Topic Maps from a Knowledge Organization Perspective

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ABSTRACT: This article comprises a literature review and conceptual analysis of Topic Maps—the ISO standard for representing information about the structure of information resources—according to the principles of Knowledge Organization (KO). Using the main principles from this discipline, the study shows how Topic Maps is proposed as an ontology model independent of technology. Topic Maps constitutes a 'bibliographic' meta-language able to represent, extend, and integrate almost all existing Knowledge Organization Systems (KOS) in a standards-based generic model applicable to digital content and to the Web. This report also presents an inventory of the current applications of Topic Maps in Libraries, Archives, and Museums (LAM), as well as in the Digital Humanities. Finally, some directions for further research are suggested, which relate Topic Maps to the main research trends in KO.

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1.0 Introduction

Topic Maps is an ISO standard for representing information about the structure of information resources (ISO13250). The origin of Topic Maps dates back to 1991 when the Davenport Group started a project to develop DocBook, which had the purpose of facilitating the exchange of UNIX documentation using SGML/XML. A byproduct of this work was Topic Maps, a model and syntax (XTM) whose original purpose was to enable the merging of back-of-book indexes of various systems of computer documentation. The creator of Topic Maps, Steven Newcomb, believed that back-of-book indexes are actually a rendition of an underlying structure that could be represented explicitly and merged on a single superstructure over the documents. The initial model was consolidated and became an ISO standard in the year 2000. It immediately proved applicable to other domains, such as Information Architecture and Web publishing. It is also considered to be one of the few mechanisms that facilitate semantic integration and structuring information on the Web.

Nowadays, Topic Maps is used in a variety of fields and for a variety of purposes. Garshol (2007) summarizes them as, including but not limited to, Semantic Portals, eLearning, Business Process Modelling, Product Configuration, Information Integration, Metadata Management, Business Rules Management, IT Asset Management, and Asset Management (Manufacturing). In the United States of America, Topic Maps has been used by the Internal Revenue Service (IRS) of the Department of the Treasury (the "tax map"), the DOE (Department of Energy), and Lexis-Nexis and in different E-Gov proceedings (Newcomb and Biezunski 2003). In Europe, it has mainly been used in

the public sector, although it has also been used in pharmaceuticals, automobiles, and publishing (Newcomb and Biezunski 2003). Its use is widespread in Germany and even more so in Norway. In Norway, there are numerous small and large scale projects using Topic Maps, including: "forskning.no" (the Norwegian government portal to popular science and research information), "Kulturnett.no" (the Norwegian public sector portal to cultural information), "Bergen Kommune" (the city of Bergen citizen portal), "Apollon" (University of Oslo research magazine), and "NRK/Skole" (a curriculum-based browsing).

Given that its original purpose was to create a model to integrate back-of-book indexes, Topic Maps seems to be a development aligned within the principles of KO. However, its relatively new appearance and its origins in the SGML community, (document description languages from the point of view of computer scientists) suggest a need for reviewing the literature which addresses the relationship between Topic Maps and KO. In addition, it would be helpful to understand the Topic Maps principles and also review its applications from a KO perspective, because almost ten years have passed since the first appearance of Topic Maps in KO literature.

2.0 Previous Research

The Topic Maps community has already tried to align the principles of its model with those of KO. The best example of this is exemplified in a study done by Garshol (2004), which describes Topic Maps in relation to what he refers to as the "techniques from library science" in considering its potential application to Web site design. This work examines the relation of Topic Maps to indexing languages, authority files, and metadata schemas, concluding that Topic Maps can not only represent, but extend all these systems.

In KO literature, Topic Maps appeared around 1999, with an article that has been, until now, the only one about Topic Maps published in the *Knowledge Organization* journal (Sigel 1999). In 2000, the XML Europe conference in Paris, France, brought together many different groups interested in Topic Maps and initiated its widespread use in the LIS and KO communities (Stringer-Hye 2005, Sigel 2003). A paper published in that conference is "Towards Knowledge Organization with Topic Maps" (Sigel 2000), one of the first articles found in the literature exploring the relation of Topic Maps with knowledge organization. In 2007, Topic Maps was mentioned for the first time in the *Annual Review of Information Science & Technology*, as part of a section on "ontologies on the Semantic Web" (Cronin 2007, 430).

The main conclusion from the KO perspective seems to be, according to Sigel (2003, 425), that Topic Maps is "a new enabling technology for KO." Sigel states that Topic Maps offers new possibilities for the enhancement of information organization and, more specifically, for semantic integration of heterogeneous systems and information sources. It also allows flexible indexing views, scope filtering, and ontology-based modeling in KO. But Siegel also points out that KO can contribute to Topic Maps by bringing extensive expertise, solid principles, and tested methods to help solve the problems of organizing knowledge which arise in the Topic Maps' design.

In addition, the Korean professor Sam Oh has suggested numerous ideas on how to apply Topic Maps to the different models and schemas currently in use and under discussion in the LIS community: Functional Requirements for Bibliographic Records (FRBR), Resource Description and Access (RDA), Simple Knowledge Organization System (SKOS), and Dublin Core (Oh 2008b, Oh 2008c). Iglesias and Stringer-Hye (2008) studied the applications of Topic Maps to Integrated Library Systems (ILS); they observed that, in this area, Topic Maps is still an 'undelivered promise,' because, even though the possibility of implementation exists, there have not been any vendors implementing the model in their products. In terms of usability studies, Yi (2008, 1902) observed that of the few studies that have been done, most have employed RDF instead of Topic Maps. Oh (2008a), Dalmau and Walsh (2007), and Bøckman (2006; 2007) refer to having done usability studies using Topic Maps-based systems, and showed generally positive results in their use.

Finally, regarding the comparison of Topic Maps with other KOS, Kongsbakk (2004) made a detailed study of the similarities and differences between Topic Maps and thesauri, both from a theoretical and a practical perspective. The study analyzed each model from different angles (background, purpose, structure, relationships, linguistic treatment, and standards) and concluded, among other things, that thesauri and Topic Maps cannot be compared directly because of the distinct nature of each model.

3.0 Methodology

This study tried to answer two questions: What has been said, conceptually speaking, on the relation between Topic Maps and KO?, and what are the existing applications of Topic Maps to the Libraries, Ar-

chives, and Museums (LAM) field, as well as to Digital libraries in the Humanities?

For this purpose, an extensive literature review was done using the following sources:

Databases: EBSCO –Academic Search Premiere, Library Information Science Technology Abstracts (LISTA)–, EMERALD, the Web of Science, and the Library and Information Science Abstracts (LISA).

Conference proceedings and presentations: Conference on Topic Maps Research (TMRA) and the Topic Maps Conference.

The main websites of the Topic Maps community: Topicmaps.org, Topicmaps.com, Coolheads.com, Techquila.com, Infoloom, Versavant, Ontopia, Ontopedia, Networked Planet, and Topicmapslab.de.

Representative websites of the LIS and KO communities: The Online Computer Library Center (OCLC), the American Library Association (ALA), Dublin Core, The International Federation of Library Associations and Institutions (IFLA), the Digital Library Federation, the DELOS Network of Excellence on Digital Libraries, and "Lifeboat for Knowledge Organization" by Birger Hjørland.

