Trends in Digital Library Research:

A Knowledge Mapping and Ontology Engineering Approach

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A Dissertation Submitted for
the Degree of Doctor of Philosophy

University of Technology, Sydney
2013

CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Acknowledgment

I am immensely grateful to following people who have helped and supported me in the journey of exploring and creation:

My great supervisor, Prof. Gobinda Chowdhury, whom I highly and deeply thank for his clear and bright ideas, guidance and support throughout my research journey.

My family including my parents, my lovely wife and adorable daughter, whom I greatly thank for giving me sweet love, ideology and power during the whole research process far away from home.

My kind and helpful UTS staff, especially Ms. Juleigh Slater, Dr. Hilary Yerbury and Graduate School and Library Staff, whom I greatly appreciate for their assistances in my research activities.

Finally and above all, I strongly thank Australian Government, Australian Leadership Awards (AusAID) for funding my PhD research, UTS International Sponsored Students staff for their assistances of my study and kind, lovely and friendly Aussie people I met in Sydney city for giving me such beautiful and joyful moments of life in Sydney, a sea - side city of peace, friendship and joys.

Table of Contents

List of Tables and Figures

Publications and Presentations Reporting the Findings of the Research

A. Peer - Reviewed Journal and Conference Papers

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Abstract

Mapping digital library research is very helpful for digital library research and education communities to have a knowledge platform to guide, evaluate, and improve the activities of digital library research, education and transforming it into a digital library ontology for various applications. However, so far, there has not been any research on mapping digital library research for serving such purposes.

The thesis was aimed to build a knowledge map of the digital library domain for analysing the past of digital library research (1990-2010) and predicting the future of the digital library research. Also, based on the knowledge map, a digital library ontology and a visual knowledge map were created.

The study was conducted in three following phases:
Firstly, in the Phase 1, the core topics and subtopics of digital library research were identified and organized in order to build a knowledge map of the digital library domain. The methodology comprised a four - step research process and two knowledge organization methods (classification and thesaurus building). A knowledge map covering 21 core topics and 1015 subtopics of digital library research was created, providing a systematic overview of digital library research of the last two decades (1990-2010).

Secondly, in the Phase 2, using the 21 core topics and 1015 subtopics of digital library research from the knowledge map, bibliometric method and regression analysis, R-Square (R^2) techniques were used to analyse the past of digital library research (1990-2010) and predict the future of digital library research.

Thirdly, in the Phase 3, based on the digital library knowledge map, the Protégé ontology software was used for creating the main components of the digital library ontology, viz. individuals, properties and classes, etc. for building the basic digital library ontology that can be visually seen as a knowledge map of digital library research.

The research added value in the following areas:
Firstly, the digital library knowledge map can be used as a knowledge platform to guide, evaluate and improve the activities of digital library research (digital library research management), education (digital library curriculum development) and practices (digital

library project management and development). Also, the research methodology can be used to map any human knowledge domain because it is a scientific method for producing comprehensive and systematic knowledge maps based on literary warrant.

Secondly, this research will help digital library researchers, educators, and practitioners to measure and foresee the digital library research outputs for planning and managing the digital library research, education and development effectively.

Thirdly, the digital library ontology can be applied to a number of areas within the digital library domain, for example as software agents and Semantic Web development; knowledge management, i.e. knowledge sharing and reuse, knowledge collaboration, knowledge interoperation, digital library research and education, etc.
The knowledge map and the ontology can be expanded in future by using other databases and open access publications in digital libraries.

Chapter 1

Introduction

1.1 Origin of the Research

Digital library research is a study on digital library domain relating to researches in histories, trends and evolutions of digital library topics. Since its inception as a new field of study about two decades ago, research and development activities in digital libraries have grown quite significantly, drawing researchers and practitioners from a range of fields, primarily from computer science (63%) and library & information science (26%) (Nguyen & Chowdhury, 2011a). A search on SCOPUS database reveals a dramatic rise in the number of publications (articles, papers, etc.) from 436 during the first decade (1990-1999) to 7469 during the second decade (2000-2010) (SCOPUS, 2011). Because of its interdisciplinary nature, the digital library research field involves a large number of topics and subtopics which should be captured, organized and structured in a knowledge map in order to help researchers, educators and practitioners in exploring and understanding the digital library knowledge domain and its evolution for various application purposes of digital library research and development (Nguyen & Chowdhury; 2011a, 2011b, 2012a, 2012b, 2013a, 2013b).

So far, many researchers have attempted to show the progress of digital library research by using a variety of bibliometric techniques, such as: analysis of impact factors, citation analysis, publication counts and H – index analysis, etc. However, predicting the trends of research in the entire field of digital libraries remains a big challenge because of two main reasons: (1) lack of a knowledge organization scheme (or a digital library knowledge map) showing the semantic relations among various digital library research topics, and (2) lack of the use of appropriate analysis tools, such as R^2 values of regression analysis (Regression analysis techniques help us predict and forecast the forms of relationships between variables), for predicting the future trends of the digital library domain.

Moreover, so far, to the best of the researcher's knowledge, there has not been any digital library ontology that can be used to map and analyse digital library research.

1.2 Research Objectives

The main question that drove this research was: how can we study the past and predict the future of digital library research? This research question gave rise to the following three research objectives:

- to create a knowledge map of the digital library research domain ,
- to analyse the current state and predict the trends of digital library research and
- to engineer and develop an ontology of the digital library domain.

In order to achieve these objectives, this research has been carried out in the following three inter-related phases:

- Phase 1: the core topics and subtopics of digital library research have been identified in order to build a knowledge map of the digital library domain. The methodology comprises a four - step research process and two knowledge organization methods (classification and thesaurus building). A knowledge map covering 21 core topics and 1015 subtopics of digital library research has been created, providing a systematic overview of digital library research of the last two decades (1990-2010).
- Phase 2: using the 21 core topics and 1015 subtopics of digital library research from the knowledge map, bibliometric methods and regression analysis, R-Square (R^2), have been used to analyse the past of digital library research (1990-2010) and predict the future of the digital library domain.
- Phase 3: based on the digital library knowledge map, Protégé software has been used for creating the main components of the digital library ontology, viz. individuals, properties and classes, etc. for building the basic digital library ontology that can be visually seen as a knowledge map of digital library research.

1.3 Significance of the Research

The research has following values:

- Phase 1: The digital library knowledge map can play as a knowledge platform to guide, evaluate and improve the activities of digital library research (digital library research management), education (digital library curriculum development) and practices (digital library project management and development). Also, the research methodology can be used

to map any human knowledge domain because it is a scientific method for producing comprehensive and systematic knowledge maps based on literary warrant.

- Phase 2: This research will help digital library researchers, educators, and practitioners to measure and foresee the digital library research outputs for planning and managing the digital library research, education and development effectively.
- Phase 3: The digital library ontology can be applied to a number of areas within the digital library domain, for example in Semantic Web development; and in knowledge management, i.e. knowledge sharing and reuse, knowledge collaboration, knowledge interoperation, digital library research and education, etc.

1.4 Limitations of the Research

This study provides a comprehensive view of the digital library knowledge map and shows the progress and trends of digital library research. However, because the sample used in the research was limited to 7905 bibliographic records of digital library publications published between 1990 and 2010 from Scopus, which is a commercial database, open-access resources could not be included, which is no doubt a limitation of this study. A more comprehensive study with commercial databases as well as open-access digital library publications would produce a more comprehensive knowledge map of digital libraries. i.e. the study sample (7905 bibliographic records) takes 11% of total records (64700) on digital libraries found in Google Scholar within 1990-2010.

1.5 Thesis Overview

The thesis is presented in 7 chapters. Chapter 2 reviews literature on three research areas, viz. (1) Studies on knowledge mapping; (2) Studies on digital library research trends, and (3) Studies on ontology. Chapter 3 describes the methodology comprising the three phases of the research. Chapter 4 reports on the findings of the digital library knowledge map covering 21 core topics and 1015 subtopics of digital library research (1990-2010). Chapter 5 reports on the findings of the digital library research trends within the period (1990-2010) and predicts the future of research in this field. Chapter 6 describes the creation of the main components of the digital library ontology, viz. individuals, properties and classes and the visual knowledge map. Finally, Chapter 7 provides a summary and conclusion of this research.

Chapter 2

Literature Review

2.1 Introduction

This study is influenced by literature in three areas of research, viz. knowledge mapping, research trend analysis and ontology engineering within the context of digital libraries. Therefore literature on: (1) knowledge mapping (knowledge mapping in general, knowledge mapping in library and information science, and knowledge mapping in the digital library domain); (2) research trends in digital libraries, and (3) ontology (ontology overview and ontology engineering) are reviewed in this chapter in order to build up the theoretical background and frameworks of the areas and identify the research gaps needed to be addressed in this research.

2.2 Knowledge Mapping

2.2.1 An Overview of Knowledge Mapping

Geographically speaking, a knowledge map or a navigation map is a visual representation of an area that provides a symbolic depiction highlighting relationships between elements of that space such as objects, regions, and themes (Njue, 2010). Road maps are regularly used by travellers on land, sailors use their charts when they go to sea, and scientists often rely on spatial knowledge maps when they practice science. Likewise, semantic or word-based knowledge maps are often used by students, teachers and researchers as learning, teaching, knowledge navigation, and assessment tools (Fisher et al, 2002). In general, a knowledge map may be considered as a knowledge "yellow pages" or cleverly constructed database pointing to knowledge (Zins, 2007b). It is a guide, not a repository (Davenport & Prusak, 1998).

The idea of knowledge mapping in the knowledge management field can be analogous to the use of concept maps and concept mapping. According to Lansing (1997), concept mapping is a technique for representing knowledge in graphs. Knowledge graphs are networks of concepts, and they consist of nodes representing concepts and links that represent the relations between concepts. Concepts and sometimes links are labelled. Links can be non-, uni-, or bi-directional. Concepts and links may be categorized, they can be simply associated,

specified, or divided in categories such as causal and temporal relations. McDonald and Stevenson (1999) showed that navigation was best with a spatial map, whereas learning was best with a conceptual map.

According to Wright (1993), a knowledge map is an interactive, open system for dialogues that defines, organizes, and builds on the intuitive, structured and procedural knowledge used to explore and solve problems. Specifically, the objective of knowledge mapping is to develop a network structure that represents concepts and their associated relationships in order to identify existing knowledge in the organization (in a well-defined area) and determine where the gaps are in the organization's knowledge base as it evolves into a learning organization.

In the context of science domain mapping, "the term knowledge map is chosen to describe a newly evolving interdisciplinary area of science aimed at the process of charting, mining, analysing, sorting, enabling navigation of, and displaying knowledge" (Shiffrin & Börner, 2004, p. 5183). The purpose of this knowledge mapping is to facilitate information access, making evident the structure of knowledge, and allowing seekers of knowledge to succeed in their endeavours. However, knowledge mapping is not new because over a long period of time scientists, academics, and librarians have attempted to codify, classify, and organize knowledge, thereby making it useful and accessible. Some of these techniques, according to Shiffrin & Börner (2004), can be applied in science, in order to: (1) identify and organize research in different categories, for example, according to experts, institutions, grants, publications, journals, citations, text, and figures; (2) discover interconnections among different subjects and topics; (3) establish the import-export and crossover of research from/among different disciplines; (4) examine dynamic changes, growth and diversification; (5) highlight the emerging patterns of information production and dissemination; (6) find and map scientific and social networks; and (7) identify the impact of strategic and applied research funding by government and other agencies (Shiffrin & Börner, 2004, p. 5183).

A knowledge map can also be used for a number of purposes. First, it is a tool for personal and social knowledge construction as well as a tool that supports meaningful learning. In the classroom, mapping can provide (Fisher et al, 2002):

- a structure for the minds-on part of hands-on/minds-on teaching,

- a systematic means for reflecting on and analysing inquiry learning,
- a knowledge arena for operating on ideas, and
- a tangible support for the transition from teacher-centred to student-centred classrooms.

According to Lanzing (1997), a knowledge map can help to:

- generate ideas (brainstorming, etc.);
- design a complex structure (long texts, hypermedia, large web sites, etc.);
- communicate complex ideas;
- aid learning by explicitly integrating new and old knowledge; and
- assess understanding or diagnose misunderstanding.

Furthermore, knowledge mapping helps in creating knowledge repositories and capturing corporate memories. According to Wiig (1995), knowledge mapping:

- is used to develop conceptual maps as hierarchies or nets;
- may support knowledge scripting and profiling, basic knowledge analysis, etc.;
- provides highly developed procedures to elicit and document conceptual maps from knowledge workers, particularly experts and masters; and
- is a broad knowledge acquisition methodology.

Most of our thoughts lie below the surface of conscious awareness, just as most of an iceberg is submerged beneath the sea. And just as only the tips of icebergs are visible to us, so only the tips of our thoughts are available to conscious knowing (Fisher et al, 2002). Knowledge mapping is used to uncover the submerged and invisible knowledge, bringing them from the dark into the light by transforming them into visual mapping forms. Thus, when looking at a visual knowledge map, we can see the boundary of the specific knowledge, the structure and relationships among concepts or topics within the map for domain understanding, and compare and identify what is missing in our knowledge.

2.2.2 Knowledge Mapping in Library & Information Science

Many library classification systems have been in use for mapping knowledge in library and information sciences, e.g.: Dewey Decimal Classification (e.g., class 020: Library &

Information Sciences), Universal Decimal Classification (e.g. class 02: Librarianship), and Library of Congress Classification (e.g., Class Z - Bibliography, Library Science), etc. which have been mapping the field of study (Zins, 2007a, 2007b). Knowledge maps of the fields can also be seen in other tools, such as: information services and databases (e.g., Library, Information Science & Technology Abstracts [LISTA]; Library and Information Science Abstracts [LISA]), thesauri (e.g., ASIS Thesaurus of Information Science and Librarianship; Milstead, 1998), ACM Computing Classification System (1998), etc. Many library and information science text books (e.g., table of contents), conferences' programs (e.g., Call for papers) and course syllabi (e.g., course names) also cover main the themes and topics that can be used to create the Library & Information Science knowledge maps. However, often such knowledge maps do not clearly represent the systematic, logical, explanatory or probabilistic relationships among different related concepts and their sub-concepts in library and information science (Zin, 2007b).

In order to formulate a systematic knowledge map of Information Science, Zins (2007a, 2007b) used the Critical Delphi method (a qualitative research methodology aimed at facilitating critical and moderated discussions among experts) and conducted a study with international and intercultural panels that comprised of 57 participants from 16 countries. This study is discussed further in Section 2.3.2.

2.2.3 Knowledge Mapping in the Domain of Digital Libraries

Many core topics and subtopics in the digital library domain have been studied and documented in many books (Arms,2000; Borgman, 2000; Chowdhury & Chowdhury, 2003; Witten & Bainbridge, 2003; Lesk, 2004) and research papers (Chowdhury & Chowdhury, 1999; Candela et al, 2007; Chen et al, 2005). While reviewing research and development in digital libraries in the nineties, Chowdhury and Chowdhury (1999) grouped digital library research into 16 major areas. More recently, two research groups attempted to find out the core topics of the digital library domain: the first research was conducted by Pomerantz et al (2006) on a sample of 1064 digital library publications (covering the period 1995-2006) that produced 19 modules (core topics) and 69 related topics. The second study was conducted by Liew (2009) with 557 publications (published between 1997 and 2007), producing 5 themes (core topics) and 62 related or subtopics. They both provided fundamental frameworks of digital library core and subtopics, with Pomerantz et al (2006) covering core

Computer Science and Library & Information Science topics, and Liew (2009) providing an insightful view of organizational and people issues of digital library research. However, their research objectives were not to develop digital library knowledge maps per se; they aimed at developing a digital library curriculum (Pomerantz et al, 2006) or studying the organizational and people issues of digital libraries (Liew, 2009).

2.2.4 Summary

The literature review, presented above, calls for having a knowledge map of digital library domain showing the semantic organization of digital library research topics and also the evolution of the field. This knowledge map can work as a knowledge platform to guide, evaluate, and improve the activities of digital library research, education, and practices. Moreover, it can be transformed into a digital library ontology for various applications.

2.3 Digital Library Research Trend Analysis

2.3.1 Studies on Digital Library Research Trends

Trends in digital library research have been discussed in various international digital library conferences, i.e. Joint Conferences on Digital Libraries (JCDL), The European Conference on Research and Advanced Technology for Digital Libraries (ECDL), International Conference on Asia-Pacific Digital Libraries (ICADL), etc. and reviewed in many publications that used both qualitative analysis (Chowdhury & Chowdhury, 1999; Brophy & Great Britain, 1999; Shiri, 2003; Chen, 2004; Chen, 2005; Nagatsuka & Kando, 2006; Liew, 2009; Jae Yun et al, 2010; Zhao & Zhang, 2011; Nguyen & Chowdhury, 2011, 2012), and quantitative analysis techniques (Jae Yun et al, 2010; Zhao & Zhang, 2011; Åström, 2010; Sin, 2011; Tang, 2004; Odell et al, 2008; Furner, 2009; Huang et al, 2011; Chang et al, 2012; Larivière et al, 2012).

Using a qualitative approach, Chowdhury & Chowdhury (1999) provided brief accounts of some major digital library projects that were then in progress, or were just completed, in different parts of the world. They categorized digital library research under sixteen major headings. Later, Shiri (2003) presented an overview of trends in digital library research in the following areas: digital library architecture, systems, tools, and technologies; digital content and collections; metadata; standards; interoperability; knowledge organization systems; users and usability; legal, organizational, economic, and social issues. In 2004, Chen provided a

review of significant past and emerging digital library research activities based on some new knowledge management concepts (Chen, 2004). Through a meta-analysis of the publications and content within ICADL and other major regional digital library conferences over the past few years, he also noted continuing interests among digital library researchers and practitioners internationally (Chen, H. et al, 2005). Nagatsuka and Kando (2006) discussed digital library research and development in the Asia Pacific region focusing on the technical and social aspects. Three years later, Liew (2009) provided a snapshot of digital library research of the past 11 years (1997-2007) that focused on organisational and people issues, including those concerning the social, cultural, legal, ethical, and use dimensions.

Many researchers have used quantitative analysis techniques to study the trends of research within digital library and library and information science fields. Jae Yun et al (2010) analysed the digital library research domain from the perspective of Library & Information Science on a search sample of *digital library/digital libraries* in LISA database from 1994 to 2008 in which 54 journals and 120 descriptors were selected and analysed with profiling, parallel nearest neighbour clustering and cluster-based network methods. Zhao & Zhang (2011) compared digital library research in China and at international level by using co-word analysis, social network analysis and mapping of knowledge domains on a sample of total 6068 and 1250 papers published between 1994 and 2010 retrieved from the China National Knowledge Infrastructure (CNKI) and Science Direct databases respectively. Many people have studied research trends in the Library & Information Science domain over the past two decades, such as bibliometric analysis of the Library & Information Science field (Åström, 2010; Sin, 2011), and evolution of interdisciplinary research in Library & Information Science (Tang, 2004; Odell et al, 2008; Furner, 2009; Huang et al, 2011; Chang et al, 2012; Larivière et al, 2012). However, to date, to the best of the researcher's knowledge, there has not been any study that predicts the future of research in the digital library field.

2.3.2 A Knowledge Map for showing Digital Library Research Trends

A knowledge map of a research field not only shows the knowledge organization of its research topics (concepts) but also maps the domain boundary and captures the evolution of the field. So far, there have been two knowledge maps in information science: one in the field of information science by Zins (2007a) and the other in the digital library research domain by Nguyen & Chowdhury (2011, 2013).

In order to generate a systematic knowledge map of information science, Zins (2007a, 2007b) used the Critical Delphi method (a qualitative research methodology aimed at facilitating critical and moderated discussions among experts) and conducted a study with expert international and intercultural panels that comprised of 57 participants from 16 countries. These experts represented nearly all the major subfields of information science, and together the panels produced 28 classification schemes portraying and documenting the profile of contemporary information science at the beginning of the 21st century. Combining these classification schemes, Zins produced a knowledge map of information science that provides a basis for formulating theories of information science, developing and evaluating information science academic programs and bibliographic resources (Zins, 2007a). Two other researchers adopted this information science knowledge map as a classification scheme to measure and evaluate the information science research trends. These studies were: *Analysis of the interdisciplinary nature of Library & Information Science* by Prebor (2010) and *Content analysis of Library & Information Science research* by Aharony (2012). These studies contributed towards the understanding of the information science field and its future development (Prebor, 2010) and suggested the tendency of authors towards collaboration in the field (Aharony, 2012).

2.3.3 Linear Regression Analysis for Predicting Digital Library Research Trends

Regression analysis techniques help us predict and forecast the forms of relationships between variables. A linear regression is used as an approach to modelling the relationship between a scalar dependent variable *y* and one or more explanatory variables denoted by *x*. With the linear regression analysis, the coefficient of determination as R^2 value is used for prediction of future outcomes on the basis of other related variables (Hair, 2007, p. 367-374). Ranging from 0 to 1, the R^2 value reveals how closely the estimated values for the trend line correspond to an actual data. A trend line is most reliable when its R^2 value is at or near 1 and if the R^2 is 0, then the trend line is the least reliable (Excel Help, 2007). For bibliometric studies on the digital library research trends, the R^2 value can help to predict the future of the trends based on variables (years, publication numbers or topic numbers).

2.3.4 Literary Warrant

According to Hulme (1911) and Beghtol (1986), literary warrant are words and phrases drawn from the literature of the field should determine the formulation of descriptors. In

library and information science, the term "literary warrant" means that an indexer or classifier has to provide adequate ground for the indexing, classifying (as well as the definition of indexing terms and classes in classification systems) in the literature. Warrant is also the justification for the inclusion of a term or a class in a controlled vocabulary as well as its definition and relations to other terms. In this research, literary warrant (Hulme, 1911; Beghtol, 1986; Hjørland, 2007a; NISO, 2005, p.6) was taken to be the guiding principle for building the knowledge map

2.3.5 Summary

Based on the literature review, so far, no research has been undertaken by using the digital library knowledge map for analysing and measuring the research trends within the whole domain of digital libraries. Also, there has been no study conducted by using R^2 values combined with the digital library knowledge map to predict the future evolution of the whole domain. The main reason for this is perhaps the lack of a detailed digital library knowledge map as discussed earlier in this chapter.

2.4 Ontology Engineering

2.4.1 Ontology Overview

Ontologies are used to capture knowledge about some domain of interest and describe the concepts in the domain, e.g. individuals (instances), classes (concepts), attributes etc. and the relationships among those concepts (Horridge, 2011).

According to Mizoguchi (1998), there are various definitions of ontology, viz.

- In philosophy, the word “ontology” comes from the Greek *ontos,* for “being” and *logos,* for “word”. It means theory of existence. It tries to explain what is being and how the world is configured by introducing a system of critical categories to account for things and their intrinsic relations.
- From artificial intelligence point of view, an ontology is defined as the explicit specification of conceptualization.
- From knowledge-based systems point of view, it is defined as a theory (system) of concepts/vocabulary used as building blocks of an information processing system. In the context of problem solving, ontologies are divided into two types: task ontology for problem

solving process and domain ontology for the domain where the task is performed (Mizoguchi, 1998).

Common components of ontologies include (Jurkevicius, 2009):

- Individuals: instances or objects (the basic or "ground level" objects).
- Classes: sets, collections, concepts, types of objects, or kinds of things.
- Attributes: aspects, properties, features, characteristics, or parameters that objects (and classes) can have.
- Relations: ways in which classes and individuals can be related to one another.
- Function terms: complex structures formed from certain relations that can be used in place of an individual term in a statement.
- Restrictions: formally stated descriptions of what must be true in order for some assertion to be accepted as input.
- Rules: statements in the form of an if-then (antecedent-consequent) sentence that describe the logical inferences that can be drawn from an assertion in a particular form.
- Axioms: assertions (including rules) in a logical form that together comprise the overall theory that the ontology describes in its domain of application. This definition differs from that of "axioms" in generative grammar and formal logic. In these disciplines, axioms include only statements asserted as a priori knowledge. As used here, "axioms" also include the theory derived from axiomatic statements.
- Events: the changing of attributes or relations.

So far, a large number of ontologies have been developed by different groups, under different approaches, and with different methods and techniques. Ontologies are now widely used in knowledge engineering, artificial intelligence and computer science; in applications related to knowledge management, natural language processing, e-commerce, intelligent integration information, information retrieval, integration of databases, bioinformatics, and education; and in new emerging fields like the semantic web (Gómez-Pérez et al, 2004; Gaševic et al, 2009).

According to Mizoguchi and Mitsuru (1996), ontologies are used for a variety of reasons, viz. used as a common vocabulary for communication among distributed agents; used as a

conceptual schema of a relational database; used as a backbone information for a user of a certain knowledge base; used for answering competence questions; used for standardization of: terminology, meaning of concepts, components of target objects (domain ontology), components of tasks (task ontology); used for transformation of databases considering the differences of the meaning of conceptual schema; used for reusing knowledge of a knowledgebase; and used for reorganizing a knowledgebase.

2.4.2 Ontology Engineering Overview

Ontology engineering refers to the set of activities that concern the design principles, ontology development process, the ontology life cycle (design, implementation, evaluation, validation, maintenance, deployment, mapping, integration, sharing, and reuse), the methods and methodologies for building ontologies, and the tool suites and languages that support them (Gómez-Pérez et al, 2004).

Engineering ontologies relate to (Sánchez, 2010):

- defining concepts in the domain (classes),
- arranging the concepts in a hierarchy (subclass-superclass hierarchy),
- defining attributes and properties that classes can have and restrictions on their values; and
- defining individuals and filling in property values.

According to the Web Science Lab (2012), ontology engineering includes:

- Manual creation of ontologies by applying various knowledge acquisition methods (e.g., interviewing, self-reporting, laddering, concept sorting, repertory grids, automatic learning techniques, etc.) and
- knowledge modelling technologies (e.g., modularization, top-level ontologies, spiral knowledge model, etc.) and existing ontology engineering methods.

Knowledge acquisition, as part of ontology engineering process, is an important prerequisite for this process by gathering, organizing, and structuring knowledge about a topic, a domain, or a problem area (Gaševic et al, 2009). Fernández-López et al. (1999) recognize the importance of knowledge acquisition in their methodology of ontological engineering. In this methodology, knowledge acquisition is the long process of working with domain experts, and

its activities are intertwined with activities from the specification and conceptualization phases. It comprises the use of various knowledge acquisition techniques to create a preliminary version of the ontology specification document, as well as all of the intermediate representations resulting from the conceptualization phase.

Noy and McGuinness (2001) propose the fundamental rules for ontology design as follows: there is no one correct way to model a domain; ontology development is necessarily an iterative process; concepts in the ontology should be close to objects (physical or logical) and relationships in one's domain of interest, etc. Moreover, Noy and McGuinness (2001) describe the ontology-building process as follows: determine the domain and scope of the ontology; consider reusing existing ontologies; enumerate important terms in the ontology; define the classes and the class hierarchy; define the properties (slots) of classes; define the facets of the slots; and create instances.

In conclusion, ontology engineering comprises a set of different activities, and there are a number of methods for ontology development, and one should choose the most appropriate alternatives depending on the domain and the available resources (Noy and McGuinness, 2001).

2.4.3 Engineering Ontology for Digital Library Domain

The digital library domain as a field of study has grown quite significantly for over two decades, drawing researchers and practitioners from a range of fields, primarily from computer science and library and information science. Because of its interdisciplinary nature, the digital library domain involves a large number of concepts (topics and subtopics) which should be captured, classified, structured and created into digital library ontologies. Such an ontology can be used for digital library collaboration, interoperation, research, education, and modelling.

However, till now, there is no digital library ontology developed for such purposes. The main reason for this problem is perhaps the lack of a knowledge map of the entire field of digital library research. This knowledge map is an important prerequisite for subsequent modelling and presenting the digital library domain ontology.

2.4.4 Summary

Based on the review of literature in the three chosen areas of research, three major gaps have been identified and addressed in the research, viz.

- lack of a knowledge map of digital library research domain that needs to be created in order to support academics and researchers in this domain (Phase 1),
- lack of an appropriate study for prediction of digital library research trends that can be addressed by using the digital library knowledge map combined with regression analysis (R^2 values) (Phase 2) and
- lack of a digital library ontology that can be used for a variety of purposes, and therefore it is important to engineer and develop an ontology of digital library domain by using the digital library knowledge map as a foundation for the knowledge acquisition process (Phase 3).

Chapter 3

Methodology

3.1 Introduction

This research was conducted in three different, but inter-related phases:

Phase 1: Core topics and subtopics of digital library research were found and organized in order to build a knowledge map of the digital library domain. The methodology comprised a four- step research process, that is discussed in Section 3.2. The outcome of this phase was a knowledge map covering 21 core topics and 1015 subtopics providing a systematic overview of digital library research of the last two decades (1990-2010).

