Transforming Existing Universal Data Models into an Enterprise Ontology for developing Enterprise Information Systems

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***Abstract*—Ontology engineering is an exciting discipline for developing ontologies of the real world concepts and that knowledge base can be shared by everyone with the help of Semantic Web. Ontology engineering gives a direction towards solving the interoperability problems brought about by semantic complications, such as the complications related to the definitions of business terms and software classes.Researchers are working on the semantic enrichment of enterprise modeling with the use of ontology. This paper aims at reusing and transforming existing universal data models into enterprise ontology for opening new trends of developing Enterprise Information Systems. In this paper, enterprise ontology of a universal data model is developed from an existing universal data model [1]and discussed as a case study. Ontology is developed using the OWL2 editor-Protégé [2].**

Keywords—Semantic web; ontology; OWL2; Protégé; reusability, enterprise modeling

I. INTRODUCTION

Enterprises always seek for cost effective and efficient information systems that could deal with their big data. They need to hire experience professionals for developing such information systems that could help enterprises in decision making and handling large records. The idea behind writing this paper is that to promote the reusability of existing enterprise data models and transforming those models into ontology. The concept of sharing and reusing data across application and enterprise is given by Semantic Web, which is the second generation of the Web [3]. The main purpose of the Semantic Web and ontology is to integrate heterogeneous data and enable interoperability among disparate systems. The domain of ontology is an emerging field of computer science in which everything is represented in a conceptual model independent from data structure and implementation. In the field of ontology engineering, the ontology engineers develop the ontologies for different domains so that it could be shared by every individual (company or a person).

The universal data models are taken from the book of Len Silverston [1], in which all universal data models are discussed in detail. The book of Len Silverston provides both a preliminary point and it is a source for validating data models. It can help data modelers minimize design costs and develop more effective and integrated database designs[1]. The enterprise model taken for this research work is Human Resources for transforming into ontology.

The problem identified is that enterprises are not taking the advantage from the area of ontology engineering. Enterprises need to re-use the existing data models and develop its ontology for developing ontology based Information Systems. This approach may lead to their success and can help implementing universal knowledge base. Domain engineering collects useful information within a particular domain that can be maintained and reused in future application development. Reusing domain information may reduce time and save the effort of gathering information [3].This paper fills the gap of developing ontology for universal data models so that enterprise may get motivation for start working in this area.

This paper is organized in four sections. Section-I gives the basic introduction including the problem statement and thesis statement of the ontology development and its importance. Section-II gives understanding of enterprise ontology modeling. Section-III gives the understanding about ontology and semantic web and in the last Section-IV related work is discussed in detail.

II. ENTERPRISE ONTOLOGY MODELING

A. *Enterprise Modeling*

Enterprise modeling is a technique which aims to construct a model of whole or part of the enterprise, and generally of any organization, considered as a system, to explain the structure and the organization or to analyze their behavior [4].

B. *Enterprise Ontology Modeling*

The Enterprise Ontology Modeling is the knowledge (concept) representation of an enterprise data model in terms of entities, individuals, data properties and object properties. The enterprise ontology aims at bridging the gap between business and IT technology by using the ontology and ontology evolution technology. The data resource in the enterprise information environment can be seen as the elements that compose the business operational targets [5]

C. *Enterprise Modeling vs Ontology Modeling*

Research in ontology in enterprise domain mainly focuses on enterprise concepts identification and description; while research of enterprise modeling also deals with the concept definition but focuses on modeling language and model construction using the language. However a deep analysis allow finding that the conceptual models developed in the enterprise modeling research are mainly informal ones and do not allow to capture precisely the semantics of the concepts. In the contrary, ontology technique used to describe enterprise concepts is more formal and thus allows better defining the semantics. The difference stands also in the contents of the models. The enterprise model represents the structure or the operation of the enterprise whereas ontology organizes only the concepts used and the relations between them. In other words, ontologies in the domain of enterprise modeling such as TOVE [6] can be considered as enterprise ontology rather than enterprise model in the sense that there is no associate modeling language in ontology to allow building an enterprise model. Ontology technique is useful to elaborate enterprise meta-model rather than developing enterprise modeling techniques and models. Thus the two approaches are complementary.

This difference can give the advantage for enterprise modeling; indeed the use of ontologies can moderate the semantic shortfall of the languages and the models that are primarily presented under their syntactic component.

