WE
Vol 2 No. 1
June 2021

Creation of Ontology-Based Knowledge Organization for Value-Added Information Retrieval

SHRABANA GHOSH[1]
PIJUSHKANTI PANIGRAHI[2]

Abstract

The limitations of the information retrieval (IR) system have brought effective constraints in complicated searching. This gave rise to the ontology to strengthen the knowledge organization refining the traditional approach towards improving searching. Overcoming the ineffective and inefficient searching, ontology can appear as one of the important components of the knowledge organization systems in the present paradigm. Because ontologies are capable of displaying different kind of relationships among terms and concepts of different hierarchies. The paper defines the concept of ontology and describes the different types of ontology. The present paper states the functions of ontology exploring the steps in developing ontology for a particular discipline. Steps towards creation of ontology for a specific discipline are demonstrated. It concludes by saying that ontology development is interdisciplinary in nature and continuous ontology improvement has to be done in order to adapt to the changing needs.

Keywords: *Information Retrieval, Knowledge Organization, Classification, Ontology, Ontology Creation, OWL, Class, Properties, Instances.*

1 INTRODUCTION

Knowledge is used for various purposes like planning, decision making, taking action in different fields, treatment and healing, satisfying curiosity, entertainment etc. In order to its effective utilization, knowledge needs to be organized in a proper manner. Classification is the main activity which serves as the basis of knowledge organization. Contextual application of classification in the google age has been explored by Hjørland (2007, 2009, 2012) with the semantic analysis of concepts. Comparing, thus, with the traditional sense of librarianship, classification may be seen as the interdependent processes of:

a) defining concepts which is equivalent to defining classes;
b) determining semantic relations between concepts is evolved from determining relationships between classes (such as hierarchical relations, among others), i.e., making a classification system; and
c) determining the elements that fall under a given concept (to assign a given "thing" to a concept) is an equivalent process of assigning elements (in Library and Information Science, documents) to a class in a given classification system.

Hodge (2000) presented three categories of knowledge organization systems:

1) term lists, which provide lists of terms, with definitions; e.g., glossaries, dictionaries;
2) classifications and categories, which provide the creation of subject sets; e.g., subject headings, classification schemes, taxonomies; and
3) relationship lists, which provide the connections between terms and concepts e.g., thesauri, semantic networks, ontologies.

[1]Librarian, Jadavpur University, Jadavpur, Kolkata-700032 gshrabana@gmail.com
[2]Professor, Dept of Library and Information Science, University of Calcutta, Kolkata-700073 ppklis@caluniv.ac.in

2 CHALLENGES FOR IR SYSTEM

a) The web content is semantically heterogeneous in nature. Yahoo and Google are the main search engines which use keywords to search the heterogeneous web content. The search list provided after a search query contains a huge number of irrelevant information. Only the top ten items on the list are often relevant. In order to improve the search results of a query and match it to the web pages, a formal vocabulary on the topic (ontology) may be used.
b) The documents retrieved by a search query in the IR systems are often not specific i.e. precision ratio is low. This is a problem of the IR system. If we need information spread over a number of documents, we have to initiate several queries to collect the relevant documents. We then have to extract the partial information manually and put it together. The use of ontology will increase the rate of precision in most of the cases.
c) Traditional search engines are unable to process spreadsheet kind files (containing values in rows and columns). The web crawler can locate the file and index it, but fails to give answers to complex queries from the spreadsheet file. The reason for not retrieving is that no metadata is incorporated to define the type of data and semantics of the value. It is possible to define classes-subclasses and pertaining data and object properties and thus the semantic relationship through an ontology.
d) In the digital environment, terms in a controlled vocabulary form a knowledge model for a subject domain. The terms function as labels and display the relations between categories of data. This means that knowledge model is converted into a data model at the implementation stage. Thesauri do not have the mechanisms for transforming into data model from knowledge model. Ontologies as a form of knowledge modeling tool can overcome this shortcoming of thesauri, because ontologies can model not only the metadata elements but also define the vocabulary for both elements and element values.
e) There are several types of associative relationships between terms belonging to different hierarchies. Thesauri represent all types of associative relationships belonging to different hierarchies with only one type of relationship i.e., 'Related Terms' or 'RT'. Thesauri do not have the mechanism to display different types of associative relationships. The studies on associative relationships between terms have necessitated the study of ontology. (Shiri, A. A. & Revie, C., 2000; Tudhope, D., Alani, H. & Jones, C., 2001)

