KNOWLEDGE ORGANIZATION SYSTEMS, NETWORK STANDARDS AND SEMANTIC WEB

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This paper is originally published in Croatian, in January 2005. Full reference: Slavic, A. Semantički Web, sustavi za organizaciju znanja i mrežni standardi [Knowledge Organization Systems, Network Standards and Semantic Web]. IN: Informacijske znanosti u procesu promjena. Zagreb: Zavod za informacijske studije, 2005. pp. 5-22.

ABSTRACT: Aimed at students of library and information science, this paper is introductory in nature and provides basic information about the relationship between knowledge organization systems, ontologies and the World Wide Web architecture known as the *Semantic Web.* The Web is expected to be gradually populated by content with formalized semantics that will enable the automation of content organization and its retrieval. As implied by its name, the Semantic Web will assume a higher level of connectivity which is going to be based on resource content and meaning while the information organization will predominantly be automatic i.e. based on *machine to machine* (m2m) information services. This is the reason why the Semantic idea is closely related to the development of ontologies (a simple explanation of an ontology and ontology languages is given based on relevant literature). Traditional knowledge organization systems (KOS) such as classifications and thesauri have been deployed for resource organization and discovery on the Internet and have become *de facto* standards in resource discovery. KOS tools are likely to become even more important with the Semantic Web, providing they can be exposed and shared using ontologically orientated standards.

1 Introduction

Speaking about resource discovery, Berners-Lee (1996) pointed out that information is there, on the Web, but is hard to discover unless put in a form that is actually a semantic statement; i.e. some knowledge representation language statement. In subsequent years he announced the idea of a global reasoning Web at the WWW 7 (1997) and the WWW 8 (1998) conferences when he formally introduced his vision of the Semantic Web. Information discovery will enter a new dimension, as the objective of the Semantic Web is to link substantial parts of human knowledge and allow them to be processed by machines. A key part is the semantics of subject metadata and their representation in contextualised and machine 'understandable' terminology. The idea of a Semantic Web, as expressed by Berners-Lee, is that machine-processable, 'meaningful' metadata will be the basis for a new generation of information retrieval services that will help both humans and computers to access information and communicate with one another. This will enable, for instance, intelligent agent programs to operate and fulfil more demanding tasks independently (Berners-Lee, 2001).

While at present there is information on the Web for the human reader that can be navigated by a simple link, in the future, data will be processed by programs designed independently of data. These programs will require machine-readable statements about resources and their relationships depending on: the existence of a common model, a link between vocabulary terms and their unique definitions; and the availability of definitions to be accessed by programs. The vision implies that software agents will be navigating a Web consisting of descriptions and "ontologies" (including unknown vocabularies), making inferences about the data collected and communicating via partial understanding.

The implication of the Semantic Web is that the Internet would be searchable not only through words but also through meaning. This obviously requires both semantic and syntactic interoperability of a subject vocabulary as it is well known that it is not sufficient if the subject description is based on conceptual isolates, it also often has to be based on propositional logic (Veltman, 2001, 2002, 2004).

In this context, existing KOS such as classification systems, for instance, have been recognized as an important source of structured and formalized vocabularies that can be exploited to support the development of the Semantic Web[1]. Regardless of the indexing term used (i.e. notation symbol or word), KOS are recognisable by the logical processes involved, their structure, or by the knowledge representation functions performed. Information system implementors look, for instance, for classification structures that can be used in information mapping, concept mapping, visualisation of subject access, interactive search presentation and distributed resource viewers. Every one of these applications is closely related to the availability of classification data in a machine processable form.

Two developments in the area of KOS, and in particular classificatory knowledge structures, are seen as a way of supporting the idea of the Semantic Web and they are likely to influence the future use of traditional KOS tools such as thesauri and classifications:

- standards and application for vocabulary exchange
- ontologies (as understood by the field of artificial intelligence)

Standardisation is primarily focused on a technological web framework and a move towards web-based representational languages using XML and XML/RDF2 encoding.

2 Ontologies and Web ontology languages

One of the most important components contributing to the creation of the Semantic Web is the development of machine-processable knowledge structures. These originally belong to the domain of knowledge engineering and AI. Information system implementors often build or adopt a machine understandable and shareable vocabulary by taking standardized and shareable formats as developed by W3C or other fora (Noy & McGuiness, 2001). The importance of *knowledge based* systems (KBS) has been analysed in information sciences since the 1980s, mostly in relation to automatic indexing (natural language processing) and information retrieval (Croft, 1989).

