# Development of Domain Ontology for Enhancing Design Understand-ability for Developers and End-Users

**Ahmad Z.H. Samsudin, Mohd Sazili Shahibi**
Faculty of Information Management
Universiti Teknologi MARA
Shah Alam, Selangor, Malaysia
ahmadzam@salam.uitm.edu.my

**Shah Jahan Miah and Hafizul Islam**
College of Business, Victoria University,
Footscray Park Campus
Melbourne, Australia.
shah.miah@vu.edu.au

*Abstract*— ***Ontology defines entity and their relationship among knowledge concepts within a problem domain that may provide better specifications of a system blue-print. Such basic specification can provide an interoperable format that enhances understand-ability to both human users and developers. This makes the ontology as one of the prominent techniques specially to systemize problem domains. In this paper, we describe importance of a domain ontology development, reporting on our experience in a user-oriented applications development project. The project was designed to address issues related to both human users' access to and developers' understandability on developed record management systems. Through a formal methodology we developed a domain ontology model and promoted its unique significance specially for developing system solution. Findings from our studies suggest that ontology enables provisions of design support both to end users and system developers to reflect user's real requirements that in turn maximize various user benefits.***

***Keywords*— Domain ontology, ontology-driven applications, system research**

## I. INTRODUCTION

Ontology refers to a concept that defines the problem entity, their attributes and relationships within a specific domain using explicit descriptions and specifications [1, 2, 3]. This technique has been a well-recognized formal approach to characterize a problem domain in an interoperable format that is of paramount importance to both human users and developers. Many studies [3] used ontology to represent empirical knowledge in structured manner to help both system developers and end users in clearly understanding the formation of domain knowledge.

Over the past decades ontology has been used to presume domain knowledge in order to share and reuse relevant components of knowledge in the problem domain. Common directions of studies related to ontology are: analysing characteristics of knowledge components within problem domain [4]; designing domain knowledge representation model; designing knowledge conceptual schema [5]; developing software tool based on knowledge ontology [6]; developing reasoning rules from domain knowledge [4]; developing rule-based algorithm for a new ontology-driven system and implementing domain knowledge reasoning techniques [4]. The capacities (reusability and share-ability) of ontology are of paramount importance for formal specifications of domain knowledge which is a basis for effective user-driven system development. Therefore, it would be an important research aspect to promote the significance of ontology for structuring knowledge from the problem space effectively to maximize provisions for developing user-oriented applications.

Ontology defines a formal explicit description of design concepts using basic terms and relationships as well as to develop rules for systemizing or modelling problem domains [7, 8]. Ontology is defined as "….Ontology is an explicit specification of a conceptualization" [3, p.199). Research on ontology is become increasingly prevalent in the information systems (IS) application development community. Guarino [2] mentioned that while ontology has been rather confined to the philosophical domain, it has now gained a specific role in computational intelligence and database design theory. The importance of ontology method has evolved in various diverse research fields such as knowledge engineering [3], knowledge representation [2], qualitative modelling [9], language engineering [10], information modelling and knowledge management [4]. Euzenat [11] discussed the advantages of the ontology extending capabilities of the web with formalised knowledge and data processing for developing applications. Euzenat [11] identified the need for mixing human-readable and structured data so humans can understand and use semantic data produced from computer applications. Haghighi et al. [12] introduced important requirements of domain ontology development for the better use of domain knowledge for informed decision making. The study of Haghighi et al.

978-1-5090-5753-5/16 $31.00 © 2016 IEEE
DOI 10.1109/APWC.on.CSE.2016.41

[12] showed the value for ontology tools to fully address the needs of managing knowledge in organisations. The developed domain ontology-based approach by Haghighi et al. [12] is functional to plan and manage domain knowledge for developing a decision support systems (DSS) solution. This represents the applicability of ontology across other domains for modelling knowledge components of the problem space that may bring clarity and understand-ability for end users and system developers.