Phase 2: In order to analyse the trends and predict the future of digital library research, bibliometric and regression analysis techniques were used to analyse the digital library knowledge map created in phase1. Details of the methods and analysis techniques are discussed in Section 3.3.

Phase 3: In order to design and engineer the ontology of the digital library domain, Protégé software was used on the digital library knowledge map created in phase 1. This is discussed in Section 3.4.

3.2 Phase 1. Method for Knowledge Mapping of Digital Library Research Domain

3.2.1 Research Process

The main objective of this phase of research was to build a knowledge map of digital library research topics. Therefore, it was necessary to identify the core topics and subtopics in digital library research which then could be used to develop a digital library knowledge map, and also to study the evolution of research in the field. The first challenge facing this study was the lack of a knowledge organization system for digital libraries. Therefore a new methodology had to be designed to build a knowledge map of digital libraries. Literary warrant (Hulme, 1911; Beghtol, 1986; Hjørland, 2007a; NISO, 2005, p.6) was taken to be the guiding principle and a multi-stage development approach was developed that included the following four major steps (Figure 3.1).

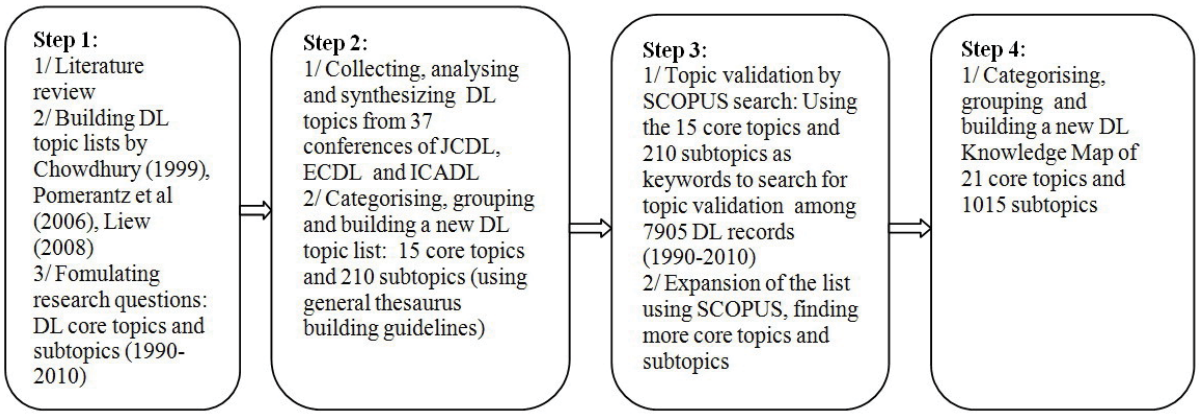

Figure 3.1: A Four - Step Method (Nguyen & Chowdhury, 2011a)

Step 1: The list of digital library research topics and subtopics (see Appendix 1) was created, based on the literature review, especially from the findings of Chowdhury & Chowdhury (1999), Pomerantz et al (2006) and Liew (2009). However, these studies provided lists of core topics and subtopics according to the viewpoints of individual researchers, and they were limited by the selection of literature studied by the concerned researchers and their study objectives, etc. As a result, it was realized that any list of core topics and subtopics prepared on the basis of these three studies would not truly represent the field of research. Furthermore the list of topics and subtopics from these studies shows more differences than commonalities. However, it paved the way for further research and investigations (Steps 2 and 3).

Step 2: Keeping in view the principle of literary warrant, call for papers (CFPs) for three major international conferences in the field of digital libraries, viz. Joint Conference on Digital Libraries (JCDL), European Conference on Digital Libraries (ECDL), and International Conference on Asia-Pacific Digital Libraries (ICADL) were chosen for this study because these international conferences are the intellectual platforms where researchers report on their new research findings. The editorial team or the programme committee of each conference comprises recognized experts in the field who bring out the CFPs. In this research, the CFPs covering various digital library topics from 37 conference volumes, viz. JCDL (2001-2010), ECDL (1997-2010) and ICADL (1998-2010) were collected from the conference websites. List of core topics and subtopics in each conference call was noted, and by manually combining these digital library topic lists with those of earlier studies (discussed in step 1), a table of 15 core topics and 210 subtopics was created (see Appendix 2). The list of core topics and subtopics was structured by using the general guidelines for thesaurus

building (NISO, 2005). The digital library knowledge map comprised a list of core and subtopics where each core topic has a list of subtopics, and some subtopics appear under more than one core topics. The reason for taking this approach was that the digital library knowledge organization system was primarily designed to be a tool for showing the concept map and research in the field, and in such a tool a given topic, for example *Interoperability*, may appear under different core topics like *Information Retrieval, Architecture - Infrastructure*, etc., depending on the context of research. This is discussed further in Step 3.

In preparing the table of 15 core and 210 subtopics (see Appendix 2), the following steps were followed:

- Building a draft table of core topics, then gathering their subtopics from the CFPs which were subsequently checked and verified manually with the resulting conference volumes,
- The core topics had the broader semantic scope Broader Terms (BT) in comparison with their subtopics that had narrower semantic scope Narrower Terms (NT),
- The core topics and their subtopics were thus linked by their BT-NT semantic relationships. Some subtopics appeared under more than one core topic because of their semantic cross-relationships, e.g. the subtopic *Interoperability* is related to two core topics: *Information Retrieval* and *Architecture – Infrastructure* and
- The original terms and phrases of all of the core topics and subtopics from the CFPs were kept although the language and terminologies used in the CFPs were sometimes loose and varied from one conference call to another, e.g. *Archives, Archiving*; *Preserving, Preservation*; *Filter, Filtering*; *EBooks, Electronic Books*, etc. These terms were standardized and/or extended in Step 3.

Problems/Issues

Although the CFPs from 37 conferences provided a good picture of digital library research activities around the globe, it was considered that limiting this study only to this approach would suffer from two major drawbacks:

- because of the limited capacity of a conference volume in terms of accommodating published papers, digital library conferences can only provide a snapshot of research in the field, and therefore they cannot provide a representation of the entire field of research, and

- often researchers are constrained by the fact that they need to submit papers within the framework of the CFPs and therefore, (a) many cannot report their research in conferences because of the incompatibility of their research topic and the CFPs, and (b) the length and breadth of the digital library research field, which is multidisciplinary in nature, and cannot be properly reflected only through an analysis of the conference papers.

It was therefore decided that the principle of literary warrant could be observed properly if a large representative database was used to verify and expand the list of 15 core and 210 subtopics, generated through the first phase of the study, and this would help us generate a larger and more comprehensive knowledge map of digital libraries.

Step 3: SCOPUS database was chosen because it is claimed to be the largest abstract and citation database of peer-reviewed literature (SCOPUS, 2011). A search for digital library publications (Search Terms: "digital librar*" in the field: Keywords) was conducted during March 2011 that produced 7905 publications covering the period (1990-2010). The list of 15 core and 210 subtopics was used as a set of keywords to conduct a series of searches within 7905 publication records in order to validate the digital library topics and identify more keywords that could be used as core topics or subtopics. The process is explained below.

For example, the topic "*Digital collections*" was used as a keyword for searching which produced 53 hits. In each record, there were always 2 sets of keywords - Author Keywords and Index Keywords, for example, Author Keywords *(Digital libraries; Information dissemination; Information services; Library collections development),* and Index Keywords *(Core journals; Digital collections; E-books; Institutional repositories; Library collections development; Multimedia database; Relationship management; Strategic plan; University libraries).* The topic "*Digital Collections*" was considered to be a valid and standard term for having several (in this case 53) records. Topics that generated no results, such as: "*Digital Library Creation*" or "*Disseminating Asian unique and indigenous knowledge and culture*", etc. were excluded for being invalid terms (not being part of the authors' and indexers' vocabulary).

Because of time limitations, all of the new keywords found within the first 5 records were included in the list. By collecting new keywords that appeared in Author Keywords & Index Keywords from each record, more digital library subtopics were found. When a subtopic

appeared in a large number of publications, and also a number of sub-subtopics appeared with a good number of publications, then a new core topic was created under that subtopic name, typical examples being *Social Web (Web2.0)*, *Semantic Web (Web3.0)*, etc. By using this method repetitively, the digital library topic list was enlarged to 21 core topics and 1015 subtopics.

Step 4: Although the research objective was to create a broad digital library knowledge map, and not building a thesaurus per se, some techniques of the Thesaurus Building (NISO, 2005) and Classification Method (Cann,1997; Dewey, 2003; Kao, 2001) were used to categorize and organize the core topics and subtopics, based on their semantic relationships, for structuring the knowledge map.

3.2.2 Organization of the Knowledge Map

Knowledge organization systems are mechanisms for organizing information. They are not only at the heart of every library, museum, and archive, but are also a fundamental platform to develop ontologies for designing the semantic web.

In this research, the organization of the DL knowledge map (1990-2010) was developed by using the principles of:

- Classification Method to categorize and organize the core topics and subtopics hierarchically from general to specific classes (Cann,1997; Dewey, 2003; Kao, 2001) and
- Thesaurus Building Method to categorize and organize the semantic relationships among the topics (NISO, 2005).

Classification Method

By grouping together of like topics and their separation from unlike topics (Cann, 1997; Dewey, 2003; Kao, 2001), the knowledge organization is made by arranging topics into classes in which the topics share a particular set of properties (have properties in common).

The digital library knowledge map provides a hierarchical structure of the domain from Super ordinate Classes (Core Topics) to Coordinate Classes (Clusters of Subtopics) and to Subordinate Classes (Subtopics) (Figure 3.2)

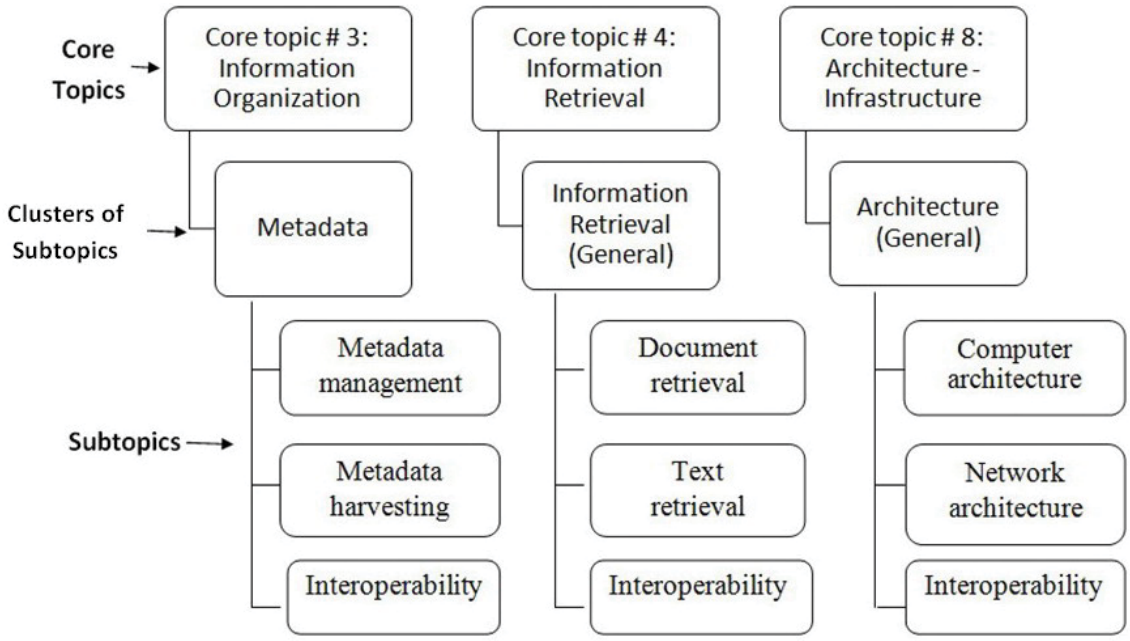

Figure 3.2: An example of topic knowledge organization

In the knowledge map, a subtopic can belong to more than one core topic because the subtopic's properties (characteristics) are inherited from its core topics or the core topics and subtopic share common properties (characteristics). For example: subtopic *Interoperability* can appear under 3 core topics: *Information Organization, Information Retrieval,* and *Architecture - Infrastructure* (Figure 3.2).

Thesaurus Building Method

A thesaurus is a tool of controlled vocabularies that is used to (NISO, 2005):

- solve the problems of homographs, synonyms and polysemes by a bisection between concepts and authorized terms.
- reduce ambiguity inherent in natural languages where the same concept can be given different names and ensure consistency.

Thus the principles of thesaurus building were applied to:

- define the scope of information space (domain) or meaning of terms (topics), e.g. define a broader term (a core topic) to which another term or multiple terms are subordinate in a hierarchy; define a narrower term (a subtopic) as subordinate to another term or to multiple terms in a hierarchy (Table 3.1).

Table 3.1: An example of broader term and narrower terms	
Broader Term	Storage
Narrower Terms	Digital Storage, Storage Systems, Storage Devices, Storage Media, Storage Technology, Storage Management, Hierarchical Storage, Data Storage Equipment, Digital Image Storage

- categorize and organize the semantic relationships between the 21 core topics and 1015 subtopics to link them together. e.g. (1) Equivalence relationship (to connect synonyms and near-synonyms), (2) Hierarchical relationship (to indicate terms which are narrower and broader in scope), (3) Associative relationship (to connect two related terms whose relationship is neither hierarchical nor equivalent) (Table 3.2).

Table 3.2: Relationship types and examples		
Relationship Types		**Examples**
Equivalence	Synonyms: These relationships are terms whose meanings are regarded as the same or nearly the same in a wide range of contexts	Electronic books/ eBooks
	Lexical variants: These relationships differ from synonyms in that synonyms are different terms for the same concept, while lexical variants are different word forms for the same expression	Filter/ Filtering; Archive/ Archiving/ Archives
	Near-synonyms: These relationships are terms whose meanings are generally regarded as different, but which are treated as equivalents for the purposes of a controlled vocabulary	Information Retrieval/ Search/ Browsing
Hierarchy	Generic: This relationship identifies the link between a class and its members or species	Multimedia / Music, Video, Document
	Instance: This relationship identifies the link between a general category of things or events, expressed by a common noun, and an individual instance of that category, often a proper name	Storage/ Storage systems, Storage devices, Storage management
	Whole/ Part: This relationship covers situations in which one concept is inherently included in another, regardless of context, so that the terms can be organized into logical hierarchies, with the whole treated as a broader term.	Social Sciences/ Art, Culture, History, Information Science
Associative	Cause/ Effect: This relationship establishes many grounds for associating terms belonging to different hierarchies presenting Cause/ Effect	Disaster/ Digital Preservation
	Process/ Agent: This relationship establishes many grounds for associating terms belonging to different hierarchies presenting Process/ Agent	Web 2.0/ Library 2.0

	Action/ Product: This relationship establishes many grounds for associating terms belonging to different hierarchies presenting Action/ Product	Knowledge Management/ Knowledge Economy
	Action/ Target: This relationship establishes many grounds for associating terms belonging to different hierarchies presenting Action/ Target	Digital Library Applications / E - Learning
	Concept or Object/ Origins: This relationship establishes many grounds for associating terms belonging to different hierarchies presenting Action/ Target	Web 2.0/ Library 2.0, Information Literacy 2.0

Like the classification method, in the thesaurus building method, there are polyhierarchical relationships by which some concepts belong, on logical grounds, to more than one category. They are then said to possess poly hierarchical relationships, e.g. *Interoperability* in Figure 3.2

In summary, the two methods: classification and thesaurus building, play a very crucial role in the knowledge organization of the map and ensure the nature and quality of the knowledge organizing processes.

3.3 Phase 2. Method for Analyzing and Predicting the Digital Library Research Trends

3.3.1 Research Tools

In order to analyse the past and predict the future of the research in digital library domain, three research tools were used: (1) the digital library knowledge map (1990-2010), (2) Bibliometric techniques (counting publications by years), and (3) A linear regression analysis (R^2 values) (Figure 3.3).

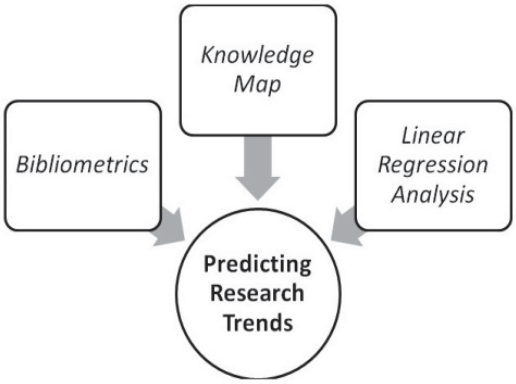

Figure 3.3: Three tools to analyse the past and predict the future research trends in digital library domain

3.3.2 Data Collection

The SCOPUS database was chosen because of its being the largest abstract and citation database of peer-reviewed literature. A search for DL publications (Search Terms: *"digital librar*"* in the field: Keywords with Date range "1990 - 2010") was conducted with a result of 7905 digital library publication records. The knowledge map with 21 core topics and 1015 subtopics was populated by searching the Scopus database. In each case the number of publications in a given subtopic was noted by year of publication. Thus for each subtopic, publication numbers by years were recorded and transferred to Microsoft Excel 2007 for further calculation and analysis. It should be noted that the number of publications under some specific core topics, e.g. *Architecture – Infrastructure (15339), DL Research & Development (14210)*, exceed the total number of 7905 digital library publications. This happened because a given paper may have several keywords and hence the same paper was counted under several subtopics, and some subtopics also appear under more than one core topic. However, the overall results of trend analysis were not affected by this because the calculation of R^2 values (discussed below) used the total number of publications under each topic and subtopic, and not the total number of papers in the database on digital libraries (i.e. 7905).

3.3.3 Calculating R-Squared Values

The R^2 value is a number from 0 to 1 that reveals how closely the estimated values for a trend line (a straight line relationship) correspond to a set of actual data. In fact, in linear regression, the trend line is a regression line drawn on a scatter graph and used to fit a predictive model to an observed data set of y (value on *y axis*) and x (value on *x axis*). After developing such a model, if an additional value of x is given without its accompanying value of y, the fitted model can be used to make a prediction of the value of y (Hair, 2007, p.367-374 ; Gray, 2009, p.485 – 491). The formula for linear regression is: $y = a + bx$ in which y = the predicted variable; x = the variable used to predict y; a = the intercept, or point where the line cut the *y axis* when $x = 0$; b = the slop or the change in y for any corresponding change in one unit of x (Hair, 2007, p.368 - 369).

In Excel, the R^2 value is calculated by the equation for the Pearson product moment correlation coefficient. The formula for R is:

$$\mathbf{R} = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

and R^2 is the square of this correlation coefficient.

In order to measure the trends in the digital library research (1990-2010), the R^2 values were calculated in Excel 2007 based on the degree of association between variables (variable *Publication* on *y axis*; variable *Year* on *x axis*). The trend lines showing the digital library research trends were classified into 3 types: *Increasing Trends (Positive Association), Decreasing Trends (Negative Association) and Not Identified Trends (No Association)*.

Type 1. Increasing Trend (Positive Association) shows the distribution of cases plotted on a graph. They are clustered closely together around a straight trend line, indicating how a strong relationship exists between the values on the two variables. In other words, as the variable *Year* increases, the dependent variable *Publication* increases. For example, in Figure 3.4, Topic 1 increases in publication numbers by increasing years with $R^2 = 0.7872$.

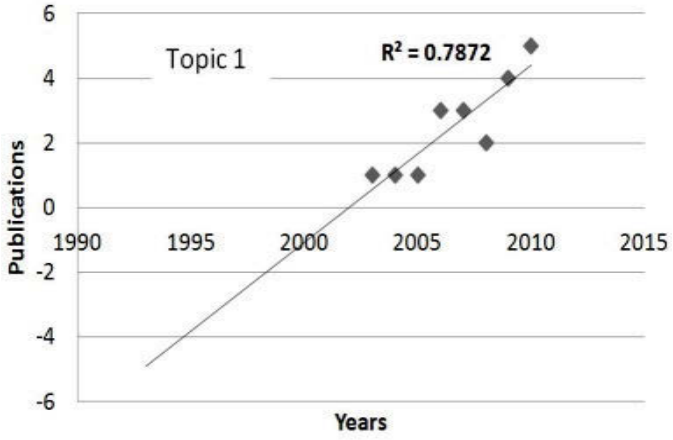

Figure 3.4: Increasing Trend (Positive Association)

Type 2. Decreasing Trend (Negative Association) also shows how a strong relationship exists between the values on the two variables but in a negative direction. In other words, as the variable *Year* increases, the dependent variable *Publication* decreases. For example, in Figure 3.5, Topic 2 decreases in publication numbers when years increase with $R^2 = 0.6011$.

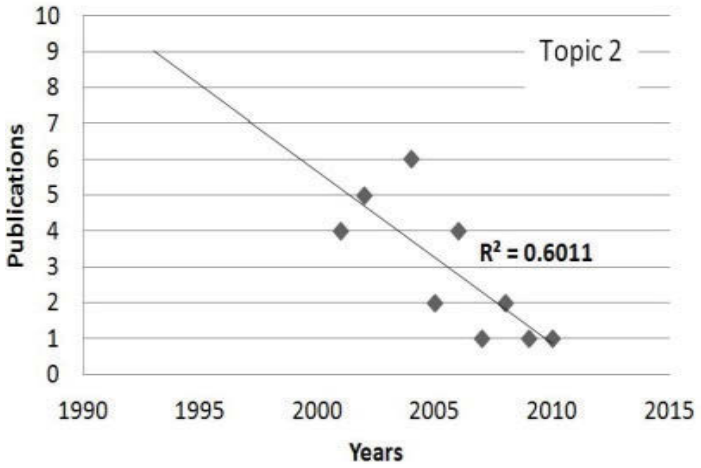

Figure 3.5: Decreasing Trend (Negative Association)

Type 3. Not Identified Trend (No Association) shows no predictable or identifiable pattern to the point. Knowing the values of *Publication* or *Year* would not tell much (probably nothing at all) about the possible values of the other variable (Figure 3.6). (Note: In Excel, if variable *Publication* or *Subtopic Number* is empty or contains only 1 data point, R^2 returns the #DIV/0! error value).

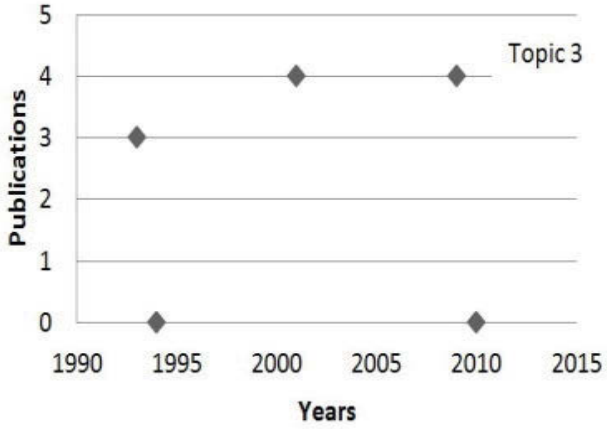

Figure 3.6: Not identified trend (No Association)

Based on this method, the past (1990-2010) and future of major research trends of 21 core topics as well as 1015 subtopics were investigated and identified. All of the findings are presented in Chapter 5.

3.4 Phase 3. Method for Designing and Engineering the Digital Library Ontology

The main objective of this phase of research was to design and engineer the ontology of digital library domain. The method for designing and engineering the digital library domain ontology was as follows (see Figure 3.7):

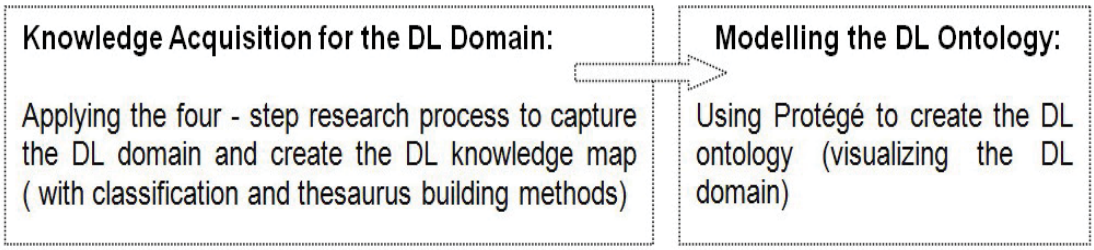

Figure 3.7: Method for designing and engineering the digital library domain ontology

The Figure 3.7 shows the method of designing and engineering digital library domain ontology including knowledge acquisition for the digital library domain and modelling the digital library ontology. However, in domain ontology designing and engineering, there are several other possible approaches in developing a class hierarchy and class organization (Uschold and Gruninger,1996):

- A top-down development process that starts with the definition of the most general concepts in the domain and subsequent specialization of the concepts.
- A bottom-up development process that starts with the definition of the most specific classes, the leaves of the hierarchy, with subsequent grouping of these classes into more general concepts.
- A combined development process comprising a combination of the top-down and bottom up approaches.

It should be noted that none of these three methods is inherently better than any of the others (Noy and McGuinness, 2001). The approach depends strongly on the personal view of the domain. If a developer has a systematic top-down view of the domain, then it may be easier to use the top-down approach. The combination approach is often the easiest for many ontology developers, since the concepts "in the middle" tend to be the more descriptive concepts in the domain.

As addressed in the Phase 1, in the light of ontology engineering, the four- step research process is the knowledge acquisition process to create a digital library knowledge map by gathering, designing, coding, classifying, organizing, and structuring knowledge about the digital library domain. This knowledge map plays an important prerequisite for later

modelling and presenting the digital library domain ontology. Then, the whole map with 21 core topics and 1015 subtopics was modelled and visualized by Protégé software 4.1.

As stated on its homepage (http://protege.stanford.edu/overview/), Protégé is a free, open-source platform that provides a growing user community with a suite of tools to construct domain models and knowledge-based applications with ontologies. At its core, Protégé implements a rich set of knowledge-modelling structures and actions that support the creation, visualization, and manipulation of ontologies in various representation formats. Protégé can be customized to provide domain-friendly support for creating knowledge models and entering data. Further, Protégé can be extended by way of a plug-in architecture and a Java-based Application Programming Interface (API) for building knowledge-based tools and applications.

By using Protégé version 4.1, main components of the digital library ontology, viz. Individuals, Properties and Classes were created to build a basic digital library ontology playing as a framework for the full digital library ontology development.

3.5 Summary

In conclusion, the research was conducted in three different, but inter-related phases. Phase 1 was to create a knowledge map covering 21 core topics and 1015 subtopics providing a systematic overview of digital library research of the last two decades (1990-2010). Then, based on the map, bibliometric and regression analysis techniques in Phase 2 were used to analyse the trends and predict the future of digital library research. Also, based on the map, Protégé software was used to develop an ontology of the digital library domain with basic Individuals, Properties and Classes (Phase 3).

Chapter 4

The Knowledge Map of Digital Library Research (1990-2010)

4.1 Introduction

This chapter presents the findings of the digital library knowledge map (Table 4.1) and its analysis providing an overview of digital library research for twenty years (1990-2010) along with the number publications for each of the 21 core topics as well as the top 10 subtopics, according to the highest number of publications, under each core topic.

4.2 Core and Subtopics in Digital Library Research

The table 4.1 shows the full digital library knowledge map covering 21 core topics and 1015 subtopics derived from 7905 bibliographic records of DL publications within two decades (1990-2010) from the SCOPUS database. All the core topics and subtopics were classified hierarchically and structured logically into 3 classes (levels), viz.

- Level 1: Superordinate Classes, e.g. Core Topics, e.g. *Digital Collections*
- Level 2: Coordinate Classes, e.g. Clusters of Subtopics, e.g. *Collections* (General), *Database* (General), *Multimedia* (General)
- Level 3: Subordinate Classes, e.g. Subtopics: *Collection Development, Collection Development Policy, Content Creation*, etc. (see Table 4.1).

Each subtopic has been assigned with the number of publication, e.g. *Resources* (603), *Digital Information* (57), *Digital Documents* (41), etc. which show research interests in each subtopic, shown by the number of publications, within the period of study (1990-2010).

A subtopic in each cluster of subtopics is shown in bold just to indicate what broadly the cluster of subtopics covers. However, the topic shown in bold is a coordinate and not a super ordinate term compared to the other terms in the given cluster; and it merely gives an idea of the overall coverage or connotation of the cluster of subtopics.

Under each core topic, there are several clusters of subtopics. All of the clusters of subtopics are created and structured based on shared common properties (characteristics) that decide

the number of clusters under each core topic. In other words, the clusters of subtopics vary in numbers among the 21 core topics because of being grouped and categorised based on their semantic relationships (Equivalence Relationship, Hierarchical Relationship and Associative Relationship).

