Controlled Vocabularies as a Sphere of Influence

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Abstract:

Objective: The objective of this citation study is to understand the use and influence of the concept of "controlled vocabularies" in Geographic Information Science (GIS) as part of a larger goal to distinguish information science from information technology.

Methods: Articles with pre-selected descriptors that represented the concept of "controlled vocabularies" within GIS were selected from GeoRef and validated in ISI indexes. Bibliographic coupling and content analysis of the article titles were used to draw clusters and understand the influence of the concept of controlled vocabularies in other discipline such as the geosciences.

Results and Conclusion: The results from this analysis provide one perspective of the LIS sub-domain of "controlled vocabularies" as represented in *GeoRef* and used in the context of GIS research and scholarship. Findings are used to suggest future research directions to address issues related to better understanding of the concept of "controlled vocabularies" and the provision of knowledge organization tools that will promote interdisciplinary understanding. The creation of special, more-finely grained in-depth classifications and thesauri for the concept itself, namely, "controlled vocabulary" is recommended.

Controlled Vocabularies as a Sphere of Influence

This paper describes an exploratory study that examined the existence of the Information Science concept of Controlled Vocabularies in Geographic Information Science (GIS). This study is part of a larger domain analysis that is mapping the scholarly output, in Geographic Information Science from 1980 onwards, with the specific goals of distinguishing Information Science (IS) concepts from those of Information Technology (IT).

The Importance of Controlled Vocabularies

The NISO Z39.19 standard for the construction and maintenance of monolingual thesauri defines a thesaurus as a "controlled vocabulary of terms in natural language that are designed for postcoordination. The need to control the formation and use of terms stems mainly from two basic features of natural language, namely synonyms (different terms representing the same concept) and polysemes or homographs (terms with the same spelling representing different concepts). The controlled vocabulary is established by information specialists or lexicographers and is generally employed in indexing." (NISO, 1993) The purpose of a controlled vocabulary is thus to improve information retrieval in systems of organization. Also, studying, creating and maintaining controlled vocabularies can be said to fall within the scope of the Library and Information Science (LIS) discipline and profession. Buckland (1999) supports this notion and in fact, argues for the centrality of "vocabulary" in LIS. "Vocabulary" he notes, "commonly refers to the stylized adaptation of natural language to form indexes and thesauri. Much of bibliographic access, filtering, and information retrieval can be viewed as matching or translating across vocabularies. Multiple vocabularies are simultaneously present. A simple query in an online catalog normally involves at least five distinct vocabularies: those of the authors; the cataloger; the syndetic structure; the searcher; and the formulated query." Buckland is thus extending the concept of "vocabulary" to include "the range (or repertoire) of values in any field of bibliographic description and, in a more extended sense, the range of types in a set at any level (word, field, collection, and library)." Buckland further suggests that vocabularies are central features of digital libraries.

Controlled vocabularies are thus both an IS and IT-related concept. As digital libraries have developed, the concept of controlled vocabularies and enabling true semantic interoperability and facilitating meaning across different disciplines has become increasingly important as we try to build the semantic web: "an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation." (Berners-Lee, et al., 2001) Investigating the notion of controlled vocabularies in other disciplines is thus timely. As Neelameghan (1972) has eloquently suggested, the universe of knowledge is a "turbulently dynamic continuum" with fragmentation and hybridization of disciplines frequently occurring and the study of other disciplines will help enhance our own understanding of Library Science and it's merger with Documentation or Information Science.

Domain analysis studies that attempt to identify the attributes of subjects and disciplines include citation analysis and bibliometrics (Hjorland, 2001; Neelameghan, op. cit.); it has been used to document *specializations* and *modes of disciplinary growth* (Ellis et al, 1999; Hurt, 1983; White & McCain, 1998), and includes:

1) Identification - for example, what is the intellectual structure of a discipline like Accounting (Bricker, 1991);
2) Fragmentation among disciplines such as Management Information Science (Culnan, 1986, 1987);
3) Fusion in Medical Informatics (Morris & McCain, 1998) and;
4) Specialization to identify the emerging directions and existing coherent structures of research specialties.