3 ONTOLOGY

Philosophers have studied ontology since the time of Aristotle. Ontology is the "branch of metaphysics that concerns itself with what exists" (Blackburn, 1996). As pointed out by Alan Gilchrist (2003), Vickery first used the term ontology in the field of Library and Information Science. The commonly used or highly cited ontology definition is adopted from Gruber where an 'ontology is a formal, explicit specification of a shared conceptualization'. "Conceptualization" refers to "an abstract model of phenomena in the world by having identified the relevant concepts of those phenomena." "Explicit" means that "the type of concepts used, and the constraints on their use are explicitly defined." "Formal" refers to "the fact that the ontology should be machine readable." "Shared" reflects that "ontology should capture consensual knowledge accepted by the communities." (Gruber, 1993).

Ontology is a multi-disciplinary field which deals with the knowledge of information acquisition, organization, natural language processing, information extraction, artificial intelligence and knowledge representation. Ontology provides a shared framework of the specific domains that can be communicated between people and application systems. It describes the semantics of a domain in both a human understandable and computer-processable way. Ontology defines reference model of application domains with the purpose of improving information consistency and reusability, systems interoperability and knowledge sharing. way. It has significant influence in the areas dealing with vast amounts of heterogeneous information, such as the world wide web and intranet information systems, complex industrial software applications, knowledge management systems, electronic commerce and e-business.

3.1 Types of Ontology

The different types of ontologies are distinguished to clarify their goals, contents and use. Several classifications of ontologies have been presented in different literature. Each of them focusses on different aspects in which ontologies can be classified. Roussey, C., Pinet, F., Kang, M.A. & Corcho, O. (2011). in the second chapter (entitled "An Introduction to Ontologies and Ontology Engineering") of the book Ontologies in Urban Development Projects classifies ontologies based on the expressivity and formality of the languages used. Another classification of ontology is based on the scope of the objects described by the ontology.

3.1.1 Classification Based on Language Expressivity and Formality

The components of ontology (or, in general, of a knowledge representation language) can be defined depending on the expressivity of ontology: concepts, properties, instances, axioms, etc. These components (concepts, properties, instances etc.) are referenced by one or more symbols. Semantic relations link only concepts together: for example, the location relationship indicates that city concept is localized in a country concept. According to the usage of these components, the following four kinds of ontologies are presented.

(1) Information Ontologies

Information ontologies are composed of diagrams and figures which are used to express and organize the ideas of collaborators in the development of a project. These ontologies are only used by humans. The characteristics of information ontologies are:

- Easily modifiable and measurable
- Novelty and schematic

They are generally used during a design process of a project: for example, information ontology can be used during the conception phase of information system development project. The goal of information ontology is to propose an overview of a project in order to express the state of the project. Information ontologies are described by means of visual languages, which can be easily understood by humans. Examples of such ontologies are Information Ontology of Architectural Design, Information Ontology of Urban Planning etc.

(2) Linguistic/Terminological Ontologies

Linguistic ontologies have twofold roles: firstly, to define the vocabulary used. This is achieved by a dictionary which lists the terms actually used in language. Secondly, linguistic ontology results from the terminology agreement within a users' community. In order to avoid ambiguity, the agreement defines the specific term to be used to represent a concept. This process is called vocabulary normalization. When a concept could be described by two synonymous terms, the normalization process selects one of the terms to be the preferred label of the concept. In this sense linguistic ontologies can be glossaries, dictionaries, controlled vocabularies, taxonomies, folksonomies, thesauri, or lexical databases. Two languages are used to describe linguistic ontologies: SKOS is used to define thesauri and RDF is used the define web metadata. Examples of linguistic ontologies are URBAMET Thesaurus on Urban Planning, Housing and Construction News and Record, GEMET or the General Multilingual Environmental Thesaurus.

