Opening Ontology Design: A Study of the Implications of Knowledge Organization for Ontology Design*

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Abstract: It is proposed that sufficient research into ontology design has not been achieved and that this deficiency has led to the insufficiency of ontology in reinforcing its communications frameworks, knowledge sharing and re-use applications. In order to diagnose the problems of ontology research, I first survey the notion of ontology in the context of ontology design, based on a Means-Ends tool provided by a Cognitive Work Analysis. The potential contributions of knowledge organization in library and information sciences that can be used to improve the limitations of ontology research are demonstrated. I propose a context-centered view as an approach for ontology design, and present faceted classification as an appropriate method for structuring ontology. In addition, I also provides a case study of wine ontology in order to demonstrate how knowledge organization approaches in library and information science can improve ontology design.

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1. Introduction

Ontologies are often cited as a critical part of information system design. Firstly, they help sustain a communications framework around the domains of interest between people, organizations, and systems by providing a shared and common understanding of a domain. Secondly, they enable knowledge re-use and sharing, since other researchers can adopt or integrate an ontology for their own purposes (Noy & McGuinness 2001). They facilitate interoperability among systems by specifying and translating different concepts and languages in a domain (or across several domains). A well-developed ontology produces cost-time benefits by eliminating or reducing the cost of re-inventing a knowledge base system for each use (Uschold & Grüninger 1996). Furthermore, ontologies help users learn domain knowledge and, in addition, browse and search for information by providing structured knowledge representation.

With these anticipated benefits, the term "ontology" has been discussed at length across disciplines and research communities in such areas as computer science, artificial intelligence, database, knowledge representation, knowledge engineering, semantic web groups, and knowledge organization. The term of ontology has been discussed in LIS research recently; several researchers have tried to identify the relationships between ontology and knowledge organization (KO) in LIS (Adams 2002, Gilchrist 2003, Jacob 2003, Soergel 1999); however, in-depth discussions of how studies in KO may advance ontology research have been noticeably absent, and with this study I aim to bridge this gap.

In this study I investigate those aspects of ontology research that call for improvement. A current study focuses on ontology design based on a solid understanding of the notion of ontology. The study of ontology design, such as current guidelines of ontology design and the strengths and weaknesses therein, is critical to future growth in the field since most ontologies are designed manually (Noy & Hafner 1997). A general understanding of the concepts of ontology is also in need for further investigation. Current studies demonstrate a lack of understanding of the fundamental concepts, including the main underlying themes and what these themes mean for the design of information systems. In addition, there are also areas of confusion in the use of the term "ontology" (Adams 2002, Ding 2001, Jacob 2003, Kim 2002, Poli 1996). Poli (1996) states that the term "ontology" is used with a variety of meanings; in some specific fields, such as Artificial Intelligence (AI), the new label of "ontology" appears merely to be attached to areas of inquiry that have already been well delimited and consolidated.

These two areas are not mutually exclusive. A clear understanding of the fundamental concepts of ontology would anchor methodological discussion of ontology design and provide an idea of what, precisely, it requires for support. Prieto-Díaz (2002) presented faceted classification in KO for ontology design. However, this paper did not explicitly clarify what areas need further discussion for ontology research and how facets can improve these inadequacies for ontology. That is, Prieto-Diaz did not provide this semantic linkage between facet classification, ontology design and ontology purposes.

To stretch this semantic link further from Prieto-Díaz's study, I hope to attempt to clarify the meaning of the term "ontology" and to improve ontology design. Therefore, the present study poses the following questions:

How do knowledge organization studies provide benefits for ontology studies in general?
What are the weaknesses of ontology studies?
How do knowledge organization studies improve upon these weaknesses?

I begin with a survey of the relationship between ontology and KO, then discuss ontology design in the context of the notion of ontology based on a Means-Ends tool, which is provided by a Cognitive Work Analysis. In investigate the kinds of problems currently facing ontology research, then demonstrate the potential contributions of KO in LIS in order to better define the limitations of ontology research. These inquiries form the methodological foundation for ontology design, based on a sound understanding of the concept of ontology itself. I propose a context-centered approach for ontology design and suggest faceted classification as a method for structuring ontology. Finally, a case study of wine ontology is included to show how KO approaches in LIS can be applied to ontology design.

2. Ontology vs. Classification in Knowledge Organization

Classification in knowledge organization (KO) and ontology are very similar: both are knowledge representation systems, both consist of terms, and both exhibit structured relationships (Adams 2002). There have been several studies of ontology in LIS (Adams 2002, Ding 2001, Fisher 1998, Gilchrist 2003, Jacob 2003, Moreira & Alvarenga 2004, Soergel 1999, Vickery 1997). Most have discussed the introduction of ontology in LIS as an emerging area in the semantic web or artificial intelligent areas along with survey backgrounds, ontology language and techniques, and projects, (Ding 2001, Jacob 2003, Soergel 1999, Vickery 1997); some researchers have attempted to identify the relationships between ontology and classification or thesaurus use in library sciences (Adams 2000, Gilchrist 2001, Jacob 2003, Soergel 1999).