Citation analysis has also been used to visualize interdisciplinary fields but studies have typically not sought to isolate Information Science from Information Technology related concepts and problems. Such a distinction is of interest because IS and IT are multi-disciplinary and share many research interests and yet there is little cross citation of their literatures. Also, IS-IT is often used as a tool in other disciplines. We are curious in understanding if the role of citation networks in disciplinary growth can provide clues as to when a new IS-IT intensive discipline becomes a science and is no longer just a research method or a tool. We also wished to use citation analysis data in conjunction with content analysis data to improve the nature of our findings and to investigate the potential, problems and strengths of these methods for helping distinguish between types of concepts that can help in mapping disciplinary structures and pinpointing their growth and status.

Research Questions:

1. How is the concept of controlled vocabularies described in GIS literature?
2. What are the relationships between articles in GIS discussing controlled vocabularies?

IS-IT concepts as an assumption for this research

Anecdotal evidence suggests that basic IT concepts include components of the computer, storage, memory, processing, input, output, hardware, software, multimedia, applications, operating systems, security, ethics, and networking. Similarly, IS concepts include, human information processing, organization, storage, retrieval, and use of information, especially recorded information. In the Dewey Decimal Classification system, Table 1, the Standard Subdivisions table outlines the many Library and Information Science and Computer Science concepts that may be combined with any topic (WebDewey, 2002). Our first step in this research was to identify how a thesaurus and a classification scheme in these disciplines may show disciplinary structures. We examined the ASIS Thesaurus for Information Science (Milstead, 1998) as well as the Dewey Decimal Classification scheme for the phrase Controlled Vocabularies and made a list of the related and narrower classes, terms and phrases and came up categories of IS terms. We also briefly

examined the ACM Classification for categories of IT terms for related concepts and terms (ACM Classification, 2002).

Methods Used:

Identifying concept terms: We qualitatively examined both the recommended core curriculum for GIS by the NCGIA (NCGIA, 2000) and *GeoRef thesaurus* (Goodman, 2000) to identify the terms and phrases used to represent Controlled Vocabularies in these documents. *GeoRef* does not use the phrase Geographic Information Science (it uses "geographic information systems") while the *NCGIA Core Curriculum* emphasizes the discipline as Geographic Information Science and use of Geographic Information Systems as methods. Our final list of selected terms were the indexing descriptors used in *GeoRef* and these include terms such as: *nomenclature, classification, digital data*, and *spatial data*. *Nomenclature* and *classification* are clearly and closely related to the IS controlled vocabulary concept. Nomenclature covers naming conventions, and classification deals with placing entities into a normalized naming scheme based on their characteristics. Digital data and spatial data deal with issues of data standardization that allow for data retrieval and use in the GIS context.

Identifying articles dealing with these concepts: The selected descriptors for controlled vocabularies were searched in *GeoRef* both separately and in conjunction with the term "geographic information systems." Retrieval of relevant articles was limited to English language publications and resulted in approximately 500 citations. From the resulting sets, non-journal articles (for example, books) and articles in journal titles that were not indexed in ISI's *Social Science Citation Index* or *Science Citation Index* were omitted (Web of Science, 2002) leaving us with a total of 62 citations. These limits were done for two reasons: one, to make the set size manageable and two, to limit the articles to high quality research. Selecting articles that were representative of high quality GIS research was important so that they would be representative of high quality research in the discipline. We could not pursue an original idea we had of limiting our analysis to a core set of GIS journals from ISI's *Journal Citation Reports* because coverage of these journals in *GeoRef* was highly selective.

Analysis and Results:

Our test set included 62 articles and these are listed in Appendix A. Of the 62 articles, 3 contained no citations. Additionally, 19 articles contained unique citations and were not coupled with other documents in the set. The remaining 40 articles formed a network of bibliographic couplings. Articles that were cited multiple times, and thus were used to establish couplings are listed in Appendix B. A list of couplings is presented in Appendix C.