As full text retrieval has become central to information discovery on the Internet, specific concepts such as knowledge domain and ontology are used more frequently in information science (Vickery, 1997) and not always with clear and well defined meaning. The term 'ontology' itself begins to embrace an entire set of meanings and comprises everything from taxonomical categories, controlled vocabularies in resource metadata, lists of products or classifications of services, database vocabulary and relationships.

2.1 What is an ontology in computing?

An ontology, i.e. a formal data structure used to build a knowledge base, is a relatively new research topic even in this field and dates back to the 1990s. (Ding, 2001 and Vickery, 1997). The term is closely related to knowledge based systems (KBS) i.e. expert systems that are designed to 'behave intelligently' and thus either help human experts to perform their task

[1] Soergel (1999: 1119) suggests that library classification, for instance, can have the following role in the networked environment: providing semantic road maps; improving communication and learning; providing a conceptual base for the design of research; providing classification for actions; supporting information retrieval; providing a conceptual base for knowledge-based systems; providing the conceptual basis for data element definition and object hierarchies in software systems; cross-discipline, cross-language and cross-culture mapping; and serving as mono-bi-or multilingual dictionary/knowledge base for natural language processing .

[2] RDF supports encoding, exchange and reuse of structured metadata and the combination of different metadata structures within one single metadata instance that can have links to an external source of reference. RDF is dependent on the possibility to identify and refer to the resources via a URI (Uniform Resource Locator).

more quickly or economically, or to replace humans in dangerous or expensive routine operations. Such a computer system has to be 'fed' with knowledge from that particular domain (knowledge base) and programmed to perform procedures (part of a program called an inference engine) to solve the task. In order to achieve this, a knowledge base has to be built on the principles of formal machine processable data structures. A knowledge base itself is actually an informal term for a collection of information that includes an ontology as one component. However, it also may contain information specified in a declarative language such as logic or expert system rules, or non-formalized information expressed in natural language or procedural code.

An ontology is built following a basic logic procedure and this results in a classification structure with clearly defined classes and conceptual relationships that, for instance, can be expressed through formalised structures called 'conceptual graphs' and formatted in a machine processable way (Sowa, 2000). *Knowledge representation* as understood within the field of AI deals with a wide range of knowledge that is computable, i.e. expressed by strict rules of logic.

The expressive power of logic, as pointed out by Sowa (2000), includes every type of information that can be stored or programmed on a computer. However, logic has no power to describe things that exist. Logic itself is a simple language with a small number of basic symbols, thus the predicates that represent knowledge about the real world have to come through an ontology. Ontological categories are collected through observation and reasoning that provide information about abstract and concrete entities, their types and relationships in a particular domain.

It could be said that an ontology is a study of the categories of things that exist or may exist in some domain. The product of such a study is a catalogue of the types of things that exist or are assumed to exist in a domain of interest from the perspective of a person who uses an agreed language for the purpose of talking about this domain. This knowledge of the physical world helps generate a framework of abstractions and provides predicates and predicate calculus necessary for computing operations. Predicates in an ontology are either domain-dependent, which means that they are specific to a particular application or are domain-independent and represent generally applicable attributes (e.g. part, set, count, member etc.). The logic combined with an ontology provides a language that can express relationships between entities in a domain of interest.

Not all ontologies share the same coverage, formality level, level of detail and purpose. In effect there are several different criteria for describing an ontology. From the point of view of their coverage, ontologies could be grouped with those that deal with knowledge limited to one specific application or domain and those that attempt to cover knowledge in its universal sense.

While philosophers build ontologies from the top down, in the field of computer science, an ontology is usually built bottom-up. These computer ontologies often start with microworlds which are easy to analyse, design and implement. Thus the choice of ontological categories could be any set of categories that can be represented in a computer application: entity relationship models (ER) in a database, set of class definitions in object-oriented system, geographical concepts needed for a particular application etc.

Ontologies that tend to share knowledge with other applications must be built upon a more general framework. This kind of ontology has the same mission and seeks the same philosophical background as any general or encyclopaedic knowledge classification (Figure 1).