In this paper we describe the applications of ontology for the purpose of modelling domain knowledge of a problem domain in higher education. In this case, the aim was to improve the user accessibility of existing electronic documents and records management systems (EDRMS) for the end users and developers who are responsible for updating and maintaining the system. End users require quick guide for accessing their records and developers require appropriate meta-records for designing adequate navigations within the system. The study objective was to employ ontology for better structuring knowledge components so the EDRMS system can effectively achieve enhanced search-ability and navigability while users retrieve, store, process and preserve documents and other forms of digital records. At the same time, developers can gain a better reflection through the meta-records details on designing a formal knowledge base of the system. Previous system was based on keyword based searching, through the meta-records details that are captured from ontology, we successfully replaced the keyword-based searching to rectify the search process.

The paper is organized as follows: the first section describes a background on the key significance of domain ontology, in particular for formulating knowledge components within a problem domain. The second section will details the methodology used for the domain ontology development. The third section describes the key design aspects that provide key benefits to the target human groups. Finally the discussion and conclusion section present a summary and overall applicability of the research.

## II. BACKGROUND

The main aim of the paper is to describe the unique significance of domain ontology development in the particular aspect of formulating knowledge components within a problem domain. In the paper we focus on the Information Systems (IS) design perspective as research on ontology is becoming of paramount useful to the IS community in particular for simplifying application design.

The main objective of domain ontology is "to reduce the conceptual and terminological confusion among the members of a virtual community of users (for example, tourist operators, commercial enterprises, medical practitioners) who need to share electronic documents and information of various kinds" [13, p. 151]. This definition has been supported by several recent studies in the context of domain ontology construction [4]. Theoretically, ontology as one of the semantic approaches enables complex and precise queries to be formulated and executed than is possible with more traditional keyword-based approaches [14]. For sustainable knowledge structuring and making them understandable both to users and developers, ontology holds the potential to be employed for generating more context-specific and systematic knowledge model that may benefit individual's effective decision making capability [15]. Table 1 illustrates previous studies on justifying the significance of domain ontology development for application development research.

Table 1: Example studies on promoting significance of domain ontology development

| *Example studies* | *Requirements of domain ontology* | *Application development areas* |
|---|---|---|
| Boyce and Pahl [16] | Specifying concepts, and their relationships in a particular subject area | Management of course content |
| Musen [17] | Developing descriptions of classes of concepts and their relationships to describe an application area | For effective application development |
| Jacinto and Parente de Oliveira [18] | Enhancing meanings of each component and making clear separation of concerns to clarifying communication | For effective learning applications |

The notion of conceptualizing problem domain is not a new research aspect. Genesereth and Nilsson [19] introduced a requirement of employing suitable formalization of knowledge components, so it may provide appropriate meanings without confusions to users and developers. For this ontology development shows promises. The conceptual knowledge has been recapped by Gruber [3] stating an ontology as a specification of conceptualization that provide a detailed account of the designs. Guarino [2] mentioned that the issues with Genesereth and Nilsson's notion of conceptualization are only on particular extensional relations between entities (within the problem domain) and the relations reflect a particular state of affairs. Guarino [2] also claimed that a specification of conceptualization should focus on the meaning of the relations and independently of a state of affairs so the meaning of relations represents certain links according to their true formation within the problem space. We therefore consider this argument for re-drawing the relationships and its meanings across the concepts within the knowledge domain. We therefore consider to identify components of the conceptual relations between their entities and its relations in order to simplify the searching process for enquires. As the

main task of EDRMS is to manage a range of digital information, including word-processed documents, spreadsheets, emails, images and scanned documents, it is important to employ a simplified method and the ontology was utilised for structuring the components with appropriate meanings for better records management functionality.