Bibliographic coupling and co-citation analysis are citation methods that can be used to identify subject relationships in articles. Figures 1 and 2 show the difference between bibliographic couplings and co-citations. In Figure 1, articles A and B are

bibliographically coupled in article C. In Figure 2, we see that article F cites articles D and E.

Bibliographic coupling is a static method that establishes a relationship between articles through the presence of citations to the same articles in their bibliographies. As seen in Figure 1, if articles A and B both cite C, A, and B are bibliographically coupled. This linking is based on intrinsic, immutable (in a print environment, at least) characteristics of an article – the references contained in its bibliography. Although there are exceptions, the coupling often indicates a subject relationship.

In co-citation analysis, articles become linked when they are both cited in another article. As seen in Figure 2, if articles D and E are both cited by article F, articles D and E are co-cited. This clustering is based on extrinsic characteristics, and patterns may change over time as an article gains or loses favor in a discipline, or as disciplinary lines shift. As with bibliographic coupling, co-citation analysis often indicates a subject relationship

The bibliographic couplings matrix was analyzed using MVSP 3.1. (MVSP 2003) to demonstrate statistical similarities amongst articles. The UPGMA method, Percent Similarity was used to generate the dendogram and draw the map of bibliographic couplings. In addition to statistical cluster analysis, content analysis to overcome the limitations of citation analysis was also done. Placing the key phrases from titles into the categories defined, prior to analysis provides an alternative method to the bibliographic coupling analysis; the rules for content analysis are shown in Table 1. We also drew a map comparing the two clusters.