Mailing lists: Topic Maps mailing list, Topic Maps in LIS mailing list, Next Generation of Library Catalogs (NGC4LIB), and the Digital Libraries Research mailing list (DIGLIB).

Blogs: Alexander Sigel, Lars Marius Garshol, and Alexander Johannensen.

Books: Park and Hunting (2003), Passin (2004), and the Annual Review of Information Science and Technology (ARIST).

Within the LIS or KO sources, the words "Topic Maps," "topic map," and "ISO 13250" were employed in the searches. For searching the sources from the Topic Maps community, since its terminology is not consistent, common expressions were used such as "library techniques" and "information organization techniques," as well as more generic terms like "library," "archive[s]," "museum[s]," "humanities," and "digital library" or "digital libraries." The documents selected were those that dealt with the relation of Topic Maps and LIS and KO; all the documents retrieved that fulfilled this criterion were reviewed.

To analyze these sources a technique applied in the Grounded Theory (GT) approach was used. For Corbin and Strauss (2008, viii) GT means "building theory grounded in data." Pickard (2007), however, makes the distinction between GT as a method of qualitative research and as a qualitative data analysis technique. In this literature review, GT was used in the latter sense mentioned by Pickard and not for building theory from the data. The data analysis technique utilized in this study consisted of coding and annotating selected sources in order to observe the emerging categories. The codes were then grouped into families, which resulted in the main concerns on the application and relation of Topic Maps to LIS and KO. This also provided direction in choosing which conceptual framework to use for the conceptual analysis, which, in this case, was Information Organization (from the work by Elaine Svenonius, cited by the Topic Maps Community) (see section 5.1.2). After identifying the preliminary categories, some additional and more specific searches were carried out, using, among others, terms such as "Dublin Core," "MARC," "FRBR," and "FRBRization." Finally, to complement and discuss some of the topics, unstructured interviews were conducted with three select people who had worked on the applications of Topic Maps to LIS: Prof. Sam Oh, Suellen Stringer-Hye, and Aki Kivelä. There were around sixty documents included in this literature review, including journal articles, conference presentations and papers, student reports and theses, some blog and mailing lists' posts, as well as a book chapter.

4.0 Conceptual Framework

4.1 Topic Maps

This section is primarily based on three documents, that of Pepper (2010), ISO/IEC 13250-1:2003 and ISO/IEC 13250-2:2006.

Basic concepts. The basic conceptual building blocks of topic maps are *topics*, *associations* and *occurrences.* The model they belong to has been referred to as the TAO of Topic Maps (Pepper 2000 rev. 2002).

Topics and subjects. The Topic Maps' concept of a subject is anything (physical or abstract, real or fictional) that the author of the topic map wishes to make assertions about, i.e., assign a name, a property, or a role in some relationship with another subject. The subject is defined in ISO/IEC

13250-2:2006 (the Topic Maps Data Model) as follows (8):

> A subject can be anything whatsoever, regardless of whether it exists or has any other specific characteristics, about which anything whatsoever may be asserted by any means whatsoever.

A topic is the symbol or surrogate that represents the subject within a topic map. Topics are informally referred to as the "proxies" of subjects in a computer domain (Pepper 2010). By definition, every topic represents a single subject. The goal of any Topic Maps application (often referred to as the "collocation objective") is to ensure that every subject is represented by one and only one topic. All constructs in a topic map (topic, association, association role, occurrence, or name) can be typed. All such types are also topics, called informally typing topics. This set of typing topics that is used within a topic map is what defines its ontology (Pepper 2010).

Identity. In order to achieve the collocation objective, Topic Maps encourages the use of explicit identifiers rather than names. Identifiers usually take the form of URIs (Uniform Resource Identifiers). These can either be subject identifiers or subject locators, and they are the basis for merging, a capability which is often described as the most powerful feature of Topic Maps.

> Subject locators are URIs that identify subjects that are "network addressable information resources" and that have a location (an address) in an information system. The network addresses of such subjects can be used to identify them directly.

> A subject identifier is a URI that identifies an arbitrary subject that may or may not have a location in an information system. It identifies its subject *indirectly* via a subject indicator (sometimes called a subject descriptor).

> A subject indicator is simply a human-readable resource (i.e., document) to which a subject identifier resolves, and which is intended to convey the identity of the subject to a human being. As the Topic Maps Data Model (TMDM) defines it, a subject indicator is an "information resource that is referred to from a topic map in an attempt to unambiguously identify the subject represented by a topic to a human being." Figure 1 exemplifies this 'indirect identification'.

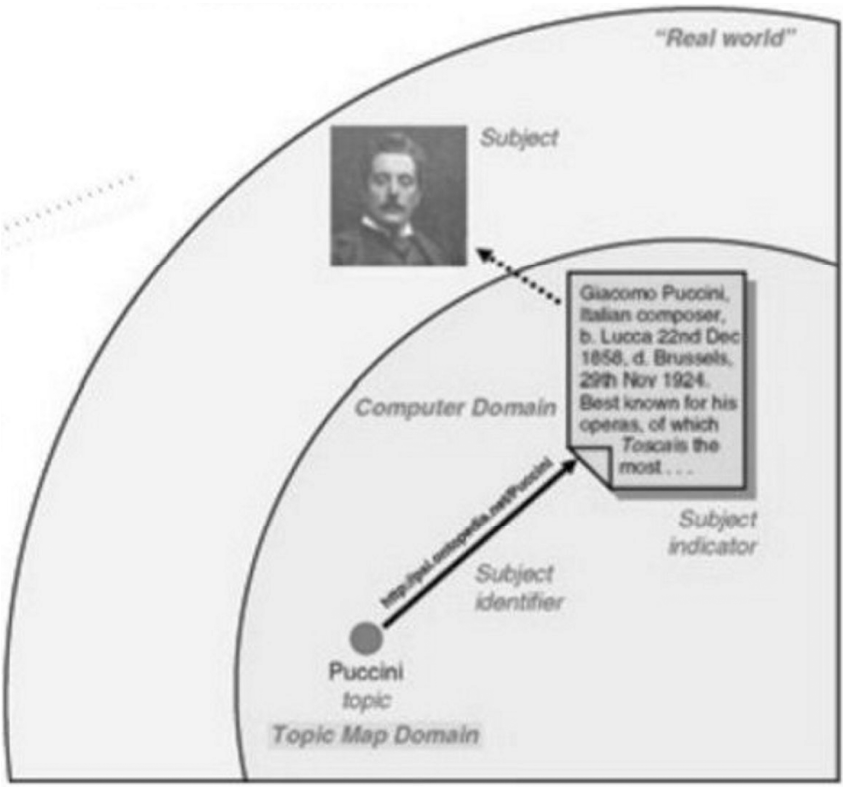

Figure 1. Subject identifiers and subject indicators (Pepper 2010)

> Subject identifiers and indicators (or descriptors) can be "published," in other words, made available, for use outside the scope of a specific application in order to achieve wider interoperability. They are then known as published subject identifiers (PSIs) and published subject indicators, respectively, or collectively as published subjects (Pepper 2010).