Some subtopics have been qualified by the word 'General', e.g. *Collections (General), Database (General), Multimedia (General)*, etc. The word or the phrase representing the subtopic, such as *Collections, Database*, etc. are valid terms as they appeared as keywords in the published documents in digital libraries. However, since they are relatively generic terms in comparison to the other coordinate subtopics in that cluster, the word (General) has been added after such words by the researchers in order to indicate that publications in those given subtopics cover general aspects, as opposed to a specific aspect, of the subtopic. This decision was made in accordance with the suggestions of the peer reviewers of the journal (Nguyen & Chowdhury, 2013a) and conference papers (Nguyen & Chowdhury; 2011a, 2011b) where this research was reported, and subsequent deliberations with leading experts at the International Conference on Asia-Pacific Digital Libraries 2011 (ICADL 2011) (Nguyen & Chowdhury; 2011a) and International Workshop on Global Collaboration of Information Schools 2011 (WiS2011) (Nguyen & Chowdhury; 2011b).

Table 4.1: The Knowledge Map of Digital Library Research (1990-2010)

Core Topic #1: Digital Collections; 5 clusters of subtopics; 48 subtopics
1. Collections(General)(363), Resources(603), Digital Information(57),Digital Documents(41),Data Collection(28),Information Sources(26) **2. Acquisition(432)**, Digitization(58),Collection Development(35),Resource Sharing(15),Content Creation(8), Collection Development Policy(3), Digitization Workflow(1) **3. Database(General)(1210)**, Image Database(29),Video Database(14),Web Databases(13),Music Database(8) **4. Collection Management(50)**, Resources Management(46),Collection Evaluation(2), Information Evaluation(2) **5. Multimedia(General)(496),** Electronic Publishing(251),Video(246),Music(112), Electronic Journals(85), Audio(73), Electronic books/eBooks(51),Document Collection(33),Manuscripts(32),Educational Resource(29), Digital Music Libraries(26),Photos(24),Newspapers(18),Digital Video Library(16),Scholarly Publishing(12), Scientific Data(12),Multimedia Collections(6),Multimedia Contents(6),Government Information(6),Video Game(6),Text Collection(5),Heritage Collections(4),Government Documents(3),Digital Talking Books(3), Scientific Resources(1),Arts Collection(1)
Core Topic #2: Digital Preservation; 4 clusters of subtopics; 46 subtopics
1. Preservation(General)(174), Cultural Heritage (Preservation)(60), Migration(24),

Curation(22),Recovery(20), File formats(20), Long-term Preservation(19),Historic Preservation(16),Restoration(14),Digital Museums(13), Disaster(12),Algorithms(Preservation)(4),Disaster Recovery(4),Life-cycle Management(4),Error Recovery(2),Data Recovery(2),Data Protection(2), Preservation Management(2),Preservation Policy(2),Preservation Technologies (1),Preservation Process(1)
2. Storage(General)(634), Digital Storage(160),Data Storage Equipment(152),Digital Image Storage(136), Storage Systems(13),Distributed Storage(6), Storage Management(5),Storage Media(4),Distributed Storage Resources(3),Storage Devices(2),Storage Technology(2),Hierarchical Storage(1)
3. Archives(General)(281), Open Archives Initiative(50),Archives Management(30), Web Archiving(6),Online Archive(5),Data Archive(4)
4. Repositories(General)(211), Institutional Repositories(32),Learning Object Repositories(8),Online Repositories(3),Open Source Repositories(2),Remote Repositories(1)

Core Topic #3: Information Organization; 13 clusters of subtopics; 141 subtopics

1. Metadata(753),
Indexing(348),Abstracting(110),Interoperability(metadata)(81),Standardization(67), Keywords(44),Thesaurus(44),Automatic Indexing(33),Dublin Core(26),Metadata Harvesting(24),Vocabulary Control(24),Metadata Extraction(19),RDF(14),Subject Headings(13),Metadata Management(12),Controlled Vocabulary(12), Terminologies(12),Url(7),Video Indexing(7),Science Citation Index(6), Metadata Aggregation(6), Object Identifier(6)
2. Structured Documents(14), XML(330),HTML(119),Markup Languages(81), SGML(14),Data Format(9),Semi Structured Data(6),Non-structured Documents(2)
3. Bibliographic(161), Cataloging(30),Bibliographic Database(26),Bibliographic Records(11), Bibliometrics(10), Bibliographic Information(10), Bibliographic Data(6),Union Catalogs(3),Bibliographic Control(2),Web Cataloguing(2)
4. Discovery(84), Data Mining(253),Links(83),Navigation(74),Harvesting(44),Text Mining(32),Data Sharing(18), Routing(14), Resource Discovery(12),Information Discovery(11),Data Exchange(10),Web Mining(9),Data Exploration(6), Information Gathering(5),File Sharing(4),Capturing(3),Data Gathering(2),Data Dissemination(2)
5.Information Organization(General)(8),
Classification(256),Taxonomy(47),Categorization(46),Text Categorization(26), Document Classification(16),Classification Systems(15),Topic maps(7),Dewey Decimal Classification(6),Automatic Classification(5),Automatic Categorization(4)
6. Conceptual(General)(47), Concept Map(14),Conceptual Design(9),Conceptual Model(8),Concept Space(6), Conceptual Frameworks(5),Conceptual Graph(2), Conceptual Discovery(1)
7. Hierarchy(General)(24), Hierarchical Systems(69),Hierarchical Structure(14), Hierarchical Clustering(10), Concept Hierarchies(3),Topic Hierarchy(2)
8. Annotation(General)(125), Image Annotation(10),Video Annotation(10),Document Annotation(4),Content Annotation(2), Digital Annotation(2)
9. Compression(General)(87), Image Compression(53),Data Compression(31), Compression Ratio(5), Compression Algorithms(3)
10. Video Processing(3), Video Recording(24),Rendering(16),Video Streaming(15), Video Segmentation(8), Streaming Media(4),Video Editing(4)
11. Information Analysis(263), Data Analysis(31),Citation Analysis(30),Content Analysis(22),Documents Analysis(15),Link Analysis(9),Text Analysis(5),Speech Analysis(3),Visual Analysis(2)
12. Recognition(General)(302), Character Recognition(101),OCR(25),Handwriting

Recognition(7),Recognition Process(4), Optical Music Recognition(4)
13. Information Processing(25), Image Processing(223),Text Processing(145),Natural Language Processing (124),Personalization(63),Encoding(60),Ranking(57),Information Extraction(48),Summarization(31), Administrative Data Processing(29),Document Clustering(27),Government Data Processing(25),Information Integration(21),Name Disambiguation(19),Interpretation(14),Named Entities(12), Personalized Information(12), Authoring Tool(9), Keyphrase Extraction(8),Text Segmentation(5), Text Clustering(6),Text Extraction(6), Document Summarization(5),Speech Processing(4),Image Interpretation(3),Data Interpretations(2)

Core Topic #4: Information Retrieval; 7 clusters of subtopics; 78 subtopics

1. Information Retrieval(General)(1376), Image Retrieval(181),Content Based Retrieval(135), Multimedia(IR) (121),Bibliographic Retrieval Systems(113), Interoperability(IR)(35),Document Retrieval(26), Modeling(IR) (25),Text Retrieval(24), Video Retrieval(19), Cross Lingual(IR)(19), Relevant Documents(13), Personalisation (IR)(10),String Matching(9),Music Retrieval(8), Retrieval Effectiveness(7),Document Frequency(5),Retrieval Techniques(4), Requirement Analysis(3)
2. Multilingual(IR)(19), Cross Language(12),Machine Translation(10),Chinese(IR)(5), Language Model(5),Asian Languages(IR)(4), Indian(IR(4),Thailand(IR)(1), Multicultural(IR)(1)
3. Search(General)(768), Search Engines(496), Searching(386),Information Seeking(58),Web Search(31), Similarity Search(13),Web Search Engine(13),Search Process(12),Image Search(12),Meta Search(11),Search Strategies(10),Meta Search Engine(8), Exploratory Search(8),Search Method(8),Personalized Search(8),Federated Search(6),Video Search(5), Distributed Search(5),Full Text Search(5),Local Search(4), Enterprise Search(4), Visual Search(3),Interactive Search(3),Integrated Search(2),Music Search(2)
4 Query(General)(474), Query Language(298),Query Processing(55),Query Expansion(15), Query Search(10), Query Formulation(10), Query Refinement(5), Dynamic Query(4),SQL Query(3),Query Reformulation(3),Query Optimization(3), Query Suggestion(2),Query Recommendations(1),Query Evaluation(1)
5. Browsing(General)(95), Video Browsing(7),Document Browsing(4),Web Browsing(3)
6. Recommendation(General)(51), Recommender Systems(57),Recommendation System(17)
7. Filtering(General)(89), Collaborative Filtering(42), Filtering(Information Retrieval)(30),Information Filtering(17)

Core Topic #5: Access; 1 cluster of subtopics; 14 subtopics

1. Access(General)(319), Access Control(58), Open Access(45),Information Access (41), Data Access(22), Connection(13), Accessibility(11),Random Access(11), Multilingual Information Access(6),Internet Access(5), Universal Access(5),Multi-lingual Access(3), Access Methods(3),Wireless Access(2)

Core Topic #6: Human - Computer Interaction; 4 clusters of subtopics; 61 subtopics

1. Interactions(General)(279), Human-Computer Interaction(General)(168), Interactive Computer Graphics (34),Model(HCI)(20), Interaction Design(13),User Interaction(10), Interactive Visualization(5),3D Interaction(5), Interactive Multimedia(5), Interaction Pattern(5), Interaction Technique(4), Physical Interactions(3), Bimanual Interaction (2),Interactive Space(2), Interactive System(1),Interactive Display(1)
2. Human Engineering(70), Artificial Intelligence(139),Machine Learning(49),Human Factors(36),Face Recognition(17),Technology Acceptance Model(11),Human Information Processing(9),Visually Impaired(8), Automatic Speech Recognition(3), Facial

Expression(3),Facial Features(3),Automatic Generation(2),Spatial Memory(2),Human Cognition(1)
3. Visualization(General(262), Three Dimensional(120),3D(78),Information Visualization(52),Knowledge Representation(51),Data Visualization(33),Visual Communication(29), 2D(10),Visualization Technique(9), Contextual Information(9), Data Representation(7),Multimedia Presentation(6),3D Visualization(6),3D Model(6), Information Representation(3),Graph Visualization(2),Visual Design(2),Visual Components(2),Geographical Visualization(1)
4. User Interfaces(790), Sensor(57),Interface Design(35),User-Computer Interface(30), Web Interface(25),Sensor Network(19),Visual Interface(9),User-Centric(6),Web Design(4),User Interface Evaluation(3), User Centred Designs(3),Object-Oriented Interfaces(1),Geographical Visualization(1)

Core Topic #7: User Studies; 4 clusters of subtopics; 59 subtopics

1. Users(1208), Students(267),Children(30),Scholars(21),User Communities(15), Teachers(14),Scientific Community(14), Adults(14),Scientists(10),Graduate Students(10),Researcher(7),Research Groups(6),Web Community(4),Community Networks(3),Blind Users(3),Professor(2)
2. Usability(76), Usage(55),Usability Engineering(30),User Modeling(20),Log Analysis(16),Adaptation(14), Usability Testing(10),Query Logs(8),Weblogs(7),Log Data(7),Usability Evaluation(7),Log Files(7),User Model(6), Usage Patterns(6), Transaction Log Analysis(5),Localization(4)
3. Information Needs(26), User Requirements(12),User Interests(11),User Query(11), User Needs(10),Needs Assessment(3)
4. User Studies(General)(97), Decision Making(94),Feedback(78),Decision Support Systems(41),Behavioral Research(34),Decision Theory(26),User Profile(23),User Evaluation(19),User Behavior(19),User Experience(18), Information Seeking Behavior(16),Search Behavior(10),User Perception(7),User Satisfaction(7),Information Behavior(7),User Preferences(6),User Feedback(4),Human Memory(3),User Testing(2),Cognitive Process(2),User Communication(1)

Core Topic #8: Architecture – Infrastructure; 14 clusters of subtopics; 144 subtopics

1. Computing(General)(509), Distributed Computer Systems(236),Grid computing (153),Clustering(136), Ubiquitous Computing(90),Client Server(84),Parallel programming(33),Distributed Computing(18),Cloud Computing(7), Scientific Computing(5),Cluster Computer(2)
2. Algorithms(General)(895), Mathematical Model(457),Computational Methods(127), Learning Algorithm(53), Linear Algebra(34),Clustering Method(11),Probabilistic Model(11),Search Algorithm(9),Classification Algorithm(9),Schema Mapping(6), Computational Tools(5)
3. Infrastructure(General)(95), Platform(70), Information Infrastructure(20), Cyberinfrastructure(10),Global Information Infrastructure(2)
4. Software(General)(1203), Software Engineering (367),Computer Simulation(350), Optimization(317), Tools(256),Artificial Intelligence(139),Operating Systems(129), Open Source(95),Open Systems(50),Software Design(38), Controllers(29),Digital Library Software(28),Software Agent(26),Intelligent Systems(20),Open Source Software(20),Software Tool(17),Software Component(15),Software Reuse(11), Computer Games(7),Simulation Model(6), Application Software(6),Software Infrastructure(5),Software Platform(2),Software Requirements(2), Open Source Tools(2)
5. Architecture(General)(472), Computer Architecture(208),Interoperability (Architecture)(184),Hardware(138), Middleware(80), Peer to Peer(50),Software

Architecture(36), Vector Spaces(30),Service-Oriented Architecture (27), Network Architecture(20), Architectural Design(20), Groupware(14),Digital Library Architecture(11), Information Architecture(11), Computer Engineering(9),Digital Library Design(8), Design and Development(7), Information Model(6),Open Architecture(5),Runtime Environments(5),Hardware Architecture(4),Centralized Architecture(2),Time and Space(1)
6. Internet(699), Web(1441),Network(875),Protocols(265),Semantic Web(137), Portals(127), Neural Network(69), Web 2.0(33),Web Servers(30),Web Technology(28), WWW(21),Web Portal(11)
7. Data Sets(80), Data Structures(305),Data Model(29),Data Grid(24),Data Fusion(14), Data Type(11), Database Objects(6),Multiple Data(5),Data Center(4),Data Integrity(4), Data Warehousing(3)
8. Digital Objects(83), Object Oriented(213),Object Oriented Programming(196), Learning Object(41),Object-Oriented Modeling(2)
9. Information Systems(393), Database Systems(1047),Multimedia Systems(402), Embedded Systems(110), Digital Library Systems(88),System Design(28),Spatial Data(22),Replication(14),Content Management System(12),Design Principle(6), Database Design(5),Entity Resolution(5),Hybrid System(5),Information Systems Design(4), Data Management System(3),Spatial Distribution(2),Database Development(1)
10. Heterogeneous(General)(58), Large Scale Systems(64),Large Scale Systems(52), Scalability(27), Heterogeneous Systems(8),Heterogeneous Data(7),Heterogeneous Information(5),Heterogeneous Collections(4), Extensibility(4)
11. Integration(General)(148), Digital Library Integration(12),Integration Systems(7), Digital Library Federation(5)
12. Distributed Digital Libraries(24), Distributed Database(84),Distributed Systems(22), Distributed Data(9), Distributed Portal(3),Distributed Collections(2)
13. Fuzzy Systems(9), Fuzzy Logic(14),Fuzzy Linguistic(9)
14. Agents(General)(165), Multi Agent Systems(50),Intelligent Agent(44),Agent Based(13)

Core Topic #9: Knowledge Management; 3 clusters of subtopics; 58 subtopics

1. Knowledge Management(General)(185), Information Management(411), Knowledge Based Systems(150), Content Management(45),Data Management(38), Expert System(28),Document Management(26),Knowledge Base(23),Information Space(14),Content Management System(12),Knowledge Organization Systems(11), Personal Information Management(10),Domain Knowledge(9),Scientific Knowledge(8), Knowledge Network(8),Topic Maps(6),Knowledge Basis(5),Knowledge Map(4), Knowledge Spaces(3),Knowledge Innovation(3),Knowledge Evolution(3), External Knowledge(2),Expert Knowledge(2), Knowledge Work(1),Multimedia Data Management(1)
2. Knowledge Process(2), Knowledge Acquisition(119),Knowledge Engineering(73), Knowledge Representation(51),Knowledge Organization(25), Knowledge Sharing(22), Information Sharing(22),Knowledge Discovery(20), Information Exchange(11), Knowledge Service(9),Information Communication(8), Knowledge Extraction(6), Knowledge Transfer(4),Knowledge Map(4),Information Flow(4),Knowledge Retrieval(3), Knowledge Mining(2), Knowledge communication (1),Knowledge Building(1), Knowledge Gaps(1),Knowledge Visualization(1), Knowledge Searching(1),Knowledge Distribution(1),Knowledge Linking(1),Knowledge Translation(1),Knowledge Exchange(1)
3. Collaboration(102), Collaborative Learning(11),Collaborative Research(6), Collaborative Work(5), Collaborative Knowledge(4),Collaborative Network(2), Collaborative Technologies(1)

Core Topic #10: Digital Library Services; 1 cluster of subtopics; 30 subtopics

1. Services(General)(1134), Information Services(572),Information Dissemination(278),Web

Services(179), Library Services(84),Telecommunication Services(43),Reference Service(35),Multimedia Services(31),Web Search(31),Personal Digital Libraries(23), Service Provider(23),Search Services(14), Personalized Service(13), Service System(12),Service Quality(11),Information Exchange(11),Online Information Services(8),Reference Model(8), Data Services(7),OPAC(6),Service Integration(6),Service Model(5), Reference Systems(4),Personalized Information Services(3),Catalog Services(3),Service Infrastructure(2),Service Platforms(2),Database Providers(1),Mobile Multimedia Services(1)
Core Topic #11: Mobile Technology; 2 clusters of subtopics; 22 subtopics **1. Mobile Library(3),** Mobile Learning(7),Mobile Users(6),Mobile Services(5),Mobile Access(4),Mobile Information(3),Mobile Content(1),Mobile Reading(1),Mobile Storytelling(1) **2. Mobile(General)(147),** Wireless(63),Mobile Devices(31),Mobile Computing(22), Mobility(15), Mobile Communications(14),Wireless Networks(13), Laptop(12), PDA(3),Mobile Application(3),Wifi(2),3G(2),Mobile User Interface(1)
Core Topic #12: Social Web(Web 2.0); 3 clusters of subtopics; 21 subtopics **1. Library 2.0(110),** Librarian 2.0(15),Information Literacy 2.0(2),Library User 2.0(1) **2. Web 2.0(37) - Social Web(2),** Social Networks(51),Social Network Analysis(17), Social Networking(9),Social Media(5),Social Navigation(5)Social Search(1),Knowledge Management 2.0(KM 2.0)(1), Social Graph(1) **3. User Generated Content(3),** Social Tagging(12),Folksonomy(7), Mashup(2), Crowdsourcing(2),Wisdom of Crowds(1),Social Engagement(1)
Core Topic #13: Semantic Web (Web 3.0); 3 clusters of subtopics; 30 subtopics **1. Semantic Digital Library(21**), Library 3.0(2) **2. Semantic Web(137)-Web3.0(2)**, Semantic Technology(16),Semantic Annotation(14), Semantic Web Service(10),Semantic Information(9),Semantic Analysis(8),Faceted Search(7),Semantic Retrieval(5),Semantic Model(4),Semantic Search(4),Semantic Zooming(4),Semantic Mapping(3),Semantic Relations(3),Social Semantics(2),Semantic Interpretation(2), Semantic Metadata(2),Semantic Resources(2),Semantic Similarity(2), Semantic Knowledge(1),Semantic Representation(1) **3. Ontologies(General)(258)**, Ontology Semantics(21),Ontology-based(19),Domain Ontology(15),Formal Ontology(4),Ontology Development(2),Ontology Services(1)
Core Topic #14: Virtual Technologies; 2 clusters of subtopics; 20 subtopics **1. Virtual Library(74)**, Virtual Reference(16),Virtual Learning(8),Library 3D(7), Virtual Community(7),3D Digital Preservation(2) **2. Virtual(General)(541),**Virtual Reality(282),Virtual Machines(50),Virtual Environments(33), Cybernetics(16), Virtual Worlds(12),Second Life(10),Virtual Laboratory(10),Virtual Instrument(10),Virtual Organization(8), Virtualization(6),3D Models(4),Web 3D(3),Virtual Platform(1)
Core Topic #15: Digital Library Management; 8 clusters of subtopics; 53 subtopics **1. Policy(General)(96)**, Information Policy(6),Digital Library Policy(1) **2. Planning(General)(145)**, Strategic Planning(45),Project Planning(9),Digital Library Planning(2) **3. Finance(10):** Cost Effectiveness(41),Investment(23),Benefits(20),Budget(14),Cost Benefit Analysis(12), Pricing(5),Information Economics(1) **4. Human Resources(6),** Staff(20),Information Professionals(14),Digital Librarians(5), Curators(2) **5. Digital Library Management(21),** Project Management(254),Management

System(126),Digital Library Project(40),Organization and Management(23),Work Flows(19),Systems Development(14),Systems Development(13),Library Organization(8),Digital Library Performance(5),Management Model(4), Management Strategy(2),Library Constructions(1)
6. Evaluation(General)(310), Digital Library Evaluation(30),Case Studies(26), Performance Evaluation(16),Field Study(8),Evaluation Method(6),Performance Measure(3),Evaluation Framework(2),Heuristic Evaluation(2)
7. Quality Control(53), Quality Assurance(46),Quality Assessment(7),Information Quality(7),Quality Indicator(4),Quality Model(3), Performance Metric(3),Performance Improvement(3),Quality Metric(3)
8. Risk Management(11), Risk Assessment(18)

Core Topic #16: Digital Library Applications; 6 clusters of subtopics; 64 subtopics

1. Research(General)(623), Scholarly Communication(27),E-science(24), Design/ Methodology/Approach(17), Information Research(5),Research Institutions(3),Cultural Institutions(3),Citizen Science(3),E-discovery(1)
2. Education(General)(645), Societies and Institutions(298),Teaching(197),Academic Libraries(110), Instruction(95),Distance Education(90),School(50),National Libraries (47), Public Library(43),Higher Education(35), Educational Digital Libraries(33), Classroom(16),Public Education(4),Educational Systems(3), Online Education(3)
3. Learning(General)(621), Learning Systems(304),E-learning(113),Learning Environment(28),Learning Technology(7),Active Learning(7),Learning Management System(6),Learning Process(6),Online Courses(6), Supervised Learning(6),Learning Activities(6),Learning Methods(6),Learning Objectives(3),Taxonomy Learning(2)
4. E-government(9), Health Care(68),Medicine(39), Television(32),News(27), Hospital(23),Military(22), Offices (11),Film(11),E-governance(4),Children Digital Library(2),Electronic Administration(1),Disability Digital Library(1)
5. Natural Science(23), Geospatial(18),Life Sciences(9),NASA(5), Astrophysics(4),Digital Earth(4),Information Industry(2), Environmental Monitoring(2)
6. Social Sciences(21), Museums(53),Art(52),Culture(31),Humanities(19)

Core Topic #17: Intellectual Property, Privacy, Security; 3 clusters of subtopics; 28 subtopics

1. Intellectual Property(General)(55), Copyright(107),Rights Management(19), Authoring(17),Copyright Law(16),Digital Rights Management(DRM)(15),Copyright Protection(12),Licensing(11),Authorship(9),Digital Asset Management(DAM)(8), Intellectual Property Protection(1)
2. Security(General)(223), Cryptography(47), Digital Watermarking(33), Validation(31),Computer Crime(27), Authentication(22),Network Security(20),Security Systems(17),Authorization(11),Data Security(10),Digital Signatures(4),Security Management(2),Security Model(1),Security Policy(1)
3. Privacy(General)(38), Privacy Protection(6),Privacy Policies(1)

Core Topic #18: Cultural, Social, Legal , Economic Aspects; 4 clusters of subtopics; 25 subtopics

1. Cultural (Aspects)(103), Heritage(96),Cultural Heritages(70),Cross-Languages(15), Cross-Cultural(8),Oral History(8),Cross-Cultural Usability(4), Multicultural Digital Library(1)
2. Social (Aspects)(221), Societies and Institutions(285),Information Society(13),Digital Divide(9),Pedagogical (Aspects)(8),Digital Age(6),Citizen Science(3),Globalization(3), Knowledge Economy(2)

3. Legal Aspects(17), Law(85),Copyright Law(16),Trust(8),Censorship(2) **4. Economic (Aspects)(46),** Electronic Commerce(122),Business(42)
Core Topic #19: Digital Library Research & Development; 3 clusters of subtopics; 48 subtopics **1. Interdisciplinary(General)(12),** Computer Science(4752),Engineering(2618),Social Sciences(2129), Mathematics(1342),Biochemistry-Genetics-Molecular Biology(648), Physics and Astronomy(252), Business, Management and Accounting(246),Archive Science(238),Information Science(225),Decision Sciences(193), Academic (domains) (181),Medicine(121),Materials Science(120),Chemistry(104),Chemical Engineering (96),Earth and Planetary Sciences(89),Industry (domains)(67),Government (domains) (58),Arts and Humanities(58), Energy(56),Museum(53),Health Professions(53), Agricultural and Biological Sciences(50),Environmental Science(42), Psychology (42),Nursing(24),Curation(23),Immunology and Microbiology(22), Economics-Econometrics-Finance(20), Neuroscience(18), Pharmacology-Toxicology-Pharmaceutics(17),Dentistry(17), Multidisciplinary(15), Interdisciplinary Research(4), Interdisciplinary Collaborations(1) **2. Research and Development(91),** Digital Library Research(17),Librarianship(11), Scholarship(4),Digital Library Development(3),Digital Library Concepts(2) **3. International Cooperation(20),** International Collaboration(20),Universal Digital Libraries(5),Global Collaboration(3),International Digital Library(2),Digital Library Collaboration(1)
Core Topic #20: Information Literacy; 1 cluster of subtopics; 20 subtopics **1. Information Literacy(General)(40),** Decision Making(90),Reading(55),Information Society(13), Digital Divide(9),Information Overload(8), Ethics(7),Information Searching(7),Critical Thinking(6),Learning Communities(6),Lifelong Learning(5),User Education(4),Information Ethics(3),Critical Evaluation(3), Decision Process(2), Adult Learning(2), Interactive Learning Environment(2), Knowledge Economy(2), Media Literacy(2), Computer Literacy(1)
Core topic #21: Digital Library Education; 1 cluster of subtopics; 5 subtopics **1. Digital Library Education(General)(148)**, Digital Library Program(20),Computer Science Education(9), Digital Library Training(2), Digital Library Curriculum(1)

4.3 Overview of Digital Library Research Trends (1990-2010)

Figure 4.1 and Figure 4.2 present an overview of digital library research trends for two decades (1990-2010). Figure 4.1 shows the proportion (in terms of percentage) of publications within each core topic, and Figure 4.2 shows the number of subtopics under each core topic.

In the Figure 4.1, *Architecture – Infrastructure* (23%), *DL Research & Development* (21%) and *Information Organization* (9%) are the top 3 core topics having the largest numbers of publications while the topics of *DL Education* (0.003%), *Information Literacy* (0.004%) and *Social Web (Web 2.0)* (0.004%) have the least number of publications.

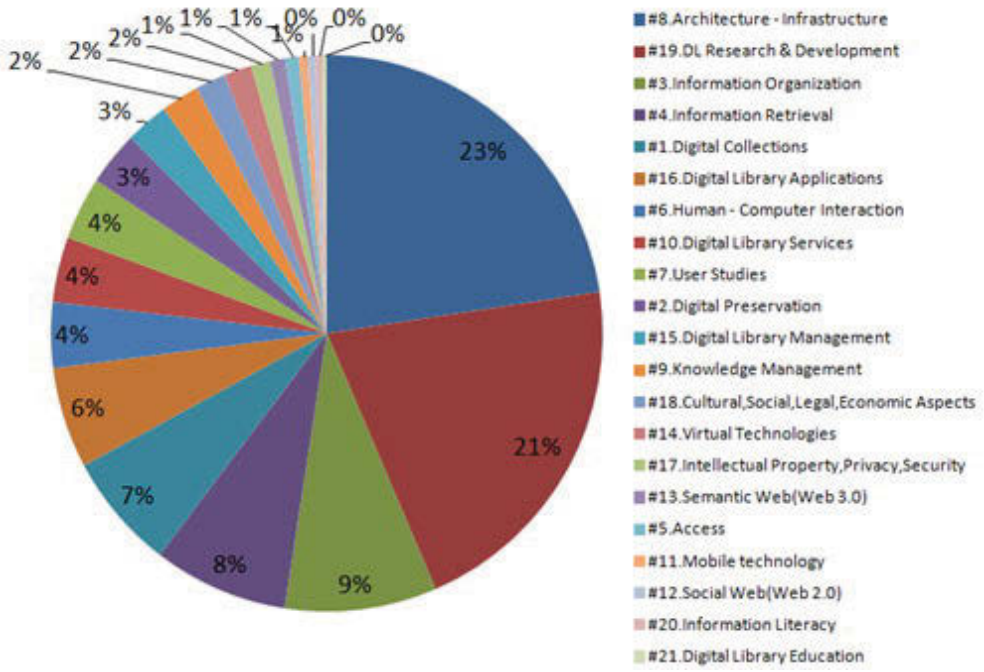

Figure 4.1: Rate of Publications within Each Core Topic of Digital Library Research (1990-2010)(Note: topics showing 0% in Figure 4.1 actually have very small percentages such as 0.003%, 0.004%)

Similarly, in Figure 4.2, *Architecture – Infrastructure* (14%) and *Information Organization* (14%) are the top 2 core topics having the highest number of subtopics while *DL Education* (0.005%) and *Information Literacy* (1%) have the fewest.