## III. Development Methodologies

We used a methodology in both design projects to develop system solutions that may provide improved user access and other relevant benefits. The development of an ontology involves a complex process of knowledge acquisition through domain independent principles of the methodology. Most of the ontology development principles offered in terms of methodologies previously are relatively similar. For instance Uschold et al. [20] proposed a methodology that sets out steps such as purpose identification, building ontology, evaluation, and documentation. This methodology is similar to the traditional system development approach, which is not involved with any knowledge acquisition and conceptualisation activities that can be applied into our ontology development. Similarly, Staab and Studer [21] described a methodology for an ontology based knowledge management system, which has followed five major steps. These steps are a feasibility study, ontology commencement, refinement, evaluation and maintenance. Another methodology for task based ontology development reported by Mizoguchi et al. [22] involved four different phases. These are the extraction of task units, organisation of task activities, analysis of task structure and organization of domain concepts. This implies that scope and purpose identification for ontology development has been skipped or assumed to be completed previously. The above-mentioned literature indicates that these methodologies commonly start from the step for identification goals/purpose of the ontology and the need for domain knowledge acquisition. However, this can only happen after a significant amount of knowledge is acquired [23]. We engaged an approach called METHONTOLOGY [24] for ontology development, which better advocates the use of a structured informal representation to support the ontology development [24], in particular for our system design.

The following diagram (Fig. 1) represents the set of activities for our ontology development.

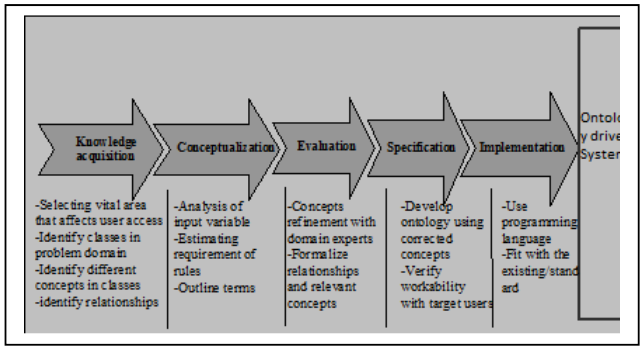


Fig. 1: Adapted methodology for developing ontology

## IV. Domain Ontology Construction

Our main aim in the EDRMS system design project was to deliver a suitable knowledge model that may provide solid meanings of design details to developers and users. The notion of conceptualization was redefined in the project through a newly scratched formal domain ontology specification. According to definition of Gruber [3], our attempt goes to further clarify the notions, making clear the relationship between concepts that are intended utilities in the conceptualization.

The domain ontology development involved participants who are involved in managing and supervising oral history projects (as a particular record). The aim of involving participants was to obtain information and use their advice to validate the ontology draft. During the development process, the ontology draft was improved and refined until complete the design satisfaction (e.g. in meeting user-demand) was achieved. Each and every ontology concept, its subclasses and the relationships between them were discussed. All the suggested changes such as deletion of some concepts, modification of relationships and addition of new concepts were recorded. Through the process of domain ontology construction, the following benefits were ensured for the users and developers:

*Clarity:* According to Gruber [3], there are three requirements for clarity as follows: i) the explanation of ontology terms should be defined formally without subjectivity; ii) natural language should be used in documenting ontology; and iii) the terms must express 'the intended meaning' with regard to the requirements of social situations and computation rather than their context. In this study, the domain ontology we developed, were based on the terms extracted from the domain-related documents and focus group meetings. Participants of focus group pointed that all of the terms we outlined did communicate the intended meaning and the relationships that were supported through the appropriate meanings to improve clarity.