Names. Topic names are properties that have naming semantics. A topic can have multiple names, each of which consists of a base name and zero or more variant names. Each name is typed (i.e., assigned a name type) and may also be scoped. A base name is the base form of a name, an alphanumeric string used as its default label.

Variant names are the alternative forms of base names that are optimized for particular computational purposes, such as sorting or display. The main examples cited of uses for variant names are sort key, plural forms, pronunciation, common misspellings/alternative spellings, and alternative orthographies.

Occurrences. Occurrences relate topics to relevant information resources that describe them. According to Pepper (2010), the resource in question may be very small, such as a string representing a date. In this case, the resource is normally included in the topic map and known as an "internal occurrence." Or else it may be stored externally, because of its size, notation, provenance, or an additional characteristic, and referenced via a locator – normally a URL–which corresponds to a page number in a back-of-book index (which is, itself, a locator for any piece of information relevant to the subject in question).

Associations and roles. Associations express relationships between subjects by relating one topic to (zero or more) other topics. They were originally meant to represent the 'See also' references that appeared in back-of-book indexes.

Each topic that participates in an association is said to play a role in the relationship that is expressed by the association. The nature of the subject's involvement in a particular relation is expressed using a role type, e.g., Puccini plays the role of pupil in the teacher/pupil relationship with Ponchielli. This mechanism obviates the need for associations to have a specific direction, and all associations are therefore inherently multidirectional.

Scope is a set of topics that is used to qualify a statement (i.e., a name, occurrence, or association) with the purpose of indicating the context in which a certain assertion may be considered valid. If no scope is explicitly specified, the scope is said to be "unconstrained." Topics that are used for scoping are informally referred to as "scoping topics."

Merging is a process or operation and as such is different from the previous elements, which are constructs in the Topic Maps model. Merging can take place both within a single topic map (to eliminate redundancy) and when combining two or more topic maps. This process lies at the core of the Topic Maps view, and can be traced back to the original motivation (merging indexes) that gave rise to the model. While merging is an operation performed by an application, its procedures are strictly defined in the standard, and it is based on the concept of identity described above.

Reification is the process of instantiating as a topic some Topic Map construct (a name, occurrence, association, role, or even the topic map itself) that, itself, is not a topic. Once this is done, whatever is represented by the construct in question becomes a subject in its own right, about which statements can be made. Reification is most often used to assign metadata to a topic map.

Figure 2 exemplifies some of the previously outlined Topic Maps concepts.

4.2 Knowledge and information organization

Within the LIS community, there are two disciplines that have to do with organizing information: Information Organization and Knowledge Organization (KO). They come from different traditions and are usually referred to as Knowledge and Information Organization. In this study, the term Knowledge Organization (KO) is used to refer to both disciplines. However, Information Organization is taken into account separately because its conceptualization of the elements of bibliographic languages is used to analyze Topic Maps (section 5.1.2).

Information Organization originated in the tradition of Anglo-American descriptive and subject cataloging. Svenonius (2000, 53), which is repeatedly cited by Topic Maps communities, synthesizes the main principles of this discipline. Information Organization, she suggests, is a body of knowledge with principles, objectives, and techniques that employ the use of a specific "special-purpose" language to describe the information and its physical embodiments with the idea of accessing both. The languages used for that purpose are called "bibliographic languages," as opposed to "natural languages." In a later work, Svenonius (2004) changes the word "bibliographic languages" to "retrieval languages," preserving the

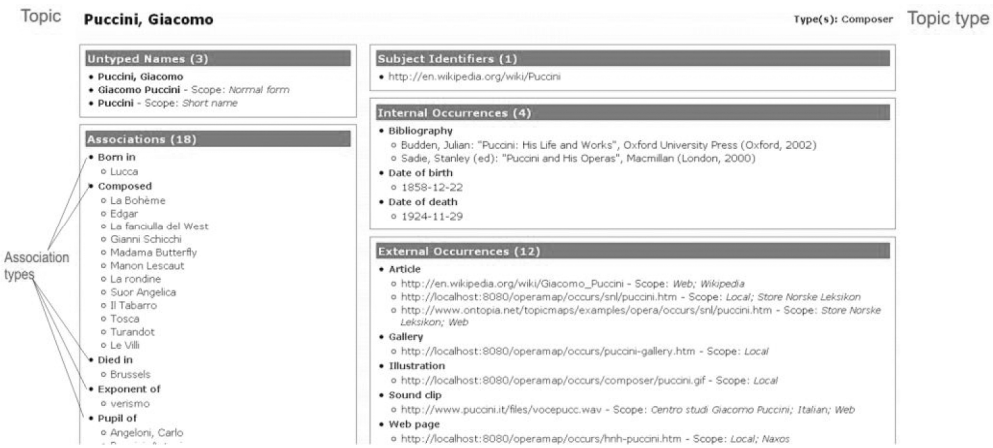

Figure 2. A topic map example (from "The Italian Opera topic map")

same interpretation of these languages as artificial languages, a subset of natural language, designed for the specific purpose of embodying knowledge representations.

According to Svenonius (2000, 31), the purpose of a bibliographic language is to describe "bibliographic entities," which are basically "works, editions, authors, and subjects" divided into two realms. The first realm, described by what she calls "work languages," is that of "information" and is equivalent to "the content of a message." The second realm, described by what she calls "document languages," is that of "information entities," or the physical embodiments of the former.

The components of a bibliographic language (as well as a natural language) are its vocabulary, semantics, syntax, and pragmatics. The vocabulary of bibliographic languages refers to the expressions used to name the values of three variables: entities, attributes, and relationships (in other words, the terms or codes of the bibliographic languages that are available for use (Svenonius 2000, 55). For example, the descriptors in a thesaurus and also the acronyms (BT, NT, RT, USE, UF) are elements of the vocabulary of bibliographic languages.

The semantics, in Svenonius' terms, refers to the "different meaning structures found in languages" (2000, 56). She identifies three of these structures, relational semantics, referential semantics, and category semantics. Relational semantics refers to the meaning of relationships between terms, i.e., the types of associations established in a thesaurus. Referential semantics covers the "techniques used to limit the meanings or referents of terms", i.e., the use of disambiguators (57). Category semantics, "has to do with the facets or grammatical categories into which the vocabulary is partitioned" (57) to indicate that the terms that belong to them have the same or similar type of referents. The syntax is the system of rules that indicate how to structure the terms in a bibliographic language, due to its artificiality (for example, term-string composition and citation order).

Pragmatics deal with the use or application of the language with the "rules for making descriptions" (58). An example of this is the cataloging or indexing procedures that specify which elements should or should not be included in a description, when to create a new element, and how many elements to include in a description (indexing depth). From a KO perspective, this would correspond to Knowledge Organization Processes (KOP).

Besides the elements of bibliographic languages, Svenonius describes the bibliographic objectives, those objectives that the bibliographic systems need to pursue: finding, collocating, navigating, choice, and acquisition.