Adams (2002) mentioned that in some research instances, ontology and taxonomies are used as synonyms. Jacob (2003) wrote that ontologies have been regarded as "classification schemes, thesauri, controlled vocabularies, terminologies, and even dictionaries." Soergel (1999) also pointed out that classification has been used in library and information science for a long period of time, and that the term "ontology" has been added only recently in areas such as AI, knowledge representation, and semantic web.

Gilchrist (2001) and Adams (2002) also tried to differentiate ontology from other knowledge organization systems in LIS such as classification systems or thesauri. The first difference asserted was intended use. A knowledge organization system strives to assist users in information retrieval, whereas ontology usually aspires to maintain problem-solving and decision-making for systems and humans in a broader sense (Vickery 1997, Jacob 2003). In addition, a knowledge organization system is a tool used to locate and interrelate information, while ontology is a tool for knowledge re-use and exchange. Jacob (2003) tried to differentiate knowledge organization system and ontology by establishing that ontology allows more semantic representation of relationships beyond the hierarchies and simple relationships among terms used in a knowledge organization system.

Discussing how ontology and knowledge organization systems differ from each other is difficult, as the broadness of the concepts of ontology and knowledge organization systems differ among researchers. An ontology has a broad range of dictionary and glossary terms, incorporating more items than classification systems and including logical inheritance. Knowledge organization systems have broadened the traditional range of use in library sciences. Recent studies in knowledge organization demonstrate how knowledge organization systems can be used in some organizations or domain settings (Hjørland 2003). Some argue that a knowledge organization system is a boundary object for a communication tool (Bowker & Start 1999, Albrechtsen & Jacob 1998) and for knowledge integration (Albrechtsen & Pejtersen, 2003). Knowledge organization research has also studied more relational structures than traditional hierarchies.

The distinction between ontology and knowledge organization systems is blurry; the discussion might prove more fruitful if the study focuses primarily on how these different approaches could benefit from each other; particularly of note in this paper is how knowledge organization design studies could provide advantages for ontology design studies.

3. Understanding Ontology

3.1. A Means-Ends Tool

The territory of ontology design is analyzed using a Means-Ends tool (M-E). M-E tools were originally developed for Cognitive Work Analysis (CWA) (Rasmussen, Pejtersen, & Goodstein 1994, Vicente 1999), and are used to map a work domain via an abstraction hierarchy system. A M-E tool features five primary units of analysis, from the most abstract level of goals and constraints, to the most concrete level of resources. The representation of a Means-Ends abstraction hierarchy for a work domain is illustrated in table 1 below. The analysis of five levels of abstraction hierarchies describes why the work domain exists, what priorities are embedded in it, what functions exist, and how it is physically framed according to activities and resources. The hierarchy also allows many-to-many mappings between levels.

MEANS-ENDS Relations	Properties Represented
Goals and Constraints	Goal, the purpose of a work domain; Constraints, the sources which affect the work domain, but cannot be changed by a work domain
Priority Measure	Properties to establish priorities according to the intention behind the work domain
General Functions	A set of main and recurrent activities conducted to satisfy the goal of a work domain
Processes and Activities	Actual activities used to support and maintain the functions in a domain
Physical Resources	Resources both used and created within a work domain including actors involved in the activities of a domain.

Table 1. *Means-Ends Abstraction Hierarchy (Albrechtsen, H., & Pejtersen, A.M., 2003)*

These levels also reveal why-what-how relationships, as shown in table 2 (Vicente 1999 165); anything in a function level ("What?") can be seen as an end ("Why?") for a lower level, as a process, and as a means ("How?") for higher level priorities. For example, in order for a work domain comprised of a classification system design team to design a classification system according to user need (priority—why), the team needs to manage external collaborations (functions—what) based on discussions with customer service centers (processes—how). A M-E tool is therefore appropriate for understanding what, how, and why people actually work in practice.

Goals Constraints	What? ↓	Why? ↑			
Priorities	How? ↓	What? ↕	Why? ↑		
Functions		How? ↓	What? ↕	Why? ↑	
Processes			How? ↓	What? ↕	Why? ↑
Resources				How? ↓	What? ↑

Table 2. *Means-Ends Hierarchy (Mai, J-E. 2004, 208)*

A M-E tool for the analysis of the territory of ontology design has two implications. First, the map of a work domain by the why-what-how relationship provides the entire structure of the ontology domain, and describes what an ontology work domain looks like. Current ontology discussions are somewhat dispersed in diverse discussion areas; some focus primarily on ontological backgrounds and goals (Chandrasekaran et al., 1999, Ding 2001, Ding & Foo 2002), some mainly discuss technologies and projects (Fensel 2002, Gruber 1993, Hyvönen et al., 2003), and others focus on design techniques (Gruber 1994, Guarino 1997, Noy and Hafner 1997). This mapping tool enables the examination of ontology design across diverse study areas and reveals a deeper understanding of semantic relationships which ultimately assists researchers in revealing the missing links within a specific ontology design and presenting appropriate improvements. For example, using this mapping tool, a researcher is able to suggest additional processes when an inadequate number exist ("What?") to support one function in a domain ("Why?").