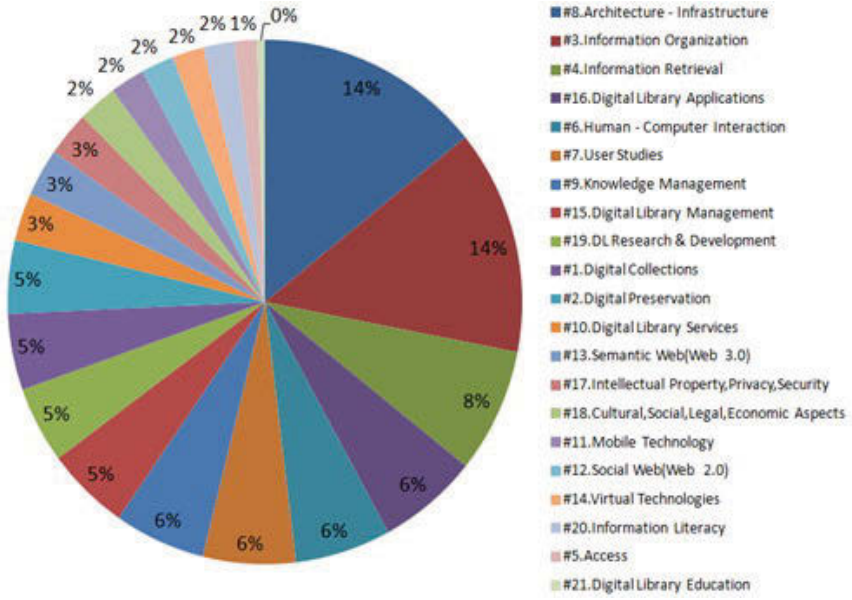

Figure 4.2: Rate of Number of Subtopics Identified Within Each Core Topic of Digital Library Research (1990-2010) (Note: subtopics showing 0% in Figure 4.2 actually have very small percentages such as 0.005%)

4.4 Domain Definition and Analysis

A pie chart has been drawn to show the proportion of publications under various subtopics within each core topic. For most of the core topics, the pie chart has been drawn to show the publications of the top ten subtopics that cover the majority of publications in the topic. However, for two core topics: *Architecture – Infrastructure* and *Information Organization,* it was noted that the publications of the top ten subtopics cover only less than half of the publications in the given topic. Hence, for these two core topics, the pie chart shows the publications of top 15 subtopics.

Core Topic #1. Digital Collections (48 subtopics)

A digital collection consists of digital objects that are selected and organized to facilitate their discovery, access, and use (NISO, 2008). This core topic is composed of 5 clusters of subtopics, viz. *Collections* (General), *Acquisition*, *Database* (General), *Collection Management*, and *Multimedia* (General).

Figure 4.3 shows the top 10 subtopics with the highest publication numbers. *Database* (General) (26%), *Resources* (13%) and *Multimedia* (General) (11%) are the 3 subtopics with the highest number of interests (publications) followed by *Acquisition* (9%), *Collections* (General) (8%), and *Electronic Publishing* (6%). Similarly areas of least interest (in terms of number of publications) are *Video* (5%), *Electronic Journals* (2%) and *Audio* (2%). Overall, the top 10 subtopics account for 84% of publications under this core topic, compared to the remaining 38 subtopics that account for only 16% publications. It may be noted that 26% of publications in this core topic come under the subtopic *Database* (General). This means that over a quarter of publications in this core topic still have the keyword *Database* which means that they cover databases in general (as opposed to specific topics like *Acquisition*, *Electronic Publishing*, *Video*, etc.) in the context of the core topic of *Digital Collections*.

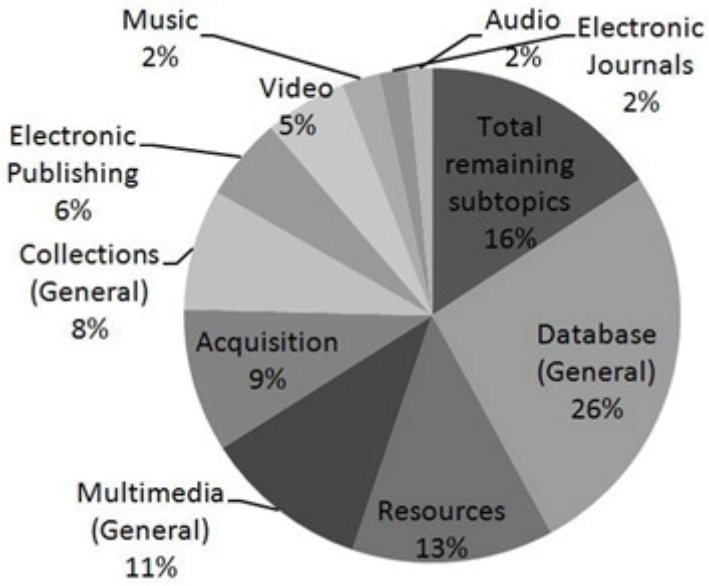

Figure 4.3: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #1. Digital Collections

Core Topic #2. Digital Preservation (46 subtopics)

Digital Preservation is the set of processes, activities and management of digital information over time to ensure its long term accessibility. The goal of digital preservation is to preserve materials resulting from digital reformatting, and particularly information that is born-digital with no analog counterpart. Because of the relatively short lifecycle of digital information, preservation is an ongoing process (JISC, 2012; DPC, 2009). In the knowledge map, there are 4 clusters of subtopics, viz. *Preservation* (General), *Storage* (General), *Archives* (General), *Repositories* (General).

As shown in Figure 4.4, the top 10 most studied subtopics account for 87% of publications under this core topic. *Storage* (General) (30%), *Archives* (General) (13%) and *Repositories* (General) (10%) are the most popular (studied) subtopics. On the lower end, there are 7 subtopics, viz. *Preservation* (General) (8%), *Digital Storage* (8%), *Data Storage Equipment* (7%), *Digital Image Storage* (6%), *Open Archives Initiative* (2%), *Institutional Repositories* (2%) and *Archives Management* (1%). The total 36 remaining subtopics account only for 13% of publications. However, it is also interesting to note that over half of the publications in this core topic cover the general aspects of three subtopics, viz. *Storage* (General; 30%), *Archives* (General; 13%), and *Repositories* (General; 10%). It means that a large proportion of research papers still have keywords like *Storage*, *Archives* and *Repositories*, and therefore a significant proportion of publications discuss the general aspects of storage, archives, etc.,

as opposed to more specific aspects like *Data Storage*, *Image Storage*, *Institutional Repositories*, *Archives Management*, etc.

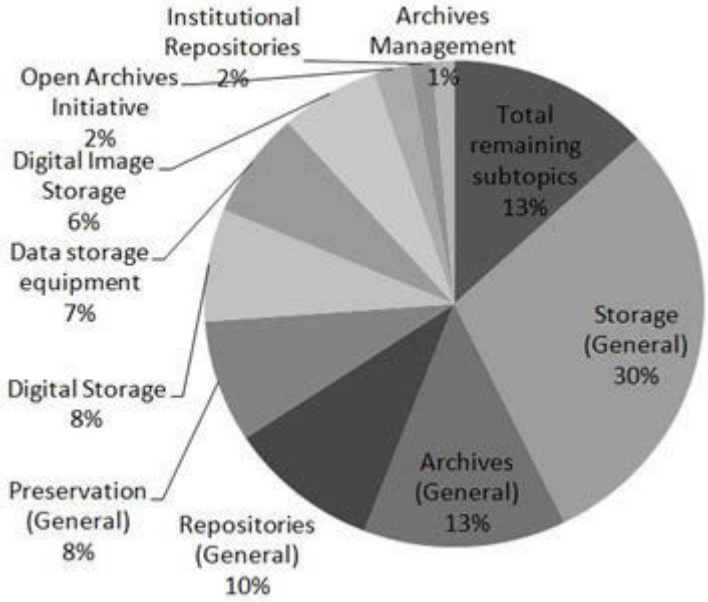

Figure 4.4: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #2. Digital Preservation

Core Topic #3. Information Organization (141 subtopics)

Information Organization is about activities such as document description, indexing and classification performed in libraries, databases, archives, etc., done by librarians, archivists, subject specialists as well as by computer algorithms. As a field of study, this core topic is concerned with the nature and quality of such knowledge organizing processes as well as the knowledge organizing systems used to organize documents, document representations and concepts (Hjørland, 2008). In the map, 141 subtopics are categorized into 13 clusters of subtopics, viz. *Metadata*, *Structured Documents*, *Bibliographic* (organization), *Discovery*, *Information Organization* (General), *Conceptual* (organization) (General), *Hierarchy* (General), *Annotation* (General), *Compression* (General), *Video Processing*, *Information Analysis*, *Recognition* (General), and *Information Processing*.

In Figure 4.5, *Metadata* (12%) stands at the top of the top 15 subtopic list. *Indexing* with 6% comes the second. There are 3 groups of subtopics having the same percentages, viz. Group 1: *Recognition* (General) and *XML* with 5% each; Group 2: *Information Analysis, Classification, Data Mining, Image Processing* with 4% each; Group 3: *Annotation* (General), *Text Processing, Natural Language Processing, HTML, Abstracting, Character Recognition* with 2% each. *Bibliographic*, standing at the middle of the list, accounts for 3%.

The chart shows that the top 15 subtopics cover 60% of total publications under the core topic and the rest (40%) is shared by total 126 remaining subtopics.

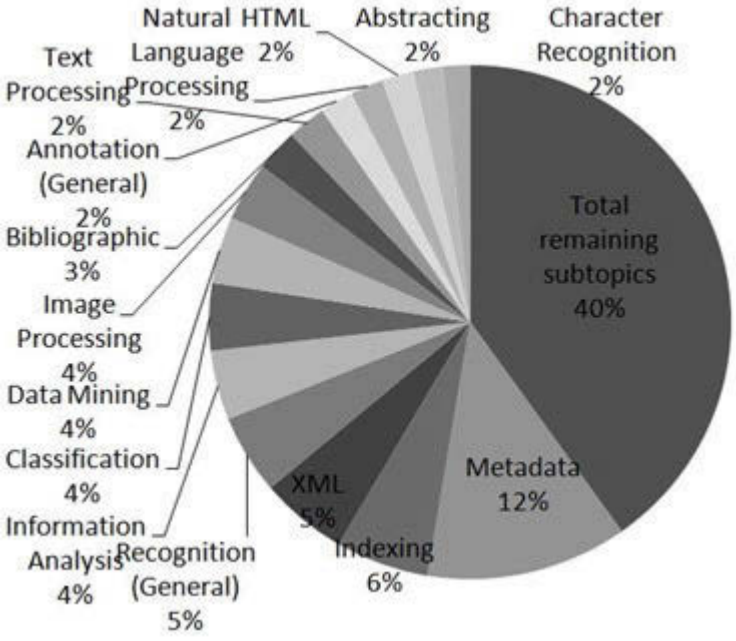

Figure 4.5: Top 15 Subtopics With Highest Publication Numbers Within Core Topic #3. Information Organization

Core Topic #4. Information Retrieval (78 subtopics)

Information retrieval deals with the representation, storage, organization of, search and access to information items (e.g. multimedia forms: text, documents, video, music, images, speech, etc.). The representation and organization of information items should provide users with easy search and access to the information in which they are interested in (Baeza-Yates et al, 1999). The core topic is interdisciplinary, based on computer science, mathematics, library science, information science, information architecture, cognitive psychology, linguistics, and statistics. There are 7 clusters of subtopics including *Information Retrieval* (General), *Multilingual (IR)*, *Search* (General), *Query* (General), *Browsing* (General), *Recommendation* (General), and *Filtering* (General).

In Figure 4.6, 40% of the publications are covered by two subtopics like *Information Retrieval* (General) (26%), and *Search* (General) (14%). Two subtopics, viz. *Search Engine* and *Query* (General) have the same percentage as 9% each. Similarly, *Image Retrieval* and *Content Based Retrieval* cover 3% publications each, and *Multimedia (IR)* and *Bibliographic Retrieval Systems* cover 2% publications each. Overall, the top 10 subtopics cover 81% of total publications under this core topic while the 68 remaining subtopics

account for only 19% publications. However, it may also be noted that nearly half of the publications have one of the three subtopics viz. *Information Retrieval* (General), *Search* (General) and *Query* (General). It means that a large proportion of research papers still have keywords like *Information Retrieval*, *Search* and *Query*, and therefore a significant proportion of publications discuss the general aspects of these subtopics, as opposed to more specific subtopics like *Image Retrieval, Content based Retrieval, Search Engines, Query Language*, etc.

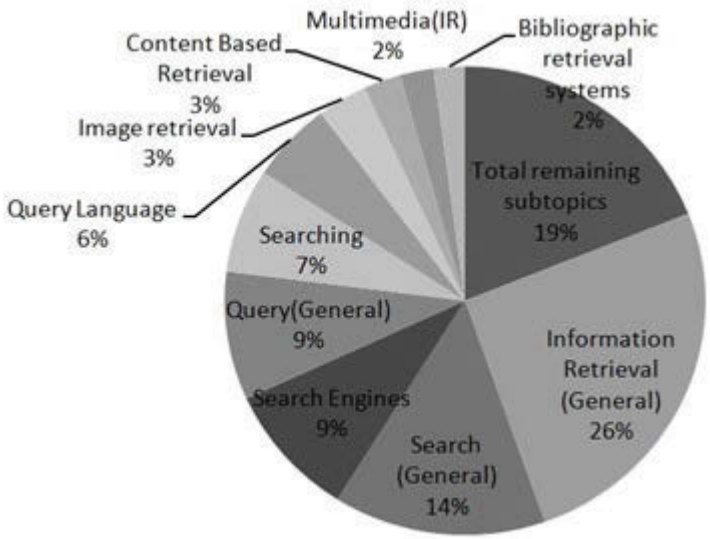

Figure 4.6: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #4. Information Retrieval

Core Topic #5. Access (14 subtopics)

Information access is a term used to describe an area of research at the intersection of Informatics, Information Science, Information Security, Language Technology, Computer Science, and Library Science. The objective of the various research efforts in information access is to simplify and facilitate access for human users and further process large and unwieldy amounts of data and information in digital library (Frederic et al, 2010). One cluster of subtopic is made under this core topic.

In the Figure 4.7, *Access* (General) is at the top of the list with 59% publications, followed by *Access Control* (11%). *Open Access* and *Information Access* have 8% publications each; *Connection*, *Accessibility*, and *Random Access* have 2% each; and *Multilingual Information* and *Internet Access* have 1% publications each. It may be noted that nearly two-thirds of the

research output in this area still cover the general aspects of information access while comparatively little research is undertaken in the specific areas of information access.

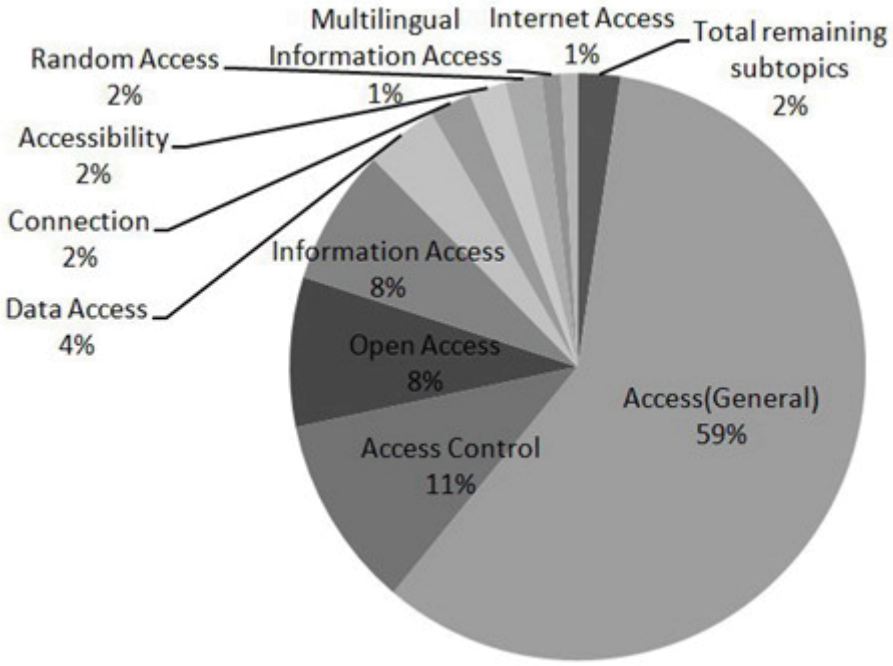

Figure 4.7: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #5. Access

Core Topic #6. Human - Computer Interaction (61 subtopics)

Human – Computer Interaction involves the study, planning, and design of the interaction between people (users) and computers. It is often regarded as the intersection of computer science, behavioural sciences, design and several other fields of study (Sears et al, 2008; Tripathi, 2011). Under this core topic, 4 clusters of subtopics with total 61 subtopics are categorized as follows: *Interactions* (General), *Human Engineering*, *Visualization* (General), and *User Interfaces*.

In Figure 4.8, *User Interfaces* (31%) have the maximum number of publications, followed by *Interactions* (General) (11%), *Visualization* (General) (10%) and *Human – Computer Interaction* (6%). There are 3 groups of subtopics having the same percentages, viz. Group 1: *Artificial Intelligence* and *Three Dimensional* with 5% each; Group 2: *3D* and *Human Engineering* with 3% each; Group 3: *Sensor* and *Information Visualization,* having the least number of publications, with 2% each. In general, the top 10 subtopics mainly account for 78% of total publication under this core topic while the 51 remaining subtopics cover only 22%.

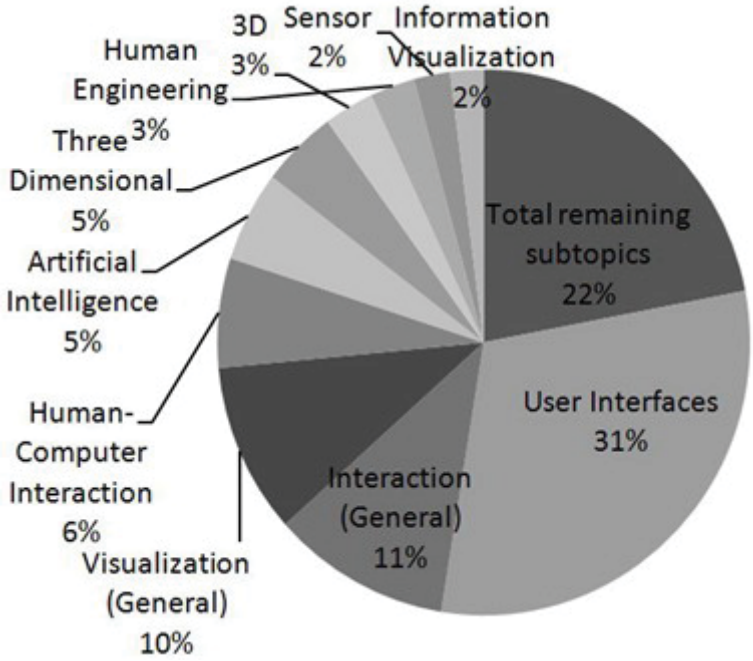

Figure 4.8: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #6. Human - Computer Interaction

Core Topic #7. User Studies (59 subtopics)

User Studies are investigations of the use and users (including non-users and potential uses and users) of documents, information, communication channels, information systems and information services of digital libraries (Hjørland, 2007b). In the knowledge map, *Users*, *Usability*, *Information Needs* and *User Studies* (General) are categorized into 4 clusters of subtopics and 59 subtopics.

In the Figure 4.9, *Users* (49%) accounts for nearly half of total publication of the core topic, followed by *Students* (11%). *User Studies* (General) and *Decision Making* cover 4% publications each, *Usability* and *Feedback* cover for 3% each, *Usage* and *Decision Support Systems* cover 2% each, and *Behavioural Research* and *Children* cover 1% each. The top 10 subtopics account for 80% of the total publications under this core topic while the 49 remaining subtopics cover only 20%.

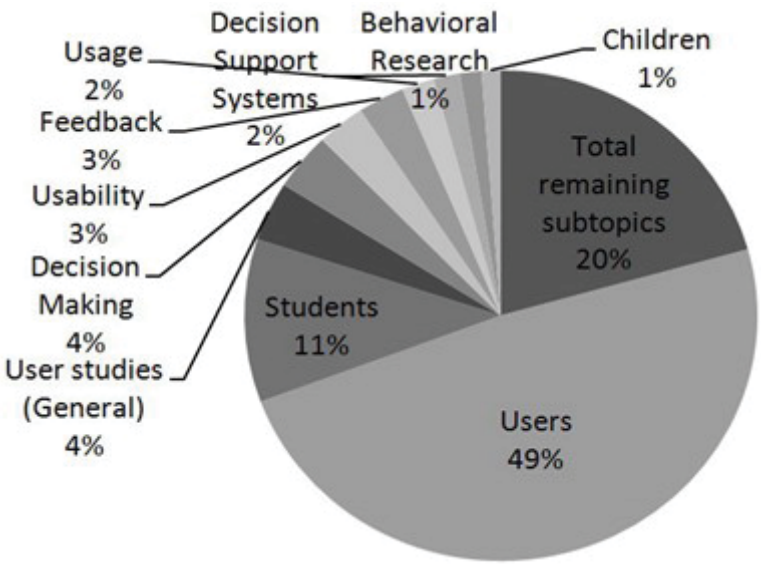

Figure 4.9: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #7. User Studies

Core Topic #8. Architecture – Infrastructure (144 subtopics)

Digital library architecture is a term that is used to denote a variety of design tools, techniques and features of digital libraries including computer hardware and software, modelling, programming, simulation, imaging and a variety of associated digital technologies (Ali & Brebbia, 2006). Digital library infrastructure is defined as a combined set of hardware, software, networks, facilities, etc. in order to develop, test, deliver, monitor, control or support information technology services in a digital library (Veen & Jan, 2007). As the most studied core topic with 144 subtopics, *Architecture - Infrastructure* has 14 clusters of subtopics: *Computing* (General), *Algorithms* (General), *Infrastructure* (General), *Software* (General), *Architecture* (General), *Internet*, *Data Sets*, *Digital Objects*, *Information Systems*, *Heterogeneous* (General), *Integration* (General), *Distributed Digital Libraries*, *Fuzzy Systems*, and *Agents* (General).

In Figure 4.10, *Web* (9%), *Software* (General) (8%) and *Database Systems* (7%) are top 3 subtopics. There are 3 groups of subtopics having the same percentages, viz. Group 1: *Algorithms* (General) and *Network* with 6% each; Group 2: *Computing* (General), *Mathematical Model, Architecture (General)*, *Multimedia Systems* and *Information Systems* with 3% each; Group 3: *Software Engineering, Computer Simulation, Optimization, Data Structures* with 2% each. At the middle of the list, *Internet* accounts for 5%. Overall, the top

15 subtopics constitute 63% of total publications under the core topic while the rest (37%) is shared by the 129 remaining subtopics.

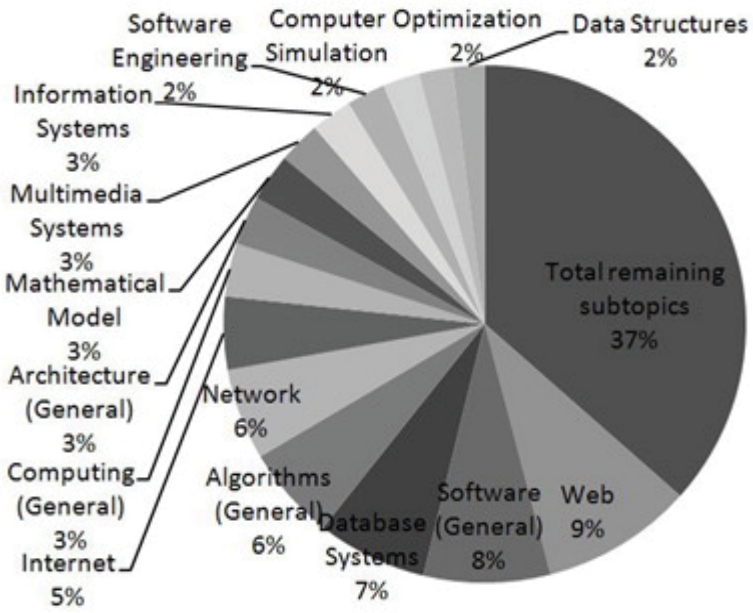

Figure 4.10: Top 15 Subtopics With Highest Publication Numbers Within Core Topic #8. Architecture - Infrastructure

Core Topic #9. Knowledge Management (58 subtopics)

Knowledge management comprises a range of strategies and practices used in an organization to identify, create, represent, distribute, and enable adoption of insights and experiences (Wang et al, 2001; Wallace et al, 2007). Under the core topic, the 58 subtopics are divided into 3 clusters of subtopics, namely: *Knowledge Management* (General), *Knowledge Process* and *Collaboration*.

In Figure 4.11, *Information Management*, at the top of the list, accounts for 27% of publications, followed by *Knowledge Management* (General) (12%), *Knowledge Based Systems* (10%), *Knowledge Acquisition* (8%), *Collaboration* (7%) and *Knowledge Engineering* (5%). There are 2 groups having the same percentages, viz. *Content Management* and *Knowledge Presentation* with 3% each, and *Data Management* and *Expert System* with 2% each. Overall, the top 10 subtopics cover 79% of total publications of this core topic while the rest (21%) is shared by the 48 remaining subtopics. It may be noted that 12% of the publications in this topic have *Knowledge Management* as a keyword which means that 12% of research publications in this core topic discuss general aspects of knowledge management as opposed to specific subtopics like *Knowledge-based Systems*, *Knowledge Acquisition*, etc.

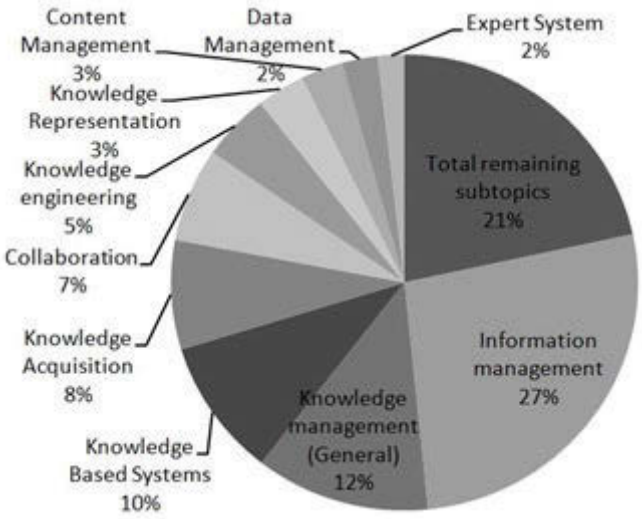

Figure 4.11: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #9. Knowledge Management

Core Topic #10. Digital Library Services (30 subtopics)

A very important role of a digital library is to provide users with services, e.g. information services, reference service, multimedia services, etc. that help users to connect, access and use the digital library collections. In the knowledge map, *Service*s (General) including 30 subtopics is only one cluster of subtopics under the core topic.

In Figure 4.12, *Service* (General) is the most studied subtopic with 44% publications, followed by *Information Services* (22%), *Information Dissemination* (11%), *Web Services* (7%) and *Library Services* (3%). Two subtopic groups having similar percentages are *Telecommunication Services* and *Reference Service* with 2% each; *Web Search*, *Multimedia Services*, and *Personal Digital Library* with 1% publications each. Overall, the 10 subtopics account for 94% publications compared to 6% covered by the 20 remaining subtopics. It may be noted that 44% of the research publications in this topic have *Service* as a keyword, i.e. 44% papers discuss the general aspects of services rather than specific subtopics like *Information Services*, *Information Dissemination*, *Web Services*, etc. in the context of digital library services.

