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Domain Knowledge Representation through Multiple Sub Ontologies: An Application Interoperability

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***Abstract*—**The issues that limit application interoperability is lack of common vocabulary, common structure, application domain knowledge ontology based semantic technology provides solutions that resolves application interoperability issues. Ontology is broadly used in diverse applications such as artificial intelligence, bioinformatics, biomedical, information integration, etc. Ontology can be used to interpret the knowledge of various domains. To reuse, enrich the available ontologies and reduce the duplication of ontologies of the same domain, there is a strong need to integrate the ontologies of the particular domain. The integrated ontology gives complete knowledge about the domain by sharing this comprehensive domain ontology among the groups. As per the literature survey there is no well-defined methodology to represent knowledge of a whole domain. The current research addresses a systematic methodology for knowledge representation using multiple sub-ontologies at different levels that addresses application interoperability and enables semantic information retrieval. The current method represents complete knowledge of a domain by importing concepts from multiple sub ontologies of same and relative domains that reduces ontology duplication, rework, implementation cost through ontology reusability.

***Keywords*—**Knowledge acquisition, knowledge representation, knowledge transfer, ontologies, semantics.

I. Introduction

APPLICATION interoperability, information exchange, share and semantic information retrieval are the major challenges in the era of digitalization. Application interoperability is a comprehensive and complex subject area [1]. Different researchers have given different definitions for the concept application interoperability in the literature. Application interoperability makes an application capable of utilizing information resources of other applications [2]. The key issues to achieve application interoperability are:

- Semantic heterogeneity: lack of common vocabulary
- Syntactic heterogeneity: lack of common structure
- Lack of application domain knowledge
- Lack of semantic relationship between various concepts of various application domains

Many researchers strongly believe that ontology driven knowledge provides solutions for many modern information systems issues such as application interoperability and semantic information retrieval etc. [3]-[6]. Ontology is a formal, explicit specification of a shared conceptualization [7]. Ontology is an effective technology that enables interlinking of related resources, sharing the right knowledge and leads to high precision and recall [8]. Ontology is approved by World Wide Web Consortium (W3C), for conceptual modeling of a domain and knowledge representation. Ontology enables machines as well as people to understand, share and reason at execution time. Ontology provides domain vocabulary [9] that illustrates a domain with meaningful information. Ontology enables semantic information retrieval and makes the extracted results more accurate [10]. In computer science, ontology is being used in wide range of applications [11] such as conceptual modeling, knowledge engineering, knowledge management, information retrieval, information integration, health informatics etc. However, there is a need of robust and generic methodology for effective representation of domain knowledge that addresses application interoperability. The current research work gives a detailed description of an effective and efficient knowledge representation method using multi-level and multiple sub ontologies. The current work represents knowledge for a domain by importing semantic concepts, relationships from multiple sub ontologies of the same or relevant domains. The main objectives of the current knowledge representation methodology are to provide application interoperability, reusability, easy deploy and management and facilitate answers to semantic queries. The current research work also describes implementation of the knowledge representation method for R&D project management domain.

Rest of the paper is prepared as follows. Section II gives related research work on various approaches and methods of knowledge representation using ontologies, Section III gives a detailed description of current method, Section IV illustrates implementation of the current method for R&D project management domain, finally Section V concludes.

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II. Related Research Work

The three concepts of information science are data, information and knowledge [12]. Data are qualitative or quantitative variable values. Information is a set of significant signs that has the ability to create knowledge. Knowledge is the general understanding and awareness generated from accumulated information. Rehman et al. [13] defined knowledge as the information combined with experience, context, interpretation, and reflection.

Data do not make sense until it is organized properly. Basically data do not provide information regarding patterns, context etc. [14]. Conceptualization transforms data into information [15]. Knowledge is a combination of genuine experiences, values, contextual information and expert approaches [16]. Knowledge comes from diverse sources such

as web, databases, contextual statistics and expert experiences etc. Knowledge representation and management deals with intellectual resources. Knowledge is an imperative asset that helps organizations for planning and rapid growth in competitive markets [17]. The structure of knowledge is more complex than data and it is difficult to represent and process by computer [18], [3].

Ontologies are introduced to handle many challenges of knowledge representation. Ontologies play a vital role in knowledge representation, usage and management. Many researchers have discussed methodologies to represent knowledge of a domain using ontologies. The current section gives a brief description of few popular methodologies of knowledge representation using ontologies.

Noy and McGuinness described Ontology Development steps [19]. The steps are derived from the author experience on the construction of wine and food ontologies and literature on object oriented design.

