Theory of Ontological Engineering

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Abstract: **Ontology research has embarked in knowledge base community, spread over the web technology community by semantic web movement. Ontological engineering is the discipline that deals with development and maintenance of ontologies. It was introduced in computer science in early nineties; as a result immense content of this discipline is available in literature. But, because of its huge extent and specialization, an exhaustive effort should be made to understand the said area. Some studies are available that are for comparative reasons or for review of the state of the art, but these address one or other aspect like comparison of methodologies or evaluation approaches. So the current study, after a comprehensive review and analysis, presents the compilation, as theory of ontological engineering that addresses all aspects from definition to evaluation, but in a concise manner with all-inclusive contents.**

Keywords: Ontology, Types of Ontology, Ontological engineering,

1. Introduction

In Artificial Intelligence, knowledge representation is the depiction of the world, with deductive ability. The traditional methods for it are semantic networks, rules and logic [1]. Ontologies have demonstrated to be a proficient representation in extraction and structure the meaning from natural language, so good for knowledge representation. Moreover, sharing and/or reuse a common understanding of information about explicit domains among people is among the utmost motive for the development of ontologies [2]. Ontology research has embarked in knowledge base community, spread over the web technology community by semantic web movement. For this community, ontology is a representation that delivers a comprehensible foundation for the Semantic Web [3]–[5].

Prior to comprehend ontology, in order to circumvent any obscurity, it is sensible to realize the distinction among terms: vocabulary, controlled vocabulary, glossary, taxonomy, thesaurus and ontology. Vocabulary is simply a collection of well defined terms with consistency in all contexts. A controlled vocabulary is restricted that have finite list of terms; a glossary additionally consists of informal description of term's semantic in natural language; Taxonomy is controlled vocabulary through only hierarchical relations; a thesaurus have also equivalence, hierarchies, homographs and associations among terms; an ontology has contextual relationship as well, in the defined vocabulary. The definition of classification, thesauri and ontology and difference among them as of its usage was presented in study [6].

Ontologies represent knowledge that is static, more or less consensual of a community, while the knowledge in knowledge base, is specific of the problem solved by knowledge base system [7]. A data model, belongs to small world, is a description of well-defined application, but ontologies, meant for open and distributed world, have generic knowledge thus independent of particular application [8]. Ontologies are viewed as information artifacts; representations; formal structures; theories; hierarchies of types. All of these are the version of the diverse facet of ontology, but compatible to each other [9]. Ontologies may be considered either as lexicons, dictionaries, thesauri or even first order logical theories, however in all these variations, ontologies exhibit its worth because of the standardization of the terms used in it [10].

Ontologies in existence for the last so many years, but still the ontology engineering, which deals with development and maintenance of ontologies, is an unfamiliar area for some researchers. Even those are known with it are lacking a knowledge of comprehensive theory of this field. It was introduced in computer science in early nineties; as a result immense content of this discipline is available in literature. But, because of its huge extent and specialization, an exhaustive effort should be made to understand the foundations of said area. Some studies are available that are for comparative reasons or for review of the state of the art, but these address one or other aspect like comparison of methodologies or evaluation approaches. So the current study after a comprehensive review and analysis presents the compilation as theory of ontological engineering, for all aspects from definition to evaluation, in a concise manner. The intended readers of this work are the researchers seeking foundations in the said area.

The paper is organized as- section 2 is about to comprehend the definition of ontology. The typology of ontology is presented in section 3. Ontological Engineering definition, design approaches, guidelines, comprehensive compilation of prevalent methodologies, evaluation metrics and the tools are introduced in section 4. The concluding points are in section 5.

2. Definition of Ontology

The term ontology has been defined with diverse viewpoints, area and varied degrees of formality. *Merriam Webster dictionary* define Ontology as a particular theory about the nature of being or the kinds of things that have existence. An ontology is a formal naming and definition of types, properties, and interrelationships of the entities that really or fundamentally exist for a particular domain of discourse as per *Wikipedia*. The term ontology received from Greek, with 'onto' means 'being', and 'logos' took as 'science'[11]. But, researchers are more interested and rely on research published contents to accept and adopt anything. The research literature has a range of definitions and all of these more or less express the same contents. The most accepted definition is *An ontology is a formal explicit specifications of shared conceptualizations* [12]. The keywords in the stated definition are formal, explicit specifications, shared and conceptualisation. For better understanding of these terms, literature explicates them.