3.2. Untangling Ontology

3.2.1. Purposes

Creating an ontology aims to serve two purposes—knowledge sharing/reusability, and cost/effort reduction. If there is an ontology for the concept of time, many domains can adopt and use this ontology for their own purposes, rather than designing a whole new concept for every specific task (Noy et al., 2001). An ontology leads to the reduction of unnecessary and duplicated efforts required to build an ontology, thereby justifying the high cost of building an ontology and enabling the sharing and use of the knowledge bases of an ontology across systems (Guarino 1997, Noy, et al., 2001, Vickery 1997). These aspects of ontology can be particularly beneficial in business sectors (Fensel 2002, Smith 1995, Uschold et al. 1998), such as international banking corporations with different branches in different countries (Smith 1995).

3.2.2. Priorities

An ontology serves knowledge sharing/reusability and cost/effort reduction by providing a shared and common understanding framework of a domain of interest between people and systems (Ding 2001, Fensel 2001, Gruber 1994, Uschold and Gruinger 1996, Uschold et al. 1996). An important sub-priority of creating an ontology is to support communication between people. Uschold and Gruinger (1996) presented several cases of how an ontology, acting as a shared and common understanding framework of a domain of interest, can facilitate interactions among people. For example, if there is a unifying research field in which people from different fields work together, diverse terms and perspectives can create disturbed communications, causing interaction problems in the absence of a shared framework. Having a shared understanding leads to minimized interaction problems and facilitates the exchange of ideas.

An ontology also purports communications among systems through interoperability (Ding 2001, 2002, Gruber 1994, Uschold 1996). By using an ontology, different systems in a domain of interest can communicate with each other and utilize shared information. This study supports communication between systems across domains by providing an integrated ontology.

3.2.3. Constraints

Constraints are vital parameters in ontology design since they may enable, as well as limit, ontology design. Language is a good example of a design constraint. The design of an ontology aims to implement a system and is defined in a machine-processable language; if an ontology needs to be developed in a specific language such as OWL (Web Ontology Language), an ontology should exist within the boundary of representation that the language permits. Time and budget are also constraints, since the preparing, designing, and testing of an ontology is restricted by both. Other constraints are more philosophical in nature. Take the term "*ontology*", for example: "*Ontology*" with an uppercase "O" refers to the branch of philosophy, while "*ontology*" with a lowercase "o" refers to the term as used in many areas related to information science (Jacob, 2003). Philosophically, the original term "Ontology" refers to "a particular theory about the nature of being or the kinds of existence" (van Hejist et al. 1996); thus, the ultimate goal of Ontology is to find truth and attempt to answer questions such as "What constitutes a complete and exhaustive description of all things in the universe? What are features and types are common to all beings?" (Guarino 1997, Smith 1995, Zuniga 2001). With these definitions in mind, ontology design must attempt to find what may or may not exist in reality, while seeking an objective description of "the nature of existence and the structure of reality" (Jacob 2003).

3.2.4. Functions

The priorities of an ontology are upheld by several activities of ontology design. Ontology design is achieved by gaining domain knowledge through scoping and design preparation, making domain knowledge more explicit (structuring), representing domain knowledge in a machine-processable language, and creating general conventions for the use of the ontology (Ding 2001, 2002, Gruber 1993, Guarino 1997, Jacob 2003, Noy and McGuinness 2001, Uschold 1996, Vickery 1997). Ontology commitment is an established agreement about the knowledge of a domain represented in ontology, such as shared assumptions or pre-existing models of a domain (Gruber 1993).

3.2.5. Process

Each function of ontology design is supported by several specific processes. In order to gain domain knowledge, ontology developers are required to scope a project; to achieve effective scoping, developers must first determine a domain and decide on the specificity of an ontology (Noy and McGuinness 2001, Uschold 1996). To make domain knowledge more explicit, an ontology can be generated from the domain knowledge gained through the scoping process, then expanded through the sub-processes of enumerating terms, defining concepts/relationships, and providing definitions (Gruber 1993, 1994, Noy and McGuinness 2001). The varied processes are approached using one of several methods: bottom-up (specification concept to generalization), top-down (generalization to specification), or middle-out (from key concepts) paradigms may be employed, depending on the specific features of the project domain (Ding and Foo 2002). Domain knowledge may also be presented using diverse granularity or specificity levels such as problem-solving, defining specific tasks, and generalizing the domain. The next function required is ontology commitment, which is an agreement on—or compromise regarding—the knowledge map represented by an ontology and a defined conformity required to use the ontology (Uschold and Grüninger 1996). To build an ontology in both human and computer understandable languages, it should be developed using code in addition to a computerized representational language.

3.2.6. Resources

The processes of ontology design employ several resources. In order to process an ontology in a machine understandable way, ontology developers, computers, programming languages, programming language skills, and individual programs are necessary. Within all abstract-hierarchy systems of ontology design, an ontology can finally be created for the role of "an explicitly defined reference model of application domains" (Ding and Foo 2002, 124), and supports shared understanding and communication. In the end, the ontology leads to knowledge sharing and reusability, saves unnecessary costs and efforts, and justifies the high costs of system development and management (Vickery 1997).