*Consistency/coherence:* According to Arbon [26] the ontology 'should sanction inferences that are not consistent with the definitions' of the important terms. The elements of ontology should avoid contradictions or ambiguity. For example, in our domain ontology the class initially 'Celebrities' was broken into five subclasses: defense, entertainment, education, security and sports. However, the inferences were considered inconsistent with and contradictory to the defined concepts because, based on the content analysis, not all of the participants are celebrities. Based on the feedback by participants, the concept of 'celebrities' was removed and replaced with 'interviewees' to represent it more generally. We had included the subclass 'Professional' under the 'Project Field', but in the final focus group meeting it was decided that this topic conveyed some ambiguity, since there could be different types of

professionals involved in Oral History Projects. These concepts are considered to be too general to be included in this field. Since the ontology-based system targets the specific field of the projects, this term was removed to avoid ambiguity and to maintain consistency. In an earlier stage, the subclasses of the Project field covered police, army, sports, education and the arts. One of the participants argued that most of the terms under project field, such as education, sports and arts, could be categorized as subjects. On the other hand, the terms 'army' and 'police' do not constitute a subject and should be replaced with subject terms. After some discussion it was determined that 'defense' was a more suitable term to use in place of such instances as 'army', 'navy', 'air force', etc. In addition, it was also determined that 'security' was a more appropriate term to use than 'police'. We finally ensured that the ontology-based system achieved consistency removing or avoiding all contradictions of terms or concepts.

*Conciseness:* According to Yu et al. [27], the conciseness required in an ontology develops for excluding unnecessary concepts or redundancies. This aspect has been carefully considered during our domain ontology development. For instance, one of the participants found that the term 'dates' in the initial draft ontology was redundant. This term was a subclass of 'Oral History Management' (also a subclass of 'Events'). However, since 'dates' is referred to under the events category, it was put under the 'events'. At the earlier stage, events, places and dates were considered as different concepts. One of the participants suggested that the terms 'place' and 'date' be placed as a subclass of 'events', since they refer to the date and place of events. The majority of participants agreed that it was unnecessary to have date and place that referred to the same events as separate entities, and therefore 'date' and 'place' became a subclass of 'events'. We ensured that all of the unnecessary concepts had been removed to improve conciseness.

*Expendability/extendibility:* The ability of ontology should be to extend further or to be applied to a specific application domain. Our domain ontology has been built in such a way that it was prepared for the reuse and extension of different parts of the modelling. One of the participants highlighted that there are other agencies which conduct Oral History Projects such as the National Archive, the National Museum, public libraries and education institutes. According to the participants, the ontology met the requirements of any oral history project due to the flexibility of the method used to capture the knowledge/contribution of interviewees. Finally the participants agreed that developed domain ontology could be reused and extended to other agencies.

*Correctness:* Yu et al. [27] noted that ontology should represent the correct modelling of real-world concepts. Our focus was for the correctness of an existing system through developing the domain ontology. Participants provided useful suggestions and feedback to correct the existing issues. For example, the initial system 'events' had subclasses of 'name', 'dates', 'places' and 'type'. These subclasses were not sufficient to represent events. Therefore the concept was revised significantly according to the feedback. (The subclasses of Events were revised thus: Events Title, Events Date, Events Venue, Theme, involvement and contribution).

*Minimal ontological commitment:* According to Gruber [3], this benefit refers to permitting more flexibility and freedom in the ontology's specialization. Yu et al. [27] look at this attribute with regard to supporting multiple views for the same information and flexibility in classifying items. We added feature by developing EDRMS user interfaces that serve the different purpose of searching activities in the domain. For example, in the early stage the system had a central term, Oral History Management, with four subclasses (celebrities, events, date and place). In the new ontology consists of Oral History Projects as the central concept, followed by five subclasses: Oral History Project Plan, Interviewees Profile, Topics, Events and Project Field. In addition, the number of instances and subclasses increased from 20 in the initial ontology-based system to 40 in the final system.