Figure 1: Bibliographic Coupling

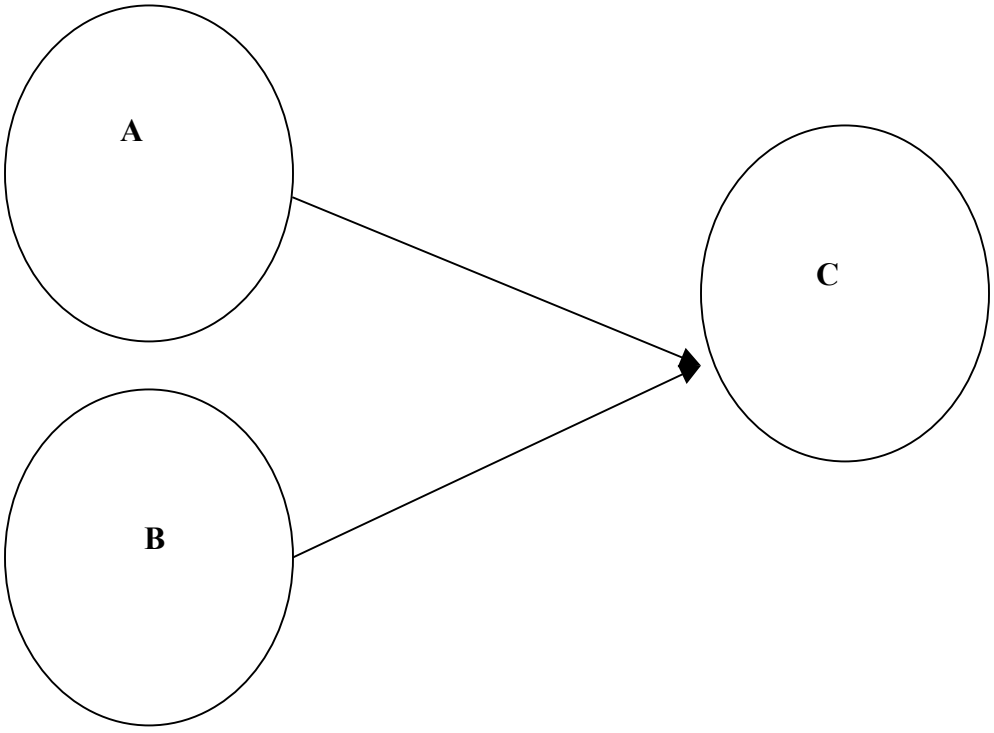


Figure 2: Co-citations

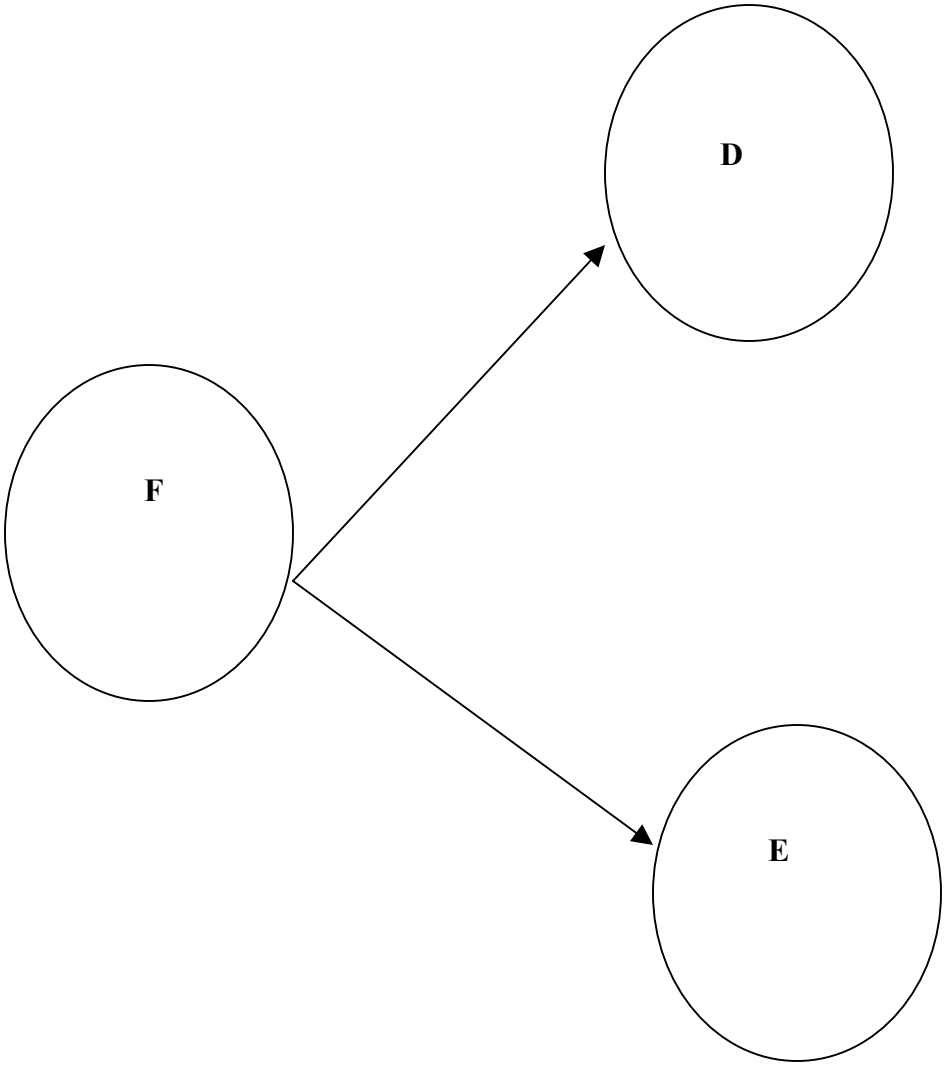


Table 1: Content Analysis Rules

Rule	Terms present	Category	Articles
1.	"map*" or "cartography"	CARTOGRAPHY	J,Y,Z,AS,AZ,BJ
2.	"classification" or "classes" or "codification"	CLASSIFICATION	I,U,AB,AC,AG,BB, BE
3.	("information system" but not "GIS") or "database" of "virtual memory"	INFORMATION SYSTEM	F,L,M
4	"GIS" or "geographic* information system*" or "SDSS"	GIS AS METHOD	N,AA,AD,AE,AI,A L,AO,AT,AU,AW, AY,BC,BD,BO
5.	"analysis" or "stat*"	STATISTICAL ANALYSIS	A,T
6.	"model*"	MODEL	H,R,S,V,X,AF,AH, AJ,AK,AM,AV,AX , BK,BP
7.	Name of Specific Software or "software"	SOFTWARE	C,E,G,AN,BL
8.	Anything else	GEOSCIENCE	B,D,K,O,P,Q,W,AP ,AQ,AR,BI,BM,BN

Table 2: Statistical clusters with strongly correlating content analysis clusters

STATISTICAL CLUSTERS	CORRELATING CONTENT ANALYSIS CLUSTERS
CLUSTER 1 C,F,H,X,AG,AH,AI,AL,BI,BO	GIS AS METHOD N,AA,AD,AE,AI,AL,AO,AT,AU,AW,AY ,BC,BD,BO
CLUSTER 2 J,P,AJ,AK,AU,BP	CARTOGRAPHY J,Y,Z,AS,AZ,BJ
CLUSTER 3 Q,R,V,W,AE,AV,AZ,BJ	MODEL H,R,S,V,X,AF,AH,AJ,AK,AM,AV,AX, BK,BP
CLUSTER 4 K,T,AD,AM,AN,AO,AS,AT,AY,BF,BN	GIS AS METHOD N,AA,AD,AE,AI,AL,AO,AT,AU,AW,AY ,BC,BD,BO
CLUSTER 5 O,U,Y,AA,AF,AW,BD	GIS AS METHOD N,AA,AD,AE,AI,AL,AO,AT,AU,AW,AY ,BC,BD,BO

Five (5) clusters were generated through statistical analysis and the content analysis cluster generated eight (8) clusters. The statistical clusters related exclusively to subject-related clusters of GIS as method, model, and cartography (Table 2). There were no relationships between a statistical cluster and what we had defined as a purely IS-IT cluster (classification, software, system) with overlap of greater than 1. The only instance of overlap with one article turned out to be with software and not classification. Articles