Knowledge Organization (KO) comes from a long tradition derived from Information Science, a discipline with which Topic Maps shares common theoretical principles (Colmenero 2005, 78). For the purpose of this work, KO is considered to be what Hjørland (2008, 1) defined as the narrow meaning of the term, that is the:

> activities such as document description, indexing and classification performed in libraries, bibliographical databases, archives and other kinds of 'memory intuitions' by librarians, archivists, information specialists, subject specialists, as well as by computer algorithms and laymen.

These activities are accomplished through the use of "knowledge organization systems (KOS)" (Hjørland 2008, 86). The term KOS was coined by the Networked Knowledge Organization Systems Working Group (NKOS) in 1998. A KOS is thought to be a tool for vocabulary control, a term sometimes even used as a synonym of KOS (Leise, Fast, and Steckel 2003). KOS systematize or arrange knowledge structures according to certain organizing principles. Topic Maps has been considered as a KOS or as an evolution of them, which will be discussed later in section 5.1.3.

5.0 Findings

5.1 Topic Maps principles from a knowledge organization perspective

5.1.1 The concepts of topic maps and knowledge organization

Even though the terminologies differ, Topic Maps' concepts seem to relate to various KO concepts. Sigel (2006a) and Hjørland (2006) equated a few of the main concepts of Topic Maps to existing concepts in KO, for instance topics to "concepts," associations to "relations," and occurrences to "information resources" or "documents." However, on closer examination, these are not completely equivalent. For example, depending on how the term "concept" is understood in the KO community, it would or would not equate to that of topic. In a topic map things which are not concepts, like a person's name, a date, an entire paragraph, or even a full text, can become a topic.

In addition, it would be inappropriate to equate occurrences and "information resources" as they are only equal in the case of external occurrences. This is due to the fact that an information resource or a document has different meanings for the Topic Maps and KO communities respectively. In a topic map, an occurrence is actually a relationship between an information resource and a topic; the information resource can be either an externally stored document or a string (or another data value) stored internally in the topic map. In a topic map, all occurrences are considered as information resources, whereas, from a bibliographic perspective, only external occurrences would be considered as information resources (in the KO sense of "documents"). An exception would be the case of an internal occurrence, which contains a full text.

Even more than the concept of information resource or document, the concept of subject and the mechanisms used to identify subjects are central to the Topic Maps model. This approach is referred to as "subject centric" by the Topic Maps communities. They consider it to be in opposition to the "document centric" view, which is represented by the LIS community and, in some ways, the Semantic Web (W3C) RDF. The different focus on traditional documents (i.e., articles, books) by the Topic Maps communities and the problems of direct and indirect identification (explained in section 4.1 and discussed further in section 6) are two aspects of the Topic Maps model that make it unique in its approach to KO.

When a document (in the sense of a bibliographic entity) is an object of description, it is regarded in Topic Maps as a subject, as any other entity in real or possible worlds. In a topic map, a "subject" (as a property, for example, "History") can also exist. However, it would be expressed as an occurrence of another topic (the document in this case), or as a topic on its own which itself can then be the object of description (if it is defined as a topic and not as an internal occurrence). Thus, in a topic map, subjects and documents (from the KO perspective) coexist at the same representation level.

There are additional comparisons which have been made between Topic Maps and KO concepts which have not been analyzed here. For instance, it has been suggested that topic types are the same as "categories," and occurrence types are the same as "document types" (Hjørland 2006, Hjørland 2008). Moreover, the term facet conflicts in its original use in Topic Maps with its use in "faceted classification" in the KO realm (as noticed by Hjørland 2006 and Pepper et al. 2000), but neither the term nor the concept is part of the latest version of the ISO standard. Another difference in jargon was noted by Hjørland (2006), who found that the term theme has a completely different meaning in the Topic Maps terminology than in KO terminology. In Topic Maps, the term theme was used to denote a member of the set of topics used to specify a scope; however, the term was jettisoned in recent versions of the standard, in favor of scoping topic.

5.1.2 Topic Maps and the Elements of Bibliographic Languages

Several characteristics of Topic Maps can be explained using the components of bibliographic languages – vocabulary, syntax, semantics and pragmatics – which were conceptualized by Svenonius (see 4.2.):

Vocabulary. The authorized forms of terms in bibliographic languages have been the central element upon which all the systems in the KO tradition are built. Topic Maps, on the other hand, doesn't specify any terms or vocabulary; that task is left to the topic map author. The reason for this flexibility is that Topic Maps doesn't use names, but emphasizes the use of entity identification.

It is for this reason that Topic Maps characterizes itself as "concept-centric"; it is focused on anything "signified" and the entity identification rather than on the normalization of names. However, if we think about how to make common use of the same identifiers for the purpose of interoperability, or how to attach all the variant names to the identified subject, we see that the nature of the problem of identity is similar in both KO and Topic Maps: one term per concept ≈ one topic per subject ≈ one URI per "proxy." The problem seems to be not how to say that these are identical (a term string or a URI) but knowing when they are identical; it is a problem of semantics. From a Topic Maps perspective, the model provides some features for allowing semantic identification. Knowing when two subjects should have the same subject identifier would be given by the use of subject indicators.

Subject indicators are meant to aid in the negotiation of meaning (when they are shared in the form of PSIs). They are intended to be read by humans (as opposed to the subject identifiers, which are meant to be interpreted by computers). Subject indicators give humans evidence of the meaning that will allow them to "unambiguously identify the subject represented by a topic" (ISO/IEC 13250-2). From the bibliographic languages perspective, this identification principle isn't new. For instance, scope notes in the thesauri, definition notes, and the other five types of notes in DDC are intended to serve the same function (Batley 2005, 35). Their purpose is to provide information about the identity or the meaning of concepts to allow the user of a bibliographic language to select the appropriate term (or, in Topic Maps terms, to aid the topic map author in selecting an appropriate subject identifier for a topic).

However--and this could be applied further on--the major difference between Topic Maps and bibliographic languages is that Topic Maps provides a standardized model and interchange syntax for addressing the issue of identity and meaning in a digital environment and on a global scale. These characteristics are not, however, exclusive to Topic Maps; RDF also provides the means for these purposes. A comprehensive comparison of RDF and Topic Maps is not made in this article, but some general issues are pointed out in the discussion part.

The so-called "term-based" mechanism of bibliographic languages is limited and inadequate for our times, because a single name or form of a name is given more importance, and this results in the passive use of 'authorized' forms. Technologies like RDF and Topic Maps that use identification for Web-sharing based on the URIs, need unambiguous identifiers to interoperate and be shared. For that purpose, in order to achieve the goal of common sets of subject identifiers that would make merging possible, the Topic Maps community has presented different points of view, approaches, and implementations. One example is the distributed identity management service Subj3ct (www.subj3ct.com).