*Completeness:* According to Gruninger and Lee [28], this benefit can be ensured by using competency questions that include queries and requirements that the ontology must be able to answer. Due to the size of the ontology-based system, only a few examples of the competency questions are presented in this study (Fig. 2).

| Competency questions | Concept | Relationships |
|---|---|---|
| Which candidates/participants should I consider when proposing/conducting Oral History Projects? | IntervieweesProfile | IsPropertyOf |
| How to conduct Oral History Projects? | Guidelines | IsPartOf |
| Which criteria should I consider when choosing interviewees? | Significant contribution | Includes |
| Which field could be considered in selecting interviewees? | Project field | Ispartof |
| How do I get the interviewees' information? | IntervieweesProfile | Ispartof |
| Which types of events are involved in the Oral History Projects? | Events | Includes |
| How do I choose a topic in conducting Oral History Projects? | Topics | Includes |

Fig. 2: An example of the competency questions used to evaluate the effectiveness of the developed application

During the ontology development, most of the participants agreed with all the definitions given. Through the participation of stakeholders in focus group meetings it was confirmed that that the ontology-based system can answer all the queries and requirements outlined initially for the EDRMS solution design. For example, the first competency question is: 'Which candidates/participants should I consider when proposing/conducting Oral History Projects?' The appropriate term to answer this question is 'Interviewees Profile', and the

relationship is 'Is Property Of'. The second question is: 'How should Oral History Projects be conducted?' The appropriate term to answer this question is 'Guidelines', and the relationship is 'Is Part Of'.

*Coverage:* Haghighi et al. [12] described about this benefits by using leximancer software. However, they found that leximancer had limitations that required significant refinement by the domain expert. In addition, it was time consuming. Based on the recommendations of Haghighi et al. [12], this study employed an expert to review, evaluate and refine the coverage. During the focus group meeting, many changes were made to improve the coverage of the ontology. For example, the initial ontology had only a small coverage with Oral History Management as a central concept and with four subclasses (celebrities, events, date and place). After seven iterations, the final ontology-based system consists of Oral History Projects as the central concept, followed by five subclasses: Oral History Project Plan, Interviewees Profile, Topics, Events and Project. We prepared the final draft of the ontology which covered the concept in Oral History Projects.

The domain ontology was implemented (see Fig. 3) through the concepts (classes), subclasses, properties and associated relationships of the problem domain in education. There are four main key concepts in the final structure of ontology was defined. As part of the ontology description we also outlined more details such as the definition of terms used and relationships related to the proposed ontology approach. These definitions were very important to the stakeholders to learn and understand the ontology, in order to simplify the navigation and searching processes. Furthermore, the components assist the ontology developers to understand what extent a term was intended to create meaning and the design purposes.

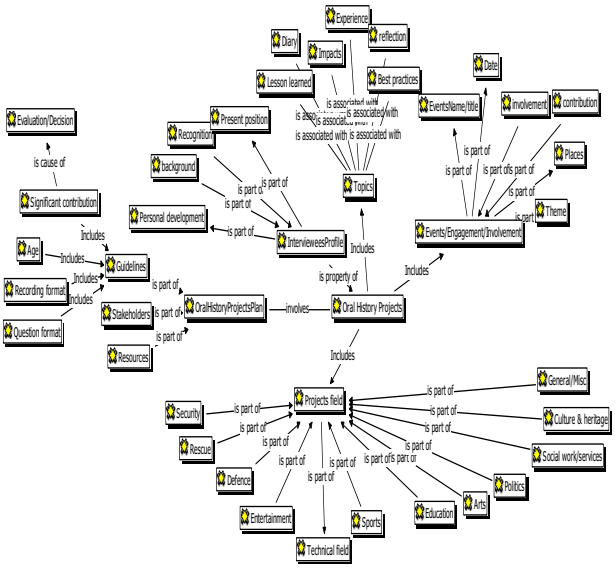


Fig. 3: The final domain ontology in education problem domain

## V. DISCUSSIONS AND CONCLUSION

The objective of the study was to reinforce the unique significance of developing domain ontology for stakeholder oriented application developments. The paper therefore described a design case in that the significance of structuring problem domain using ontology was presented. The study has also presented on how should problem components be integrated in solution design through stakeholder's active participation for enhancing developed systems' accessibility. The ontology development became a recognized approach in system development [29; 30; 31] as the technique is able to provide a basis for application development that could provide a common understanding for a solution model that is reusable, sharable and interoperable. We have practically justified this through our case demonstration. Sharing and reusable provisions for end-users were implemented for the benefits of users. In the existing EDRMS, the searching was based on keywords that bring mismatches between user need and the content of the database. In the direction of KM the ontology offer advanced user oriented features thus attempting to develop a more effective system.