Conceptualisation denotes a semantic structure [13], a set of concepts and their inter-relationships [14], an abstract model of concepts [12], a set of conceptual relations and states [15], set of objects and relations between them [16] of some phenomenon in the world, so it is accomplished that, conceptualisation yields to identification of relevant concepts and their relations in a specified domain. Formal implies that ontology should be machine understandable i.e. readable as well interpretable correctly by machine. Explicit specifications involve the precise description of any type(s), constraints on the usage of identified concepts and on the relationships among them. Shared requires that there should be consensus on the ontology, obviously not easy to obtain. The present study analyze the presence/absence of these terms in number of definitions of ontology in literature [1], [3], [9], [17], [12], [14], [15], [18]–[35] in order to find the importance of it, for definition reasons. Essentially most of the definitions provide complete or partial requirement for an ontology.

Table 1: Definition(s) of Ontology

Total Number of definitions	24
formal	08
Explicit	21
shared	07
conceptualisation	24

It is evident from Table 1 that among them, conceptualisation is the core ingredient of any ontology and other terms may or may not be reflected in definitions of the ontology, depending on researcher interpretation or the type(s) of ontology. So ontology is at least a conceptualisation of some domain. Some of the definitions [1], [17], [18], [25], [27], [29], [34] explicitly include domain in it, but domain is implicit as conceptualisation is always of a particular area. The domain can be narrower or broader; abstract or concrete; personal or public. Some of the definitions have 'explicit' word precisely in specifications. 'Formal' and 'shared' terms are not in much definitions but these are also very importance from their purpose and usage perspective. As far as 'Formal' terms is concerned, if humans are only users of ontology then obviously natural language is more readable as of formal language [36]. Even 'shared' not in some definition(s) but any ontology always be destined to agree on shared terminology, as its goal [21]. In few studies 'shared' and 'conceptualisation' are treated as single term 'shared conceptualisation', it enables knowledge pooling. So this can be concluded that more applicable definition of '*An ontology is a conceptualisation with complete or partial explicit specifications, shared or personal perspective and either in formal or natural language depends on its usage and area of application'*.

3. Types of Ontologies

Different ontologies differ not only in their content, but vary in structure, details of description, conceptual scope and specification of language as well [29]. A number of studies suggested the typology of ontologies tabulated in Table 2. Literature establish different name for some ontologies like for Upper ontology other names like Generic, Foundational or top level also exists, but their purposes are same. Ontologies are also classified on the basis of level of formalism, expressiveness of language, purpose and many other criteria as depicted in the table. So it can be concluded that an ontology can be classified on the basis of these criteria. It is worth to mention that classifications are mutually exclusive within criteria but not across them e.g. an upper ontology can be semi formal, static and be used for core reference as well, but cannot be an application or domain ontology.