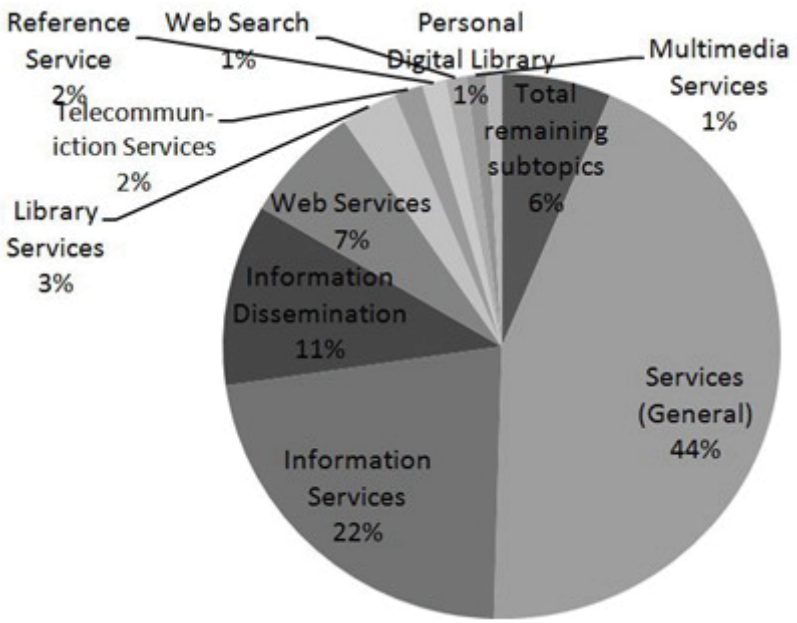

Figure 4.12: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #10. Digital Library Services

Core Topic #11. Mobile Technology (22 subtopics)

Mobile technology is a collective term used to describe various types of cellular communication technology (Gloire Tech, 2010). Adopted in digital library environment, this technology has transformed digital library services moving from desktop to laptop, smart phones, tablet PCs etc. via Wireless - Wi-Fi, 3G networks etc. Under this core topic, 22 subtopics are categorized into 2 clusters of subtopics, viz. *Mobile Library*, *Mobile (General)*.

In Figure 4.13, *Mobile (General)* is the top subtopic with 41%, followed by *Wireless* (17%), *Mobile Devices* (9%) *Mobile Computing* (6%) and *Laptop* (3%). *Mobility*, *Mobile Communication* and *Wireless Network* have the same proportion of publications with 4% each. Similarly, *Mobile Learning* and *Mobile Users* account for 2% each. Thus, the top 10 subtopics account for 92% of total publications compared to 8% covered by the 12 remaining subtopics. It may be noted that 41% of the publications in this topic have *Mobile* as a keyword, i.e., a large proportion of publications cover general aspects of *Mobile* rather than the specific subtopics like *Wireless*, *Mobile Devices*, etc. in the context of digital libraries.

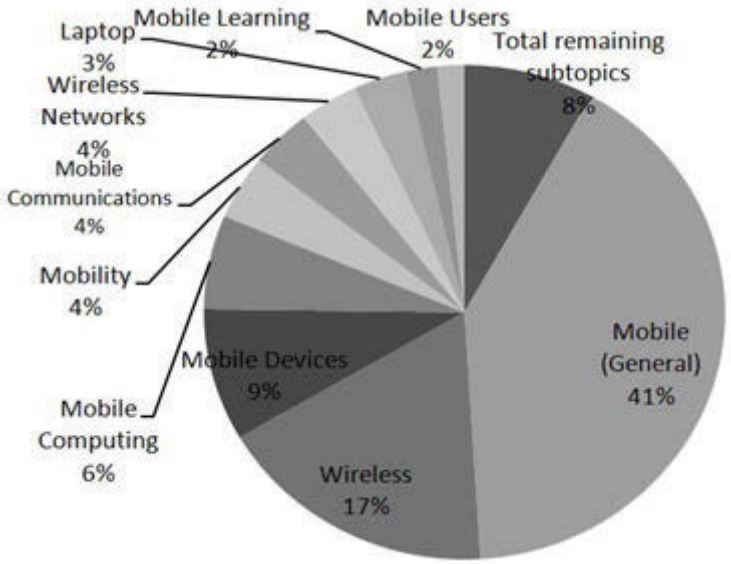

Figure 4.13: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #11. Mobile Technology

Core Topic #12. Social Web (Web 2.0) (21 subtopics)

The Social Web (Web 2.0) is commonly associated with web applications that facilitate interactive information sharing, interoperability, user-centred design, and collaboration on the World Wide Web (O'Reilly, 2005). The technology has created an evolution for digital libraries and it has given rise to new concepts like *Library 2.0*. Under this core topic, 21 subtopics are structured into 3 clusters of subtopics, viz. *Library 2.0*, *Web 2.0* and *User Generated Content*.

In Figure 4.14, the top subtopic *Library 2.0* accounts for 37% publications, followed by *Social Networks* (17%), *Web 2.0* (12%), *Social Networking* (7%), *Social Network Analysis* (6%), *Librarian 2.0* (5%) and *Social Tagging* (4%). There are 3 subtopics having the same percentage (2%), namely *Folksonomy*, *Social Navigation* and *Social Media*. The top 10 subtopics mainly account for 94% of total publications compared to the rest (6%) covered by the 11 remaining subtopics.

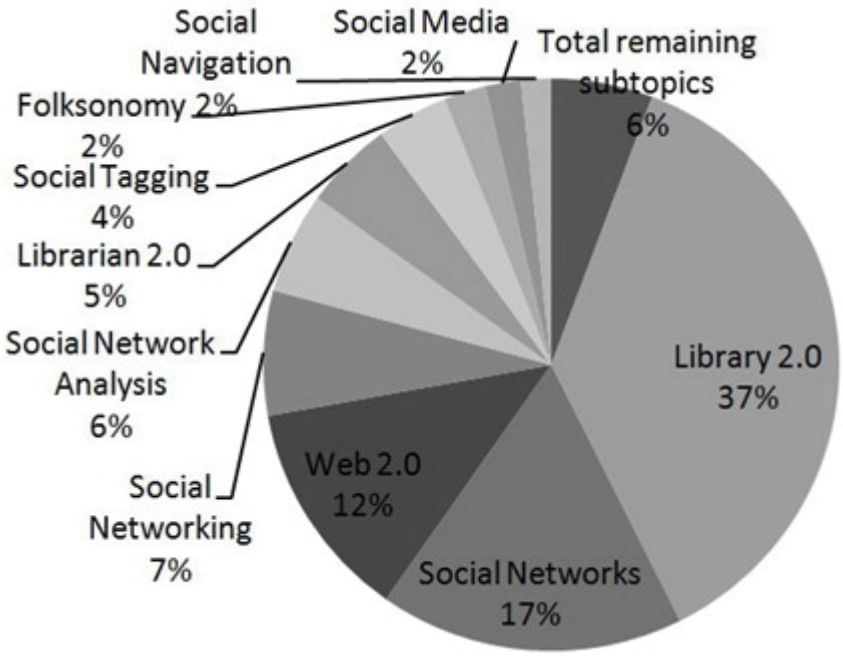

Figure 4.14: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #12. Social Web(Web 2.0)

Core Topic #13. Semantic Web (Web 3.0) (30 subtopics)

The Semantic Web is a collaborative effort led by W3C with participation from a large number of researchers and industrial partners (W3C, 2012). In fact, it is the extension of the World Wide Web that enables people to share content beyond the boundaries of applications and websites (Semanticweb.org., 2012). Under this core topic, 30 subtopics are classified into 3 clusters of subtopics, viz. *Semantic Digital Library*, *Semantic Web*, and *Ontologies* (General).

In Figure 4.15, two subtopics, viz. *Ontologies* (General) (44%) and *Semantic Web* (Web 3.0) (23%) are ranked first and second respectively. Three groups viz. *Ontology – Based*, *Semantic Digital Library*, *Ontology Semantics*, have 4% publications each; *Domain Ontology* and *Semantic Technology*, have 3% publications; and *Semantic Annotation* and *Semantic Web Service* have 2% publications each. At the bottom of the list, *Semantic Information* accounts for only 1%. In general, the top 10 subtopics account for 90% of total publications compared to 10% covered by the 20 remaining subtopics. However, it may be noted that 44% of the publications have *Ontologies* as a keyword, i.e. they discuss general aspects of ontologies as opposed to specific issues like *Semantic Digital Library*, *Domain Ontology*, etc.

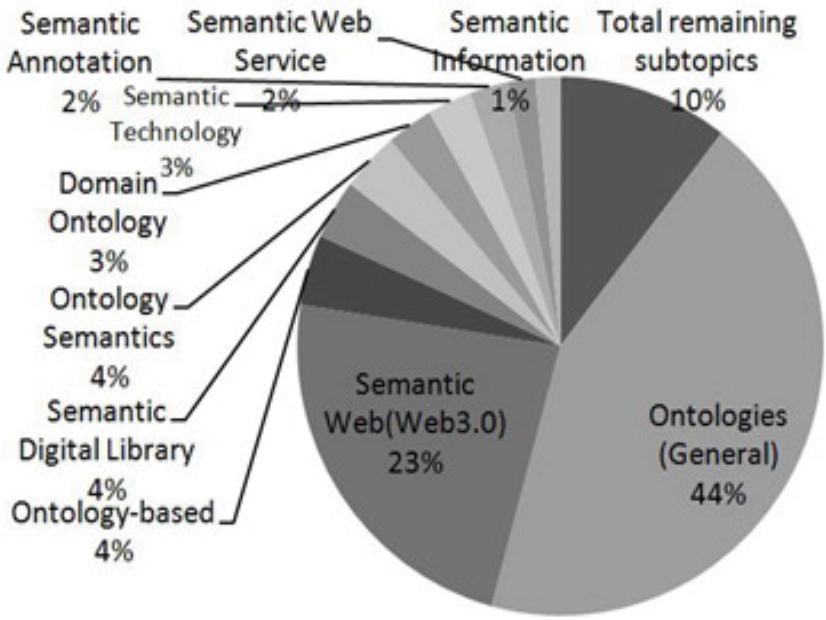

Figure 4.15: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #13. Semantic Web(Web 3.0)

Core Topic #14. Virtual Technologies (20 subtopics)

Virtualization, in computing, is the creation of a virtual (rather than actual) version of something, such as: a hardware platform, operating system, a storage device or network resources. As part of an overall trend in IT enterprise, the usual goal of virtualization is to centralize administrative tasks while improving scalability and overall hardware-resource utilization (IBM, 2007). Under this core topic, 20 subtopics are grouped into 2 clusters of subtopics, viz. *Virtual Library* and *Virtual* (General).

In Figure 4.16, *Virtual* (General) (49%) and *Virtual Reality* (26%) are the top 2 subtopics of the list, followed by *Virtual Library* (7%), *Virtual Machines* (5%) and *Virtual Environments* (3%). *Virtual Worlds*, *Cybernetics*, *Virtual Reference*, *Virtual Instrument* and *Virtual Laboratory* cover 1% publications each. Overall, the top 10 subtopics account for 95% of total publications compared to 5% covered by the 10 remaining subtopics. However, it may be noted that nearly half (49%) of the publications have *Virtual* as a keyword, i.e. they discuss general aspects as opposed to specific technologies like *Virtual Reference*, *Virtual Instrument*, etc.

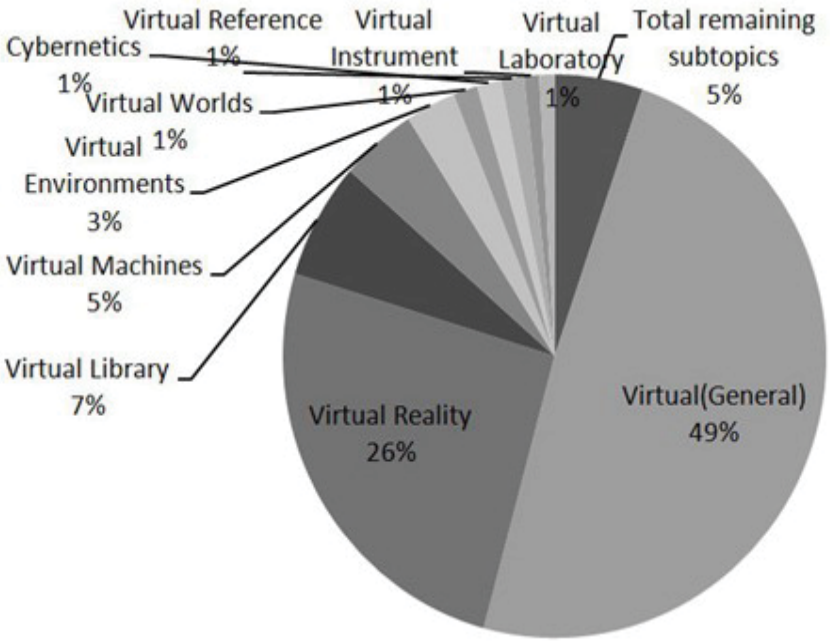

Figure 4.16: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #14. Virtual Technologies

Core Topic #15. Digital Library Management (53 subtopics)

Digital library management is a broad term that brings together professionals, researchers, educators, librarians of digital library field and those from related fields such as Computer Science, Knowledge Management, Communication, Business, Law, Museum etc., to accomplish desired goals and objectives of digital library management activities, such as: planning, organizing, staffing, leading or directing, and controlling the staff, project management, etc. Under this core topic, 53 subtopics are categorized into 8 clusters of subtopics, viz. *Policy* (General), *Planning* (General), *Finance*, *Human Resources*, *Digital Library Management*, *Evaluation* (General), *Quality Control*, and *Risk Management*.

In Figure 4.17, *Evaluation* (General) is on the top with 18% publications, followed by *Project Management* (15%), *Digital Library Education* (9%), *Planning* (General) (8%), *Management System* (7%), and *Policy* (General) (6%). Three subtopics, namely *Quality Assurance, Quality Control* and *Strategic Planning* share the same proportion of publications (3% each). *Cost Effectiveness* is at the bottom of the list with 2% publications. Overall, the top 10 subtopics account for 74% of total publications compared to the rest (26 %) covered by the 43 remaining subtopics. It may be noted that three subtopics *Evaluation* (General), *Planning* (General) and *Policy* (General) cover about a third of the publications in

this core topic. In other words, about a third of the publications cover the general aspects of one of these subtopics, rather than specific subtopics like *Quality Assurance*, *Quality Control*, etc.

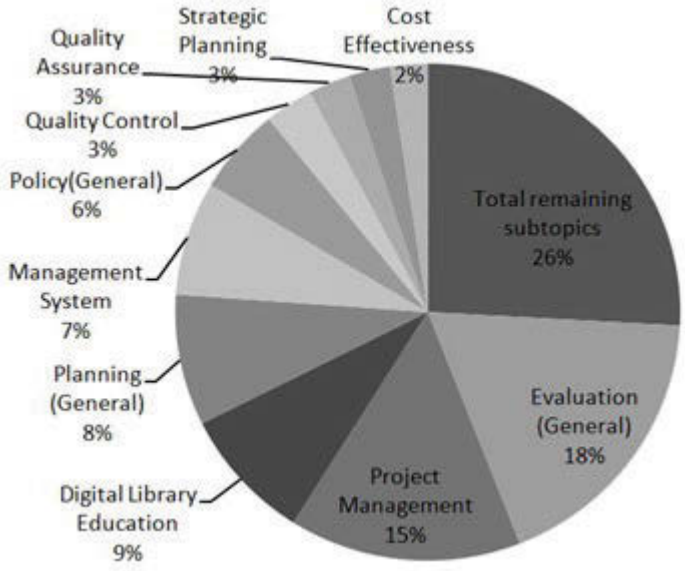

Figure 4.17: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #15. Digital Library Management

Core Topic #16. Digital Library Applications (64 subtopics)

Digital libraries are created for a variety of applications and uses. Digital libraries are not only used in academic and research environment, they are also applied in other sectors, such as: in offices of government, military, healthcare, geospatial, space, art, culture, etc. Under this core topic, 64 subtopics are categorized into 6 clusters of subtopics, viz. *Research* (General), *Education* (General), *Learning* (General), *Offices*, *Natural Science*, and *Social Sciences*.

In Figure 4.18, the top 3 subtopics viz. *Research* (General), *Education* (General), *Learning* (General) have similar proportion of publications (16% each), followed by *Learning Systems* (8%), *Societies and Institutions* (7%) and *Teaching* (5%). Two subtopics viz. *E-learning*, and *Academic Libraries* have 3% publications each while *Instruction,* and *Distance Education* have 2% publications each. In general, the top 10 subtopics account for 78% of total publications compared to the rest (22 %) covered by the 54 remaining subtopics. It may be noted that three subtopics *Education* (General), *Research* (General) and *Learning* (General) cover about a third of the publications in this core topic. In other words, about a third of the publications cover the general aspects of one of these subtopics, rather than specific subtopics like *Teaching, E-learning, Distance Education*, etc.

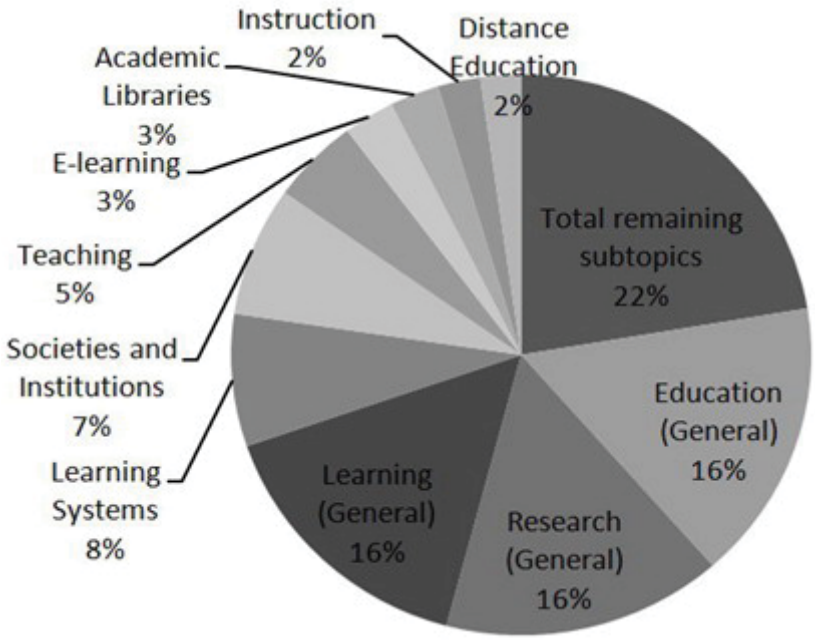

Figure 4.18: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #16. Digital Library Applications

Core Topic #17. Intellectual Property, Privacy, Security (28 subtopics)

This core topic cover 3 separate but interrelated concepts. First, Intellectual Property is a legal term referring to a set of exclusive rights associated with a creative content (Raysman, 1999; Joshi, 2006). Second, Information Privacy (or data privacy) is the relationship between collection and dissemination of data, technology, the public expectation of privacy, and the legal and political issues surrounding them (Solove et al, 2009; Library of Congress, 1997). Third, Information Security means protecting information and information systems from unauthorized access, use, disclosure, disruption, modification, perusal, inspection, recording or destruction . Under this core topic, 28 subtopics are divided into 3 clusters of subtopics, viz. *Intellectual Property* (General), *Security* (General), *Privacy* (General).

In Figure 4.19, *Security* (General) (29%) stands first, followed by *Copyright* (General) (14%), *Intellectual Property* (General) (7%), *Cryptography* (6%) and *Privacy* (5%). *Digital Watermarking*, *Validation*, and *Computer Crime* cover 4% publications each. *Authentication* and *Network Security* cover for 3% publications each. The top 10 subtopics account for 79% of the total publications compared to the rest (21%) covered by the 18 remaining subtopics. It may be noted that half of the publications in this topic have three

keywords like *Security*, *Copyright* and *Intellectual Property*, i.e. they discuss the general aspects of these three subtopics, as opposed to specific subtopics like *Crytography*, *Privacy*, *Digital Watermarking*, etc.

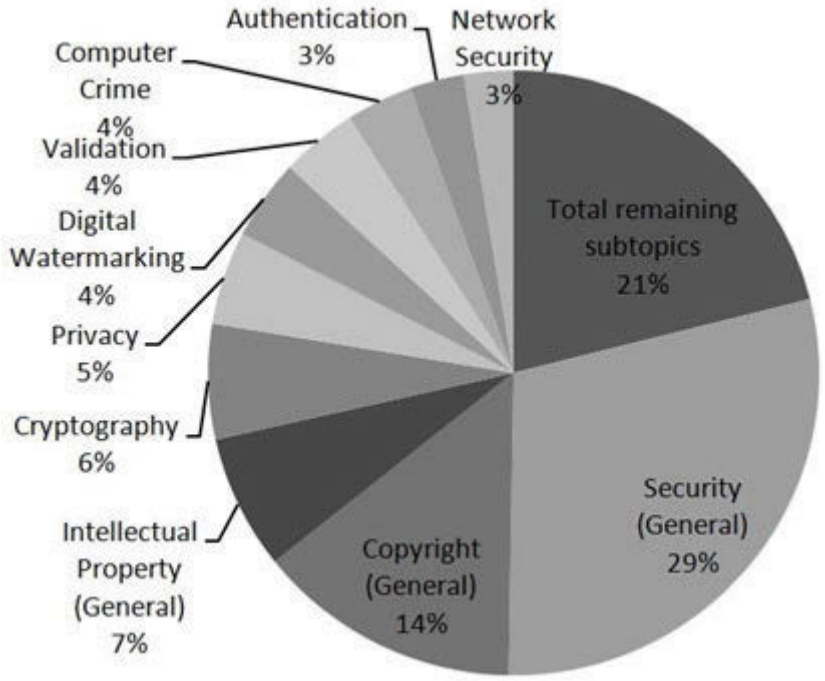

Figure 4.19: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #17. Intellectual Property, Privacy, Security

Core Topic #18. Cultural, Social, Legal, Economic Aspects (25 subtopics)

Digital libraries are the hubs of knowledge and culture. Therefore, any digital library is always functioned within a specific related cultural, social, economic and legal environment. Under this core topic, 25 subtopics are structured into 4 clusters of subtopics, viz. *Cultural (Aspects)*, *Social (Aspects)*, *Legal (Aspects)*, and *Economic (Aspects)*. The subtopics, *Cultural*, *Social*, etc., appeared as keywords in the published abstracts, but the word *Aspects* has been added with these subtopics in order to indicate that they cover cultural, legal, social and economic aspects of digital library.

In Figure 4.20, *Societies and Institutions* (24%), *Social (Aspects)* (19%) and *Electronic Commerce* (10%) are the top 3 subtopics, followed by *Cultural (Aspects)* (9%), *Heritage* (8%), *Law* (7%), *Cultural Heritages* (6%), *Economic (Aspects)* (4%), *Business* (3%), and *Legal (Aspects)* (1%). Overall, the top 10 subtopics account for 91% of total publications while the rest 15 remaining subtopics cover for only 9% publications in this topic.

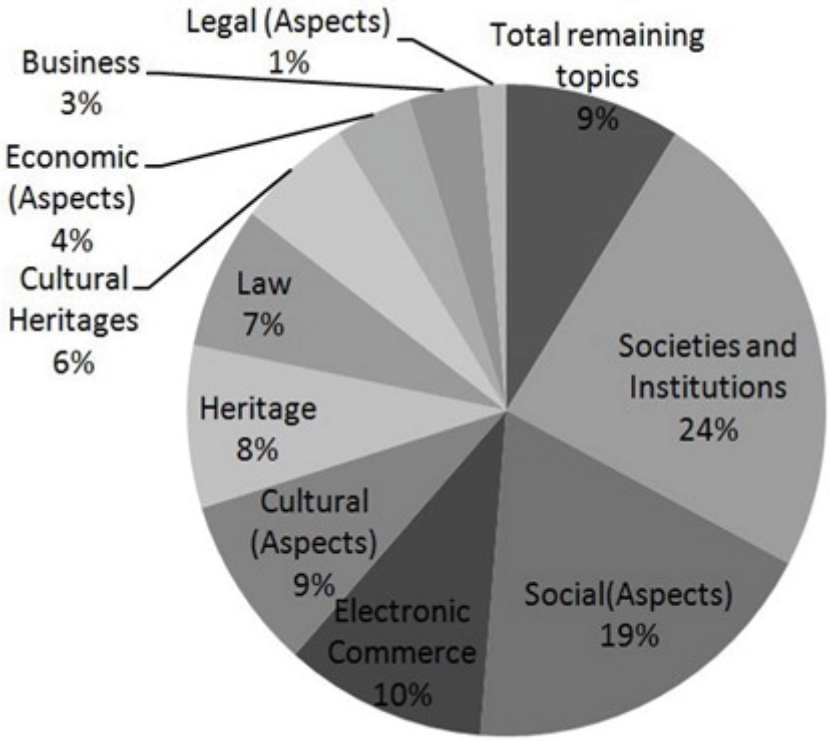

Figure 4.20: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #18. Cultural, Social, Legal, Economic Aspects

Core Topic #19. Digital Library Research & Development (48 subtopics)

Digital library research is multidisciplinary and interdisciplinary by nature and the major domains include Library & Information Science, Information and Computer Science, Media and Communication, Archives and Recordkeeping, and Business Management, etc. (CISAP, 2012). Under this core topic, 48 subtopics are structured into 3 clusters of subtopics, viz. *Interdisciplinary* (General), *Research and Development*, and *International Cooperation*.

In Figure 4.21, *Computer Science* is the top subtopic accounting for 33% publications, followed by *Engineering* (18%), *Social Sciences* (15%), *Mathematics* (9%), and *Biochemistry, Genetics* (5%). Four subtopics, namely *Archive Science*, *Physics and Astronomy*, *Business Management*, and *Information Science* have the same proportion of publications, 2% each. *Decision* is at the bottom of the list with 1%.In general, the top 10 subtopics account for 89% of total publications compared to the rest 11% covered by the 38 remaining subtopics.

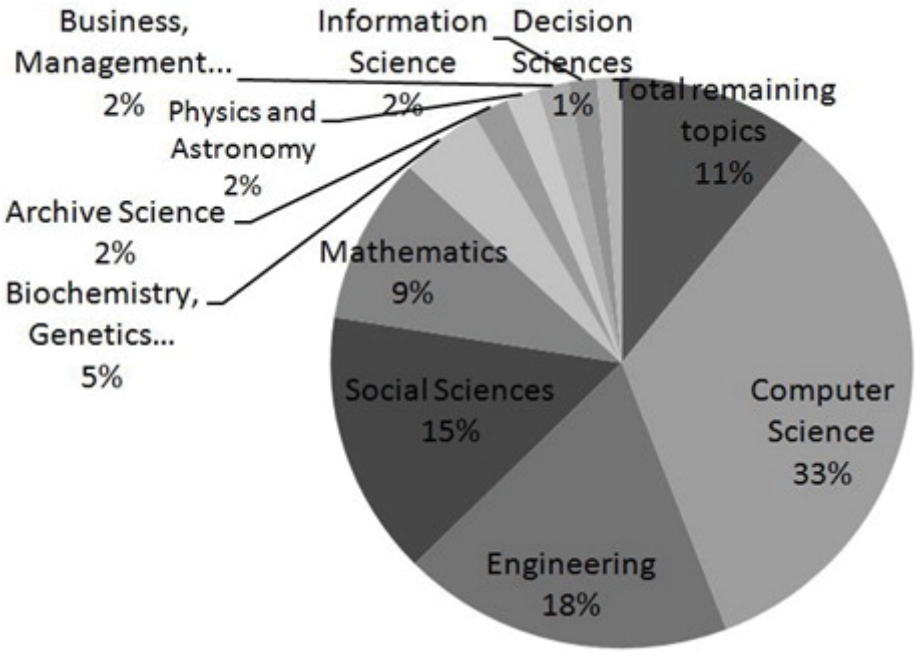

Figure 4.21: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #19. Digital Library Research & Development

Core Topic #20. Information Literacy (20 subtopics)

"Information Literacy is a set of abilities requiring individuals to recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information" (ALA, 2006). Under this core topic, 20 subtopics are structured into only one cluster of subtopics as *Information Literacy* (General).

In Figure 4.22, the top subtopic is *Decision Making* accounting for 34% publications, followed by *Reading* (20%), *Information Literacy* (General) (15%), and *Information Society* (5%). *Digital Divide*, *Information Overload* and *Ethics* have 3% each; *Information Searching*, *Learning Communities and Critical Thinking* have 2% publications within this topic. The top 10 subtopics cover 90% of total publications compared to the rest 10% covered by the remaining subtopics. It may be noted that 15% publications in this topic have the keyword *Information Literacy*, and thus 15% publications cover the general aspects of information literacy as opposed to the specific aspects of the topic like *Information Society*, *Digital Divide*, etc.