Methonology [20] was developed based on the activities of the software product development process and knowledge engineering. The framework of this methodology identifies the ontology development process and a life cycle based on evolving prototypes. The development process of this methodology allows user to add, change and remove terms in each new version.

As part of On-To-Knowledge project [21], York et al. defined an ontology development methodology named On-To-Knowledge. The goal of the project is to improve the knowledge management quality. This methodology was developed to build the ontology with future idea how the ontology will be used in further applications. This methodology offers ontology learning. The ontologies developed using this methodology is highly application dependent.

Diligent [22] model is presented by Sofia for ontology engineering. The aim of this methodology is to allow domain experts for developing ontologies in collaborative and distributed fashion.

UPON [23] stands for combined Process for Ontology building. Antonio et al. have developed this ontology as a novel approach to build large scale ontologies. It is derived from combined software development process. It uses UML (Unified Modeling Language) to design an ontology project blue prints. UPON is an iterative and incremental methodology. Incremental nature of UPON begin with core terms then enriches them with semantic definitions and adding relationships among them.

Human Centered Ontology Engineering (HCOME) method [24] allows collaborative ontology development by a community of people. It is an iterative model that defines goals and scope of an ontology. The activities of the methodology enable ontology developer to find knowledge resources, acquire knowledge, ontology development, maintain, use and evaluate ontology. NeOn methodology gives a scenario-based methodology [25], [26]. NeOn Methodology provides guide lines for all important aspects of the ontology engineering process such as ontology reuse, collaborative development etc.

Grigori et al. [27] presented an innovative mechanism of knowledge representation using multiple ontologies for disaster management domain. This methodology includes three steps for knowledge representation. 1) Construct core domain ontology from top level ontologies such as DOLCE and DnS etc. 2) Construct multiple sub ontologies for various subject areas of a domain 3) Construct deploy ontology that links concepts of sub ontologies of various subject areas. In each step it imports concepts from ontologies of previous step. Donghee et al. [28] discussed mixed ontology building methodology to represent military knowledge for implementing the intelligent army tactical command information system. Mixed ontology development methodology defines mapping rules that extract concepts and semantic relationships from targeted databases.

- There is no standard method and clear approach for knowledge management
- There is no proper approach for uniform representation of heterogeneous data
- Majority of the methods gives procedure to build a single ontology for the whole domain. It leads to many issues such as difficult to manage, future updates etc.
- There is no method that links top level ontologies and domain ontologies, it limits to application interoperability issue
- Knowledge management is complex

The current research work proposes a methodology to easily represent knowledge for a domain and addresses application interoperability. The current method is a robust, efficient and effective methodology for knowledge representation of a domain using multiple sub ontologies of various subject areas of the domain.

III. Methodology

The main objective of the current approach is to provide effective methodology for knowledge representation of a domain using multi-level and multiple sub ontologies. Features of the current methodology are:

- Semantic interoperability
- Application interoperability
- Easy of knowledge management
- Concept based information retrieval using multiple sub ontologies

Fig. 1 shows the phases of knowledge representation of a domain using multiple sub ontologies.

To meet the above objectives, the current approach uses ontology import mechanism at different levels of ontology development process. Ontology import is a process of importing concepts and semantic relationships into an ontology from one or more ontologies. Ontologies developed by the current method enable applications to interact with other applications through top level ontologies. The current approach adopts ontology import mechanism at two levels in the whole process.

1. Construct ontologies for different subject areas relevant to the domain by importing concepts and semantic

relationships from top level ontologies. Ontologies of various subject areas of the domain are known as core domain ontologies. Importing concepts from top level ontologies provides application interoperability.

2. Establish semantic relationship between concepts of core domain ontologies and link concepts of one ontology with the concepts of another ontology, a new ontology named deploy is constructed. Deploy ontology imports concepts to be linked and object properties from core domain ontologies. Deploy ontology establishes semantic relationship between concepts of core domain ontologies.

The current approach follows a sequence of steps for knowledge representation of a domain using multiple sub ontologies.