(3) Software Ontologies

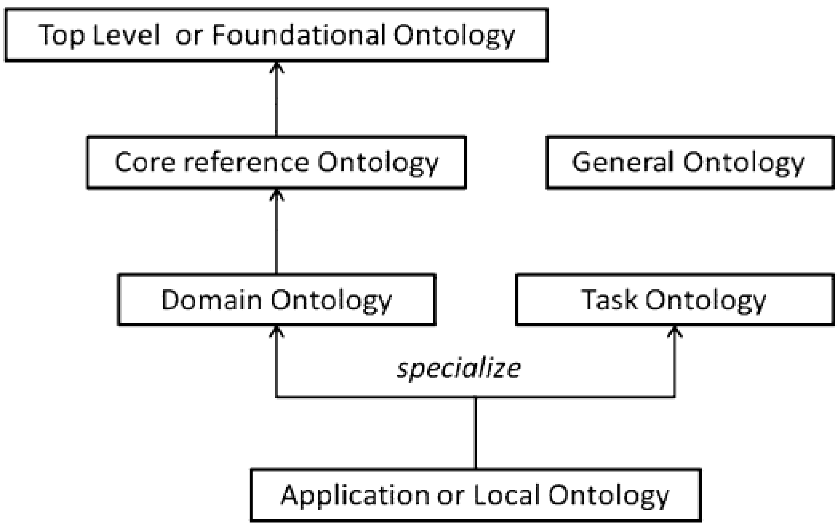
Software ontologies provide conceptual schemata whose main focus is data storage and data manipulation. Software ontologies are used for software development activities. Its goal is to provide data consistency. A concept consists of a set of properties; all concepts are linked to each other by the relations between them. These relations are also associated to constraints. During execution, data is stored in the properties of object that is in an instance of a concept. Thus, data can be processed in various treatments (called methods). Software ontologies are generally defined with conceptual modeling languages. These languages are used during software design procedure in software and database engineering: for example Entity-Relationship Model language or Object Model Language. The Unified Modeling Language (UML) is a standard used for modeling software and information systems.

(4) Formal Ontologies

Formal ontologies need separate and distinct semantics for the language to define the concepts, the distinctions between concepts as well as strict rules about how to define concepts and relationships. This is obtained by using formal logic (usually first order logic or Description Logic) where the meaning of the concept is guaranteed by formal semantics. There are different formal languages used to describe formal ontology like Description Logics (DL), Conceptual Graphs (CG), First Order Logic (FOL), etc. The standard language recommended by W3C is Web Ontology Language (OWL). Examples of Formal Ontology are research project initiated in South Korea to model an ontology for the Korean architectural domain and the CoBra ontology to facilitate the pervasive computing environment.

3.1.2 Classification Based on the Scope of the Ontology

The figure below describes ontology classification based on domain.



Ontology Classification based on Domain Scope

i. **Local Ontologies/Application Ontologies**
Local or application ontologies are specializations of domain ontologies where there is no knowledge sharing and the domain is represented according to a single viewpoint of a user or a developer. This kind of ontology is presented as a combination of domain ontology and task ontology in order to fulfill the specific purpose of an application. The task ontology models knowledge to achieve a task, while the domain ontology describes the knowledge where the task is applied.

ii. **Domain Ontologies**
Domain ontology represents a domain with a specific view point. This viewpoint corresponds to the conceptualization and visualization of a specific phenomenon by a group of users. For example, Urban Sprawl Ontology is applicable only on urban morphological evolution.

iii. **Core Reference Ontologies**
Core reference ontology is a standard used by different group of users. This type of ontology of a domain integrates the different viewpoints related to specific group of users. It is the result of the integration of several domain ontologies. A core reference ontology is built to bring out the central concepts and relations of the domain. For example, Hydrontology describes the hydrographic features.

iv. **General Ontologies**
General ontologies are not dedicated to a specific domain or field. They contain general knowledge of a huge area. For example: OpenCyc Ontology. It is a general knowledge base and commonsense reasoning engine. The entire Cyc ontology contains huge number of terms, along with huge number of assertions relating the terms to each other and forming a general formal ontology.

v. **Foundational Ontologies/Top Level Ontologies/Upper-Level Ontologies**
Foundational or top-level ontologies are generic ontologies applicable to various domains. They define basic notions like objects, relations, events, processes and so on. Foundational ontology can be compared to the meta model of a conceptual schema. The most well-known foundational ontology are the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) and the Basic Formal Ontology (BFO).