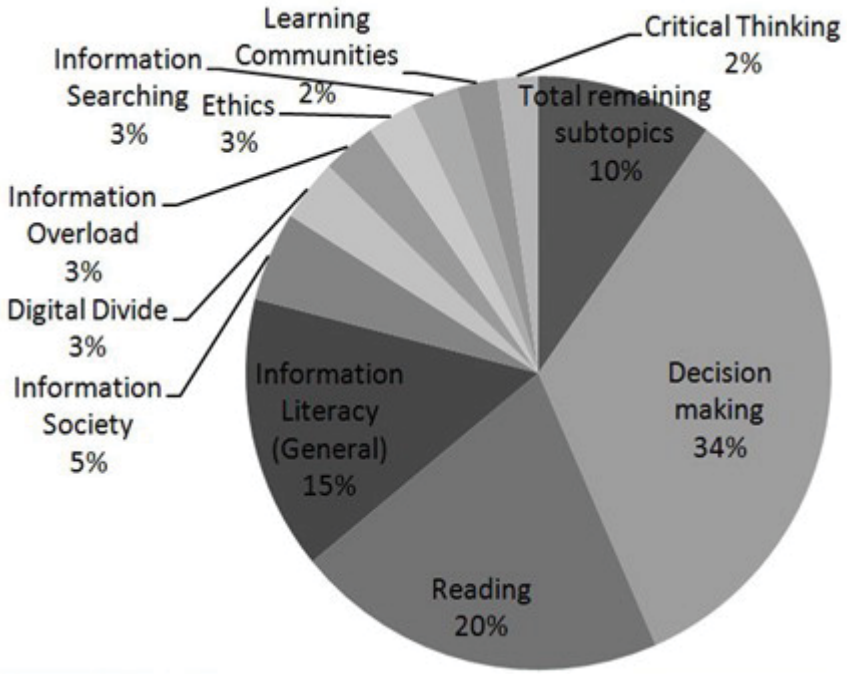

Figure 4.22: Top 10 Subtopics With Highest Publication Numbers Within Core Topic #20. Information Literacy

Core Topic #21. Digital Library Education (5 subtopics)

This core topic is related to digital library curriculum development. Only one cluster of subtopics with 5 subtopics is created under this core topic. In Figure 4.23, *DL Education* is the most studied subtopic with 82% publications, followed by *DL Program* (11%), *Computer Science Education* (5%), *DL Curriculum*(1%), and *DL Training* (1%). It may be noted that 82% of publications in this topic have the keyword *DL Education*. In other words majority of publications in this core topic cover general aspects of *DL Education* rather than specific subtopics like *DL Program*, *DL Curriculum*, etc.

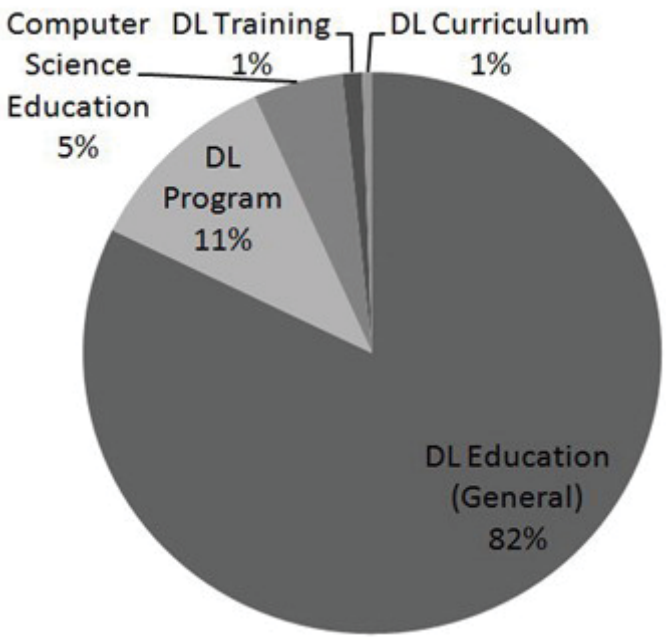

Figure 4.23: Subtopics With Highest Publication Numbers Within Core Topic #21. Digital Library Education

4.5 Summary

In conclusion, the chapter 4 presented the findings of the digital library knowledge map with analysis providing an overview of digital library research for twenty years (1990-2010). The knowledge map showed the knowledge organization of digital library core topics, subtopics and their semantic relationships in the hierarchical order as well as the interdisciplinary nature of digital library research. Overall, the knowledge map, as an illustration of modern Information Science, captured 3 core domains of Information Studies, viz. Information, Technology and People.

Chapter 5

Digital Library Research Trends (1990-2010): Analysis and Prediction

5.1 Introduction

This chapter presents the findings with analysis of major trends of digital library research:

- in terms of the number of publications during (1990-2010) in 21 core topics;
- in terms of subtopics numbers within each core topic during (1990-2010); and
- in terms of the number of publications of subtopics within each core topic during (1990-2010).

In this analysis, trends in publication number by year and subtopic number by year show digital library research trends in the past 20 years (1990-2010), and R^2 values show their future trends. A series of tables in 21 appendices (From Appendix 4 to Appendix 24) show the R^2 values of 1015 subtopics of 21 core topics from the digital library knowledge map in 3 types: Increasing Trends (Positive Association), Decreasing Trends (Negative Association) and Not Identified Trends (No Association).

As shown in Table 5.1, R^2 values within range of (0.50 – 1.00) are considered as strong correlation coefficients, R^2 values within the range (0.30 – 0.49) are considered as medium correlation coefficients, and R^2 values within the range (0.10 – 0.29) are considered as small correlation coefficients (Cohen, 1988). In this study, the R^2 values and the strength of association (Table 5.1) were used to predict the future research in digital library domain.

Table 5.1: Strength of Association

Correlation Range (R^2 value)	Strength of Association
0.10 – 0.29	Small
0.30 – 0.49	Medium
0.50 – 1.00	Strong

5.2 Major Trends in Publication Numbers of Digital Library Research (1990-2010)

Figure 5.1 and Figure 5.2 show the major trends in publication numbers of digital library research for the period (1990-2010). In the Figures 5.1, publication number of a core topic is the sum of its subtopics' publications. It should be noted that the number of publications under some specific core topics, e.g. *#8. Architecture – Infrastructure (15339), #19. DL Research & Development (14210)*, exceed the total number of 7905 digital library publications. This happens because a given paper may have several keywords and hence the same paper is counted under several subtopics, and some subtopics also appear under more than one core topics. However, this does not affect the overall results because the correlation values are computed based on the relative number of publications for each core topic and subtopics, and not based on the total number of publications (i.e. 7905).

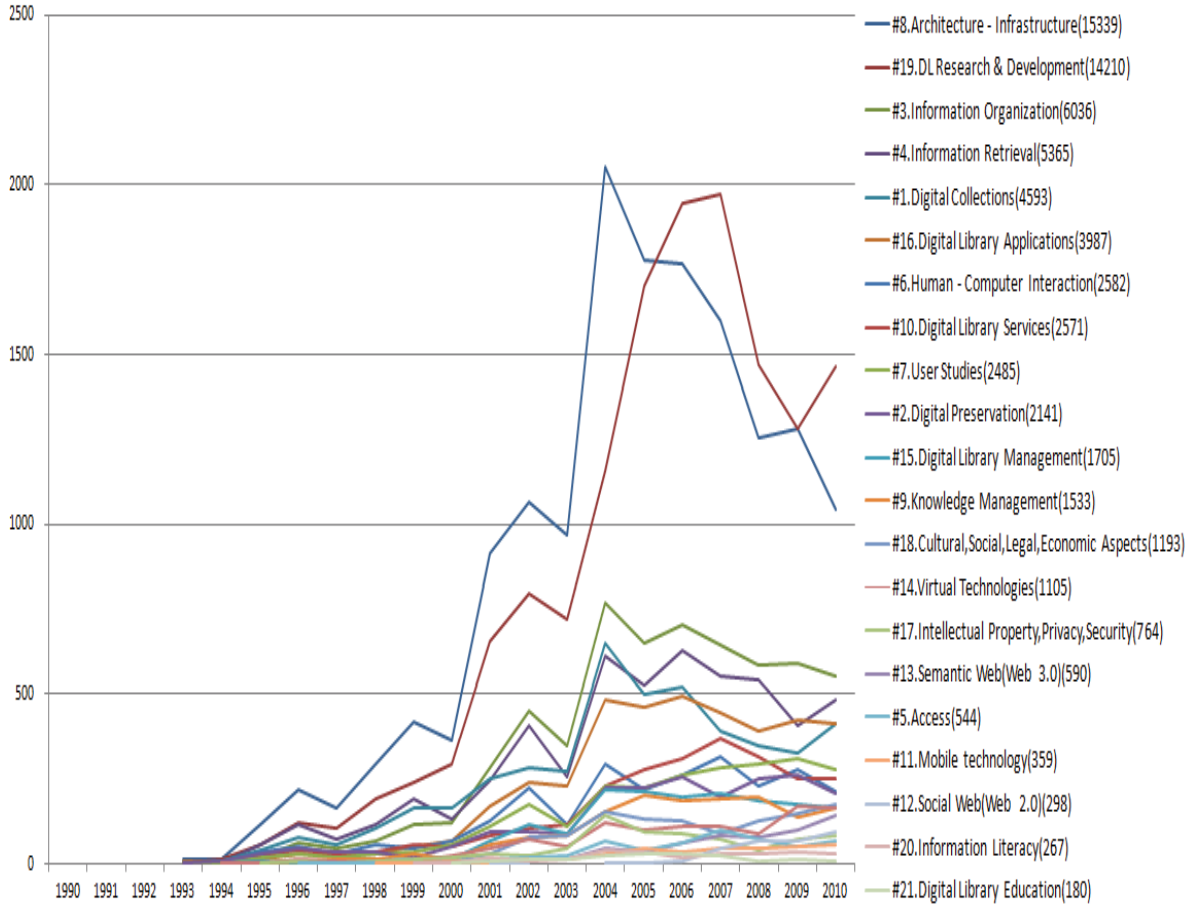

Figure 5.1: Trends in Publication Numbers of Digital Library Research (1990-2010)

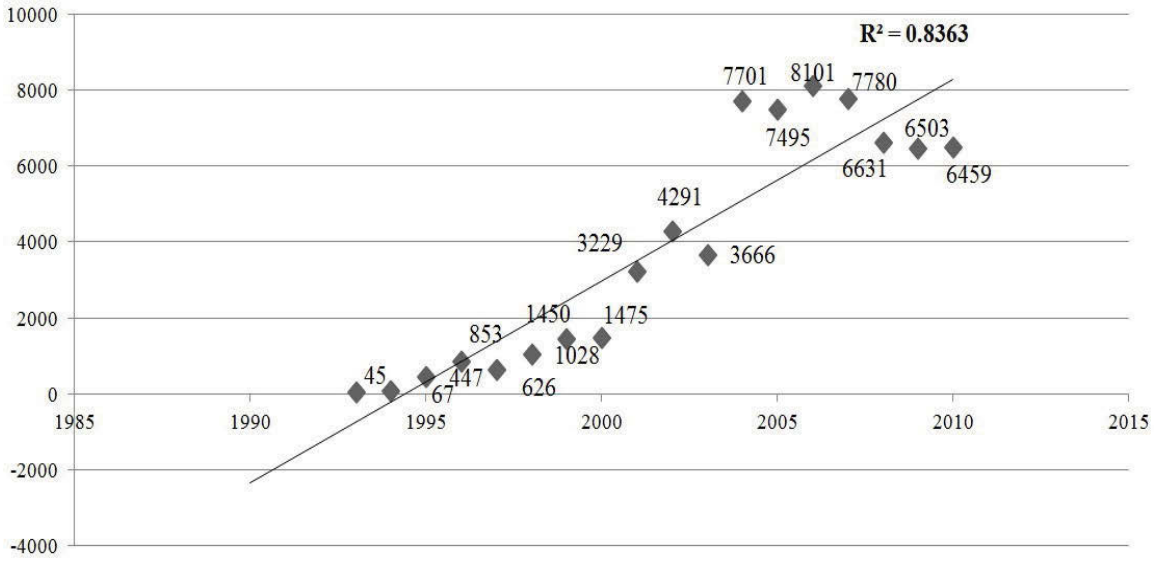

Figure 5.2: Trend in Total Publication Numbers of Digital Library Research (1990-2010)

In the Figure 5.1, 1993 is observed as the beginning of digital library research with appearances of 9 core topics having publication numbers of: *Architecture – Infrastructure (16), DL Research & Development (5), Information Retrieval (4), Digital Collections (3), Digital Library Applications (7), Human - Computer Interaction (1), Digital Library Services (5), User Studies (2), and Digital Preservation (2)*. One year later, 6 core topics (*Information Organization; Digital Library Management; Knowledge Management; Cultural, Social, Legal, Economic Aspects; Virtual Technologies and Access*) appeared with publications: 3, 1, 1, 1, 2, and 1 respectively. Later, five other core topics also attracted research interests, namely: *Intellectual Property, Privacy, Security (6) in 1995; Semantic Web (Web 3.0) (1)* in 1996*; Digital Library Education (2)* in 1996*; Social Web(Web 2.0) (1)* in 1999 and *Information Literacy (2)* in 1999. All of the 21 core topics were gradually increasing leading to a total of 1450 publications in 2000 (see Figure 5.2) and then, from this year onwards, they grew rapidly to a total publications of 7495 in 2005 and at their peak of 8101 in 2006 then slowly fell to 6503 in 2010. It clearly indicates that the period (2004 - 2010) was the booming time for digital library research interests increasing to their peaks. It may be noted that, 6 core topics were at the peak in 2004, viz. : [*Architecture – Infrastructure (2052); Information Organization (771); Digital Collections (649); Digital Library Management (219); Intellectual Property, Privacy, Security (145);* and *Information Literacy (39)*]; 1 core topic viz. [*Knowledge Management (201*)], was at the peak in 2005, 4 core topics were at the peak in 2006, viz.: [*DL Research & Development (1945), Information Retrieval (630),*

*Digital Library Applications (495)*and *Digital Library Education (33)*], 3 core topics were at the peak in 2007, viz. : [*Human - Computer Interaction (317); Digital Library Services (372) and Access (103)*], 3 core topics were at eh peak in 2009, viz. : [*User Studies (311); Digital Preservation (264);* and *Virtual Technologies (169)*], and 4 core topics were at the peak in 2010, viz. : [*Cultural, Social, Legal, Economic Aspects (178); Semantic Web(Web 3.0) (144); Mobile Technology (59)* and *Social Web(Web 2.0) (93)*].

Table 5.2: Publication Numbers vs. R-Square Numbers of 21 Core Topics of Digital Library Research (1990-2010)

	Core Topics	Number of Publications	Core Topics	R^2
1	#8.Architecture - Infrastructure	**15339**	#7.User Studies (Increasing Trend)	**0.92**
2	#19.Digital Library Research & Development	**14210**	#11.Mobile Technology (Increasing Trend)	**0.92**
3	#3.Information Organization	**6036**	#14.Virtual Technologies (Increasing Trend)	**0.87**
4	#4.Information Retrieval	**5365**	#13.Semantic Web(Web 3.0) (Increasing Trend)	**0.84**
5	#1.Digital Collections	**4593**	#2.Digital Preservation (Increasing Trend)	**0.84**
6	#16.Digital Library Applications	**3987**	#18.Cultural,Social,Legal, Economic Aspects (Increasing Trend)	**0.83**
7	#6.Human - Computer Interaction	**2582**	#16.Digital Library Applications (Increasing Trend)	**0.83**
8	#10.Digital Library Services	**2571**	#10.Digital Library Services (Increasing Trend)	**0.82**
9	#7.User Studies	**2485**	#9.Knowledge Management (Increasing Trend)	**0.82**
10	#2.Digital Preservation	**2141**	#19. Digital Library Research & Development (Increasing Trend)	**0.82**
11	#15.Digital Library Management	**1705**	#6.Human - Computer Interaction (Increasing Trend)	**0.80**
12	#9.Knowledge Management	**1533**	#3.Information Organization (Increasing Trend)	**0.80**
13	#18.Cultural, Social, Legal, Economic Aspects	**1193**	#4.Information Retrieval (Increasing Trend)	**0.79**

14	#14.Virtual Technologies	**1105**	#15.Digital Library Management (Increasing Trend)	**0.79**
15	#17.Intellectual Property, Privacy, Security	**764**	#12.Social Web(Web 2.0) (Increasing Trend)	**0.75**
16	#13.Semantic Web(Web 3.0)	**590**	#5.Access (Increasing Trend)	**0.74**
17	#5.Access	**544**	#8.Architecture – Infrastructure (Increasing Trend)	**0.69**
18	#11.Mobile Technology	**359**	#1.Digital Collections (Increasing Trend)	**0.69**
19	#12.Social Web(Web 2.0)	**298**	#20.Information Literacy (Increasing Trend)	**0.57**
20	#20.Information Literacy	**267**	#17.Intellectual Property, Privacy, Security (Increasing Trend)	**0.54**
21	#21.Digital Library Education	**180**	#21.Digital Library Education (Increasing Trend)	**0.13**

In Table 5.2, it can be noted that although *Architecture – Infrastructure (15339), DL Research & Development (14210), Information Organization (6036), Information Retrieval (5365) and Digital Collections (4593)* are the top 5 core topics with highest publication numbers, they are not the most trendy core topics with R^2 values = 0.69; 0.82; 0.80; 0.79; and 0.69 respectively. Vice versa, *User Studies (2485), Mobile Technology (359), Virtual Technologies (1105), Semantic Web(Web 3.0) (590), and Digital Preservation (2141)* are the 5 core topics having less number of publications than the top 5, but they get the highest R^2 values = 0.92; 0.92; 0.87; 0.84; and 0.84 respectively. It should be noted that values of publication numbers by years just tell us how digital library research happened in the past while R^2 values show the trends for future. In other words, based on the calculations of the actual data of two variables "Year" and "Publication", R^2 reveal how closely the estimated values for a trend line (a straight line relationship) correspond to a set of actual data.

Overall, there is a significant increase in digital library publication numbers, especially in the period (2000-2010) and the future trend of digital library research is strongly increasing and estimated as $R^2 = 0.836$ which is very reliable (very close to 1).

5.3 Major Trends in Digital Library Research (1990-2010) in terms of Subtopic Numbers

Figure 5.3 and Figure 5.4 show subtopic numbers appearing for the first time under each core topic. The digital library research trends (1990-2010) are described as follows:

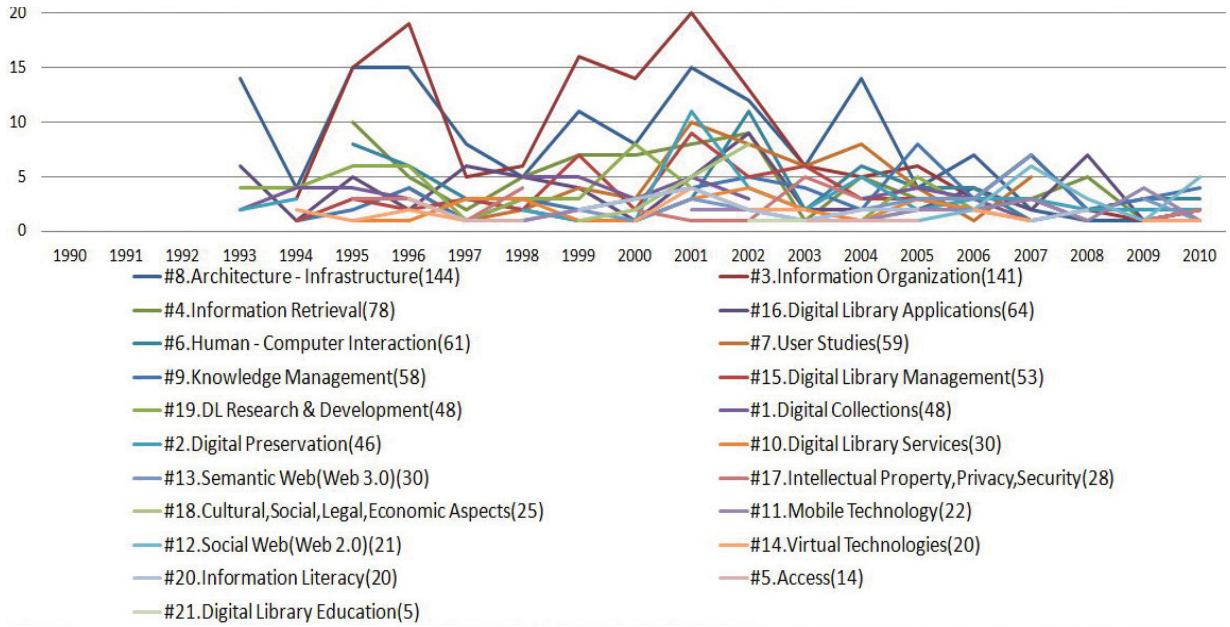

Figure 5.3: Trends in Subtopics Numbers of Digital Library Research (1990-2010)

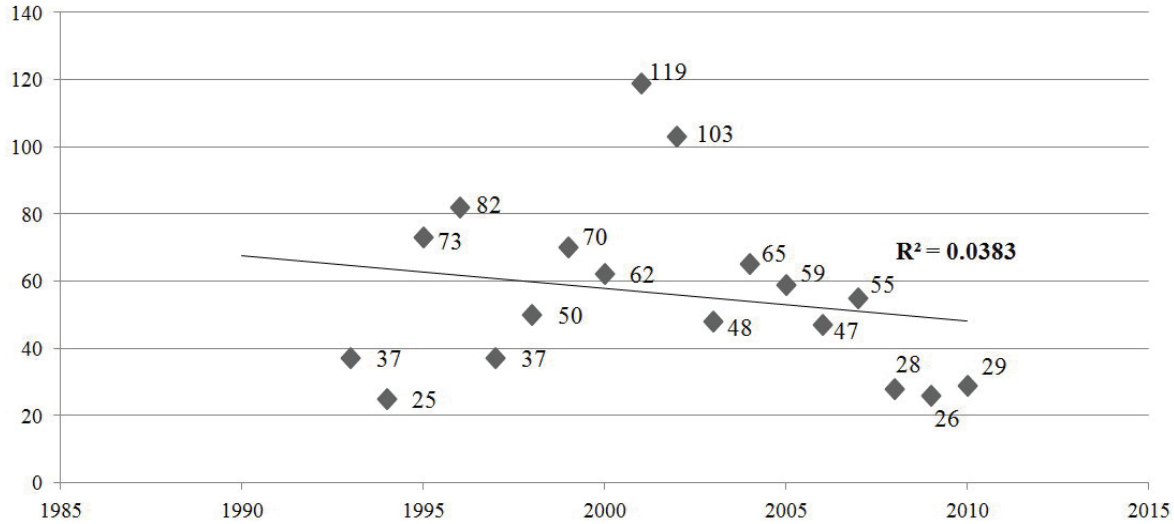

Figure 5.4: Trend in Total Subtopics Numbers of Digital Library Research (1990-2010)

In Figures 5.3, there were 9 core topics with subtopic numbers emerging in 1993. These are: *Architecture – Infrastructure (14); Information Retrieval (3); Digital Library Applications (6); Human - Computer Interaction (1); User Studies (2); DL Research & Development (4);*

Digital Collections (2); Digital Preservation (2) and *Digital Library Services (3)*. One year later, 6 core topics appeared with following subtopic numbers: *Information Organization (3); Knowledge Management (1); Digital Library Management (1); Cultural, Social, Legal, Economic Aspects (1); Virtual Technologies (2)* and *Access (1)*. Several years later, 6 remaining subtopics were firstly recorded with the following subtopic numbers: *Intellectual Property, Privacy, Security (3)* in 1995*; Semantic Web (Web 3.0) (1), Mobile Technology (1) and Digital Library Education (1)* in 1996*; Social Web(Web 2.0) (1)* and *Information Literacy (2)* in 1999. It is shown that 2001 was a booming year for many core topics getting the highest numbers of subtopics, viz. *Architecture – Infrastructure (15) (it also peaked at 15* in 1995 and 1996*); Information Organization (20); User Studies (10); Digital Library Management (9); Digital Collections (5)* (it also peaked at 5 in 1998 and 1999); *Digital Preservation (11); Virtual Technologies (4); Information Literacy (4)* and *Access (3)*. Then, it was ranked second for 2002 having core topics with top subtopic numbers, viz. *Digital Library Applications (9); Human - Computer Interaction (11); Digital Library Services (4);* and *Cultural, Social, Legal, Economic Aspects (8)*. Finally, 5 remaining subtopics increased to their peaks, viz. *Intellectual Property, Privacy, Security (5)* in 2003*; Knowledge Management (8)* in 2005*; Semantic Web (Web 3.0) (7) and Social Web (Web 2.0) (6)* in 2007*; Mobile Technology (4)* in 2009.

In an overall view, the total number of new subtopics started with 37 in 1993, then fluctuated within the range of 82 – 37 during 1995 - 2000, and rapidly climbed up to the top at 119 in 2001, and all declined to 29 in 2010 (see Figure 5.4).

Table 5.3: Subtopic Numbers vs. R-Square Numbers of 21 Core Topics of Digital Library Research (1990-2010)

	Core Topics	Numbers of Subtopics	Core Topics	R^2
1	#8.Architecture - Infrastructure	**144**	#8.Architecture – Infrastructure (Decreasing Trend)	**0.38**
2	#3.Information Organization	**141**	#20.Information Literacy (Decreasing Trend)	**0.35**
3	#4.Information Retrieval	**78**	#12.Social Web(Web 2.0) (Increasing Trend)	**0.24**
4	#16.Digital Library Applications	**64**	#3.Information Organization (Decreasing Trend)	**0.23**
5	#6.Human - Computer Interaction	**61**	#1.Digital Collections (Decreasing Trend)	**0.23**

6	#7.User Studies	**59**	#13.Semantic Web(Web 3.0) (Increasing Trend)	**0.19**
7	#9.Knowledge Management	**58**	#4.Information Retrieval (Decreasing Trend)	**0.18**
8	#15.Digital Library Management	**53**	#9.Knowledge Management (Increasing Trend)	**0.18**
9	#19. Digital Library Research & Development	**48**	#19. Digital Library Research & Development (Decreasing Trend)	**0.17**
10	#1.Digital Collections	**48**	#11.Mobile Technology (Increasing Trend)	**0.12**
11	#2.Digital Preservation	**46**	#5.Access (Decreasing Trend)	**0.09**
12	#10.Digital Library Services	**30**	#17.Intellectual Property, Privacy, Security (Decreasing Trend)	**0.05**
13	#13.Semantic Web(Web 3.0)	**30**	#10.Digital Library Services (Decreasing Trend)	**0.03**
14	#17.Intellectual Property, Privacy, Security	**28**	#14.Virtual Technologies (Decreasing Trend)	**0.03**
15	#18.Cultural,Social,Legal,Economic Aspects	**25**	#16.Digital Library Applications (Decreasing Trend)	**0.02**
16	#11.Mobile Technology	**22**	#7.User Studies (Increasing Trend)	**0.01**
17	#12.Social Web(Web 2.0)	**21**	#6.Human - Computer Interaction (Decreasing Trend)	**0.01**
18	#14.Virtual Technologies	**20**	#15.Digital Library Management (Decreasing Trend)	**0.01**
19	#20.Information Literacy	**20**	#18.Cultural,Social,Legal, Economic Aspects (Increasing Trend)	**0.01**
20	#5.Access	**14**	#2.Digital Preservation (Increasing Trend)	**0.00**
21	#21.Digital Library Education	**5**	#21.Digital Library Education (Not Identified Trend)	**#DIV/ 0!**

Based on the calculation of the actual data of two variables "Year" and "Subtopic Number" of 21 core topics, table 5.3 shows that there are 7 increasing trend in core topics, 13 decreasing trend in core topics and 1 not identified trend in core topic. Although, *Architecture – Infrastructure; Information Organization; Information Retrieval; Digital Library Applications* and *Human - Computer Interaction* were the top 5 core topics with highest subtopic numbers, viz. 144, 141, 78, 64, and 61 respectively, their future as shown by R^2 values show decreasing trends, such as: *Architecture – Infrastructure (0.38); Information Organization (0.23); Information Retrieval (0.18); Digital Library Applications (0.02)* and *Human - Computer Interaction (0.01)*. With regard to the top core topics with

increasing trends in subtopic numbers, there were top 5 core topics, viz. *Social Web (Web 2.0) (0.24); Semantic Web (Web 3.0) (0.19); Knowledge Management (0.18); Mobile Technology (0.12); and User Studies (0.01).*

In general, there was an increasing trend in subtopic numbers of 21 core topics at peak in 2001. However, the overall trend (1990 - 2010) in the chart shows a decreasing trend with estimated R^2 value = 0.0383 (not very reliable for being close to 0).