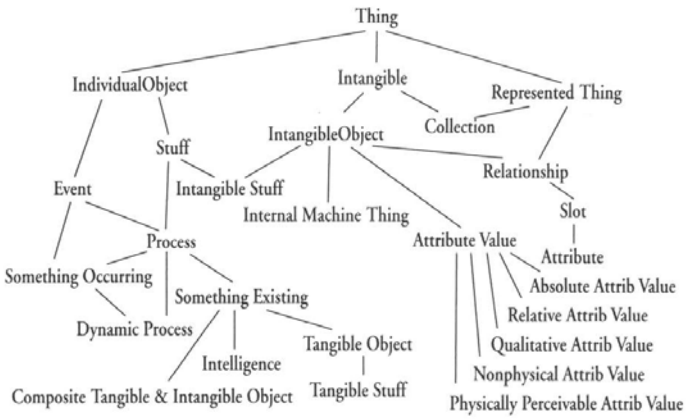

Figure 1. Graphical representation of the concept framework for a Cyc (a general ontology) (from Sowa, 2000: 54)

Ding (2001) summarizes other criteria and categorizations from abundant AI literature:

- According to the level of formality, purpose and subject:
  formality: highly informal, expressed in natural language; semi-formal, expressed in a restricted and structured form of natural language; semi-informal, expressed in an artificial formally defined language; rigorously formal, with meticulously defined terms with formal semantics and theorems
  purpose: communication, inter-operability, reusability, knowledge acquisition, specification, reliability.
  subject: subject matter (such as a domain ontology); subject of problem solving, subject of knowledge representation languages

- According to level of detail and level of dependence:
  detail: meta-level ontology, reference ontology, shareable ontology, domain ontology
  dependence: top-level ontology, task ontology, application ontology

- According to coverage, dependence:
  knowledge representation ontologies
  general/common ontology
  top-level ontology
  meta-ontology
  domain ontology
  task ontology

In the context of the Semantic Web, an ontology can have a very broad meaning, usually based on the classification structure and vocabulary control that is inherent to every ontology. A helpful categorization in terms of the practical application of ontologies that reveals this link to classification is given by McGuinness, who draws a distinction between *simple ontologies* and *structured ontologies* (McGuinness, 2002).

When talking about *simple ontologies,* she provides examples of taxonomies or simple hierarchical vocabularies (examples: DMOZ http://www.dmoz.com, UMLS - Unified Medical Language System at http://www.nlm.nih.gov/research/umls). According to the way she defines their purpose, it is obvious that she speaks of ontologies that are used in the same way as, for instance, any bibliographic classification would be used:

- to provide controlled vocabulary
- for site organization and navigation support
- as "umbrella structure" from which to extend content
- as browsing support
- for search support
- for sense disambiguation support

Structured ontologies, however, apart from machine-readable encoded hierarchical relationships, contain information about properties and value restrictions on the properties which link a concept to the instance to what it can be applied. For instance, a class 'goods' can have a property 'price' whose value could be restricted to numbers or a number range. As a concept in an ontology is described in term of classes, properties and roles, and these are encoded to be machine readable, any part of the concept encoded structure can be more specifically defined in terms of values that can be associated with it. Because of this quality such, so called, *structured ontologies*, according to McGuinness, could be used as a part of an application environment to help:

- consistency checking
- completion (property enables automatic inlcusion/exclusion of other properties)
- interoperability support (missing information can be restored through the link to other properties)
- encode entire test suites
- configuration support (information on the system it is applied to)
- support, structured, and customized search
- exploit generalization/specialization information

Some well known ontologies from the fields of linguistics and knowledge engineering are:

WordNet - general linguistic domain (top-level ontology in its upper level) containing structured vocabulary of English language with lexical categories and semantic relations

Cyc - general common ontology consisting of knowledge captured from different domains: space, time, causality, agents).

SENSUS - a linguistic domain ontology built by extracting and merging information from existing electronic resources for the purpose of machine translation; STEP (Standard for exchange of product model data) - ontology built to exchange products data among different computer systems etc.

2.2 Ontology languages

The machine readability of an ontology is based on the representation language which will provide the necessary machine-processable encoding. An ontology encoding language which will have to support an expert system with a complex ontological framework, domain concepts and reasoning rules will naturally be very powerful as opposed to the language whose purpose would be used, for instance, only to support simple taxonomical relations between concepts. Recent research activities have been focusing on establishing the necessary standardisation in this area and today's ontology language encoding standards are trying to merge language expressive power along with reasoning power that will provide a powerful representational language with known reasoning properties (McGuinness, 2002). From the field of software engineering emerge, also, alternative approaches for modelling ontologies based on modelling constructs, analysis and design of object-oriented software systems. (Cranefield, 2001).

Languages used to represent ontologies belong to three categories: logic based (first-order logic), frame based (frame logic) or web based (RDF, XML, HTML). While the first two are particular to AI applications, web based ontology representation languages could be used to a certain extent to support representation of vocabularies outside the AI domain and will be described here in more details.