The summary of the analysis of ontology design is presented in table 3 below.

3.3. Current Limitations of Ontology Design Research

The analysis of ontology design according to the abstract-hierarchy system discloses clear weaknesses in ontology design research. The first weak point is presented in Function 1—gaining domain knowledge. Although previous studies of ontology design have acknowledged the practicality of gaining domain knowledge for ontology design, how exactly to acquire the required knowledge for ontology design in detail has been missing. Although the process of ontology scoping supports the function in a M-E analysis, most research mentions this process only briefly—only two tactics for defining ontology participants and specificity were described in processes for function1.

Gaining domain knowledge is closely related to two additional processes that have yet to be discussed: defining the perspective ontology developers need to acquire the knowledge they require, and methodological frameworks they can use to do so. Currently there is no agreement as to what the "big picture" must be in order to build an ontology. While the philosophical background influences the objective view for ontology development, indicators of "users" or "context" provide a more subjective view for ontology development (Guarino 1997, Poli 1996, Chandrasekaran et al. 1999). Currently, there is not a sufficient amount of research on how to gain needed knowledge in a domain either. These are vital elements for design, as good domain knowledge guides the rest of the design process (Mai 2006).

Goals	Knowledge sharing and reusability; Reduced cost waste and efforts
Constraints	*Budget and timeline allowed for ontology design, human resources, ontology designer domain knowledge, number of participant designer technologies, languages, approaches of ontology design*
Proprieties	To provide a shared and common understanding framework of a domain: Communication between people; Communication between systems
Functions	Function 1: To analyze domain knowledge Function 2: To make domain knowledge more explicit Function 3: Ontological-Commitment Function 4: To represent dmain knowledge in a computer-processable way
Process	Process 1: Decide the scope of an ontology (Function 1) Process 1-1: Decide a domain (Function 1) Process 1-2: Decide the specificity of an ontology (Function 1) Process 2: Collect the terms required in a domain (Function 2) Process 3: Define categories and relationships (Function 2) Process 3-1: Choose an approach—top-down, middle-out, and bottom-up (Function 2) Process 4: Provide definitions (Function 2) Process 5 : To form an agreement with the terms and structures of an ontology (Function 3) Process 6: To form an agreement with the use of an ontology for the system in a consistent manner (Function 3) Process 7: Coding an ontology (Function 4) Process 8: Implementing an ontology with technology (Function 4)
Resource	Domain; Users in a domain; Ontology developers; Domain experts; Language; Technology; Domain experts' skills, using technology; Domain experts' familiarity with the domain; Ontology design guidelines

Table 3. *Means-Ends Analysis for an Ontology*

The second limitation pertains to how an ontology is to be structured (function 2). The chosen paradigm of ontology design, whether it be bottom-up, top-down, or middle-out, describes this function in a mechanical way. These paradigms have not been discussed in great detail, and it is still unclear how ontology should be structured or how to form appropriate categories and relationships. Structural methods in knowledge organization are generally divided into two approaches, enumerative and faceted. Concepts are structured hierarchically in an enumerative method, while ideas are structured according to aspects or characteristics of a domain in a faceted method. The structural method ultimately influences the processes detailed in Function 2, and relevant discussion is currently missing in discussions on ontology design. Without a detailed structural method, it is difficult to build a well-organized ontology.

Most ontology development has been conducted on an ad-hoc basis (Noy & Hafner 1997), and has focused almost exclusively on Functions 3 and 4. Recent articles have discussed application technologies like RDF (Resource Description Frameworks) or OWL (Web Ontology Language)—for which ontology design has been explored—or on well-known or on-going ontology projects. Noy and McGuinness (2001) published development guides of ontologies in order to support ontology development using semantic web technologies such as Protégé, and the guidelines developed were compliant with what Protégé supports. These examples suggest that ontology design has been limited to representing ontologies in a machine-processable way.

In summary, a M-E analysis revealed a lack of discussion of Functions 1 and 2 and their processes. These are not disconnected issues in ontology design, and without a sufficient understanding of these functions, processes are not specified in sufficient detail. This generates a set of fairly limited guidelines for the use of resources in ontology design and ultimately leads to inefficient ontology design. A well-developed ontology produces cost-time benefits and supports knowledge sharing (Uschold and Grüninger 1996); with these expected benefits, ontologies have been discussed at length in many disciplines and research communities. Despite the many advantages of creating an ontology, it is difficult to understand how an ontology can present benefits in application areas improve communications among systems and people, and exemplify knowledge sharing and reuse. One reason that these intricacies are difficult to pinpoint is that an excess of mechanical discussion of ontology development in Function 3 and 4 has been conducted, while structuring an ontology (Function 2) based on the understanding of a domain (Function 1) is limited.