Table 2: Types of Ontology

Typology	Description	Criteria and Study
Upper/ Generic/ Top Level/ Foundational	Represents common sense world/ generic across many fields/ abstract and general notions	Level of Abstraction [1], [24], [28], [37]
Domain/ Low Level	Express conceptualizations for specific domain	
Task Ontology	Conceptualization for particular task	
Application Ontology	definitions to model the knowledge for particular application	
Highly informal	Natural language, non machine readable	Expressiveness of Language [14]
Semi informal	Structured natural language, machine readable	
Semi formal	Formally defined language and machine readable	
Rigorously formal	Formal language with strict rules, machine readable	
Informal	Normalized but with no or partial axioms	Level of Formalism [38], [15]
Axiomtized taxonomy	Taxonomy with axioms	
Ontology library	Set of axiomtized taxonomies with relations among them	
Lightweight	Concepts and properties without axioms and constraints	
Heavyweight	Concepts and properties without axioms and constraints	
Terminological	Terms to represent knowledge	Purpose [24][39]
Informational	Record structure of databases	
Knowledge modelling	More structured representation of knowledge	
Informational	Organize the ideas of collaborators in the development of project	
Linguistic	Terminology agreement between user's community	
Software	For software development activities	
Formal	To provide full semantics of conceptualization	
Static	Describe things that exist	Contents of Concepts [40]
Dynamic	Describe aspects that change with time	
Intentional	Aspects of world of motivation, goals, beliefs	
Social	Social aspects such as organizational structures, nets or	
Personal	Result of individual development effort	Degree of Consensus [41]
Application	In context of specific project for predefined purposes	
Openly developed	By open community of users, which are free to contribute to the	
Standard	Developed for standardization purposes	
Meta-ontologies	Knowledge of ontologies	
Transcendent	Defined external to application that use them	Usage [32]
Immanent	Structure defined by domain knowledge content	
Representational	More broader concepts	Others [24][39][37][35]
Core Reference	Standard by different group of users	
Mid Level	Bridge between low and upper level, more concrete representation of abstract concepts	
System	Parts, connections and other things that constitute a system	

The most prevalent classification is on the basis of level of abstraction i.e. Upper, Domain, Task and Application ontologies. . The relation among these is shown in Figure 1. Upper to application is from generalization to specialization and other way it is generalization.

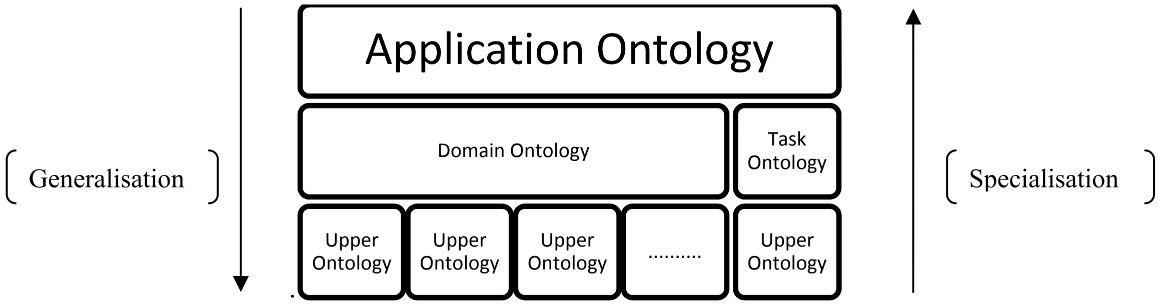

Figure 1: Typical structure of typology

4. Ontological Engineering

In literature it is defined as a methodology [26], discipline [17], [42], set of activities [43], [44] to develop a conceptualisation, implementation and deployment of ontology of the domain of interest.

Design Approaches

Several approaches have been proposed in the literature [14], [39]: Bottom-Up, Top-Down and Middle-Out. The bottom-up starts from specific to generalization. Top down starts from generic concepts to specialization. A middle out begin with identification of central concepts of the domain and then go for generalization or specialization as per the requirement, this approach is preferred over others as it balances the level details.

Design Criteria

A preliminary set of design criteria reviewed in the study [45] suggested in study [19] and some other studies involve- Clarity, Coherence, Extensible, Minimal encoding bias, Ontological distinction principle, modularity and minimum semantic distance

Methodologies

Ontology building is much in practice, so there is a need of well defined methodology for having high quality ontology. The popular methodologies are- TOVE based [21], based on Enterprise model [46], a unified approach [47], MethOntology [48], of ONIONS project [15], Ontology Development 101 [2], DILIGENT [49], HCOME [50], DOGMA approach [51], Melting Point [52], NeON [53], UPON [54]. The commonphases of Most of them have all, some or additional of phases, more or less varies in detail of these phases.

There are also studies that compares some of these methodologies [55]–[58]. As the present work is just to compile the literature from traditional to state of the art, to know about the various methodologies published, the details or comparison is out of the scope of this paper, so the readers interested in details, refer the cited studies.