Our design effort goes to the direction of conceptual study by Noy and McGuinness [8] in that the importance of ontology development has been described for its practical implications. In this study, the authors have shown the practical situations of using ontology method in order to achieve the following key benefits: develop common understanding of the structure of information among users and developers; make the problem domain knowledge explicit for the target solution design; separate domain knowledge from operational knowledge; and analyze the domain knowledge for the application development. We extended the study as we practically defined these benefits of using domain ontology development method throughout the study. We therefore would argue that domain ontology can provide a structural basis for application development that could offer a common understanding for developing stakeholder-oriented solution model that is reusable, sharable and interoperable.

## REFERENCES


[1] Y.J. Chen, "Development of a method for ontology-based empirical knowledge representation and reasoning", Decision Support Systems, 50, 1-20, 2010

[2] N. Guarino, "Formal Ontology in Information Systems". Proceedings of FOIS'98, Trento, Italy, 6-8 June 1998. Amsterdam, IOS Press, pp. 3-15.

[3] T.R. Gruber, "A translation approach to portable ontology specification", Knowledge Acquisition, 5(2), 199–220, 1993.

[4] Y.J. Chen, H.C. Chu, Y.M. Chen, C.Y Chao. "Adapting domain ontology for personalized knowledge search and recommendation. Information and Management", 50, 285–303, 2013.

[5] S. W. Liddle, K.A. Hewett, and D.W. Embley, "An Integrated Ontology Development Environment for Data Extraction", 2nd International Conference on Information Systems Technology and its Applications, National Technical University, Kharkiv, Ukraine, June 19-21, 2003.

[6] S.J. Miah, D. Kerr, and J. Gammack, "A design environment ontology for stakeholders developed decision support tools in the Australian dairy industry" Proceedings of the 17th Australasian Conference on Information Systems (ACIS2006), Adelaide, Australia, 2006.

[7] P. Lambrix and A. Edberg, "Evaluation of ontology merging tools in bioinformatics", Proceedings of pacific symposium on Bioinformatics, 8, 589-600, 2003.

[8] N.F. Noy and D.L. McGuinness, "Ontology Development 101: A Guide to Creating Your First Ontology". Stanford Knowledge Systems Laboratory Technical Report, Stanford Medical Informatics Technical Report, 2001. (URL: http://www-ksl.stanford.edu/people/dlm/papers/ontologytutorial-noy-mcguinness.pdf, Accessed on May, 12 2014).

[9] R. Casati and A. Varzi, "Spatial Entities. In O. Stock (ed.) Spatial and Temporal Reasoning", Kluwer, Dordrecht, 1997.

[10] J.N.K. Liu, Y.L. He, and E.H.Y. Lim "Domain ontology graph model and its application in Chinese text classification". Neural Computing and Applications, 1–20, 2012.

[11] J. Euzenat, "Research challenges and perspectives of the Semantic Web", Intelligent Systems, IEEE, 17(5), 86–88, J. 2002.

[12] D. P. Haghighi, F. Burstein, A. Zaslavsky, and P. Arbon, "Development and evaluation of ontology for intelligent decision support in medical emergency management for mass gatherings", Decision Support Systems, 54(2), 1192–1204, 2013.

[13] R. Navigli and P. Velardi, "Learning domain ontologies from document warehouses and dedicated web sites", Computational Linguistics, 30(2), 151–179, 2004.

[14] B. Abrahams, "Tourism Information Systems Integration and UtilisationWithin the Semantic Web". Unpublished PhD thesis. School of Management and Information Systems,Victoria University, Melbourne, Australia, 2006.