Step1. Identify domain for which ontology needs to be constructed
Step2. List various subject areas relevant to the domain
Step3. Identify relevant top level ontologies (e.g. Time, cost etc.) and foundational ontologies (e.g. DOLCE DnS, WordNet etc.) which cover the concepts of the domain
Step4. Construction of core domain ontologies: For each subject area
4.1. Identify ontologies from ontology libraries [29] that cover various concepts of subject areas. Reference [30] presents research question that helps to identify ontologies of respective subject areas.
4.2. If ontology exist for a subject area, follow the below steps:
4.2.1. Select ontology which covers maximum concepts of the subject area
4.2.2. Remove concepts and properties which are not been used for long time
4.2.3. Add concepts and properties (both data type and object properties) which are not covered in existing ontology
4.3. If ontology does not exist for a subject area, then
4.3.1. Construct ontology for the subject area using any ontology development methodology.
4.4. Identify domain and range of data type properties
4.5. Identify domain and range of possible object properties with in the same ontology
4.6. Import foundational ontologies which covers the terminology of the subject area
4.7. Establish semantically equivalent relationship between appropriate concepts of the core domain ontology and foundational ontologies.
Step5. Link concepts of core domain ontologies:
5.1. Create a new ontology named deploy
5.2. Import core domain ontologies into deploy ontology
5.3. Link concepts of one core domain ontology with appropriate concepts of another core domain ontology
5.4. Remove the following ontology constructs from deploy ontology
5.4.1All data type properties imported from core domain ontologies

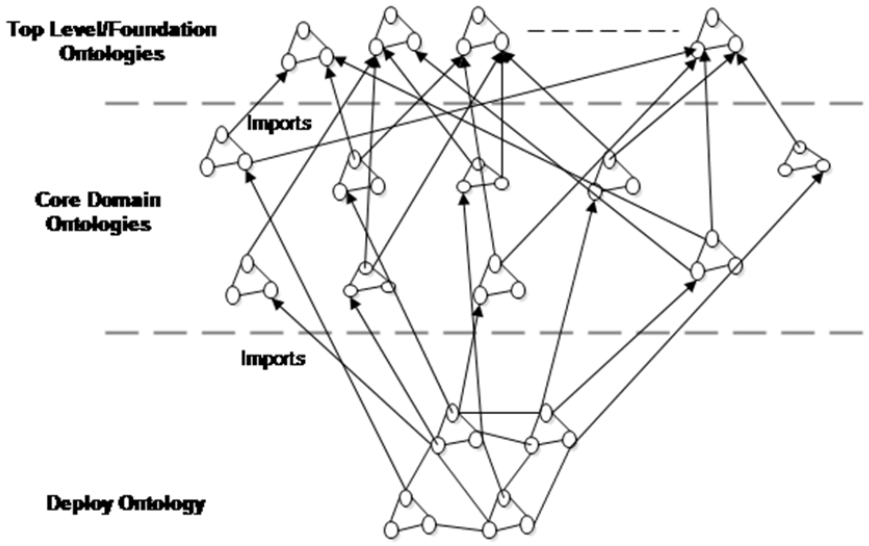

Fig. 1 Knowledge representation of a domain using multiple sub ontologies

5.4.2 Delete the concepts and object properties which are not utilized

Thus, the current method constructs a sub ontology (core domain ontology) for every subject area of the domain.

A. Advantages

Core domain ontologies import top level ontologies and establish semantically equivalent relationship between concepts of core domain ontologies and concepts of top level ontologies. The connection between concepts of core domain ontologies and top level ontologies supports:

- Application interoperability
- Sharability
- Common vocabulary
- Reusability

Deploy ontology imports core domain ontologies and establishes semantic relationship. It supports semantic information retrieval through multiple sub ontologies of the domain.

TABLE I
CURRENTLY EXISTING ONTOLOGIES OF PROJECT MANAGEMENT DOMAIN

Subject Area	Ontology Name	Representation Language	URL
Document	Documentation ontology	OWL	http://mayor2.dia.fi.upm.es/oeg-upm/files/european/Documentation_Ontology.owl
Event	Event ontology	OWL	http://mayor2.dia.fi.upm.es/oeg-upm/files/european/Event_Ontology.owl
Organization	Organization ontology	OWL	http://mayor2.dia.fi.upm.es/oeg-upm/files/european/Organization_Ontology.owl
Person	Person ontology	OWL	http://mayor2.dia.fi.upm.es/oeg-upm/files/european/Person_Ontology.owl
	Person	OWL	http://ebiquity.umbc.edu/ontology/person.owl
	People	OWL	http://protege.cim3.net/file/pub/ontologies/people.pets/people+pets.owl
Project	Project Ontology	OWL	http://mayor2.dia.fi.upm.es/oeg-upm/files/european/Project_Ontology.owl
Document+Event+Organization+Pesron+Project	Ka	OWL	http://protege.cim3.net/file/pub/ontologies/ka/ka.owl