Syntax. It is important to notice that the meaning of the term "syntax" from the perspective of "bibliographic languages" is different than that of the Topic Maps community. In the Topic Maps community, "syntax" refers to the interchange format of the topic maps, i.e., XTM. The traditional cataloging rules provide guidelines for such vocabulary constructions. The AACR2, ISBD, ISAAR (CPF), the ALA and Library of Congress Filing Rules, the ISO, and ANSI/NISO standard for thesaurus construction are a few examples. On the contrary, Topic Maps specifies neither vocabulary nor "syntax" in the sense used by Svenonius. Some "rules of thumb" have been developed in order to accommodate the need to agree on base name forms (for sorting and displaying purposes). Among the many features related to the construction of the ontology, the Topic Maps Constraint Language (TMCL) formalizes a number of these aspects by specifying which data types and forms of names are valid. For example, TMCL rules state that "Topics of type person must have two explicit names, the full name and a nickname," but they don't go to the same level of detail in specifying the exact form of the nickname or the full name. Even though the need for complex syntaxes is reduced with the use of Topic Maps elements, this is one of the areas where Topic Maps could benefit from KO and bibliographic languages expertise and history of building vocabularies. Not to mention, Topic Maps could serve as a potential experiment in current research in KO on how to use the existing syntax of bibliographic languages to create facets from subject headings or UDC notations.

Referential semantics. Bibliographic languages have primarily used disambiguation techniques for

clarifying the meaning of identical terms. Svenonius (2000, 148) reports that some of the methods in use are: domain specification, qualifiers, notes, and hierarchy. According to Garshol (2004), disambiguation in Topic Maps "is not necessary, because the types, occurrences, and associations of the topics will generally give enough information to distinguish them" (385). For example, in the case in which two topics have the same name (for example, "Paris"), the most common way to disambiguate (as natural languages do), would be its category (topic type): "Paris (city)," "Paris (god)." If it is the case that there are two cities with the name "Paris," a third step in disambiguating would be the association type "located in": Paris (city-France), Paris (city-United States). If there are two cities in France with the name "Paris," an occurrence type could be use as a third disambiguator, and so on. However, the difference in the mechanism used by Topic Maps and bibliographic languages to provide qualifiers is that, in bibliographic languages, they are part of the name string [as it is, for example, in the names of author names that have an added date of birth as qualifier or in the case of the General Material Designations (GMD)]. In Topic Maps, the different blocks correspond to different elements of the model (topic type, association type, occurrences) and can be automatically displayed when they correspond to the same string in the base name. Scope is used as well, as in the example showed above, to add specify the context and validity of the assertions when the three mentioned elements are not enough.

Category semantics. Examples of this type of semantics are: personal names and corporate names (in authority lists); classes, facets, subfacets (arrays), and foci (in analytico-synthetic languages); topic, place, time, and form (in alphabetic languages such as LCSH); and top term –TT– (in thesauri). In document languages like Dublin Core (DC), category semantics correspond to the "classes," such as an agent (for person, organization, and software agent) or a bibliographic resource (for book, article, or other documentary resource). The potential use of the categories employed in bibliographic languages would make it possible to eventually indicate one part of its ontology (the typing topics) in a topic map, or, in other cases, indicate the types of relational structures to be modeled through association types.

In considering a particular element of category semantics, the typing topic or association type depends on whether or not it belongs to a genus-species hierarchy or to another type of hierarchy. This is due to the fact that, despite being an associative (as opposed to a hierarchical) model, Topic Maps does have a built-in hierarchical association type called superclass-subclass (or supertype-subtype; the terms are used interchangeably in Topic Maps). Associations of this type are binary, and each of the two role players is, by definition, a topic type. This relationship corresponds exactly to the genus-species relationship.

Category semantics in document languages are particularly important since conceptual models such as FRBR and CIDOC-CRM are the necessary level of abstraction to create ontologies for metadata schemas such as MARC, where the category semantics is poorly developed. As shown in the following section (5.1.3), Topic Maps provides one possible model for representing those categories for expressing the ontology.

Relational semantics. The capacity of each KOS to express different types of associations among terms determines its place in the scale of complexity. Thesauri have been considered among the most expressive systems in this sense, because they permit the user to specify five different types of relations (i.e., BT, NT, RT, USE, UF), while a synonym ring, for instance, only allows the user to express USE and UF relationships.

Because of this, Topic Maps has been considered by some authors to be a further development of KOS, because it makes it possible to express any type of relationship between terms. From this perspective, Topic Maps would have a designated place on the "semantic ladder," as shown by Sigel (2006a):

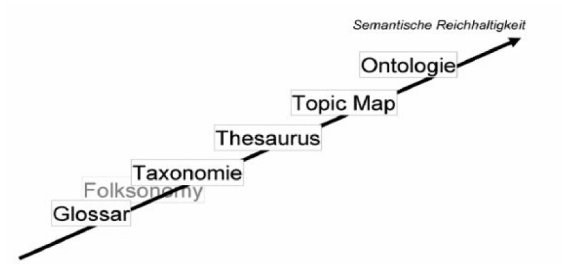

Figure 3. The "Semantic Ladder". From Blumauer et al., 2006.

However, Topic Maps can express ontologies, which would locate it on top in the previous figure, as it will be explained in 5.1.3.

Pragmatics. One of the possible impacts of Topic Maps on Knowledge Organization Processes (KOP) in KO (i.e. cataloging, classification and indexing)

comes from its subject-centric view. In traditional KOP, the center is the document, which is described through the use of a set of "properties" that come from a controlled vocabulary, as well as from the item itself (assigned terms). The subject-centric view of Topic Maps implies a change in those processes, from starting the process of cataloging based on the "item at hand" (as recommended by the AACR2) to starting with the "subject at hand;" from cataloging physical embodiments of information to describing "works" and concepts. This seems to suggest a collaborative perspective through the establishment of global mechanisms for the use of published identifiers, such as for works. Sigel (2000, 10) noticed that the characteristics of Topic Maps represent important possibilities for the decentralized creation and exchange of metadata (enhanced with mechanisms such as scope). This would present a challenge to "redesigning" KO methodologies for "collaborative knowledge building activities on distributed resources."

5.1.3 Topic maps and ontologies: topic maps as a bibliographic meta-language

Because of its capacity to express any relational semantics, Topic Maps has been referred to in a variety of ways. Among the many names it has been given, it has been called a "metadata format" (Walsh and Dalmau 2006), a "metamodel" (Kaminsky 2002, 83), a "metadata model"(Johannesen 2007), a "generalized data model" (Johannesen 2006), "both a conceptual model and an XML exchange format" (Johannesen and Pearce 2004), an "ontology framework for information retrieval" (Garshol 2004), and simply "a framework" (Johannesen 2007); in 1999 Topic Maps was included in a conference called "Metastructures."

One of the creators of the model even referred to it as a "neutral envelope[s], hospitable to any existing or future schema for knowledge representation" (Newcomb and Biezunski 2003, 3). Johannesen (2006) agrees with this and says that "you can do any classification scheme and structure inside Topic Maps." Ahmed (2003), also in line with this idea, proposed the use of "design patterns" (a term used in Computer Science) to represent bibliographic languages and KOS. These design patterns would be based on the generalizations that can be made about solutions that are recurrent in the topic maps design of KOS.