Without an appropriate ontology to reflect a domain, ontology may be unable to serve as a communication framework in a domain. It may not provide sufficient benefits for knowledge sharing, use, or cost-reductions. Further discussions of ontology—specifically, how to gain needed knowledge of a domain and how to construct an suitable ontology—would be valuable for the field of ontology design.

4. The Implications of Knowledge Organization for Ontology Construction

4.1. A Context-Centered View on Ontology

A recent trend in knowledge organization research is to develop organizational schemes using context as a primary motivator (Mai 2004). Traditional knowledge organization research focuses on the development of objective and universal guidelines or structures of knowledge, whereas knowledge organization in context considers user groups and the social, cultural, and historical dimensions of the context to be served. Context-based knowledge organization is one step further from a user-centered approach, which primarily focuses on users and their needs. The rise of context-centered approaches in knowledge organization is fundamentally driven by the recognition of the limits of system-centered approaches—a single classification scheme does not necessarily reflect the level of specificity of document representation across specific domains (Hjørland 2002, Mai 2005), and often fails to meet the required point of view, which could be specific to the user, a library, or an information center (Hjørland 2002, Mai 2005). Traditional knowledge organization approaches are limited. Reflections of context and classification cannot be regarded as absolute, objective, or neutral any longer; rather they should be conditioned contextually (Hjørland 2002).

Below are some examples that further illustrate the dependency of the meanings of words in context. Lakeoff (1987, 93) developed a classification that expresses relativity of knowledge in traditional Dyirbal, an aboriginal language of Australia:

I.	Bayi:	(human) males; animals
II.	Balan:	(human) females; water; fire; fighting
III.	Balam:	Non-flesh food
IV.	Bala:	Everything not in the other classes

Table 4. *Cultural Dependency of Categories (Lakeoff 1989, 93)*

The basic schema of this categorization consists of four entities. According to the Dyirbal classification, women, water, fire, and fighting are all in the same category: fire is dangerous, and water extinguishes fire, hence they fall into the same category. Women are just as dangerous as fire in the Dyirbal cognition, and therefore belong to the same category. To understand this classification is to understand Dyirbal beliefs and myths, i.e., the working of a language that mirrors its culture. Such a classification is unique to Dyirbal and is not likely to be applicable in other cultures (see table 4).

Kwasnik and Rubin (2003) also established the differences in knowledge structures of fourteen different cultures by mapping out the words related to "kinship." While the domain of "kinship" is universal, the meanings of words for "relatives" vary from culture to culture. For example, the English language does not distinguish between one's mother's sister and brother from one's father's sister and brother—they are all categorically called "aunt" or "uncle". However, in other cultures, such as Korean, paternal and maternal designations are quite different.; in order to o translate the English word "aunt" into its Korean counterpart, therefore, one must know its specific context.

These arguments demonstrating the dependency of a point of view on context apply to ontology research as well. There is an ontological approach in which the construct should be based on identifying common concepts that are pertinent across domains and points of view. This expresses the idea that ontology should be constructed objectively and neutrally, centering on the system and the data. Although there is no guarantee that ontology based on an independent view will provide benefits for use across a number of applications, or knowledge sharing and re-use, some ontology researchers are currently obstructed by assuming that it will not.

Ontology is "a shared and common understanding of some domains of interest" (Gruber 1994, 909). Ontology is the particular view of the domain of interest, as agreed upon by people in that domain. Ontological commitment means more than just agreement in terms of vocabularies; it represents shared assumptions and conceptualizations of the ontology of the domain. If a particular view of the domain of interest is diverse and relative to certain domains, objectively and neutrally constructed ontology would fail to serve the domains of interests that the ontology actually aims to serve. This may lead developers to "sub-optimize" the functions or goals of ontology. Ontology ought to acknowledge the limitations of the objective and neutral approach to ontology design, rather taking a context-centered view, in order to make the domain knowledge explicit. Ontology development deriving from a more in-depth understanding of context would boost ontology's contribution to knowledge sharing and re-use.

How, then, can we go about studying context in ontology, a missing area of ontology research? Even though some KO researchers (e.g., Albrechtsen and Pejtersen 2003; Hjørland 2002) have noted this need and suggested methodological studies of context, current research in classification system design considering user and users' context are very conceptual and theoretical. They have not given specific practical guidelines to adopt for classification system design, and they have not actually shown how these approaches would help the design of classification systems. Much research needs to be done before they are adaptable to practice. For example, Hjørland (2002) proposed eleven approaches to domain analysis—literature guides, special classifications and thesauri, indexing and retrieving specialties, empirical user studies, bibliometrical studies, etc. He did not, however, specify how to employ each method to gain knowledge of user context. He also did not point out when to use a specific method, and did not detail how to incorporate the study of user context into design of classification systems. Albrechtsen and Pejtersen (2003)'s CWA takes into account various dimensions from macro levels to individual resources, and aims to understand user context; however, it is still challenging to transform the analysis into actual classification systems. This transformative process from the analysis of work practice into classification system design has yet to be discussed, and only a few results of this study such as Bookhouse (Pejtersen 1989), which is a fiction retrieval system, have appeared. Therefore, this research area should be advanced in the future by KO and ontology research communities.