that fell into IS-IT clusters based on title words did not correspond to the statistical clusters, indicating little or no commonality with bibliographic couplings. Figure 3 shows the relationships between the statistics and the content clusters. Thus, while the content analysis clusters contain all the articles, the statistical clusters do not. Figure 4 shows map of bibliographic couplings and confirms that the concept of controlled vocabulary is not a research front within GIS. Table 2 shows the statistical and content analysis clusters and we briefly explain the content analysis rules used to derive these clusters.

"GIS as Method" was a category that only required the presence of GIS or geographic(al) information system. The phrase "as method" was added to the category name to indicate that the term almost always appeared in contexts that indicated its use as a research method. In addition, Geoscience "catch-all" category was used for titles that did not seem to form any patterns or natural groupings. Additionally, "Information System" and "Software" could easily be combined into a single category without losing much meaning. Data was not included as a rule in the content analysis because of the varieties of contexts in which it appeared. There were several references, for example, to data sets, but they were usually the object of another process. The term data was also used in the context of data structures, data processing and data handling. Although this limited the analysis of controlled vocabulary concepts in GIS, spatial data and digital data were not as core to the concept of controlled vocabulary as classification, a term that was used as a

term for grouping in content analysis. More work is needed on the exact meaningful use of specific terms such as classes, ontologies, taxonomies, and arrays in the context of GIS data.