III. ONTOLOGY & SEMANTIC WEB

Semantic Web gives the concept of sharing and reusing data across application, enterprise, and community boundaries [3]. It is the second generation of the Web. The domain of knowledge is modeled by a set of representational primitives. The main purpose of the Semantic Web and ontology is to integrate diverse data and enable interoperability among dissimilar systems. Ontology has been used to model software engineering knowledge by denoting the artifacts that are designed or produced during the engineering process. The Semantic Web contains the reusable software engineering knowledge resources and providing services for searching and querying.

The W3C standards for the Semantic Web include the Web Ontology Language (OWL) [7], Resource Description Framework (RDF) [8], etc. OWL is an ontology specification language and RDF is a language for describing resources that exist on the Web. The disadvantages of natural language can be overcome by Semantic Web such that it represents formal, precise and unambiguous contents. It maintains information in the form at that can be understood and processed by automated tools[9]. It provides an integrated framework so that information can be well organized, widely published, broadly shared, easily retrieved, and simply integrated [3]

A. *OWL*

For defining and creating web ontologies, OWL language is used for this purpose. The classes, properties and the instantiation of objects define the descriptions of objects of those classes.

OWL uses both URIs for naming and the description framework [7] for the Web provided by RDF to add the capabilities to ontologies such as ability to be distributed across many systems, scalability to Web needs, compatibility with Web standards for accessibility and internationalization and Openness and extensibility.

OWL builds on Resource Description Framework (RDF) and RDF Schema and adds more vocabulary for describing properties and classes, relations between classes (e.g. disjoint classes), cardinality (e.g. “some”, “maximum”), equality, various type of properties, and characteristics of properties (e.g. functional / non-functional / transitive/ symmetry etc.), and enumerated classes.

B. *OWL2*

OWL 2 is a knowledge representation language, designed to express, exchange and reason with knowledge about a domain of interest. These basic concepts are:

- **Axioms:**
  OWL ontology expresses Axioms, which are the basic statements. The ontology states that its axioms are true. In general at a given state of affairs, OWL statements might be either true or false [7]
- **Entities:**
  Entities are the elements used to refer to real-world objects
- **Expressions:**
  Expressions are the combinations of entities to form complex descriptions from basic ones

Statements that are made in ontology are called *axioms* in OWL 2, and the ontology states that its axioms are true. In general at a given state of affairs, OWL statements might be either true or false.

In OWL 2, objects are represented as *individuals*, categories are represented as *classes* and relations are represented as *properties*. Owl-2 Properties are further subdivided.

i. ***Object properties*** relate objects to objects (like a person to their father)
ii. ***Datatype properties*** assign data values to objects (like a name to a person).
iii. ***Annotation properties*** are used to encode information about parts of the ontology itself instead of the domain of interest.

IV. IMPORTANCE OF RE-USABILITY

Reusing existing information saves time and efforts. The scope of reuse has been expanded from reusing pieces of code to reuse all kinds of information, such as requirements, project processes, and software designs [3]. It is hard to manage, retrieve, and reuse current representation of such information. It is highly demanded that a method is required that facilitates information retrieval and promotes reuse. Software systems are usually developed among teams that are geographically dispersed due to globalization. Consequently, diversity exists

among the processes used by different teams. For example, teams working at different locations use different processes and may also possess different sets of knowledge. Information sharing helps to avoid inconsistency.
Semantic web provides information sharing and reuse that results in improve productivity, development life cycle becomes shorten, cost decreases, and product quality increases. These are the benefits of reusability and Semantic web.

V. RELATED WORK

For conducting this research, an existing universal data model [1] "Human Resources" is taken for transforming it into ontology. In this section, some steps are being suggested for developing enterprise ontology from an enterprise data model. After that, case study of Human Resources is discussed in another section.

A. *Suggested Steps for developing an Enterprise Ontology from an Enterprise Data Model*

In order to create the enterprise ontology, first we carefully analyze the enterprise and identifying the determined goals for it. Following this step we can determine the basic concepts governing the organization such as organizational chart, resources, products and the relationship among them. Enterprise ontology can be extracted using enterprise structure diagrams and Entity Relationship Diagram (ERD) (see Fig. 1 [11]). Ontology offers things that are too general and thus are shared by various instances. Certain concepts of a system will be created on the ontology of that system. In the path of this approach, enterprise ontology is a set of things which are general and are shared by the enterprises. Ontology modeling refers to a process which leads to a formal presentation of the defined ontology. For this end, we apply enterprise ontology for enterprise operation and enterprise applications relying on process-based new methods.