A typical example of a **logic based ontology language** is *Knowledge Interchange Format (KIF)*- which is a format that enables mapping of ontology *from* and *to* computer languages and allows for predicate logic to be expressed in KIF specific type syntax. KIF's primary purpose is to serve as an interchange language between heterogeneous knowledge bases and databases. This format is characterized by high computational complexity.

Examples of **frame based ontology languages** are: *Knowledge Language One (KL-ONE)* - that supports a frame data structure with network notation and clearly defined semantics, and *Frame Representational Language (FRL)* - a language supporting a frame data structure that is used to represent a stereotyped situation.

Web orientated ontology languages are listed in the next section.

3 Network standards for use and exchange of knowledge organization systems

Development in the area of Web ontology languages has important implications for understanding future use of traditional KOS such as classification or thesaurus in the networked environment. One, most important feature of an ontology is the basic classification structure or taxonomy. Modelling of this structure in an ontology has to conform to the most strict logical rules.[3]

However, even if we look into classification systems only, they have a very different level of formality in data structuring and representation and it is obvious that efforts have to be made within each of these systems to express more clearly their semantics and syntax. Usually when indexing languages are formatted to be machine processable this ought to be based on the analysis and transparency of their own micro-ontology that consists of vocabulary, syntax, semantic and inference rules. There is a tendency to make this process more standardized in order to exploit KOS in the development of the Semantic Web (Soergel, 1999; Soergel, 2001; Gilchrist, 2002). Complementary to the goals of the Semantic Web would be to have all the KOS available and accessible on the Web in such a way that each indexing term would be uniquely identifiable but also explained through the structure of the system to which it belongs.

Important steps have already been made in order to provide common standards for representation of indexing languages. Prerequisites for such a development are open and platform independent vocabulary encoding standards. Soergel defines the purpose of these standards to be:

- input of KOS data into a program and transfer of data from one program to another;
- accessing KOS for applications and querying KOS and viewing results
- identifying specific terms/concepts in specific KOS
- prescribing and giving guidance on good practices
  (Soergel, 2001: 1)

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[3] A good illustration here are rules for the creation of an ontology proposed by Guarino & Welty (2002), which explain the principles of, e.g., class essence and rigidity; class identity and unity; taxonomic relation or subsumption; instantiation; difference between part of and subclass; disjunction/type restriction etc.

New developments in the wider Internet community include efforts to make use of existing data by providing a platform for the linking and exchange of different indexing languages, seeking for common representations and protocols (Qin & Paling, 2001; Vizine-Goetz, 2003; Vizine-Goetz et al. 2004; Zeng & Lois, 2004). One of the active initiatives in this area is the "Networked Knowledge Organization Systems/Services (NKOS) which acts through workshops, publications and a mailing list and brings together implementors and standard developers from different domains (http://nkos.slis.kent.edu/).

Standards that are being developed in specific information sectors and domains (librarianship, digital libraries, geographical data, government data, archives, e-learning) are now being analysed, evaluated and tested using more transparent and flexible data transport standards such as XML. Such is the case for standards for machine-processing (translation) and exchange of dictionaries and glossaries, thesauri, concept maps as well as those already created for the exchange of thesauri and classifications. Some of these standards are designed with an ontology in mind.

3.1 Web-based ontology languages

DARPA Agent Markup Language (DAML) is designed specifically to become a language and tool for facilitating the concept of the Semantic Web. DAML is a typical example of a standard that uses a Web-compatible language along with a reasoning paradigm developed in the field of AI.

DAML+OIL is a combination of a Web language, description logics, and a frame reasoning system as defined by The Ontology Inference Layer (OIL). It provides a rich set of constructs with which to create ontologies and to markup information so that it is machine-readable and understandable. DAML is compatible with the RDF Schema (RDFS), and includes precise semantics for describing term meanings (Fensel, 2000).

Ontology Web Language (OWL) is a semantic mark-up language developed by W3C. It is derived from DAML+OIL for the purpose of the Web ontology creation and exchange (http://www.w3.org/TR/owl-ref/). OWL contains three 'sub-languages' characterised by different levels of complexity: OWL Lite, OWL DL and OWL Full.