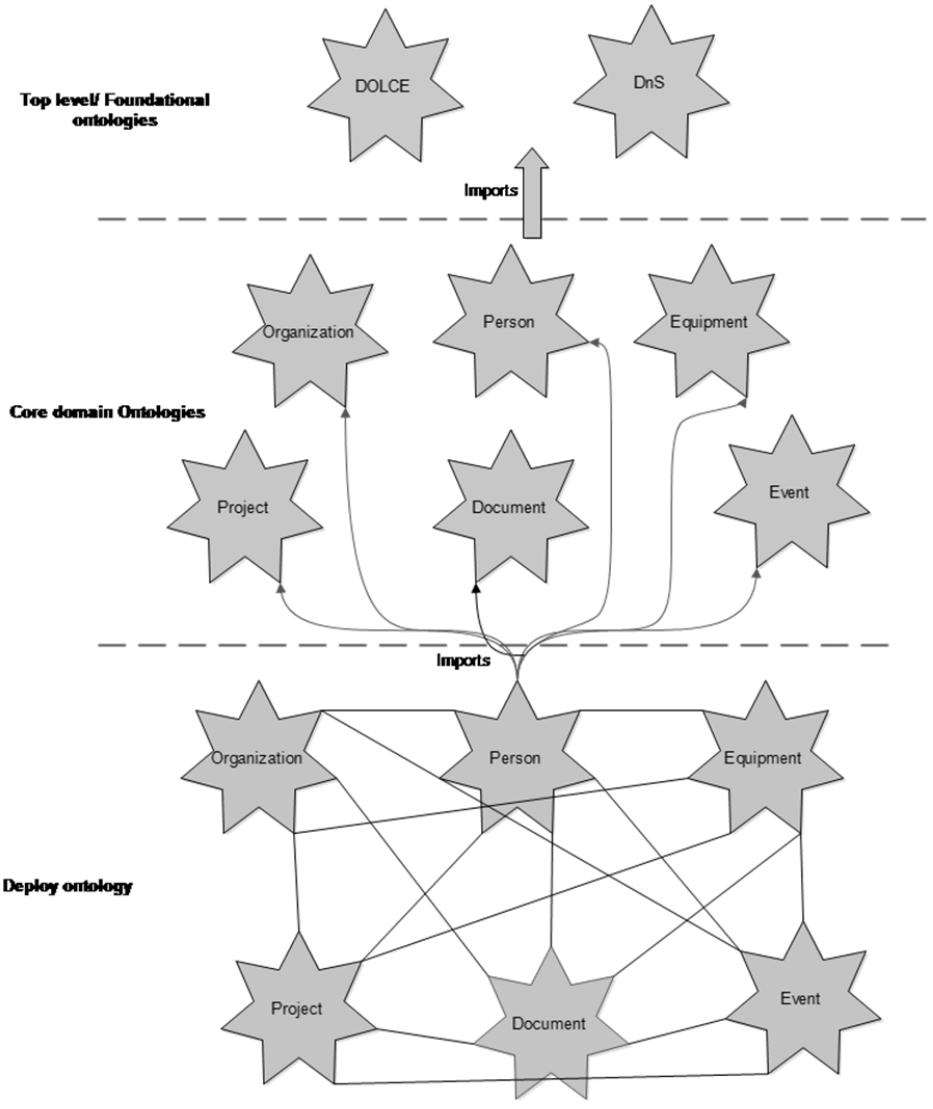

Fig. 2 R&D project ontology construction

Construction of an ontology for every subject area of the domain supports easy of knowledge management such as:

- Versioning
- Update
- Reasoning
- Understand the domain
- Check and rectify inconsistency

B. Tool Support

Two popular ontology development tools protégé [31] and

Neon Toolkit [32] provides a facility to develop ontology by importing concepts from multiple ontologies. Protégé provides plugin support to import and reuse the concepts and properties of one or more ontologies in another ontology. ProSE [33] is a protégé plugin that allows to import concepts and properties of one ontology into another. Neon Toolkit provides direct support reusability mechanism. Portege is used in the construction of project management core domain ontologies and deploy ontology.

IV. Implementation

The current approach is implemented in project management domain. It is used for knowledge representation using multiple sub ontologies of the domain.

As per the current approach, several subject areas relevant to the project management domain are identified.

