperability. Several domains have been using ontologies as common, shared repositories. In the scope of EIS with ontology development, several conceptualization and categorizations of concepts are most likely to occur, which have lead to the multiple representations problem. In order to support the multi-representation aspect of an ontology element, an approach of contextual ontology was proposed in this paper, where contexts are used as a partitioning mechanism to the domain ontology. The contextual ontology approach is aiming at coordinating a set of context-dependent ontologies without constructing a global ontology. Thus, the problem of updating, cost, and the loss of information are avoided when bypassing the global ontology. The approach is based on well-founded theory of modal description logics to build a semantically rich conceptual model that supports scalability, and extensionality. Moreover, the proposed formalism of contextual ontology supports information accessibility, filtering, and reasoning services based on their contextual information. In the domain of EIS, the approach can be exploited to contribute to the existing problems of semantic interoperability, and re-usability related to multi-representations. The approach is being applied to the project named EISMO. As future work, we intend to complete the proposed formalism with satisfiability algorithm for richer DL language such as $\mathcal{SHOIQ}$ along with a prototype implementation based on EISMO project architecture.

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