Simple HTML Ontology extension (SHOE) - which is an HTML-based knowledge representation language that offers categories, relationships, attributes, inferences, etc. that can be defined by ontologies. SHOE provides a relatively rich level of semantics and abilities, which enables Web designers to embed documents with information about the overall "content" of those documents. SHOE also allows agents to make automatic inferences about the data they learn, provides a hierarchical categorization scheme and a sophisticated ontology mechanism designed specifically for the needs of the Web (http://www.cs.umd.edu/projects/plus/SHOE/).

3.2 Standards for terminology exchange

Open Lexicon Interchange Format (OLIF) is an XML compliant, user-friendly, format for exchanging terminological and lexical data. The OLIF (version 2.0) lexicon and terminology exchange standard is currently under development within the OLIF Consortium, a collaborative group of industrial firms active in the field of language technology (http://www.olif.net/).

ISO 12200:1999 - MAchine-Readable Terminology Interchange Format (MARTIF) is an SGML-based format for data interchange among concept-oriented terminological databases. MARTIF is intended for interchange between partners (e.g., two translation companies) who know about each other and are able to “negotiate” details of the format to minimize information loss.

ISO 16642:2003 - Terminological Markup Framework (TMF) is built on OLIF and MARTIF, which are primarily focused on lexical data. TMF is, however, more network-orientated and includes features for conceptual and ontological aspects of terminology data (Romary, 2001). TMF defines underlying structures and mechanisms needed for computer representation of terminologies, regardless of any specific format. The purpose of this standard is to express constraints on the representation of computerised terminology and to maintain interoperability between representations. One specific representation format generated from TMF is Terminological Mark-up Language (http://www.loria.fr/projets/TMF/).

3.3 Standards for bibliographic KOS

MARC Authority Formats provide support to classification authority data. Their application is heavily limited by their bibliographic format encoding and, so far, an alternative Web-orientated encoding does not exist. They are tailored for library system applications with particular classification systems in mind and from the point of view of data modelling they are more suitable for database applications than for the Web environment.

Representatives are:

MARC 21 Concise Format for Classification Data (http://www.loc.gov/marc/classification/eccdhome.html).

Concise UNIMARC Format for Classification Data (http://www.ifla.org/VI/3/p1996-1/concise.htm).

The Zthes profile - Zthes is a Z39.50 profile for thesaurus navigation. The profile describes an abstract model for representing and searching thesauri (e.g. hierarchies of terms as described in ISO 2788: 1986) and specifies how this model may be implemented using the Z39.50 protocol. It also suggests how the model may be implemented using other protocols and formats: a Zthes DTD for XML is provided as an appendix to the profile. Real Zthes datasets have been exchanged in the form of XML documents conforming to this DTD (Taylor M., 2001).

BS 8723 - Structured vocabularies for information retrieval - guide. This is a new British Standard in development that will supersede the existing British and ISO standards for thesaurus establishment and development: ISO 2788-1986, ISO 5964-1985. The standard is planned to consist of five parts: (a) definitions; (b) guidance for creation of thesauri, electronic functions of thesauri and thesaurus management software; (c) guidance for creation of other types of structured vocabularies (classification schemes, search thesauri, subject heading lists, taxonomies and ontologies); (d) guidelines for interoperability between vocabularies, mapping etc. and (e) protocol and formats for vocabulary exchange (Dextre Clarke, Gilchrist & Will, 2004).

3.4 E-learning vocabulary standard

Vocabulary definition exchange (VDEX) is an IMS Global Learning Consortium specification that defines a grammar for the exchange of value lists of various classes (i.e. any collections of terms denoted as "vocabulary"). VDEX can be used for the exchange of simple machine-readable lists of values, or terms, together with information that may aid a human being in understanding the meaning or applicability of the various terms.

VDEX XML syntax can be used for strictly hierarchical schemes. The IMS Technical Board approved the VDEX Version 1 Final Specification in February 2004 (http://www.imsglobal.org/vdex/).

3.5 General (not domain specific) standards for vocabulary exchange

*ISO/IEC 13250:2000 Topic Maps (*and *XTM)* is a specification that provides a model and grammar for representing the structure of information resources used to define topics and associations (relationships) between topics. Web-based Topic Maps, called XML Topic Maps (XTM) are developed in order to facilitate the use of the topic maps paradigm on the Web, and to help realise its potential for finding and managing information

(http://www.topicmaps.org/xtm/1.0/). Topics have their characteristics represented within limited contexts in which they are given their name, resource and relationship characteristics. One or more interrelated documents employing this grammar are called a 'topic map'.