- Project
- Person
- Document
- Event
- Equipment
- Organization

Foundational ontologies DOLCE [34], DnS [35] and several currently existing ontologies are identified from ontology libraries for the subject areas of project management domain. Table I presents currently existing ontologies, formats and URL links. The ontologies are enhanced to make them as more domain specific. We could not find ontology that covers concepts of equipment subject area in project management domain. An ontology for the equipment subject area is constructed using Noy & McGuinness methodology [19]. Semantically equivalent relation between concepts of ontologies of the subject areas and concepts of foundational ontologies are established.

A deploy ontology is constructed. Deploy ontology imports all ontologies of subject areas in the domain project management and establishes semantic relationship between concepts of one subject area ontology with the other subject area ontologies. Fig. 2 shows project ontology construction process using multiple sub ontologies.

V. Conclusion

This paper presents a method for knowledge representation of a domain using multiple sub ontologies of various subject areas of the domain. The current approach has two phases: 1) Construct ontologies for various subject areas of a domain - constructs core domain ontologies for various subject areas of a domain through importing top level ontologies; 2) Establish semantic relationship between concepts of ontologies - construct an ontology by linking core domain ontologies. This approach and methodology provides a good solution for many open issues of ontology based knowledge representation using multiple sub ontologies. The future research includes evaluating the methodology for various domain.

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References

[1] R. Reza, K. C. Thiam and P. L. Sai and S. A. Zeinab, "Interoperability Evaluation Models: A Systematic review", *Computers in Industry, Elsevier*, Vol. 65, pp. 1-23, 2014.

[2] S. Saurabh, E. Miklos, M. Andre and J. Shantenu, "Understanding Application-Level Interoperability: Scaling- out MapReduce over High-Performance Grids and Clouds", *Future Generation Computer Systems, Elsevier,* vol. 27, pp. 590-599, 2011.

[3] M. Lenzerini, "Ontology-based data management", In *Proc. of the 20th ACM international conference on Information and knowledge management (CIKM 11), ACM*, pp. 5-6, 2011.

[4] J. Zhang, W. Zhao, G. Xie, and H. Chen, "Ontology- Based Knowledge Management System and Application", *Advanced in Control Engineering and Information Science*, *Elsevier*, pp. 1021-1029.

[5] A. Uszok, L. Bunch, J. M. Bradshaw, T. Reichherzer, J. Hanna and A. Frantz, "Knowledge-Based Approaches to Information Management in Coalition Environments", *Intelligent Systems, IEEE*, Vol. 28, Issue 1, pp. 34-41, 2013.

[6] Z. Ming-jian and T. Jun-cai, "A framework for ontology-based knowledge management", *Business Management and Electronic Information (BMEI-2011), IEEE*, vol. 4, pp. 428-431, 2011.C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.

[7] T. H. Davenport and L. Prusak, "*Working Knowledge: How Organizations Manage what they Know*", Harvard Business School Press, 2000.

[8] S. Arsovski, B. Markoski, P. Pecev, N. Petrovaki and D. Lacmanovi, "Advantages of Using an Ontological Model of the State Development Funds", *International Journal of Computers, Communications and Contro*l, Vol. 9, No.3, pp. 261-275, 2014.

[9] C. Sarma, and S. Maija, "*Development of a personalized e-learning model using methods of ontology*", Procedia Computer Science, Vol. 26, pp. 113-120, 2013.

[10] L. Lu and P. Tao, "Post-processing of Deep Web Information Extraction Based on Domain Ontology", *Advances in Electrical and Computer Engineering*, 2013, Vol. 13, No. 4, pp.25-32.

[11] P. Xia and H. Zhou, "Enabling Semantic Queries against the Spatial Database", *Advances in Electrical and Computer Engineering*, 2012, Vol.12, No. 1, pp. 46-50.

[12] Z. Chaim, "Conceptual Approaches for Defining Data, Information and Knowledge", *Journal of the American Society for Information Science and Technology*, vol. 58, issue 4 , pp. 479-493, 2007.

[13] Z. Rehman and S. Kifor, "A Conceptual Architecture of Ontology Based KM System for Failure Mode and Effects Analysis", *International Journal of Computers, Communications and Control*, Vol. 9, No.4, pp. 463-470, 2014.

[14] R. J. Thierauf, "*Knowledge Management Systems for Business*", QUORUM Books, Westport, CT. KM2, 1999.

[15] Sunitha Abburu, G Suresh Babu, "A Framework for Ontology Based Knowledge Management", International Journal of Soft Computing and Engineering (IJSCE), Vol. 3, no.3, 2013, pp. 21-25.