Figure 3: Relationships between clusters

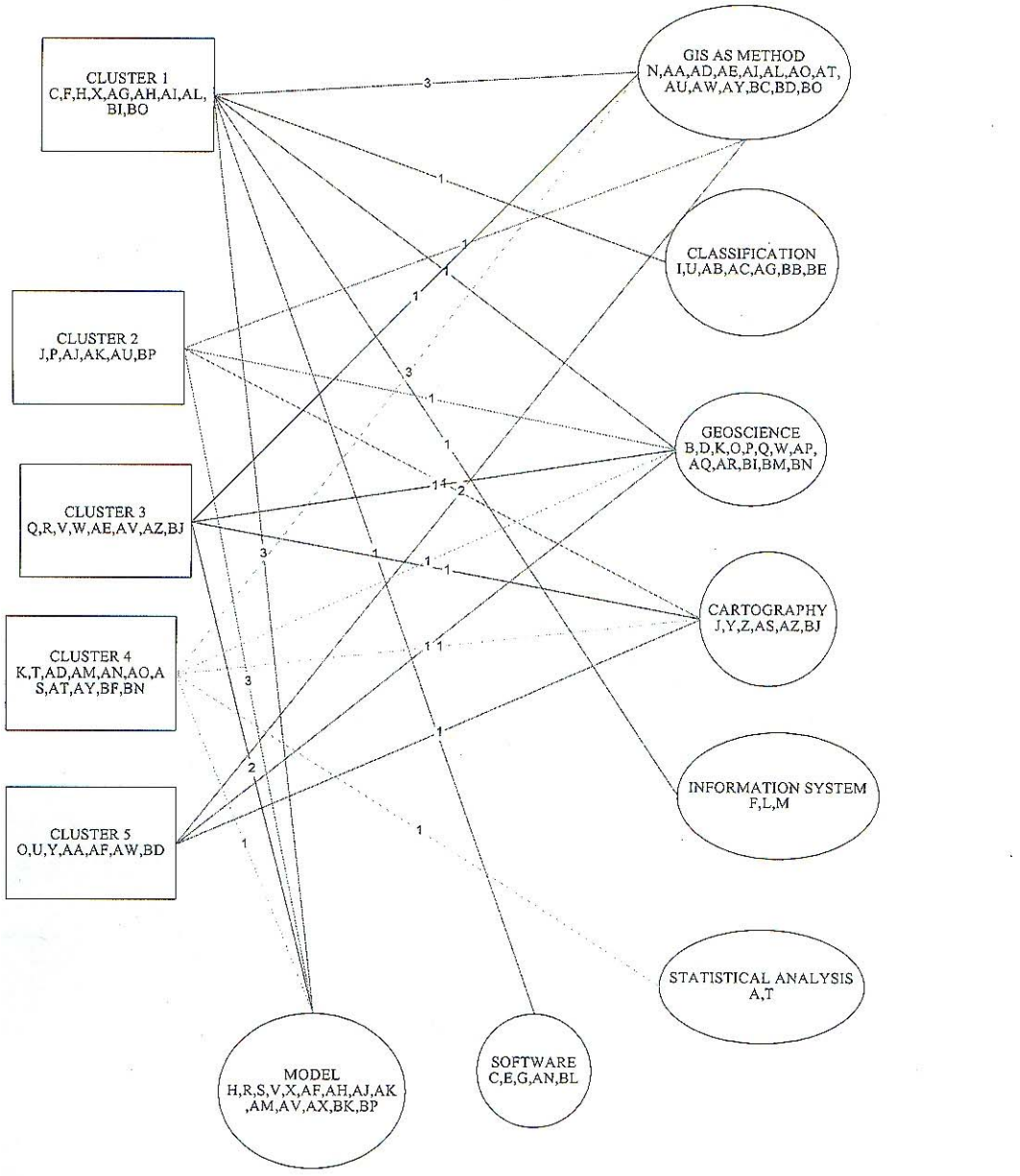
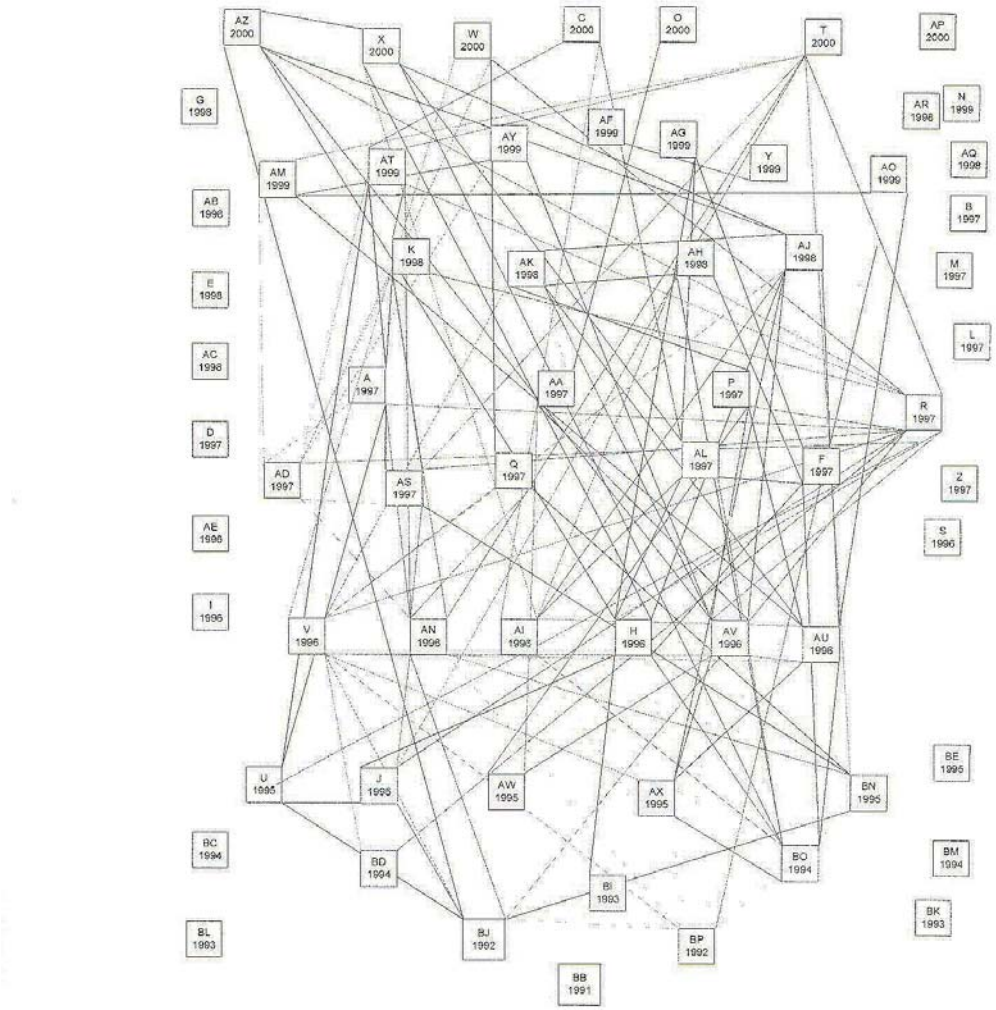