[15] J. Joo and S.M. Lee, "Adoption of the Semantic Web for overcoming technical limitations of knowledge management systems", Expert Systems with Applications, 36(3), 7318–7327, 2009.

[16] S. Boyce and C. Pahl, "Developing domain ontologies for course content", Educational Technology & Society, 10(3), 275–288, 2007

[17] M.A. Musen, "Domain ontologies in software engineering: use of Protégé with the EON architecture", 37, 540-50, 1999.

[18] A.S Jacinto, and J.M. Parente de Oliveira, "An ontology-based architecture for Intelligent Tutoring System", Interdisciplinary Studies in Computer Science, 19 (1), 25–35, 2008.

[19] M. R. Genesereth and N. J. Nilsson, Logical Foundation of Artificial Intelligence. Morgan Kaufmann, Los Altos, California, 1987.

[20] M. Uschold and M. Gruninger, "Ontologies: principles, methods and applications". The Knowledge Engineering Review, 11, 93–155, 1996.

[21] S. Staab, H. P. Schunurr, R. Studer, and Y. Sure, "Knowledge processes and ontologies", IEEE Intelligent Systems, Special Issue on Knowledge Management, 16(1), 26-34, 2001.

[22] R. Mizoguchi, M. Ikeda, K. Seta, and J. Vanwelkenhuysen, "Ontology for Modelling the World from Problem Solving Perspectives", Proceedings of IJCAI-95 Workshop on Basic Ontological Issues in Knowledge Sharing:1-12, 1995.

[23] M. Fernandez-Lopez, A. Gomez-Perez, J.P. Sierra, and A.P. Sierra, "Building a Chemical Ontology Using Methodology and the Ontology Design Environment", IEEE Intelligent Systems,14(1): 37-46, 1999.

[24] M. Fernandez, A. Gomez-Perez, and N. Juristo, "METHONTOLOGY: From Ontological Art Towards Ontological Engineering", Presented to AAAI97, Workshop on Ontological Engineering, Stanford University, 33-40, 1997.

[25] J. Bally, T. Boneh, A. E. Nicholson, and K. B. Korb, "Developing An ontology for the Meteorological Forecasting Process", Decision Support in an Uncertain and Complex World: The IFIP TC8/WG8.3 International Conference, 2004, http://vishnu.sims.monash.edu.au:16080/dss2004/proceedings/pdf/08_Bally_Boneh_Nicholson_Korb.pdf, Accessed 05-May-2010

[26] P. Arbon, "The development of conceptual models for mass-gathering health", Prehospital and Disaster Medicine. The Official Journal of the National Association of EMS Physicians and the World Association for Emergency and Disaster Medicine in association with the Acute Care Foundation, 19, 208–212, 2004.

[27] J. Yu, J. A. Thom and A. Tam, "Evaluating ontology criteria for requirements in a geographic travel domain", in: Proc. of Intl. Conf. on Ontologies, Databases and Applications of Semantics. Agia Napa, Cyprus, 2005 .

[28] M. Gruninger, and J. Lee, "Ontology applications and design. Special Issue in Communications of the ACM (CACM), 45, 39–45, 2002.

[29] D. Hyland-Wood, D. Carrington, and S. Kaplan, "Enhancing software maintenance by using semantic web techniques", International Semantic WebConferences(ISWC)-2006, URL:http://www.itee.uq.edu.au/~dwood/papers/SoftwareMaintenanceViaSemWeb.pdf, Accessed on June 10, 2012.

[30] S.J. Miah, "A new semantic knowledge sharing approach for e-government systems", 4th IEEE International Conference on Digital Ecosystems and Technologies, Dubai, United Arab Emirates, 457-462, 2010, URL: http://ieeexplore.ieee.org/document/5610607/, Accessed on June 10, 2014.

[31] S.J. Miah, "An ontology based design environment for rural decision support", Unpublished PhD Thesis, IIIE and Griffith Business School, Griffith University, Brisbane, Australia, 2008