Tools and Languages

There are number of tools and editors. An exhaustive review and comparison of these are in literature. A comparison of OntoLingua, WebOnto, ProtégéWin, OntoSaurus, ODE, KADS 22 were reviewed in the study [59]. Protégé 2000, OilED, Apollo, RDEedt, OntoLingua, OntoEdit, WebODE, KAON, ICOM, DOE, WebONTO, K-infinity were compared [60]. OntoEdit [61], Hozo, WebODE and ODEClean were discussed in the study [62]. Another comparison was in study [63]. Swoop, TopBraid were also compared with already stated tools [64]. The W3C standard for defining ontologies is OWL.

Evaluation

In ontology engineering, evaluation of ontology is considerable phase and it is either for the estimation of ontology for assessment reasons or it is to make decision to choose the best alternatives for reuse purposes among the available ontologies by ranking the alternatives. The ontology gets evaluated for the correctness as well the quality.

Ontology Verification is to ensure that their definition satisfies the ontology requirements and competency questions, or function correctly in the real world. *Ontology Validation* refers to check whether the definitions of ontology model the intended real world. To evaluate a given ontology, the criteria is: consistency, completeness, conciseness, expandability and sensitiveness [65].

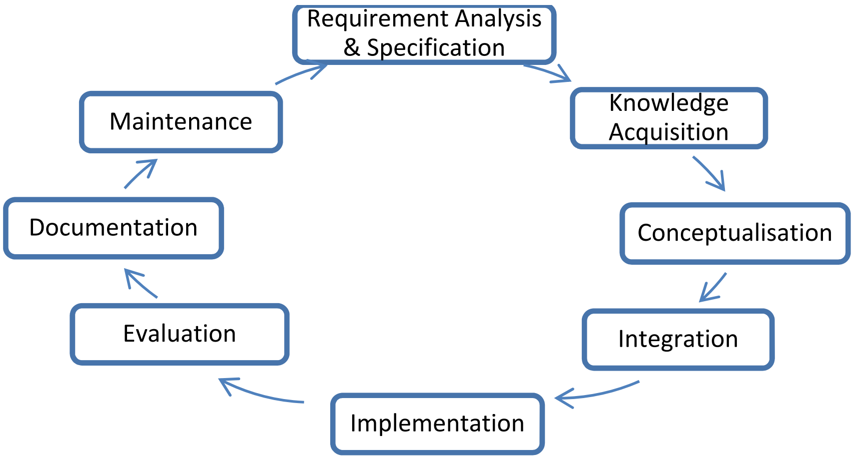

Figure 2: Phases of Ontology Development

Broadly, the evaluation approach can be classified as – that compares it with the golden standards [66]; on the basis of outcome for particular application [67]; on the basis of user/ expert opinion [68]; or approximate coverage against data standards [69]. The dimensions – *structure, expressiveness, granularity, reasoning, strictness, design* are suggested for evaluation of ontology from these perspectives. [70]. The metrics are developed for exclusively for ranking [71]–[74]of ontologies as well for individual assessment of the ontologies [75]–[80]. These metrics can be used interchangeably i.e. metric for ranking can also be used for the assessment of individual and metrics for individual assessment can be for ranking the group of ontologies.

Terminology

A number of processes that deals with ontologies in literature are [3], [81]

- *Ontology Transformation* means development of new ontology as of new requirements by existing one.
- *Ontology Translation* translates the representation formalism but with same semantic
- *Ontology Merging* is process to create single from two or more existing ontologies of same domain
- *Ontology Integration* creates a new ontology from other ontologies that belongs to different domain
- *Ontology Mapping* is to find semantic relationship among entities from different ontologies
- *Ontology Alignment* is to bring two or more ontologies into mutual agreement.
- *Ontology Morphism* is to identify related entities and axioms among different ontologies.
- *Ontology Evolution* to implement change(s) to source ontology
- *Ontology Versioning* to provide access to different versions of an ontology

5. Conclusion

The definition of ontology varies as per the requirement and aim of the ontology to be built. The ontologies can be classified on the basis of abstractness, level of formalism and other criterion. Building, evaluation and maintenance are all the phases of ontological engineering discipline. The current study covers all aspects of the ontological engineering in a concise manner. This work is an outcome of the exhaustive review of the related literature. The paper helps in precise understanding the ontological engineering.

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