4.2. Facet Classification as Guidelines for Structuring Ontology

Faceted classification, which has been devised by Ranganathan (1962), aims to provide a way to build classification systems based on facet analysis. Facet analysis primarily comprises the following procedures: analyzing a subject domain into terms, then sorting terms into a facet (Ellis and Vasconcelos 1999) so that the subject description of a document can be represented by combining terms in multiple facets. The indispensable concept of faceted classification is the facet, which is a clearly defined, mutually exclusive, and collectively exhaustive aspect, property, or characteristic of a class or specific subject that reveals the different views, perspectives, or dimensions of a particular domain. The faceted classification has benefits over enumerative classification structures in that it is more than hierarchies and it allows more flexibility in adding new concepts and structuring in general. This type of classification has been employed by information system researchers primarily because it has the potential for enhanced knowledge representation, information retrieval, and browsing by information systems. Ranganathan, who originally developed the faceted classification, established the theory of faceted analysis. Later, the Classification Research Group modified Ranganathan's theory of facet analysis to enhance its functionality (Spiteri 1998). Spiteri (1998) combined these two models and developed a simplified model of faceted analysis. She represented a model based on principles for the choice of facets, principles for the citation order of facets and foci, and principles for the verbal plane.

Principles for the choice of facets are as per the following:

Differentiation: A facet should represent a distinguished characteristic.
Relevance: A facet should indicate a target and scope of the classification system.
Permanence: A facet should reflect a permanent characteristic.
Ascertainty: A facet should be explicit and determinative.

Homogeneity: Facets should be homogeneous, and one facet needs to represent only one characteristic.
Mutual exclusivity: Facets should not be overlapping.
Fundamental categories: A facet should represent a fundamental characteristic.

Principles for the citation order of facets and foci consist of the principle of relevant succession, chronological order, alphabetical order, and spatial/geometric order, simple to complex order, complex to simple order, canonical order, increasing quantity and decreasing quantity, and the principle of consistent succession. Principles for the verbal plane, lastly, are composed of context, symbolizing that the meaning of terminology should be subject to context. Currency, which denotes that terminology, should reflect the current usage in a domain.

The main reasons that the faceted classification bear relevance for ontology, especially insofar as it might improve ontology structure, are as follows: some ontologies, such as the Wine and Enterprise ontology, illustrate similar types of faceted classifications. For example, an Enterprise ontology, which supports business modeling, consists of activity and process, organization, strategy, marketing, and time, which represent the particular dimensions of a business. A wine ontology consists of winery, wine region, wine grapes, etc., implying the properties of a wine domain. These categories are very similar with facets, in that they try to show different characteristics of that domain, although they do not use the term—facets in ontologies. Some ontology projects recently employed the term "facet" for ontology (Hyvönen et al. 2003, Noy & McGuinness 2001, Prieto-Díaz 2002, Tzitzikas et al. 2002). Prieto-Díaz (2002) presented faceted classification for ontology, which directly inspired this paper to address how facets can improve ontology design, why ontology design needs to be studied, in what aspects ontology design has been missing, and how KO can contribute to ontology in detail to ontology design and ontology purposes (Prieto-Diaz did not provide this semantic linkage between facet classification),.He introduced faceted classification instead of representing how faceted classification can make difference. In addition, as McIlwaine & Broughton (2000) argued, facet has been used as a buzzword in ontology and other knowledge representation areas, and people have adopted facet without in-depth knowledge of classification theories. Therefore, providing explicit definition and principles of faceted classification is expected to encourage a more structured ontology construction than current ad-hoc-based ontology development. In the next section, a case study is conducted to demonstrate how a guideline of a faceted classification is applied to wine ontology. A wine ontology based on a faceted classification is different from current wine ontologies.

4.3. Case Studies of Wine Ontology

The following wine ontology is employed to display how context-centered viewpoints and Spiteri's faceted analysis are applied in ontology design. The wine ontology used below was developed by Noy and Machiness (2001), based on the following development process: 1) defining classes in the ontology, 2) arranging the classes in a hierarchy, 3) defining properties and values, 4) defining the facets of the properties of classes. They employed the term "facet" to build their wine ontology. The aim of the ontology is for use among applications related to restaurant-managing tools, such as making menu suggestions, explaining wine to people, managing an inventory list of a wine to purchase, etc. It is represented as figure 1.

Information about how this ontology was designed and constructed has not been made publicly available to date, including information regarding whether the ontology is based on the study of the domain of wine or on restaurant-managing domains, or regarding what kinds of methods are employed to create the structure.