Abecker,A., Bernardi,A., Hinckelmann, K., Kuhn, O. & Sinteck, M. (1998) enlist three kinds of ontologies:

- An organizational ontology describes the information meta-model, e.g., the structure and format of the information sources. This is the lowest level ontology.
- A domain ontology is used to describe the content of the information sources.
- An enterprise ontology is used for modeling business processes. Its purpose is to model the knowledge needs in a business process in order to describe a process context, which enables active knowledge delivering.

3.2 Functions of Ontology

The knowledge organization systems serve many critical functions (Soergel, 1999) in thinking and in communicating, organizing, and retrieving information by people and machines. The functions of the ontology fall within the purview of the knowledge organization systems (Synak, M., Dabrowski, M. & Kruk, S. R., 2009) which may be identified as the following:

1) It determines the semantic mapping in the field of applications (domain) by describing the different aspects that are specific to particular field. It is used as a conceptual backbone for structuring the domain information. The ontology represents conceptual relations, such as a topic hierarchy, and also taxonomic and non-taxonomic relations. The ontology clarifies concepts, relates concepts to terms and provide definitions.
2) This ontology improves the existing classificatory structure in the specific field of study to help in information retrieval and search. An ontology must adapt to the changing needs. New concepts are always being added in a subject field. Some relationships among concepts also change due to research activities. The new concepts and their relationships are to be accommodated in an ontology.
3) Ontology is a development of structure, which connects different concepts to evolve a pattern. It helps to examine the status of the ontology in relation to others. The ontology provides a semantic map to individual fields and the relationships among fields, thus providing orientation and serving as a reference tool.
4) Ontology functions as an improved device for user-centred indexing and improves information retrieval. It supports hierarchically expanded searching and provides knowledge-based support to end-users; as for example, searching menu trees, guided facet analysis of a search topic, browsing a hierarchy or concept map to identify search concepts.
5) Ontology is developed as a tool to facilitate unified access to several databases at a time, mapping from the user's query terms to descriptors used in one or more databases. Ontology is used for simple searches starting from a single search term or advanced searches using multiple criteria, and also for a recommendation system based on guided navigation through an ordered set of categories.

3.3 Ontology Creation

Ontology describes the concepts in the field of application or domain and also the relationships that hold between those concepts. The most recent development in standard ontology languages is OWL (Web Ontology Language) from the World Wide Web Consortium (W3C). OWL not only makes it possible to describe concepts but also provides new facilities to define concepts. It has a set of operators - e.g., intersection, union and negation. Complex concepts can be built out of simpler concepts. The logical model allows the use of a reasoner which can check whether all the statements and definitions in the ontology are mutually consistent. The reasoner can help to maintain the hierarchy correctly.

OWL may be categorized into three species or sub-languages: OWL-Lite, OWL-DL and OWLFull. A defining feature of each sub-language species is based on its expressiveness. OWL-Lite is the syntactically simplest sub-language. It is intended to be used in situations where only a simple class hierarchy and simple constraints are needed. OWL-DL is more expressive than OWL-Lite. OWL-DL is based on Description Logics (DL). It is to mention here that OWL-Lite is also a Description Logic based language. OWL-Full is the most expressive species among the sub-languages. It is intended to be used in situations where very high expressiveness is required.

- *Ontology Editor*

Ontology editors allow for creation and maintenance of ontologies in a graphical manner. OntoEdit is a prominent commercial ontology editor. Protégé is a free, open-source ontology editor and a knowledge acquisition system written in Java language. Protégé allows users to create ontologies in OWL language. Protégé 4.2 is used for creating OWL ontology for this research work.