The main reason that explains this fact is that Topic Maps, as said before, is not name-based; in other words, any type of relational semantics can be expressed. This need to make the nature of the relationships explicit is a tendency that emerged with the development of terminological ontologies, and is well known in the KO community (Fischer 1998, Sigel 2006b). *Figure 4* shows a familiar taxonomy of KOS, in which Topic Maps is placed, according to the described view, at the top of the semantic ladder, together with other models that express ontologies, such as RDF:

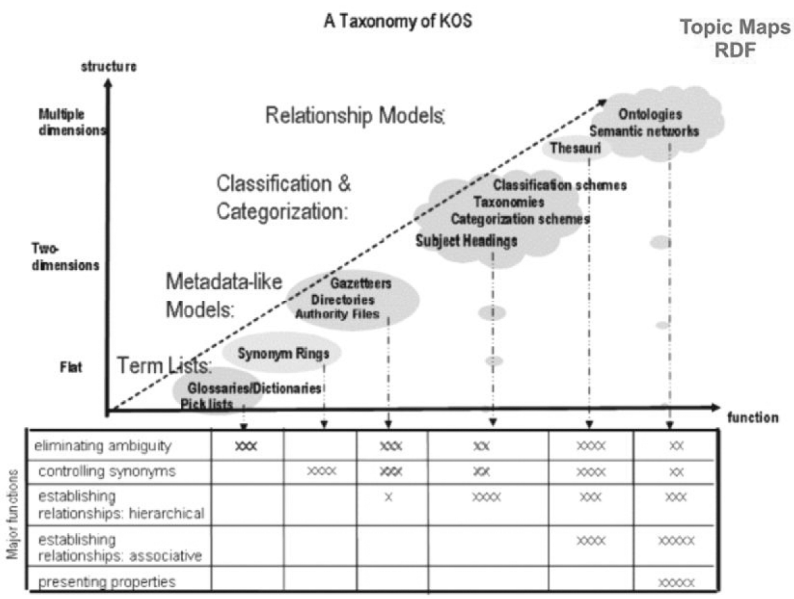

Figure 4. Topic Maps as an ontology model for KOSs. The original figure from: Zeng, M. L. (2008). Topic Maps and RDF in red added by the author of this article.

According to this figure, Topic Maps from a KO perspective, could be defined as an ontology model for KOS, and/or as a bibliographic meta-language.

Auillans et al. (2002) have actually defined Topic Maps as "a meta-language for structuring meta-data" (70). However, this seems to be a partial view, given that, in Topic Maps, not only metadata schemes (or document languages) can be represented, but rather, all existing KOS (and work languages) can be represented. There are already efforts being made within the Topic Maps community to represent the existing KOS, for instance, to represent thesauri (Ahmed 2003), to represent faceted classification (Garshol 2004), and to represent hierarchies (Ahmed 2003). Topic Maps can also represent synonym rings and taxonomies (Garshol 2004).

All KOS seem to be built on the relational semantics between terms (equivalence, hierarchical, near-relatedness) as well as on relational structures (term list, synonym ring, taxonomy, faceted structure, thesaurus structure and, in metadata schemas, the property-value structure). Basically, those three types of relational semantics can be expressed in Topic Maps with the use of association types and topic types. Topics and topic names and the relational structures can be expressed through a certain combination of association types and topic types.

Finally, Topic Maps can also be used to represent codified texts, given it was originally designed to merge back-of-book indexes, as in the case of the TEI documents (which will be addressed shortly). In addition, as mentioned previously, metadata schemas or "document languages" (such as Dublin Core) can also be represented with Topic Maps. For instance, Pepper (2008a) and ISO/IEC DTR 29111: 2007 present proposals for expressing Dublin Core using Topic Maps. Lee et al. (2006) also proposed MARCXTM, an XTM way to model MARC21 bibliographic elements. That said, however, the difficulty in representing these document languages is the lack of categories or conceptual structures, which could be provided by FRBR or the CIDOC/CRM conceptual models and can also be represented with Topic Maps.

The most obvious conclusion derived from these facts is that Topic Maps facilitates the creation of a model to bring existing structures in KOS and document languages one step further in their abstraction level and, mostly, to integrate them all. Because of this, Topic Maps is known as a language for expressing ontologies, as "an ontology framework for information retrieval" (Garshol 2004, 378), and as a standard for representing ontologies (Pharo 2008).

The term "ontology" is used in Knowledge Representation (KR), Computer Science and LIS with different meanings, which could be explained by the degree of formalization, their scope and purpose. In KR, ontologies are (Sowa 2000, 492 emphasis added):

> the *categories* of things that exist or may exist in some domain … a catalog of the types of things that are assumed to exist in a domain of interest *D* from the perspective of a person who uses a language *L* for the purpose of talking about *D.*

This definition is in accordance with that which is commonly agreed upon in Topic Maps literature; ontology is defined as the kinds of topics, occurrences, and associations that constitute a topic map (Pepper 2000 rev. 2002). When Topic Maps function as a bibliographic meta-language, the term "ontology" would then refer to the "kinds of things" present in the bibliographic realm, i.e., the entities, attributes, and relations that are defined in the conceptual frameworks of metadata schemas and in the semantic structures of the special KOS.

With respect to semantic networks, Topic Maps, sometimes confused with the term "concept map," also involves knowledge representation formalisms or the ways to represent knowledge graphically: mind maps, conceptual graphs, concept maps, semantic networks, etc. The main difference between semantic networks and Topic Maps, as explained by Pepper (2000 rev. 2002), is that Topic Maps adds the topic/occurrence axis to the topic/association model. It is important to add that, like semantic networks, topic maps relate to knowledge representation formalisms, but, unlike semantic networks, they incorporate the ability to search.

In summary, Topic Maps is one of the possible models to represent ontologies, in which everything (a property, a value, a name, a note, a subject entry, a document, etc.) is able to be represented as a topic and can become an "object" of description by itself. This links KO with KR and Computer Science, as well as with digital and Web technologies. But the fact that Topic Maps is a model of KR makes it independent of any specific technology and also, in principle, able to be transmitted, reused and shared across space and over time.

5.2 *Applications of topic maps to the libraries, archives and museums (LAM) and to the digital humanities*

Topic Maps has been applied for a variety of purposes in the LAM field, mainly for digital libraries in the Humanities, integration and FRBRization of library catalogs, web publishing, content delivery, and other small applications for specific purposes, which are briefly covered below:

Enhancement of existing KOS. The first obvious application is the enhancement of existing KOS, which involves their integration and migration to digital environments and to the Web, by using the current standards and syntaxes to be machine-understandable. Colmenero (2005) found this adaptation to be one of the main uses of Topic Maps (78). For instance, thesauri applications are already making it possible to export them as XTM files. Tools like "Tema Tres" have been developed in Argentina for the creation of thesauri. Leuenberger et al. (2006) also used a topic map in the "Living Memory" project, a cooperative effort of various institutions in Germany to give access to visual resources in different media. The original idea was to document a big scale urban planning project. The topic map served both to design a specific thesaurus for the application, which was based on the Getty Art and Architecture Thesaurus, as well as design the navigation and searching tools for the user. All that said, in a key text on how to migrate existing KOS to ontologies expressed with semantic web technologies (RDF, OWL, Topic Maps), Sigel (2006b) points out the still limited use of the enhancement of semantic tools.