The Vocabulary Markup Language (Voc-ML). A NISO workshop on Electronic Thesauri: Planning for a Standard held in 1999 (Milstead, 1999) concluded (amongst other things) that there was a need for a metadata content standard for the description of knowledge organisation systems. NKOS has since then defined a set of attributes for the description of knowledge organisation systems, and developed a draft XML DTD known as the Vocabulary Markup Language (Vocabulary ML, 2000).

The schema includes Dublin Core metadata that would describe the knowledge organisation systems being encoded. It also defines tags and syntax for uniquely identifying each term, its relationship to other terms, and provides place for descriptive information like scope notes and definitions. It is hoped that the schema, when finalised, will work for a range of different types of system, including authority files, hierarchical thesauri, classification schemes, digital gazetteers and subject heading lists (Hodge, 2000).

eXchangeable Faceted Metadata Language - XFML Core (http://www.xfml.org/spec/1.0.html). The purpose of the XFML format is the use and exchange of a faceted vocabulary. In essence, similar to the XTM, XFML is "a model to express topics, organised in hierarchies or trees within mutually exclusive containers called facets" and enables vocabulary to be published in an XML format. It is possible to built connections between different XFML topic maps, by indicating that a topic in one map is equal to a topic in another map (Tzitzikas et al., 2002; Van Dijk, 2003).

SKOS – Simple Knowledge Organization System is a standard and specification (SKOS Core) for expressing knowledge organisation systems (KOS) in a machine understandable way. SKOS is a development by the W3C SWBP-WG Thesaurus Task Force within the SWAD-Europe project. SKOS Core is a model for expressing the basic structure and content of conceptual schemes. SKOS Core is a 'conceptual scheme' or 'concept scheme', defined here as: a set of concepts, optionally including statements about semantic relationships between those concepts.

SKOS uses a flexible XML/RDF syntax and is meant to be used not only for thesauri but also for taxonomies, glossaries, Web directories etc. It is meant to be used as an ontology and is complementary to Ontology Web Language (OWL). The SKOS core provides a framework for publishing KOS terms and their relationships in order to support searching and browsing but is also supposed to support mapping and linking between different KOS.

The SKOS Core was declared in 2004 to be an 'open' development (http://www.w3.org/2004/02/skos/).

4 Concluding remarks

Resource discovery on the Internet emphasizes the importance of subject retrieval and has contributed to the revived interest in traditional knowledge organization systems (classifications and thesauri in particular). The development of the Semantic Web depends on a metadata infrastructure which can be understood as a machine processable vehicle for use and exploitation of indexing languages. Vocabularies used in metadata description are now being formatted and encoded in a standard manner in order to make them easier to be processed and exchanged by machines. The value of traditional knowledge organization systems is likely to be determined by their ability to be published and shared by machines in the open networked environment.

The networked environment endorses general and system independent solutions and imposes the philosophy of an open information space in which the same technological vehicle is used to transport many different kinds of content. One of the main concerns in metadata architecture and Semantic Web infrastructure in general is how to establish permanent identifiers for different vocabulary schemes so they can be referred to from within metadata. Developments in vocabulary mark-up standards and Web ontology languages are in line with the Web architecture in which machine understandable thesauri and classification schemes would be made available and would be shared via the Web. For this to work every concept in every controlled vocabulary in this context need to have its unique identifier that would enable its semantic interpretation, reuse and sharing between metadata schemas (Van de Sompel et al., 2004; Vocabulary ML, 2000; see also NKOS web site at http://nkos.slis.kent.edu/). The proposals on a vocabulary 'registry' and 'terminological services' are currently being discussed (Pepper & Garshol, 2002; Vizine-Goetz, 2003; Vizine-Goetz et al., 2004).

One of the developments in the area of identifying vocabulary scheme concepts is a suggestion of a published subject identifier - PSI: "*Published Subjects is an open, distributed mechanism for defining unique global identifiers. Based on URIs, the Published Subjects mechanism has two unique characteristics: it works from the bottom up, and it works for humans AND computers*" (Published subjects: introduction and basic requirements, 2003).

At present, traditional KOS and the accompanying know-how are not available in a form that could be used and shared on the Internet and the infrastructure necessary for the exchange of traditional knowledge organization tools is still not in place (Cordeiro & Slavic, 2002; Slavic & Cordeiro, 2004). The use of classification vocabulary in metadata and general in supporting resource discovery on the Internet will be closely tied to the way a given vocabulary is made available in the networked environment. As pointed out by Vizine-Goetz et al. (2004) in order to create terminological services the existing vocabulary formats will need to be significantly enhanced.

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