- *Components of OWL Ontologies*

OWL ontologies have similar components to Protégé frame-based ontologies. The terminology used to describe these components is slightly different from that used in Protégé. An OWL ontology consists of Individuals, Properties, and Classes, which roughly correspond to Protégé frames Instances, Slots and Classes.

3.3.1 Steps in Ontology creation

We have carried out a research work where the following steps are adopted towards ontology creation (Ghosh, Srabana, 2015).

Step 1. *Determining the domain and scope of ontology*: In order to create ontology, the interest field of knowledge for developing the ontology has to be ascertained. For example, the domain may be the subject of Library and Information Science.

Step 2. *Determining which existing ontologies or vocabularies can be reused*: There are a number of existing controlled vocabularies and ontologies covering different fields. The existing controlled vocabularies in the relevant domain may be used as the source for the terms for the proposed ontology. In the present study the Colon Classification7th ed., Dewey Decimal Classification 23rd ed., Universal Decimal Classification (Standard ed.) and the Library of Congress Subject headings 33rd ed. have been used.

Step 3. *Collecting important terms*: This step is aimed at collecting a vocabulary of terms of the selected field that is to be described by the proposed ontology. In order to ensure a complete ontology, it is important that a comprehensive list of concepts and terms is to be collected without the overlap between concepts.

Step 4. *Defining classes*: In general, the determination of classes and its hierarchy depends on the possible uses of the ontology, the level of the class is necessary for the application, personal preferences and requirements for compatibility with other models. Of the known approaches to developing hierarchical classes, any one of the three approaches is followed.

- Top-down approach, identifies the most general concepts and then breaking down of the concepts into more specialized concepts. The top-down approach is always encircled by competency questions to model a domain. Domain mapping is generated at a generic level and subsequently they are refined to shape the possible restrictions with feasibility. The concepts in the ontology are derived from an analysis and study of relevant information sources about the domain (collection of attributes).
- Bottom-up approach starts in the opposite direction i.e., first defines the specific concepts and then group them under general concepts. Bottom-up approach may be applied to populate the classes with lexical entities collected from standard documents (Davies, J., 2003). But it can be easily inferred that, both the two exist and work at the idea and verbal planes.
- Hybrid approach includes the combination of both the methods.

➢ *Creation of classes, subclasses and sibling classes in Protégé*

The main building blocks of an OWL ontology is classes. In Protégé, the empty ontology contains one class called **Thing**. OWL classes are interpreted as sets of individuals (or sets of objects). The class **Thing** is the class that represents the set containing all individuals. Hence all classes are subclasses of **Thing**. Here, Library and Information Science has been treated as a subclass of **Thing**. The schedule of subjects, place or countries and languages are all treated as separate classes under the class **Thing.**

A new subclass under the selected class **Thing** may be created with the **'Add Subclass'** button. A dialog box will appear to name the class. Here the subclass **Library_and_Information_Science** has been entered under the class **Thing**. Similarly,

A**pplication_areas_of_information**, **Information_evaluation_and_research**,

Legal_aspects_of_information, **Library_activities** etc. are all subclasses of Library_and_Information_Science created in the same way. (Ghosh, Srabana, 2015).

The **'Add Sibling class'** button creates a new class in the same array of the selected class. The classes **Countries, Languages**, **Subjects** were created as sibling classes of **Library_and_Information_ Science** class. (Ghosh, Srabana, 2015).

Step 5. *Defining Class Properties:* A class is known to have two kinds of properties: datatype and object property. Datatype properties are used to describe object's physical characteristics (intrinsic properties) as well as abstract concepts (extrinsic properties). Object properties are commonly used to represent relationships between individual persons or objects.

➢ *Creation of Properties in Protégé*

OWL Properties represent relationships. There are two main types of properties, Object properties and Data type properties. Object properties are relationships between two individuals. The 'Add Object Property' button is used to create a new Object property. The property is to be added in the 'Property Name Dialog' box. In this study some of the Object properties are has Activites, has Areas, has Collection Of etc. (Ghosh, Srabana, 2015).