The study of this ontology, based on Spiteri's faceted analysis, presents several insights. The choice of facets, first of all, it does not meet the principle of mutual exclusivity. As seen in figure 1, "Consumable Things" and "Meal Course" include the same foci. This does not provide different instances or form any differences at all, which violates the principle of differentiation following the principles of mutual exclusivity, these two facets could be merged into one facet. Secondly, "Wine Region" and "Winery" are not at the same level; "Wine Region" is a subset of "Winery" and may not be compliant with the principle of homogeneity and fundamental categories—"Wine Region" calls for a place under "Winery". Thirdly, in this ontology, "Consumable Things" and "Meal Course" both include food and wine; however, if wine is a theme or a subject of the ontology and food is used to suggest which wine is suitable for which food, food might be considered another facet of the wine, rather than sub-facets with wine under

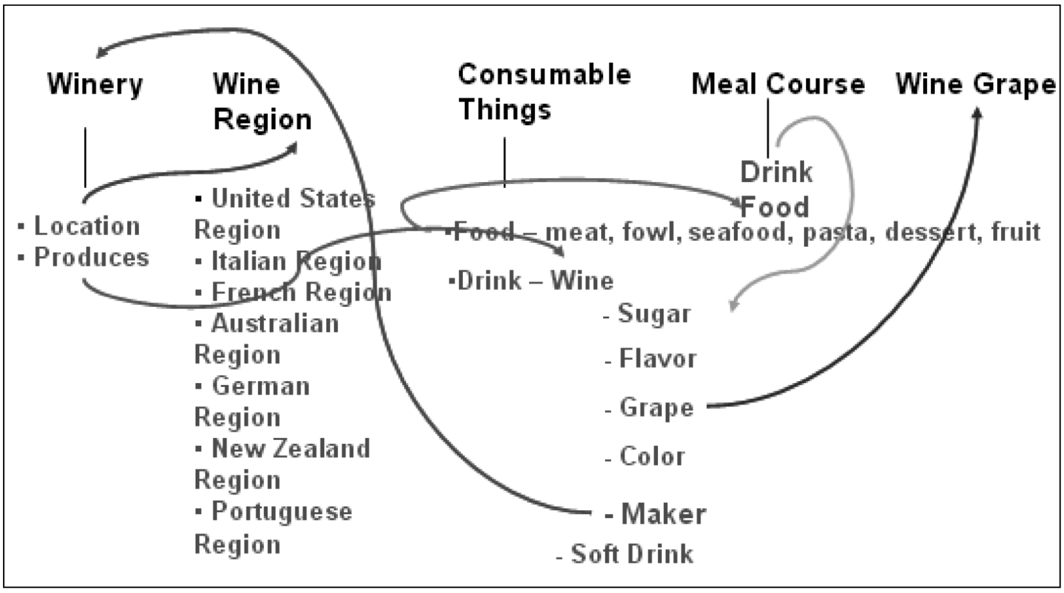

Figure 1. *Wine Ontology*

"Meal Course" or "Consumable Things". Fourth, the ontology also includes wine grapes as a facet, and sugar, color, and flavor as sub-facets. This is also in-compliant with the principle of homogeneity—these categories should be placed in the same level. Fifth, the ontology also includes soft drinks as a sub-facet under "Consumable Things/Drink"; however, the ontology aims to provide the information regarding wine and suggest proper wines associated with food in a restaurant, therefore, "drink" might not be a useful concept here, according to the principle of relevance.

This discussion is also applicable in terms of the arrangement of facet and foci. Foci under the "Food" facet, according to principle of relevant succession, needs to arrange foci as per the following: appetizer, main dishes—meat, fowl, seafood, and pasta, and dessert. "Wine Region" can also be placed under the United States region, according to the principle of relevant succession, and alphabetical orderings can be used. Domain study is also important for the principle of relevant succession.

It is difficult to identify how useful this ontology is for a communication framework for this domain. It is also difficult to say to what extent the context-centered view would generate a different ontology, and such an issue lies beyond the scope of the paper. However, some considerations of the wine domain employing a M-E analysis in table 5 below lead us to identify that this ontology is missing some important concepts in the wine domain, such as wine price, occasion, vintage year, and wine types, (covering not only color, but bubbly, dessert, low carb, and kosher wines, for example). This might be because of a lack of studies of wine domains. This ontology might have some limitations for other people in the wine domain in terms of adoption and use.

Goals Constraints	G1: To recommend wines for restaurant customers to meet their needs *Waiter or Waitress's timeline to be familiar with wines, Budget of restaurants for purchasing wines, Communications with wine sellers*
Proprieties	P1: To increase gains of wine selling
Functions	F1: Manage a wine menu; F2: Recommends wines; F3: Manage an inventory list of wine
Processes	F1-P1: Make categories of wine F1-P2: List prices & vintage years F2-P1: Ask customers' needs such as flavor or prices F2-P2: Consider food menus F2-P3: Provide some suggestions with description F3-P1: Manage winery and wine region F3-P2: Keep familiar with wine trends such as critics or competitions
Resources	Waiter or waitress' wine knowledge, contact lists of wine cellar, Wine writers, wine critics, wine competitors

Table 5. *A partial M-E analysis for wine domain*

Based on this discussion, the revised wine ontology suggests the following primary facets: Wine Types,