B. *Case Study*

The Human Resources enterprise model is taken from Len Silverton [1]. Without human resources, an enterprise cannot employ and use the key resources it needs to stay in business. Information that an enterprise may want to keep includes the following:

- Who is employed, and what is the history of employments?
- What positions exist in the company?
- Are they filled? If so, who has what position, and what are his or her responsibilities?
- Who reports to whom?
- What is the rate of pay for these positions?
- Who received raises and when?
- What benefits does the enterprise provide and to whom?
- What is the cost of these benefits?
- What is the status of employment applications?
- What are the skills of employees?
- What is the performance of employees?
- What are the preferences, deductions, and payroll information needed to process payroll?
- What applicants have there been, and how many of them have turned into employees?
- What have been the rate of turnover and the causes of turnover?

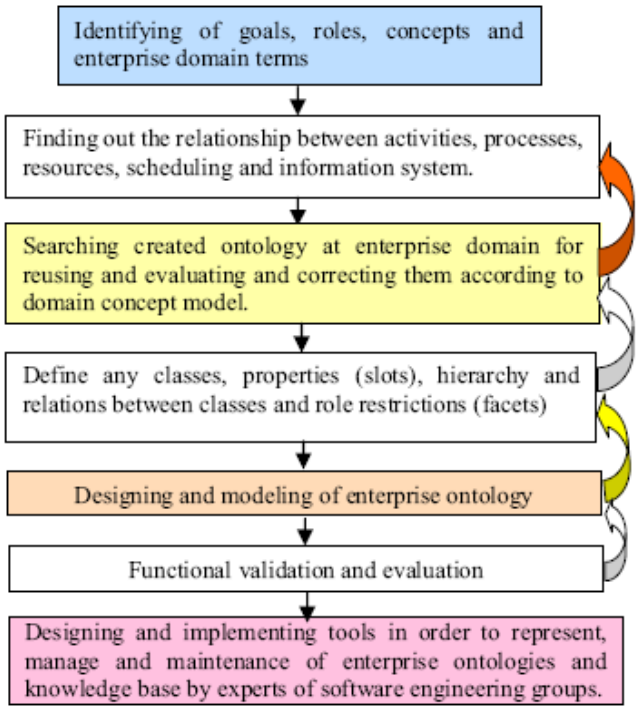

Figure 1.

There are various tools for developing ontologies but the editor used in this research work is Protégé [2].

a) ***Protégé-OWL editor:*** Protégé is a free of cost, open sourceeditor and knowledgebase framework. The Protégé platform supports web and desktop modeling ontologies. Protégé ontologies can be developed in OWL, RDF(S), and XML Schema [2]. Protégé is based on Java, which is extensible, and provides a user friendly environment that makes it a flexible base for rapid prototyping and application development.

First of all, we need to register our ontology. On saving the ontology using Protégé, the ontology is registered on the semantic web in the following terms:

```
<Ontology
xmlns="http://www.w3.org/2002/07/owl#"
xml:base="http://www.semanticweb.org/onto
logies/2012/HumanResources.owl"
xmlns:rdfs="http://www.w3.org/2000/01/rdf
-schema#"
xmlns:xsd="http://www.w3.org/2001/XMLSche
ma#"
xmlns:rdf="http://www.w3.org/1999/02/22-
rdf-syntax-ns#"
```

```
xmlns:xml="http://www.w3.org/XML/1998/nam
espace"ontologyIRI="http://www.semanticwe
b.org/ontologies/2012/HumanResources.owl>
```

In Protégé, every class is a child class of "Thing" that is, Thing is the universal class of all classes; or we can say that it is a parent/ root of all. In the figure below, all the classes of human resources system are children of Thing.