➢ *Property Domain and Range*

Since the Object property expresses relationship between two individuals, the two individuals are expressed as domain and range. Properties link individuals from the domain to individuals from the range. For example, in this ontology, the property **hasActivities** would link individuals belonging to the class **types_of_libraries** to individuals belonging to the class of library_activites. In this case the domain of the **hasActivities** property is **types_of_libraries** and the range is **library_activities**. (Ghosh, Srabana, 2015).

➢ *Inverse properties*

An Object property may have a corresponding inverse property. If some property links individual A to individual B then its inverse property will link individual B to individual A. In order to add an inverse property, the object property has to be created. The 'Add object property' button on the 'Object Properties' tab has to be pressed to create a new Object property Guides (this will become inverse property of isGuidedBy). Then the 'Add inverse property' button on the inverse property has to be pressed. This will display a dialog box from which properties may be selected. The **isGuidedBy** property has to be selected and 'OK' has to be pressed. The property **isGuidedBy** should now be displayed in the 'Inverse Property' view. The properties hierarchy should also now indicate that **isGuidedBy** and Guides are inverse properties of each other. (Ghosh, Srabana, 2015).

Step 6. *Defining property restrictions:* Property restrictions work together with properties. They are used to specify usage of the property, its features, allowed values etc. Restrictions in OWL fall into three categories: Quantifier Restrictions, Cardinality Restrictions and hasValue Restrictions. Quantifier Restrictions can be further categorized into Existential Restrictions and Universal Restrictions. In the study I have used Existential Restrictions. In Protégé the word some is used to denote Existential Restriction.

Step 7. _Creating Instances:_ This is the last step. A class is chosen and an individual is created of the chosen class. The individual may have property values. (Synak, M., Dabrowski, M. & Kruk, S. R. , 2009) In some cases, the number of instances is larger than the number of classes in an ontology. The number of instances varies from hundreds to thousands or even more. In Protégé, there is the provision to define the individuals of a class as members or instances. We have treated the names of individual countries as instances of the class countries.

Step 8. _Evaluation:_ Evaluation is not included within the development process. Any development is incomplete without evaluation as it acts as a check-gate to verify the appropriateness and feasibility of the conceptual model and addresses the robustness of the development in order to cater different necessities of the target groups/stakeholders. In building ontology, the evaluation is based on validating two aspects. They are- design feasibility and expected utility. (Pattuelli, M.C., 2011). Some competency questions automatically rise here, they are-

a) What is the extent to which the ontology can give the appropriate term and associated concepts with relations?
b) Level of granularity in defining the concepts.
c) Facilitation of knowledge flow in which direction?
d) Pluripotency of the ontology.

4 CONCLUSION

Ontology development falls under the purview of knowledge engineering. It is interdisciplinary in nature requires the knowledge of the subject field as well as the expertise of using the semantic web tools and technologies. Hence building ontologies is a collaborative work. At the international level collaborative projects are being undertaken in different subject areas. However, more research projects for development and evaluation of ontologies are to be undertaken.

Automated and semi-automated techniques are being employed for data and concept extraction in ontology development. Relation extraction is a very complex and difficult problem to resolve. Further research is going on to find appropriate and efficient ways to detect or identify the relations. Though various methods are available in ontology evaluation, there is no standard methodology in ontology evaluation. A better understanding of the connection between the features of an ontology and quality criteria remains an important open research challenge in ontology evaluation.

The ontologies must continuously adapt to the changing needs of the users and the subject field. Ontology evolution is timely adaptation of the ontology to changes and the consistent management of these changes. (Haase, P., Völker, J. & Sure, Y. ,2005) . Due to the variety of sources and consequences of the changing scenario and needs of the users, the changes in the ontology cannot always be incorporated single-handedly by the ontology developer. This process is supported by the evolution management infrastructure. One of the important aspects of ontology evolution is to identification of changes. In some cases, changes to the ontology may be requested explicitly but the actual challenge is to obtain and examine the non-explicit knowledge about the needs of the end-users. This can be done by analyzing various data sources related to the content that is described using the ontology and also the end-users’ behaviour which include the information about their likes, dislikes, preferences or the way they behave., The ontology developer can make changes in the ontology based on the analysis of the information which will result in an ontology better suited for the needs of end-users.