Navigation of TEI encoded full-text collections: This seems to be the most fruitful application field of Topic Maps to date. The main examples in this area are The New Zealand Electronic Text Centre (NZETC) of the University of Wellington, Australia and the Swinburne Project. The NZETC was recognized as the most successful application of Topic Maps to digital libraries in cultural domains at the Topic Maps Users Conference in Oslo in 2008. This project makes use of Topic Maps as a tool for presenting TEI-encoded texts given the limitations of HTML in presenting information that is highly structured (Tuohy 2007). In 2005, Indiana University professors, John A. Walsh (a researcher in the areas of Digital Humanities and Digital Libraries) and Michele Dalmau (a Usability librarian) created The Swinburne project, a topic map-based digital collection devoted to the life and work of Victorian poet Algernon Charles Swinburne (Walsh and Dalmau 2006).

Digital libraries. The Finnish National Gallery (FNG), the largest art museum organization in Finland, developed its digital library through the use of Wandora (a general purpose knowledge extraction, management, and publishing application based on Topic Maps and Java). It was developed in 2000 at Grip Studios Interactive, with the idea of applying Topic Maps to museum collections in Finland. It is a free and open source tool, which, since then, has been successfully used in Finland for projects at the FNG and in other areas (Kivelä and Lyytinen 2007). Topic Maps has also been considered one of the fundamental elements of digital library architecture, to provide the association of Structured Digital Objects (SDOs) with information resources that can be located in existing digital libraries or in a global digital library, as proposed by Li and Ishizuka (2004).

FRBRization of library catalogs: Since FRBR is a conceptual model, in other words, an abstract specification of conceptual structures, there is a need for its specific implementation through a data model and technology. For this purpose, MARC bibliographic records are converted into FRBR by creating the association between the entities (there have been several efforts to do this conversion, one of them was the algorithm released by OCLC). This FRBRized MARC is formalized into an ontology, using Topic Maps or W3C OWL (Aalberg 2005). This has been the main use of Topic Maps to Integrated Library Systems (ILS) reported in literature (Aalberg 2005; Aalberg, Haugen, and Husby 2006; Oh 2008a, b, and c) with respect to conceptual models in LIS. These ideas of FRBRizing library catalogs through Topic Maps appear to date back to 2002, as suggested by Sigel (2004), who reports on the visions of Art Rhyno and the "PHYTEAS project" of Topic Maps as a suitable model to implement the FRBR associations. Other conceptual models, such as CIDOC/CRM, are also possible to model with Topic Maps, as was done by Kivelä and Lyytinen (2007) in the creation of a topic map for the Finnish National Gallery. Norrish and Stevenson (2008); Tuohy (2005, 2007); and Stevenson, Tuohy, and Norrish (2008) have also mentioned using Topic Maps for this purpose.

Integration of library catalogs and records: Topic Maps is considered to be a model that can be used for mapping different metadata schemas at different levels. In this way, it facilitates the integration of different information systems, which allows users to perform federated searches or browse different and dis-

parate types of materials and vocabularies using a single system. Lourdi, Papatheodorou, and Nikolaidou (2007) used it in the Department of Greek Literature at the University of Athens in Greece, where each metadata element belonging to different schemas was converted into a *topic*, and *associations* were used to link the different elements between diverse schemas. Pharo (2008); Bøckman (2006, 2007); Norrish and Stevenson (2008); Stevenson, Tuohy, and Norrish (2008); Laursen and Henrikson (2006); and Farquhar and Bandholdtz (2003) report on similar approaches.

Kivelä and Lyytinen (2007) have developed the possibility of doing mashups when integrating different sources, to combine information from different sources, including third party topic maps.

Linguistic interoperability: Lixin, Zhang, and Wang (2008) report on this capability of Topic Maps, which provides the mechanisms for creating a cross-language information retrieval model (Cross Language Information Retrieval -CLIR) for digital library systems. Schmitz-Esser and Sigel (2006) sketched the first ideas on how to represent ICLO (an Integrative Cross-Language Ontology) concepts and semantic relations with Topic Maps.

Subject guides and pathways: Tramullas and Garrido (2006) did a study of university libraries in Spain to develop an application for the creation of subject portals or pathways called Potnia which used Topic Maps together with RDF and Dublin Core. One particular library service based on library catalogs is the elaboration of subject guides. This has been considered by Iglesias and Stringer-Hye (2008) to be "the most visible and widespread evidence that topic maps are indeed making inroads into evolving library technologies" (17). Peng and Ke (2008) describe how Topic Maps was applied to build the Chung Hua University Library pathfinder (or subject guide), changing its previous simple HTML base to a topic map built with the TM4L tool.

Other applications: The capability of Topic Maps to provide contextual semantic information (Leuenberger et al. 2006, 110) proved to be advantageous to new users in the Digital Humanities. Both Bøckman (2007) and the Swinburne Project confirmed this in their applications of Topic Maps. In the Swinburne Project, their usability study showed that "for students, the additional contextual information provided by the glossary and encyclopedic reference features inherent in the Topic Maps metadata standard is critical for understanding obscure and unfamiliar references and allusions in literary texts" (Dalmau and Walsh 2007, 4). The needs of both expert and novice users in the context of the Humanities (and perhaps in other areas as well) opens up the potential role, noted by Michel and Dalmau in their Swinburne project, of Topic Maps as a teaching and research tool. Although this literature review doesn't address that issue in particular, it does seem that there are more applications of Topic Maps to Education than to LIS. Topic Maps is also suitable for small scale online applications in MLA. Bøckman (2007), for instance, suggested the use of Topic Maps to cover specific thematic areas such as exhibitions or educational projects. This has already been done in Hungary, where the National Library uses a topic map for an e-learning application on Hungarian literature for secondary school students. The LAM field could also take advantage of situations in which Topic Maps has been successfully implemented, such as the online delivery of newspaper archive content (Stevenson and Styron 2006), or the creation of temporary exhibition websites. An example of this is "The National Treasures," an implementation of Topic Maps for a traveling exhibition of a collection of items from the Australian State and National libraries, which toured the country between 2006 and 2007. Both the publication of selected media documents produced during a computer fans event Kivelä and Lyytinen 2004) and the report on the use of Topic Maps for a digital collection on independently produced movies Ahmed 2007) give ideas for the potential application of Topic Maps in MLA. Finally, Sigel (2006a) suggested some of the Social Sciences as possible disciplines for the application of Topic Maps, and Howarth and Miller (2005) reported on the use of Topic Maps for visualizing searching results from digital libraries in cultural domains.