Figure 4: Map of bibliographical couplings



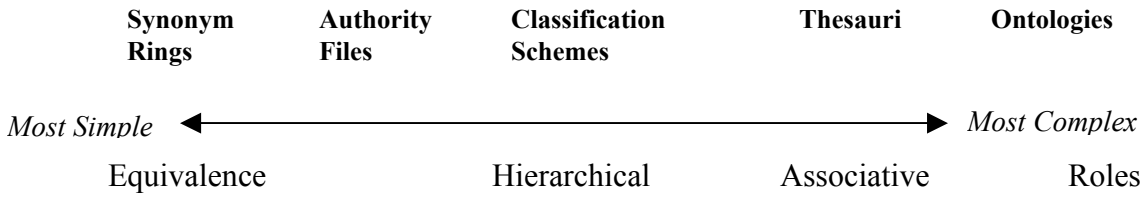
The two analyses of the sets of documents (statistical and content) thus present two different views of the documents. Controlled vocabularies seem to be well integrated with GIS-research when it is necessary in the examination of another topic but their sphere of influence in GIS based on our findings appears to be controversial and limited. Indeed the argument about the "ambiguity" of GIS as science or tool is reflected in these clusters (Wright et al, 1987). Replicating the study with a larger document set for validation is necessary before other conclusions can be made.