REFERENCES

Abecker,A., Bernardi,A., Hinckelmann, K., Kuhn, O. & Sinteck, M. (1998). Towards a technology for organizational memories. *IEEE Intelligent Systems*, *13* (3), 40-48

Ghosh, Srabana (2015). *Development and Evaluation of Domain Ontology: A Study in Library and Information Science Domain* (Unpublished Ph D Thesis). University of Calcutta, Kolkata, India

Gilchrist, A. (2003). Thesauri, taxonomies and ontologies: an etymological note. *Journal of Documentation*, *59*(1), 7-18. doi:10.1108/00220410310457984

Gruber,T.R. (1993). A Translation approach to portable ontology specifications. *Knowledge Acquisition,5*(2), 199-220. Retrieved from http://tomgruber.org/writing/ontolingua-kaj-1993.pdf

Haase, P., Völker, J. & Sure, Y. (2005). Management of dynamic knowledge. *Journal of Knowledge Management, 9*(5), 97 – 107. http://dx.doi.org/10.1108/13673270510622483.

Hjørland, B. (2007). Semantics and knowledge organization. *Annual Review of Information Science and Technology*, *41*, 367-405.

Hjørland, B. (2009). Concept theory. *Journal of the American Society for Information Science and Technology*, *60* (8), 1519-1536. doi 10.1002/asi.21082

Hjorland, B. (2012). Is classification necessary after google? *Journal of Documentation*, *68* (3), 299-317. doi:10.1108/00220411211225557

Hodge, G. (2000), Systems of Knowledge Organization for Digital Libraries. *Beyond Traditional Authority Files*, Council on Library and Information Resources, Washington, DC. Retrieved May 16, 2011, from www.clir.org/pubs/reports/pub91/contents.html.

Horridge, M., Jupp, S., Moulton, G., Rector, A., Stevens, R. & Wroe, C. (2007). *A Practical Guide To Building OWL Ontologies Using Protégé 4 and CO-ODE Tools* (1.1Ed.). Manchester: University of Manchester

Noy, N.F. & McGuinness, D.L. (2001). Ontology development 101: a guide to creating your first ontology, technical report KSL-01-05. Retrieved July 12, 2015, from Stanford University, Stanford Knowledge Systems Laboratory Website: www-ksl.stanford.edu/people/dlm/papers/ontology-tutorial-noy-mcguinness.pdf

Pattuelli, M.C. (2011). Modeling a Domain Ontology for Cultural Heritage Resources: A User-Centered Approach. *Journal of the American Society for Information Science and Technology* , *62*(2), 314-342. doi: 10.1002/asi.21453

Roussey, C., Pinet, F., Kang, M.A. & Corcho, O. (2011). In Falquet, G., Métral, C., Teller, J. & Tweed, C. *Ontologies in Urban Development Projects*. London: Springer-Verlag. doi:*10.1007/978-0-85729-724-2_2*

Shiri, A. A. & Revie, C. (2000). Thesauri on The Web: Current Developments and Trends. *Online Information Review*, *24*(4), 273-279. doi: 10.1108/14684520010350623

Soergel, D. (1999). The Rise of Ontologies or the Reinvention of Classification. *Journal of the American Society for Information Science*. *50*(12), 1119–1120. doi:

10.1002/(SICI)1097-4571(1999)50:12<1119::AID-ASI12>3.0.CO;2-I

Synak, M., Dabrowski, M. & Kruk, S. R. (2009). Semantic Web and Ontologies. In S.R. Kruk & B. McDaniel (Eds.). *Semantic Digital Libraries* (pp. 41-54). Germany: Springer

Tudhope, D., Alani, H. & Jones, C. (2001). Augmenting thesaurus relationships: Possibilities for retrieval. Journal of Digital Information, 1(8). Retrieved from https://journals.tdl.org/jodi/index.php/jodi/article/view/181/160