6.0 Discussion and further research

As it was concluded above, there are other models which in principle could serve for many of the same purposes mentioned for Topic Maps. RDF for instance is one of them. It has been widely accepted inside and outside the LIS community as the default model for the idea of a more semantic Web. Even though the comparison between RDF and Topic Maps was not a component of this study, it could be said that both are ontology models. In this case, the differences between the two must be found by looking at their potential ability as a model to represent ontologies and how expressively they are able to do

so. Three main issues that emphasize the existing differences between the two arise:

1) Until the appearance of the hash URIs and the 303 URIs (http code) solutions by the Semantic Web community, the main difference between Topic Maps and RDF was that Topic Maps had clearly developed an identity model (through the already explained direct and indirect identification). In RDF, there was a lack of clarity in this regard; the RDF community didn't specify whether a URI such as "http://www.w3.org/Consortium" identified the W3C or a web page about the W3C. This was eventually referred to as the "identity crisis of the Web" (Pepper and Schwab 2003). The approach to the identification problem continues to be one of the main differences between Topic Maps and RDF/OWL (Semantic Web and Linked Data).
2) RDF/OWL is focused on machine-based inferencing, which implies the use of formal logic and formal ontologies. Topic Maps, on the contrary, uses a model that is closer to human reasoning and the ways to express knowledge used by KO (from the tradition of the back-of-book indexes). For some applications, this way of expressing knowledge is more suitable than RDF/OWL, as was seen in section 5.2 with various applications in the Humanities.
3) Topic Maps provides better mechanisms for expressing natural language. Firstly, through the use of *scope*, it is possible to express context. Secondly, through the use of non directional and n-ary associations, it is possible to expand the expressivity of relationships (also through the use of role types) and to represent more than just binary associations. Thirdly, through the use of variant names, it is possible to support different orthographic representations and synonyms. Reification represents the ability to view an event, situation, or relationship as a thing in itself; RDF/OWL is more limited in this respect. Sigel notes, "Topic Maps are more natural than RDF since the modelling takes part on a more useful level" (Sigel 2006b).

Today, the interoperability between Topic Maps and RDF is high, and "no-one has to fear not being in the right semantic web camp, just because most people use RDF, and topic mappers are only a few" (Sigel 2006b).

6.1 Limitations

Besides the previously noted limitation of this study (the lack of comparison with similar models), it has other shortcomings. For instance, it has been extensive, but not comprehensive nor exhaustive (the resources selected for review were limited, and the selection of people for the interviews was not systematic). It has not focused on any specific feature of Topic Maps. Instead, it tried to give an overview of the model at a basic level, its applications and some conceptual relations to KO. Many of the documents found were not academic publications, thus the information was limited or only referential; some technical barrier problems were also present in analyzing the corpus. In addition, many of the mentioned applications are not available online or are still in their prototype stage, which made it impossible to review some of their specific features. The use of Grounded Theory as a data analysis tool proved to be useful for extracting the categories and starting the writing process through annotations, but the full potentials of the method were not used.

6.2 Future research.

Most agree that Topic Maps is an opportunity to implement the principles and expertise of KO and to interconnect Topic Maps with research directions in KO (Adams 2002; Pepper et al. 2000; Pharo 2008; Sigel 2003; Stringer-Hye 2005). Topic Maps seems to act as a kind of boundary object for the different communities and provides direction for further research. Yi (2008) already made an inventory of these directions; however, one way to conduct this research is to use theoretical frameworks to guide and also integrate the disparate research and working efforts on Topic Maps (and similar models) in KO. Joseph Tennis recently presented a classification of KO research to the KO community which was situated in a meta-theoretical framework (Tennis 2008). This framework would be suitable to provide directions for future research on Topic Maps and Semantic Web models and technologies.

Following, there is a list of some possible research topics on Topic Maps and KO within the framework designed by this author:

01 Epistemology
Topic Maps claims to be a model that better represents the way humans think (Pepper 2008b), as opposed to RDF/OWL, which is more machine oriented. The epistemological foundations of these two views and also the implications of the different models of representing knowledge (as in Svenonius 2004; Shirky 2003) need to be investigated. Along a similar line of thought, new direction for research could include the use of topics in a concept theory perspective, as well as the theoretical roots of Topic Maps and the assumptions that this model presents with respect to language and knowledge aggregation through merging.

02 Theory
As mentioned in 5.1.1, RDF is resource-centric (or document centric), whereas Topic Maps is more subject-centric, or "assertion-centric," according to Sigel (Sigel 2006b). The implications of this have been called a "paradigm shift" by the Topic Maps communities. Limited research has been done on shift theories and "Document centric" vs. "subject centric."

03 Methodology
From a methodological point of view, the most important area for research is the ontology design for KO with Topic Maps. At a lower level, the classification, indexing, and cataloging with Topic Maps (including the Knowledge Organization Processes) has not yet been fully explored.

04 Design
The application of Topic Maps to specific systems is the area that is most commonly covered in the existing literature. However, the representation of KOS with Topic Maps (the design patterns explored by Ahmed 2003) could be updated and extended. There is also a need for procedures which outline how to build KOS with Topic Maps. Although Sigel (2006c) has provided all the guidelines for implementation, there have not been any cases of implementation from which to gather information about building specific KOS with Topic Maps. Another area for research with respect to Topic Maps design is the ontology creation based on special KOS. For instance, Topic Maps could serve as a potential experiment in current research in KO on how to use the existing syntax of bibliographic languages to create facets from subject headings or UDC notations. The use of scope for multilingual applications, uses of merging for metadata and semantic interoperability (federated searches with topic maps, as studied by Kongsbakk 2004), and browsing and visualization of search results with topic maps are other topics that require further exploration.

05 Study
Research must be done in order to understand the specific problems which arise in topic maps design, as well as the applications to solve these problems (for example, how could authority control be solved from a Topic Maps perspective, also looking at how to integrate bottom-up and collaborative perspectives on it).

06 Critique
Critical research should also be done on the Topic Maps communities, their history, views, practices, and terminologies. The current research begs the question, why has RDF instead of Topic Maps been so widely accepted (including the LIS community)? There is a current lack of information regarding Topic Maps as an ISO standard, the politics of KO standards and their incorporation in KO discourses, theories and practices, not to mention, the implications of global identification made possible by semantic web technologies (Topic Maps among them).

7.0 Conclusions

Topic Maps is a development aligned within the principles of KO. The model created in approximately 1991 as a structure that overlaid documents to merge back-of-book indexes, was just the beginning. It provided the impetus and foundation for the development of a technologically independent ontology model, a "bibliographic" meta-language able to represent, extend, and integrate almost all KOS and bibliographic languages. Topic Maps provides a standardized model and interchange syntax—XML—to represent and exchange the products of KO in digital environments and the Web. Conceptually speaking, it falls within the boundaries of KO and Knowledge Representation, bringing to KO all the

mechanisms needed for taking existing KOS to the Web through the use of ontologies. Topic Maps questions some of the more traditional KO views (such as name-based vocabulary control), but the principles of semantic identification remain the same. Topic Maps provides the current mechanisms for semantic integration and identification of entities and concepts in a digital environment and on a global scale through the use of URIs. This implies a host of challenges for KO research, among them the difficulty of working methodologies with decentralized collaboration in building KOS. The advantage of Topic Maps over similar models (such as RDF), besides its identification mechanisms, is the capacity of the model itself to express assertions in a more natural way, which more closely resembles a humans' ability to identify than that of a machine.

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