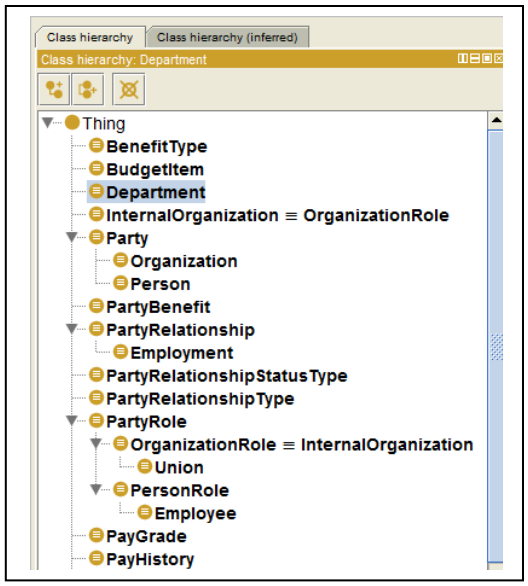

Figure 2

There is a class named Internal Organization which is equivalent to another class that is Organization Role. Similarly, Organization Role is equivalent to Internal Organization under the class of Party Role as shown in the figure below:

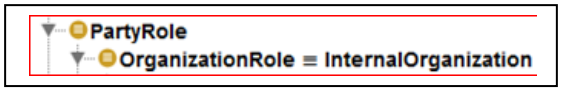

Figure 3

Object properties are known as the term phrases that show the relationship developed between entities/ classes. In the figure below, Person Role is a class that defines the various roles of an employee in the tenure of job. Employee is a sub-class of Person Role and the relationship is defined as: "An employee is the only manager of other employees" and "Employee reports to an Employee (Manager)"

```
<Class IRI="#Employee"/>
<ObjectIntersectionOf>
<Class IRI="#PersonRole"/>
<ObjectAllValuesFrom>
<ObjectProperty IRI="#managerOf"/>
<Class IRI="#Employee"/>
</ObjectAllValuesFrom>
<ObjectAllValuesFrom>
<ObjectProperty IRI="#reportsTo"/>
<Class IRI="#Employee"/>
</ObjectAllValuesFrom>
```

Data properties represent the attributes/ fields of a class. In the following figure, Party Relationship class has a property named which is *defined byParty Relationship Status Type*. Similarly other data properties are referred to as: *Party Relationship has FromDate*having type as *date Time. Party Relationship has Comment* having data type *string.*

```
<EquivalentClasses>
<Class IRI="#PartyRelationship"/>
<ObjectIntersectionOf>
<Class abbreviatedIRI=":Thing"/>
<ObjectMinCardinality cardinality="1">
<ObjectProperty IRI="#definedBy"/>
<Class IRI="#PartyRelationshipStatusType"/>
</ObjectMinCardinality>
<DataSomeValuesFrom>
<DataProperty IRI="#hasFromDate"/>
<DatatypeabbreviatedIRI="xsd:dateTime"/>
</DataSomeValuesFrom>
<DataMinCardinality cardinality="0">
<DataProperty IRI="#hasComment"/>
<DatatypeabbreviatedIRI="xsd:string"/>
</DataMinCardinality>
<DataMinCardinality cardinality="0">
<DataProperty IRI="#hasThruDate"/>
<DatatypeabbreviatedIRI="xsd:dateTime"/>
</DataMinCardinality>
</ObjectIntersectionOf>
</EquivalentClasses>
```

Restrictions are the cardinalities in the data model represents in form of ontology as in the following figure:

Figure 4

The figure shows that the data type property*hasFromDate* has some date time value and it has an optional cardinality, whereas, data type property *hasComment*and*hasThruDate*has minimum cardinality as '0'.

```
<DataSomeValuesFrom>
<DataProperty IRI="#hasFromDate"/>
<DatatypeabbreviatedIRI="xsd:dateTi
me"/>
</DataSomeValuesFrom>
<DataMinCardinality
cardinality="0">
<DataProperty IRI="#hasComment"/>
<DatatypeabbreviatedIRI="xsd:string
"/>
</DataMinCardinality>
<DataMinCardinality
cardinality="0">
<DataProperty IRI="#hasThruDate"/>
<DatatypeabbreviatedIRI="xsd:dateTi
me"/>
</DataMinCardinality>
```

Final Ontology can be seen on this blog [13]

VI. CONCLUSION & FUTURE WORK

This research meets its objectives for transforming universal data model into ontological model for organizing semantics in such a way that can be re-used and shared by everyone.Hence it is concluded that the area of enterprise modeling also needs to be considered for developing ontology models for the enterprise models that have already developed. The only need is to re-use models for developing ontologies. These ontologies may help out developing Enterprise Information Systems backed with ontologies. The library of universal data models is compiled by Len Silverston [1]. The ontology validation is also an important factor after development of ontology. So it must also be considered while using ontologies for developing ontology driven information systems. Protégé is a powerful editor that provides easy way to develop ontologies. This research resolves the issue stated in [6]

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