We also find that the subject of 'controlled vocabularies" is represented very poorly and at a most superficial level in Library and Information Science thesauri and classification schemes. Interestingly, descriptive and subject cataloging along with authority control of names and titles and vocabulary control of subjects is a widespread and standard

technique used to organize information resources in traditional libraries. It is a technique that is increasingly gaining in popularity in the world of digital libraries and with the use of metadata and the advent of the semantic web. The web world, however, is chaotic and naïve in the use of many of terms and processes related to controlled vocabulary: consider for example, that large scale projects in the United States such as the NSDL or DLESE both of which use flat, short lists of terms and call them a controlled vocabulary use this phrase in the most narrow sense. The small vocabularies (lists of controlled values is a better way to describe them) have few relationships of limited hierarchies; they in no way represent the richness and depth that a true controlled vocabulary that a thesaurus potentially offers. A distinction must be made between simple and complex vocabularies, such as thesauri and ontologies, which have varying types of relationships between terms and can number in the thousands for even a small concept.

A controlled vocabulary, as LIS professionals know, includes a range of knowledge organization tools. Both of these, a list of equivalent terms in the form of a synonym ring or a list of controlled or preferred terms in the form of Authority Files, are types of controlled vocabularies. Additionally, logic and a range of analytical methods can be used to build the controlled vocabulary for any discipline or subject. For example, faceted classification structuring may be used in a thesaurus, which is another form of a controlled vocabulary, making it a faceted thesaurus. Two modern faceted thesauri are the Art & Architecture Thesaurus (A&AT), and Medical Subject Headings (MeSH). MeSH is part of the Unified Medical Language System (UMLS), referred to as an ontology. Figure 5 graphically shows how controlled vocabularies can be placed on a continuum of simple to complex.

Figure 4: Types of controlled vocabularies



Simple vocabularies such as preferred lists of terms have long been proved to be clearly insufficient for efficient information retrieval. The do not represent the range of relationships among terms and phrases. The new NISO Z39.19 standard just released (2003) tries to help increase understanding about the concept of a "controlled vocabulary" and the creation of a true end-user thesaurus (Bates, 1986). If controlled vocabularies are to become a major sphere of influence that LIS exerts on other disciplines, and for LIS professionals to continue to be accepted as the experts in this area by new entrants into the field such as ontologists, taxonomists, knowledge managers, and information architects, we need to do two things: 1) an in-depth and finer-grained controlled vocabulary of the concept of "controlled vocabularies" itself with definitions of terms and their scope and context of all relationships (in particular the equivalence

relationships of synonyms and using qualifies and polyhierarchies), and the many disciplines that are now engaged in this area must be created. This could be represented as a classification scheme or a thesaurus but adapted from currently existing ones. 2) The newly developed controlled vocabulary should be used to replicate the study reported herein in order to examine our sphere of influence – both to see how this important topic has infiltrated other disciplines and how it is being used in others disciplines. Using machine classification methods on the full-text of the articles may also yield a different picture of the influence of this important concept on IT and specific disciplines.

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Appendix A: Document Set Used in Study

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Appendix C: Bibliographic Couplings

Please note that BH (J), BG (U), BA (AW), and BF (AX) were duplicates and have been removed; no citations: B, L, Z; no couplings: D, E, G, I, M, N, S, AB, AC, AE, AP, AQ, AR, BB, BC, BE, BK, BL, BM.

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