[16] Z. LI and Y. Sun, "Ontology-based Knowledge Management in Intelligent Tutoring Systems", In *Proc. International Conference on Management and Service Science, IEEE*, pp.1-4, 2009.

[17] L. Haisheng, L. Wenzheng, C. Qiang, and L. Hongzhi, "A Framework of Ontology based Knowledge Management System", In *Proc. 2nd IEEE International Conference on Computer Science and Information Technology (ICCSIT 2009)*, *IEEE*, pp. 374-377, 2009.

[18] R. Zhao and C. Zhang, "An Ontology Based Knowledge Management Approach for E-Learning System", In *Proc. International Conference on Management and Service Science*, pp.1-4, 2009.

[19] N. Noy and D. L. McGuinness, "Ontology Development 101: A guide to Creating your First Ontology", Stanford Medical Informatics, Technical Report No. SMI-2001-0880, 2000.

[20] M. Fernndez-Lpez, A. Gmez-Prez and N. Juristo, "Methontology: From Ontological Art towards Ontological Engineering", In *Proc. Symposium on Ontological Engineering of AAAI. Stanford University, California, Springer*, pp 33-40, 1997.
[21] S. York and S. Rudi, "*On-To-Knowledge Methodology Final Version*", EU-IST Project IST-1999-10132, 3rd September 2002.
[22] H. S. Pinto, S. Staab and C. Tempich, "*DILIGENT*: towards a fine grained methodology for distributed, loosely-controlled and evolving engineering of ontologies", In *Proc. 16th European Conference on Artificial Intelligence (ECAI 2004)*, Valencia, Spain., August 22-27 , pp. 393-397, 2004.
[23] A. De Nicola, M. Missikoff and R. Navigli, "A proposal for a Unified Process for Ontology building: UPON", In *Proc. 16th International Conference on Database and Expert Systems Applications (DEXA), Springer*, pp. 655-664, 2005.
[24] K. Kotis, G. A. Vouros and J. P. Alonso, "HCOME: A tool-supported methodology for engineering living ontologies", *Semantic Web and Databases, Springer*, pp. 155-166, 2005.
[25] A. De Nicola, M. Missikoff and R. Navigli, "A *software engineering approach to ontology building",* Information Systems, Vol. 34, Issue 2, pp.258275, 2009.
[26] A. Gmez-Prez, E. Motta and M. C. Surez-Figueroa, "Introduction to the NeOn Methodology", NeOn Project, IST-2005-027595 http://www.neon-project.org/webcontent/media/book-chapters/ chapter-01.pdf, 2005.
[27] B. Grigori, P. Florian, H. Jrg and O. Daniel, "*Ontology Design for Information Integration in Disaster Management*", GI Jahrestagung, pp. 3120-3134, 2009.
[28] Y. Donghee, N. Sungchun and R. Minyoung, A Practical Military Ontology Construction for the Intelligent Army Tactical Command Information System, *International Journal of Computers, Communications and Control* , Vol. 9, No.1, pp. 93-100, 2014.
[29] A. Mathieu and F. N. Natalya, "Where to publish and find ontologies? A survey of ontology libraries", *Web Semantics: Science, Services and Agents on the World Wide Web, Elsevier*, Vol. 11, pp. 96-111, 2012.
[30] L. Shuangyan, B. Christopher and S. Duncan, "Ontologies for Crisis Management: A Review of State of the Art in Ontology Design and Usability", In *Proc.10th International ISCRAM Conference Baden-Baden, Germany*, pp.1-10, 2013.
[31] Protégé, (online) http://protege.stanford.edu/ (Accessed on 20th may, 2014)
[32] Neon Toolkit, (online) http://neon-toolkit.org/wiki/Main Page (Accessed on 20th may, 2014)
[33] J. R. Ernesto, C. G. Bernardo, S. Ulrike, S. Thomas, and B. Rafael, "ProSE: A Protégé plugin for Reusing Ontologies, Safe and Economique", In *Proc. 5th European Semantic Web Conference (ESWC)* Tenerife Spain June 15 Springer LNCS, 2008.
[34] A. Gangemi, N. Guarino, C. Masolo and A. Oltramari, "Sweetening WordNet with DOLCE", AI Magazine, Vol. 24, issue 3, pp.13-24, 2003.
[35] G. Aldo and M. Peter, "Understanding the Semantic Web through Descriptions and Situations", *Lecture Notes in Computer Science, Springer*, Vol. 2888, pp. 689-706, 2003.