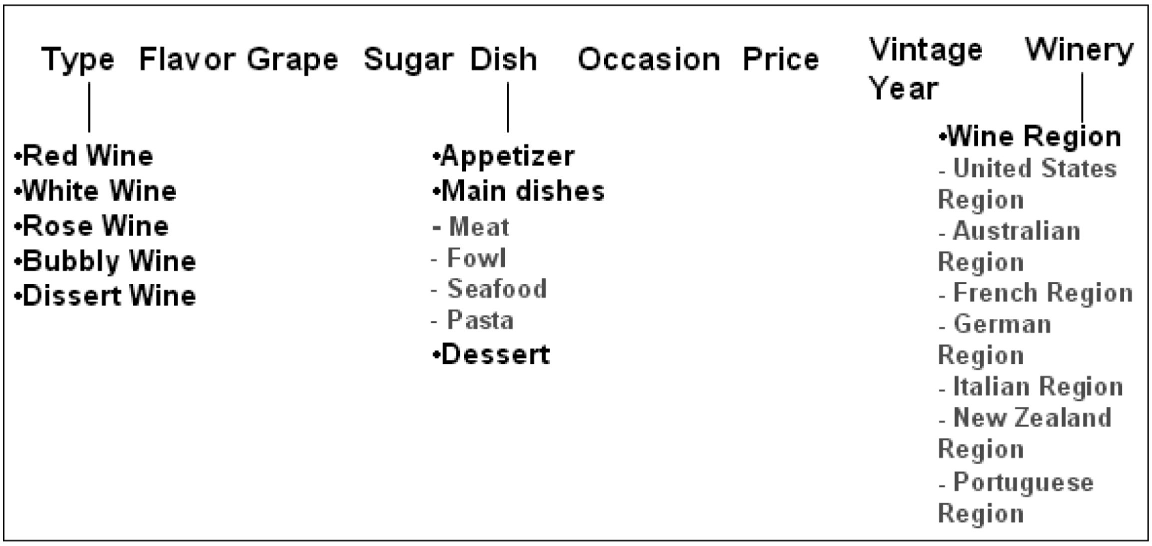

Figure 2. *Revised Wine Ontology*

Flavor, Sugar Content, Winery, Grape Type, Prince, Occasion, Vintage Year, Dish. (See figure 2).

Throughout the study, ontology development processes should be based on a context-centered approach. For the structuring of knowledge representation of ontology a faceted classification would be proposed, with Spiteri's guidelines of facet analysis and arrangement appearing to be fruitful. This simplified model of ontology development is not a stand-alone ontology development model; the faceted classification may not work for some ontology structures in specific domains. This study aims to provide some possible options for practical and explicit guidelines in ontology development, and to display how knowledge organization has the potential to help ontology design.

5. Conclusion

I have investigated possible answers to the research question "How can the study of knowledge organization be exploited for use in ontology?" To answer this question, I explored the domain of ontology design as well as a concept of ontology—purposes, constraints, priorities, functions, processes, and resources—based on a Means-Ends analysis provided by a Cognitive Work Analysis. The analysis of ontology domain revealed two major areas in a function-level to be improved upon: the general analysis of domain knowledge and explicit investigation into structuring of domain knowledge. In this paper I am asserting that these deficient areas are related to a lack of research on process-level ontological design. Current ontology research has concentrated on answering "what" questions: what kinds of benefits ontologies can bring, what background the term ontology has in being introduced to different disciplines and research areas, what projects are well known in ontology research, what kinds of technology ontology research has developed, etc. Current studies of ontology design have been limited to the suggestion of ontology design processes and very simple guidelines, seemingly avoiding the specificities that are sorely lacking. They have not thoroughly discussed how ontology design is approached, how the required information for ontology design may be obtained in the domain of interests, or how ontology should be structured. Discussions of ontology technology and language have focused on the functions that they bring to ontology construction, rather than on how new ontology technology and language can enhance ontology design. The descriptions of well-known ontology projects do not sufficiently explain how they were constructed. This lack of specific instruction has led to the current state of largely ad-hoc ontology development (Noy & Hafner 1997).

The kinds of approaches ontology design should take and how to construct good ontology in a process level should be created to compliment qualified ontology and move ontology design to the next level. The semantic hierarchy relationships of ontology domain by a M-E analysis further found that without this complimentary material, there is an insufficient amount of reinforcement to support additional uses and purposes, such as communication frameworks, knowledge sharing and re-use. I have discussed here two primary themes—context-centered perspectives and faceted classifications—to determine how knowledge organization studies might be applied to address these issues.

Of these themes, I would encourage a context-centered view rather than context-independent, neural-objective viewpoints. Knowledge organization studies recognize the limitations of general knowledge organization systems across different domains and demonstrate how important context-centered perspectives reflecting users' needs are. Secondly, I presented faceted classification as a guideline for the development of ontology structure. Wine ontology was applied as a case study and the model of ontology development was redefined, based on the studies presented.

The context-centered view and faceted classification are two approaches used to develop knowledge organization. It is risky to suggest that these will provide all the necessary information required for ontology design. To apply these two views in ontology might not work when developing ontology across several system types or purposes; however, they may serve as a guide to help ontology development research obtain a sense of direction in the future. The evaluation of ontology developed here may prove useful in determining how this ontology model, and the ontology developed using this approach, might work in practice.

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