5.4 Trends in Publication Numbers of Subtopics

Core Topic #1. Digital Collections (48 subtopics)

In Appendix 4, among the total 48 subtopics, 77% subtopics show increasing trends (including 20% of strong association, 17% of medium association and 40% of small association); 6% subtopics show decreasing trends with only small association; and 17% subtopics show no identified trends. Subtopics with the strongest increasing trends are *Content Creation* (R^2 = 0.99), *Resources* (R^2 = 0.84) *and Collections* (R^2 = 0.84). Overall, there is an increasing trend in the core topic *Digital Collections* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.6906 (Figure 5.5).

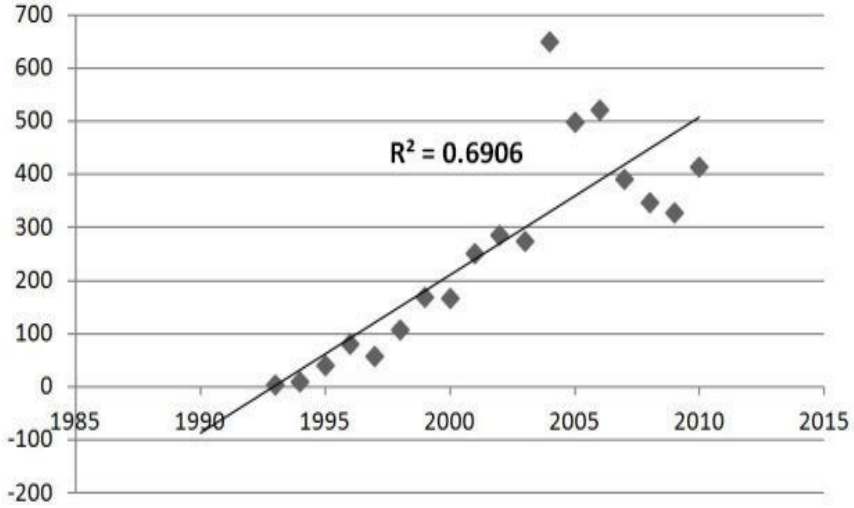

Figure 5.5: Overall Trend in the Total Publications within Core Topic #1. Digital Collections (1990-2010)

Core Topic #2. Digital Preservation (46 subtopics)

In Appendix 5, among the total 46 subtopics, there are 52% subtopics showing increasing trends (including 13% of strong association, 13% of medium association and 26% of small association); 13% subtopics showing decreasing trends (including 6% of strong association, 4% of medium association and 3% of small association); and 35% subtopics showing not identified trends. A subtopic with the strongest increasing trend is *Disaster Recovery* (R^2 = 0.96). A subtopic with the strongest decreasing trend is *Algorithms (Preservation)* (R^2 =0.96). Overall, there is an increasing trend in the core topic *Digital Preservation* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.8427 (Figure 5.6).

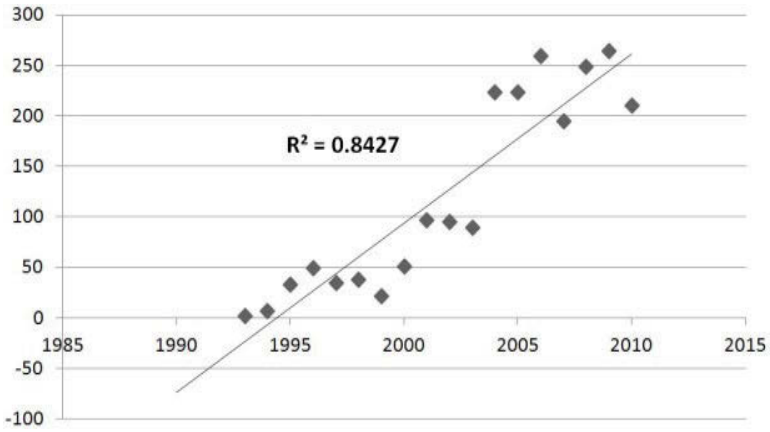

Figure 5.6 : Overall Trend in the Total Publications within Core Topic #2. Digital Preservation (1990-2010)

Core Topic #3. Information Organization (141 subtopics)

In Appendix 6a – 6b, among the total 141 subtopics, there are 68% subtopics showing increasing trends (including 18% of strong association, 18% of medium association and 32% of small association); 14% subtopics showing decreasing trends (including 3% of strong association, 1% of medium association and 10% of small association); and 18% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Concept Hierarchies* (R^2 = 1), *Compression Algorithms* (R^2 = 1), *Conceptual Frameworks* (R^2 = 0.89), *Discovery* (R^2 = 0.89), and *Metadata Extraction* (R^2 = 0.88). Subtopics with the strongest decreasing trends are *Document Summarization* (R^2 = 0.96) and *Semi Structured Data* (R^2 = 0.89). Overall, there is an increasing trend in the core topic *Information Organization* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.7958 (Figure 5.7).

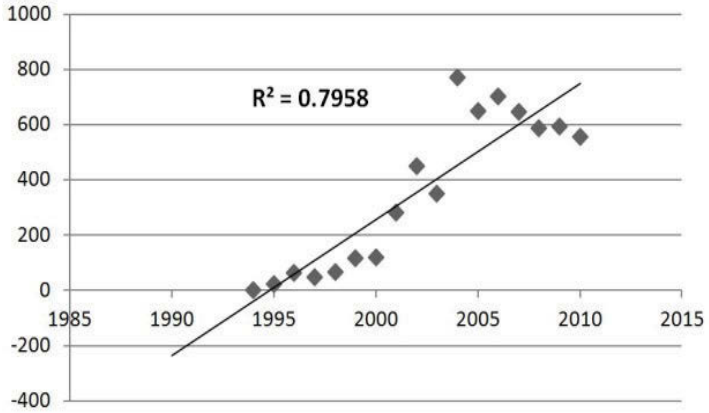

Figure 5.7 : Overall Trend in the Total Publications within Core Topic #3. Information Organization (1990-2010)

Core Topic #4. Information Retrieval (78 subtopics)

In Appendix 7, among the total 78 subtopics, there are 70% subtopics showing increasing trends (including 29% of strong association, 6% of medium association and 35% of small association); 9% subtopics showing decreasing trends (including 1% of strong association, and 8% of small association); and 21% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Visual Search* (R^2 = 1.00), *Interactive Search* (R^2 = 1.00), *Query Optimization* (R^2 =1.00), *Search (General)* (R^2 = 0.89), *Document Frequency* (R^2 = 0.88), *Search Strategies* (R^2 = 0.87), *Retrieval Effectiveness* (R^2 = 0.86), *Web Search* (R^2 = 0.81), *Recommendation (General)* (R^2 = 0.80). A subtopic with the strongest decreasing trend is *Query Refinement* (R^2 = 0.96). Overall, there is an increasing trend in the core topic *Information Retrieval* in the period (1990-2010) with the future increasing trend estimated as R^2 = 0.7943 (Figure 5.8).

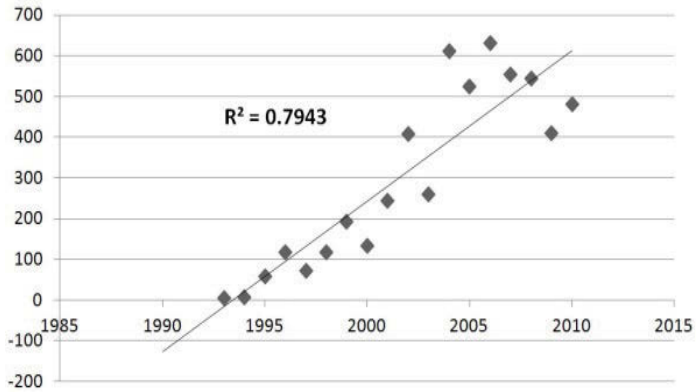

Figure 5.8: Overall Trend in the Total Publications within Core Topic #4. Information Retrieval (1990-2010)

Core Topic #5. Access (14 subtopics)

In Appendix 8, among the total 14 subtopics, there are 57% subtopics showing increasing trends (including 21% of strong association, and 36% of small association); 22% subtopics showing decreasing trends of small association; and 21% subtopics showing not identified trends. A subtopic with the strongest increasing trend is *Access* ($R^2 = 0.82$). Overall, there is an increasing trend in the core topic *Access* in the period (1990-2010) with future increasing trend estimated as $R^2 = 0.7375$ (Figure 5.9).

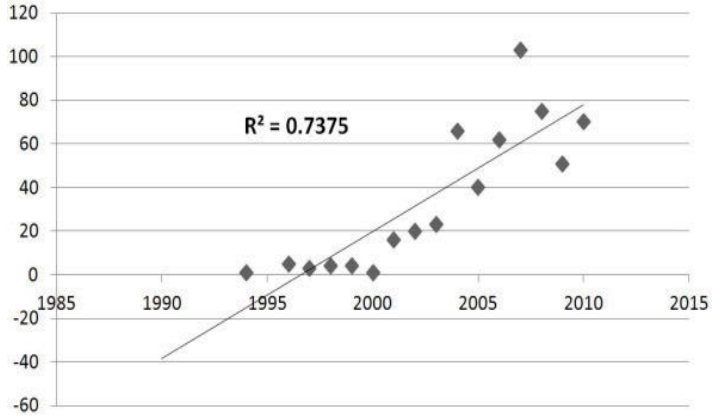

Figure 5.9: Overall Trend in the Total Publications within Core Topic #5. Access (1990-2010)

Core Topic #6. Human - Computer Interaction (61 subtopics)

In Appendix 9, among the total 61 subtopics, there are 57% subtopics showing increasing trends (including 21% of strong association, 15% of medium association and 21% of small association); 15% subtopics showing decreasing trends (including 3% of strong association, 3% of medium association and 9% of small association); and 28% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Automatic Speech Recognition* ($R^2 = 1.00$), *User Centred Designs* ($R^2 = 1.00$) and *Contextual Information* ($R^2 = 0.94$). Subtopics with the strongest decreasing trends are *Physical Interactions* ($R^2 = 1.00$) and *Information Representation* ($R^2 = 1.00$). Overall, there is an increasing trend in the core topic *Human - Computer Interaction* in the period (1990-2010) with future increasing trend estimated as $R^2 = 0.8017$ (Figure 5.10).

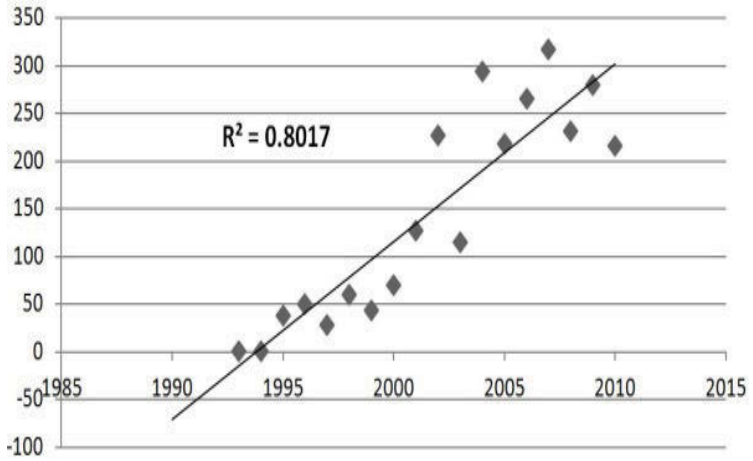

Figure 5.10: Overall Trend in the Total Publications within Core Topic #6. Human - Computer Interaction (1990-2010)

Core Topic #7. User Studies (59 subtopics)

In Appendix 10, among the total 59 subtopics, there are 76% subtopics showing increasing trends (including 29% of strong association, 20% of medium association and 27% of small association); 5% subtopics showing decreasing trends (including 2% of medium association and 3% of small association); and 19% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *User Perception* (R^2 = 0.96), *User Feedback* (R^2 = 0.92), *Search Behaviour* (R^2 = 0.91), *Users* (R^2 = 0.85) and *Weblogs* (R^2 = 0.85). Overall, there is an increasing trend in the core topic *User Studies* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.9189 which is very reliable (Figure 5.11).

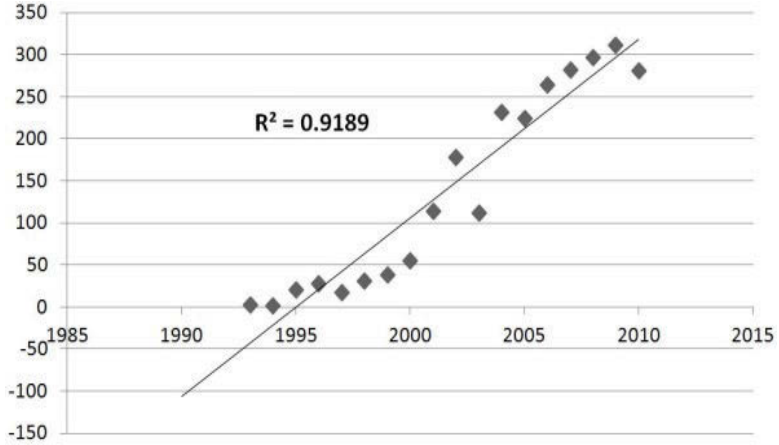

Figure 5.11: Overall Trend in the Total Publications within Core Topic #7. User Studies (1990-2010)

Core Topic #8. Architecture – Infrastructure (144 subtopics)

In Appendix 11a–11b, among the total 144 subtopics, there are 73% subtopics showing increasing trends (including 23% of strong association, 13% of medium association and 37% of small association); 14% subtopics showing decreasing trends (including 2% of strong association, 3% of medium association and 9% of small association); and 13% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Fuzzy Linguistic* (R^2 = 1), *Design Principle* (R^2 = 1), *Tools* (R^2 = 0.85), *Design and Development* (R^2 = 0.84), *Semantic Web* (R^2 = 0.83) and *Open Source* (R^2 = 0.82). Subtopics with the strongest decreasing trends are *Data Warehousing* (R^2 = 1) and *Scientific Computing* (R^2 = 0.89). Overall, there is an increasing trend in the core topic *Architecture – Infrastructure* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.6907 (Figure 5.12).

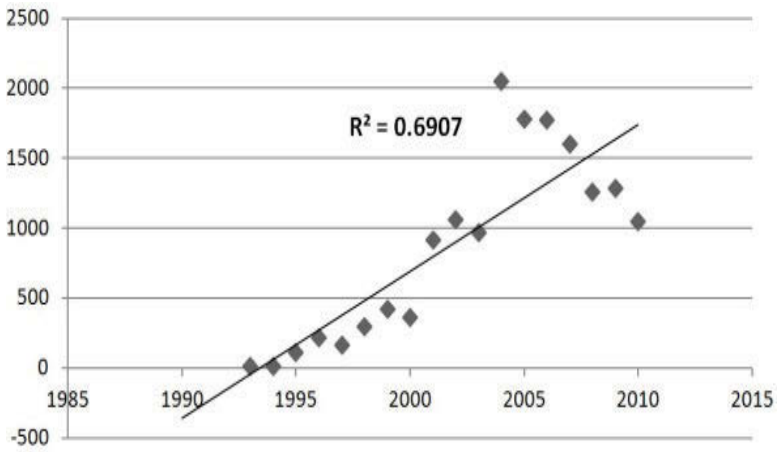

Figure 5.12 : Overall Trend in the Total Publications within Core Topic #8. Architecture – Infrastructure (1990-2010)

Core Topic #9. Knowledge Management (58 subtopics):

In Appendix 12, among the total 58 subtopics, there are 51% subtopics showing increasing trends (including 14% of strong association, 16% of medium association and 21% of small association); 10% subtopics showing decreasing trends (including 5% of strong association and 5% of small association); and 40% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Knowledge Service* (R^2 = 0.84), *Collaborative Research* (R^2 = 0.84) and *Knowledge Management(General)* (R^2 = 0.83). Subtopics with the strongest decreasing trends are *Knowledge Innovation* (R^2 = 1.00), *Knowledge Evolution* (R^2 = 1.00) and *Knowledge Transfer* (R^2 = 0.84). Overall, there is an increasing trend in the core

topic *Knowledge Management* in the period (1990-2010) with future increasing trend estimated as $R^2 = 0.8198$ (Figures 5.13)

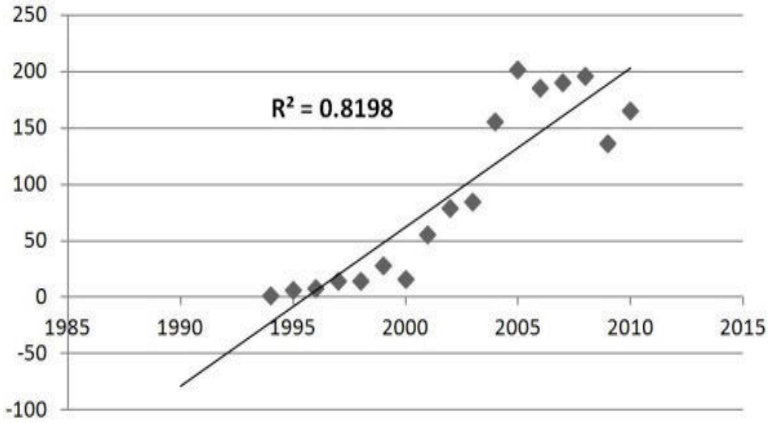

Figure 5.13: Overall Trend in the Total Publications within Core Topic #9. Knowledge Management (1990-2010)

Core Topic #10. Digital Library Services (30 subtopics)

In Appendix 13, there are 69% subtopics showing increasing trends (including 24% of strong association, 17% of medium association and 28% of small association); 7% subtopics showing decreasing trends of small association; and 24% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Services (General)* ($R^2 = 0.82$) and *Web Search* ($R^2 = 0.81$). Overall, there is an increasing trend in the core topic *DL Services* in the period (1990-2010) with future increasing trend estimated as $R^2 = 0.8199$ (Figures 5.14).

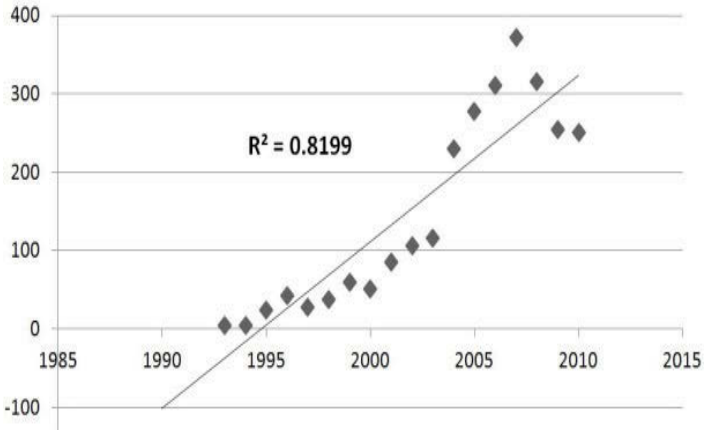

Figure 5.14: Overall Trend in the Total Publications within Core Topic #10. Digital Library Services (1990-2010)

Core Topic #11. Mobile Technology (22 subtopics)

In Appendix 14, among the total 22 subtopics, there are 50% subtopics showing increasing trends (including 14% of strong association, 9% of medium association and 27% of small association); 10% subtopics showing decreasing trends (including 5% of strong association, and 5% of medium association); and 40% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Mobile Application* (R^2 = 1.00) and *Mobile Devices* (R^2 = 0.84). Overall, there is an increasing trend in the core topic *Mobile Technology* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.9175 which is very reliable (Figure 5.15).

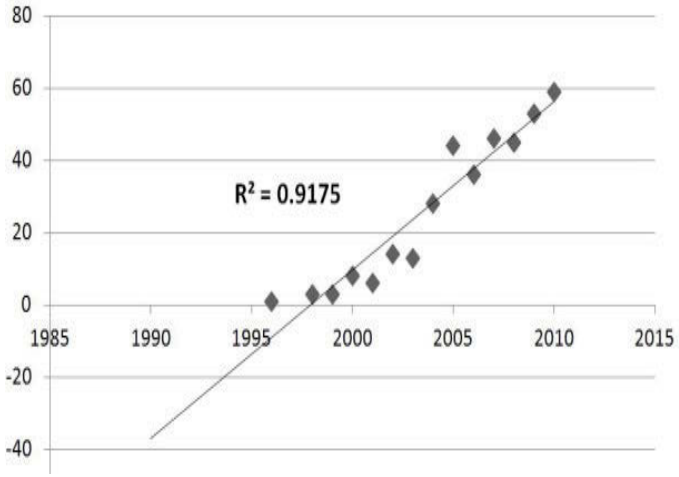

Figure 5.15 : Overall Trend in the Total Publications within Core Topic #11. Mobile Technology (1990-2010)

Core Topic #12. Social Web (Web 2.0) (21 subtopics)

In Appendix 15, among the total 21 subtopics, there are 43% subtopics showing increasing trends (including 33% of strong association, and 10% of small association); 10% subtopics showing decreasing trends (including 5% of medium association and 5% of small association); and 47% of not identified trends. Subtopics with the strongest increasing trends are *Social Media* (R^2 = 1.00), *User Generated Content* (R^2 = 1.00) and *Social Networking* (R^2 = 0.82). Overall, there is an increasing trend in the core topic *Social Web (Web 2.0)* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.7548 (Figure 5.16).

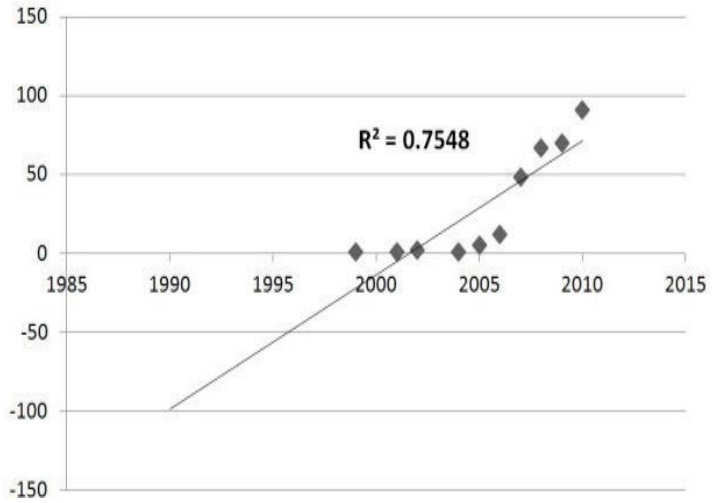

Figure 5.16: Overall Trend in the Total Publications within Core Topic #12. Social Web (Web 2.0) (1990-2010)

Core Topic #13. Semantic Web (Web 3.0) (30 subtopics)

In Appendix 16, among the total 30 subtopics, there are 50% subtopics showing increasing trends (including 27% of strong association, 13% of medium association and 10% of small association); 3% subtopics showing decreasing trends of strong association; and 47% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Semantic Search* (R^2 = 1.00), *Ontologies (General)* (R^2 = 0.90), *Semantic Technology* (R^2 = 0.89) and *Semantic Web (Web3.0)* (R^2 = 0.83). Overall, there is an increasing trend in the core topic *Semantic Web (Web 3.0)* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.843 (Figure 5.17).

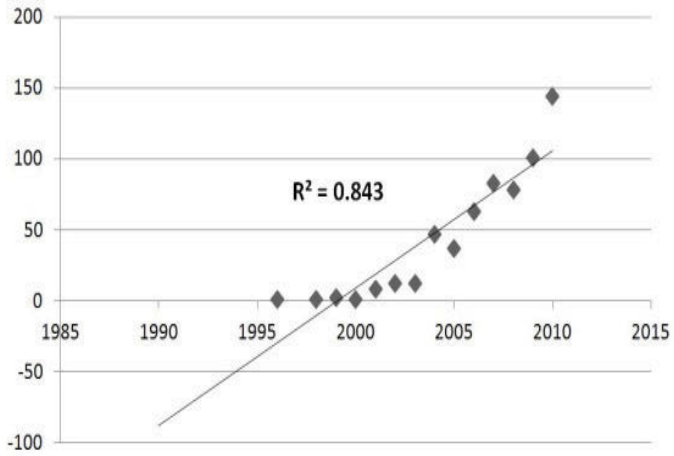

Figure 5.17: Overall Trend in the Total Publications within Core Topic #13. Semantic Web (Web 3.0) (1990-2010)

Core Topic #14. Virtual Technologies (20 subtopics)

In Appendix 17, among the total 20 subtopics, there are 70% subtopics showing increasing trends (including 50% of strong association, and 20% of small association); 15% subtopics showing decreasing trends (including 5% of strong association, and 10% of small association); and 15% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Virtual Organization* (R^2 = 0.90), *Virtual (General)* (R^2 = 0.87) and *Second Life* (R^2 = 0.86). Overall, there is an increasing trend in the core topic *Virtual Technologies* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.872 (Figure 5.18).

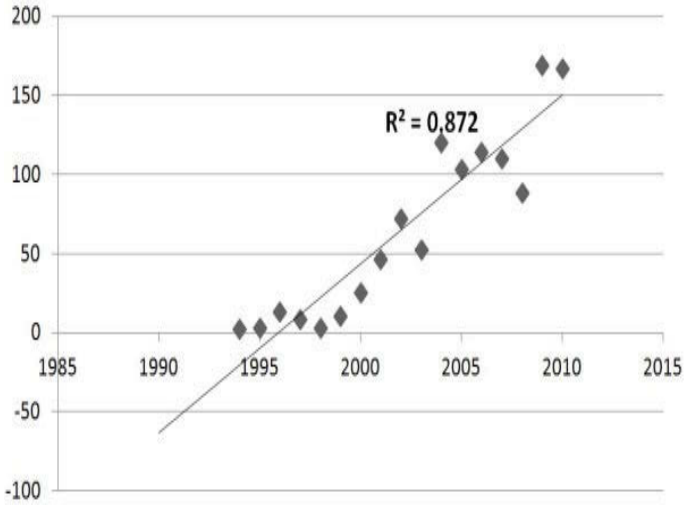

Figure 5.18: Overall Trend in the Total Publications within Core Topic #14. Virtual Technologies (1990-2010)

Core Topic #15. Digital Library Management (53 subtopics)

In Appendix 18, among the total 53 subtopics, there are 64% subtopics showing increasing trends (including 17% of strong association, 11% of medium association and 36% of small association); 13% subtopics showing decreasing trends (including 2% of strong association, 11% of small association); and 23% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Quality Indicator* (R^2 = 1.00), *Performance Improvement* (R^2 = 1.00) and *Evaluation(General)* (R^2 = 0.86). A subtopic with the strongest decreasing trends is *Quality Model* (R^2 = 1.00). Overall, there is an increasing trend in the core topic *DL Management* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.7894 (Figure 5.19).

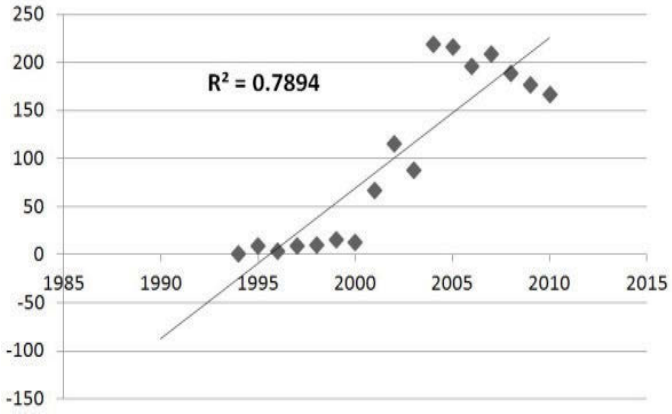

Figure 5.19: Overall Trend in the Total Publications within Core Topic #15. Digital Library Management (1990-2010)

Core Topic #16. Digital Library Applications (64 subtopics)

In Appendix 19, among the total 64 subtopics, there are 66% subtopics showing increasing trends (including 19% of strong association, 14% of medium association and 33% of small association); 14% subtopics showing decreasing trends (including 3% of strong association, 6% of medium association and 5% of small association); and 20% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Research institutions* (R^2 = 1.00), *Design/ Methodology/ Approach* (R^2 = 0.96), *Research(General)* (R^2 = 0.85) and *School* (R^2 = 0.81). Subtopics with the strongest decreasing trends are *Learning Activities* (R^2 = 1.00) and *Citizen Science* (R^2 = 1.00). Overall, there is an increasing trend in the core topic *DL Applications* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.8322 (Figure 5.20).

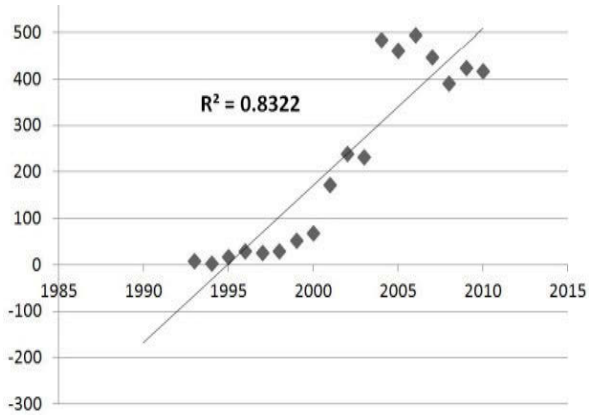

Figure 5.20 : Overall Trend in the Total Publications within Core Topic #16. Digital Library Applications (1990-2010)

Core Topic #17. Intellectual Property, Privacy, Security (28 subtopics)

In Appendix 20, among the total 28 subtopics, there are 57% subtopics showing increasing trends (including 14% of strong association, 7% of medium association and 36% of small association); 20% subtopics showing decreasing trends (including 10% of medium association and 10% of small association); and 23% subtopics showing not identified trends. A subtopic with the strongest increasing trends is *Privacy Protection* (R^2 = 0.89). Overall, there is an increasing trend in the core topic *Intellectual Property, Privacy and Security* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.5383 (Figure 5.21).

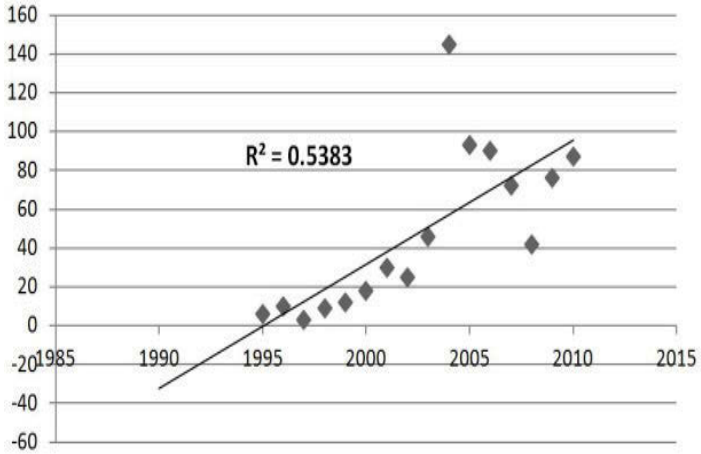

Figure 5.21: Overall Trend in the Total Publications within
Core Topic #17. Intellectual Property, Privacy, Security (1990-2010)

Core Topic #18. Cultural, Social, Legal, Economic Aspects (25 subtopics)

In Appendix 21, among the total 25 subtopics, there are 46% subtopics showing increasing trends (including 20% of strong association, 8% of medium association and 8% of small association); 24% subtopics showing decreasing trends (including 8% of strong association, 4% of medium association and 12% of small association); and 20% subtopics showing not identified trends. Subtopics with the strongest increasing trends are *Business* (R^2 = 0.87), *Social(Aspects)* (R^2 = 0.86) and *Heritage* (R^2 = 0.80). Subtopics with the strongest decreasing trends are *Citizen Science* (R^2 = 1.00) and *Cross-Cultural Usability* (R^2 = 0.92). Overall, there is an increasing trend in the core topic *Cultural, Social, Legal, Economic Aspects* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.8337 (Figure 5.22).

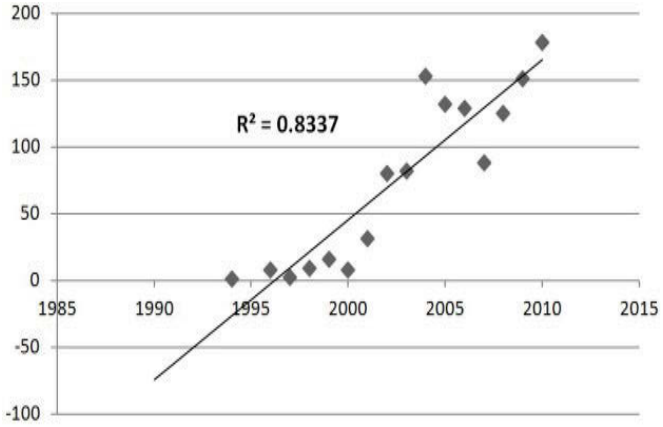

Figure 5.22: Overall Trend in the Total Publications within
Core Topic #18. Cultural, Social, Legal , Economic Aspects (1990-2010)

Core Topic #19. Digital Library Research & Development (48 subtopics)

In Appendix 22, among the total 48 subtopics, there are 79% subtopics showing increasing trends (including 38% of strong association, 17% of medium association and 24% subtopics showing small association); 8% subtopics showing decreasing trends (including 4% of strong association and 4% of small association); and 13% of not identified trends. Subtopics with the strongest increasing trends are *Interdisciplinary Research* (R^2 = 0.99), *Academic (domains)* (R^2 = 0.93) and *Computer Science* (R^2 = 0.87). Subtopics with the strongest decreasing trends are *Digital Library Development* (R^2 = 1.00) and *Global Collaboration* (R^2 = 1.00). Overall, there is an increasing trend in the core topic *DL Research & Development* in the period (1990-2010) with future increasing trend estimated as R^2 = 0.8174 (Figure 5.23).

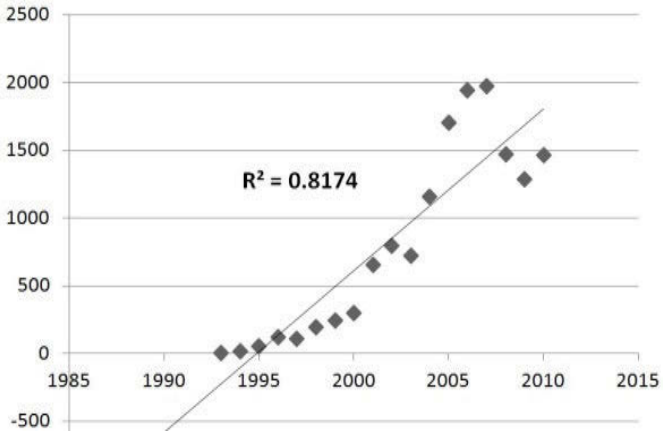

Figure 5.23 : Overall Trend in the Total Publications within
Core Topic #19. Digital Library Research & Development (1990-2010)

Core Topic #20. Information Literacy (20 subtopics)

In Appendix 23, among the total 20 subtopics, there are 25% subtopics showing increasing trends (including 5% of strong association, 5% of medium association and 15% of small association); 30% subtopics showing decreasing trends (including 10% of strong association and 20% of small association); and 45% subtopics showing not identified trends. There are no subtopics with the strongest increasing trends. But there is a subtopic with the strongest decreasing trend which is *Learning Communities* ($R^2 = 0.87$). Overall, there is an increasing trend in the core topic *Information Literacy* in the period (1990-2010) with future increasing trend estimated as $R^2 = 0.5793$ (Figure 5.24).

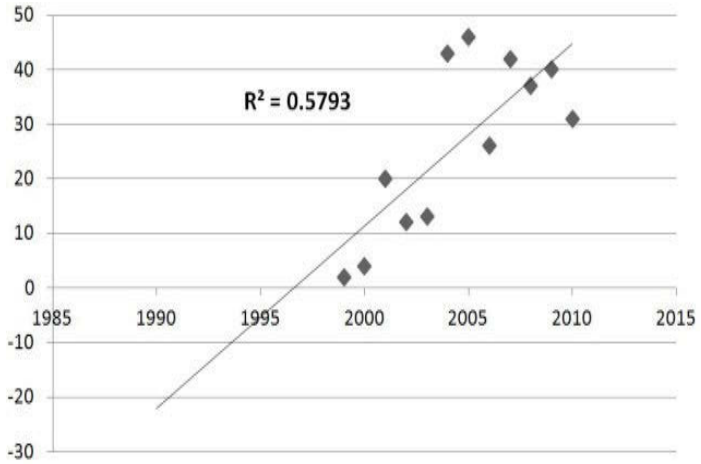

Figure 5.24 : Overall Trend in the Total Publications within
Core Topic #20. Information Literacy (1990-2010)

Core Topic #21. Digital Library Education (5 subtopics)

In Appendix 24, among the total 5 subtopics, there are 40% subtopics showing increasing trends of small association; 20% subtopics showing decreasing trends of small association; and 40% subtopics showing not identified trends. Overall, there is an increasing trend in the core topic *Digital Library Education* in the period (1990-2010) with future increasing trend estimated as $R^2 = 0.1254$ (not at all reliable) (Figure 5.25).

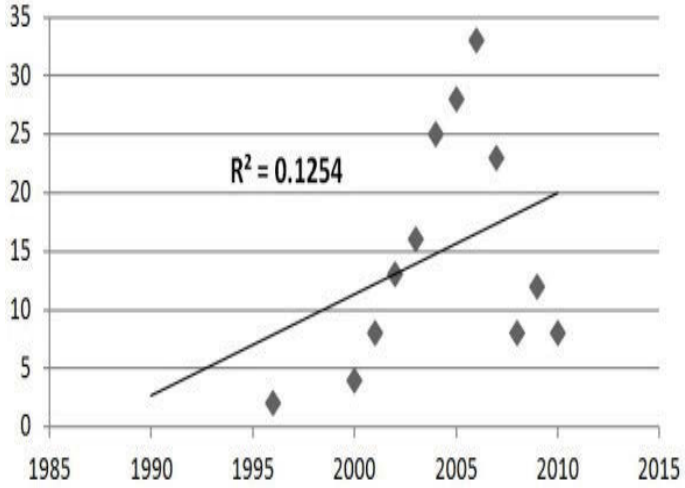

Figure 5.25: Overall Trend in the Total Publications within Core Topic #21. Digital Library Education (1990-2010)

5.5 Summary

In conclusion, this chapter has presented analysis and predictions on the trends in research in the whole field of digital libraries by using bibliometric analysis based on R^2 values and the digital library knowledge map (1990-2010). To the best of researcher's knowledge, this is the first study addressing predictions on the future digital library research by using R^2 values of linear regression analysis. With these findings, digital library researchers, educators, practitioners can not only see the progress of digital library research in the period (1990 – 2010) but also foresee the future trends of research.

Chapter 6

Designing and Engineering the Digital Library Ontology

6.1 Introduction

This chapter describes how the digital library ontology was designed, engineered and created by using the Protégé ontology software on the knowledge map of digital libraries created in the first phase of this research (see Chapter 4). The main components of the digital library ontology, viz. Individuals, Properties and Classes are presented to show the semantic relationships of 21 core topics and 1015 subtopics in visual forms (see from Appendix 25 to 45 for the visualized ontology of 21 core topics). The main objective of this phase of the research was to build a basic ontology framework for the domain of digital libraries including the 21 core topics and 1015 subtopics. This chapter also provides some examples showing the expansion and enrichment of the ontology such as: proposing the addition of individuals (member lists) of topic *Access (General), viz. Authors (top 5 authors), Institutions (top 5 institutions), Publication number within (1990-2010) and First year of appearance of the topic;* proposing the addition of Object Properties, viz. *IsAuthorOf, IsInstitutionOf, IsPublicationNumber(1990-2010), IsTheFirstYearOfAppearanceOf)* which are considered to be useful for digital library researchers. The data in relation to the number of publications, top five authors, top five institutions, etc. in relation to a given core topic and subtopic was collected from the SCOPUS database and was manually added to the ontology.

6.2 Main Components of the Digital Library Ontology

Individuals

According to Horridge (2011), individuals are instances or objects (the basic or "ground level" objects). In the digital library ontology, individuals are 21 core topics and 1015 subtopics representing the basic and specific concepts at ground level of the domain. However, some other individuals (member lists), such as: member lists of topic *Access (General),* viz. *Authors (top 5 authors), Institutions (top 5 institutions), Publication number within (1990-2010)* and *First year of appearance of the topic* are added for showing some examples of Object Properties and Data Properties for the digital library ontology.

Properties

According to Horridge (2011), properties represent relationships. There are two main types of properties, viz.

- Object Properties that describe the relationships between two individuals and
- Datatype Properties that describe the relationships between an individual and data values.

Moreover, there is a third type of properties called Annotation Properties which can be used to add information (metadata) to classes, individuals and object/datatype properties.

Object Properties

In the digital library ontology, there are 2 Object Properties, viz. *HasPart* and *IsPartOf* which link and show the relationships between individuals (topics) and 4 Object Properties, viz. *IsAuthorOf, IsInstitutionOf, IsPublicationNumber(1990-2010), IsTheFirstYearOfAppearanceOf* which link and show the relationships between individual members and topics (see Figure 6.1).

Figure 6.1: List of Object Properties in the Digital Library Ontology

The functions of the Object Properties *HasPart and IsPartOf* are Part – Whole relationships showing the relationships between core topics and subtopics. In the digital library ontology, there are some types of object properties as discussed below.

For example:

- Object Properties: the property *IsPartOf* links *Digital Library Research* to *Architecture - Infrastructure* (see Figure 6.2)

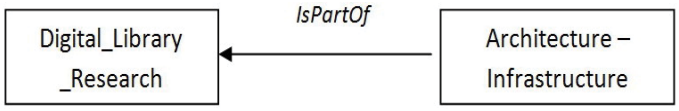

Figure 6.2 : An Illustration of Object Property

- Inverse Properties: the property *IsPartOf* links *Architecture - Infrastructure* to *Digital Library Research*. This property is the inverse of *HasPart* by *IsPartOf*. This property shows bidirectional relationships of the two individuals by adding a value to one property also adds a value to the inverse property (see Figure 6.3)

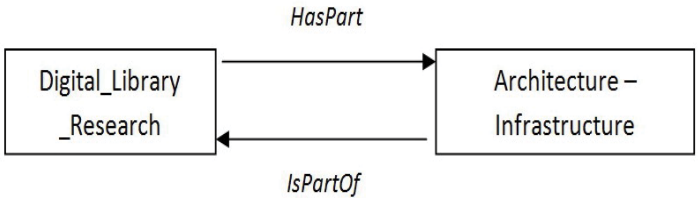

Figure 6.3 : An Illustration of Inverse Properties

- Transitive Properties: If *Software (General)* is related to *Architecture - Infrastructure* and *Architecture - Infrastructure* is related to individual *Digital Library Research* then *Software (General)* is also related to *Digital Library Research* (see Figure 6.4)

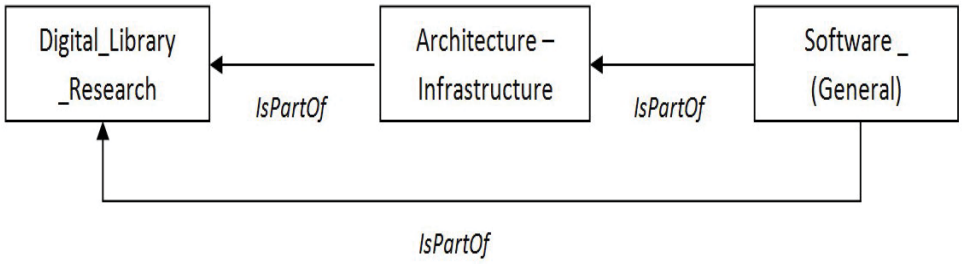

Figure 6.4 : An Illustration of Transitive Properties

The functions of the Object Properties *IsAuthorOf, IsInstitutionOf, IsPublicationNumber(1990-2010), IsTheFirstYearOfAppearanceOf* are described as follows:

- *IsAuthorOf:* links and shows the relationships between a topic and its author having publications on the topic,
- *IsInstitutionOf:* links and shows the relationships between a topic and an Institution in which the authors having publications on the topic and
- *IsPublicationNumber(1990-2010):* links and shows the relationships between a topic and the number of publications within (1990-2010) and
- *IsTheFirstYearOfAppearanceOf* : links and shows the relationships between a topic and the year when a publication was first published.

For example, topic *Access (General)* relates to individuals *Authors (top 5 authors, viz. Agosti_M.; Bertino_E.; Ferrari_E.; Ferro_N.; He_D.), Institutions (top 5 institutions, viz. University_of_California; University_of_Maryland; University_of_Pittsburgh; Università_degli_Studi_di_Padova; Wahan_University), Publication number within (1990-2010), viz. 319 and First year of appearance of the topic, viz. 1996* (see Figure 6.5 – 6.6).

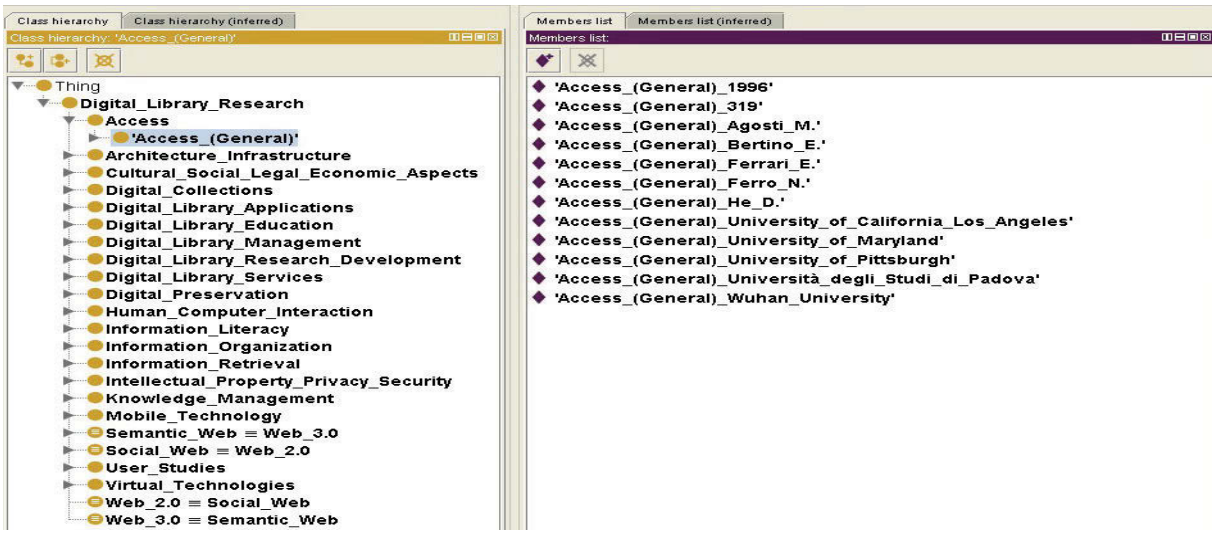

Figure 6.5 : A Screenshot of topic *Access (General)* with its related Individuals (member list) *Authors, Institutions, Publication number(1990-2010), First year of appearance.*

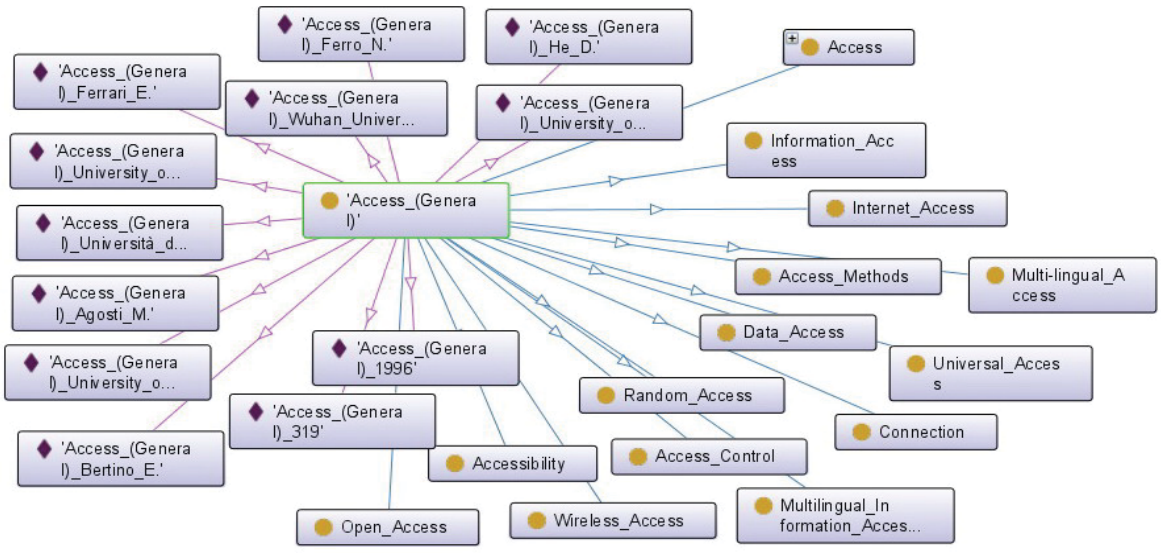

Figure 6.6: A Visualization of Relationships between topic *Access (General)* with its related Individuals (member list) *Authors, Institutions, Publication Number(1990-2010), First Year of Appearance.*

Data Properties

In the digital library ontology, some datatype properties are used to describe the *NamesOfAuthors, NamesOfInstitutions* and the number *of Publications(1990-2010), FirstYearOfAppearance* of a topic (Individual).

- For example, Restricted filter for *NamesOfAuthors and NamesOfInstitutions* is Name, i.e. names of authors having papers on the topic *Access (General)* are *Agosti M., Bertino E., Ferrari., Ferro N. and He N.*; and names of institutions in which the authors having papers on the topic *Access (General)* are *University of California Los Angeles, University of Maryland, University of Pittsburgh, Università degli Sudi di Padova* and *Wuhan University* (see Figure 6.7).

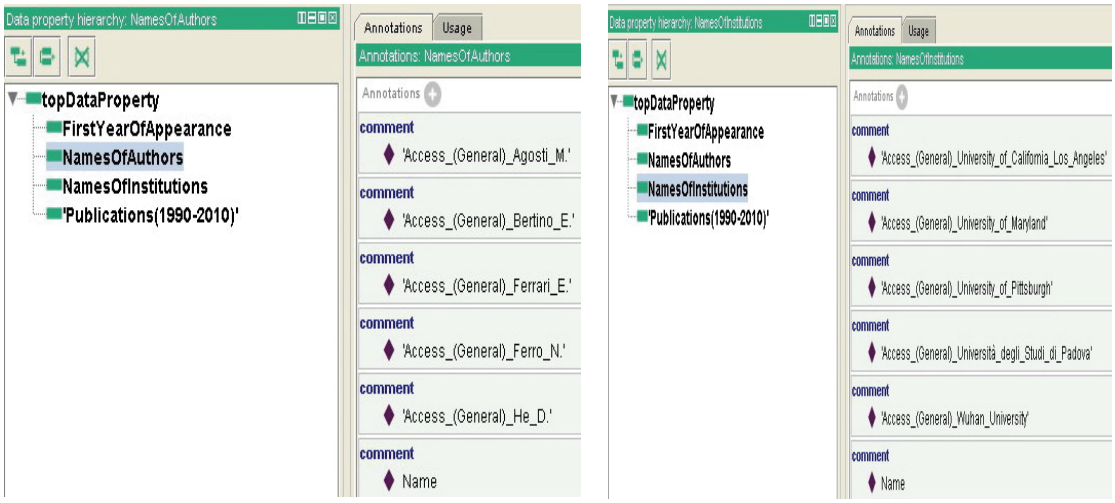

Figure 6.7: A Screenshot of Datatype *NamesOfAuthors and NamesOfInstitutions*

- For example: Restricted filter for the numbers *of Publications(1990-2010)* and *FirsYearOfAppearance* is Integer (for Number). For example: the number of publication within the period (1990-2010) on the topic *Access (General)* is 319; the year when the topic *Access (General)* appears for the first time is 1996 (see Figure 6.8).

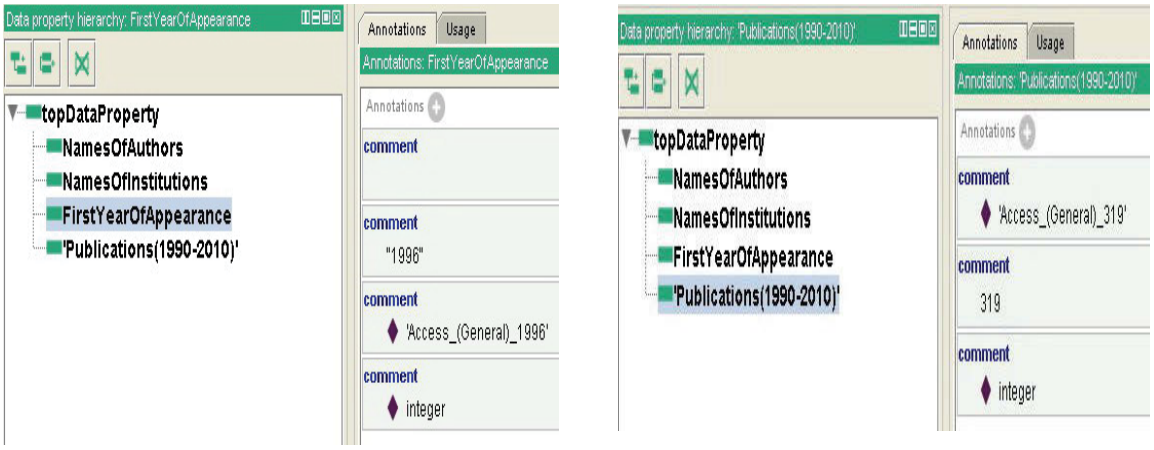

Figure 6.8: A Screenshot of Datatype *Publications(1990-2010)* and *FirstYearOfAppearance*

Annotation Properties

In the digital library ontology, some initial Annotation Properties are created for adding information (metadata) to classes, individuals and object/datatype properties.

For example:

- Annotations of Classes: giving the definitions of the domains (Note: only 21 definitions are provided for 21 core topics in the digital library ontology for the purpose of illustration) (see Figure 6.9).

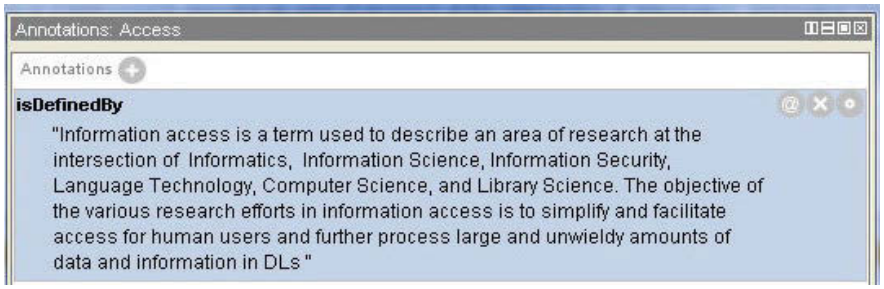

Figure 6.9: A Screenshot of Annotations of Classes

- Annotations of Object Properties: adding information to object properties (see Figure 6.10).

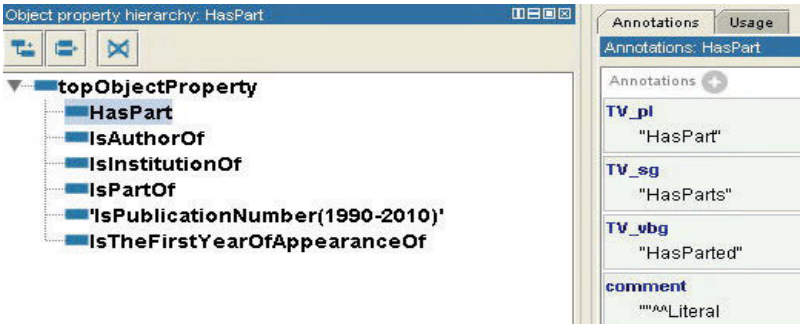

Figure 6.10: A Screenshot of Annotations of Object Properties

- Annotations of Datatype Properties: adding information to datatype properties (see Figure Datatype Properties) (see Figure 6.11).

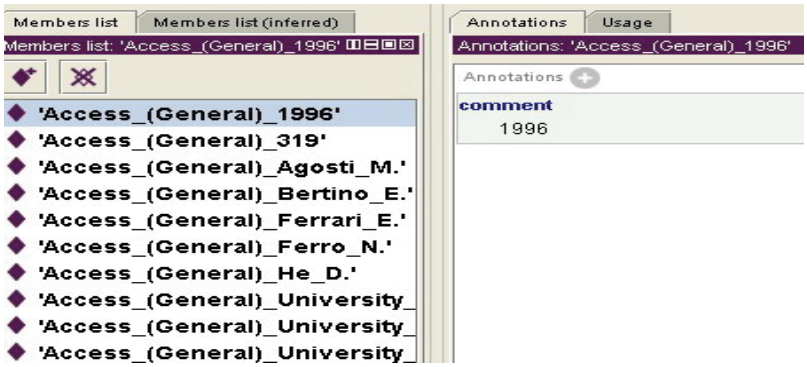

Figure 6.11: A Screenshot of Annotations of Datatype Properties

Classes

According to Horridge (2011), ontology classes are interpreted as sets that contain individuals with common characteristics. They are described using formal (mathematical) descriptions that state precisely the requirements for membership of the class (see Figure 6.12).

Figure 6.12: An Illustration of Digital Library Research and its 21 Main Classes (21 Core Topics)

The digital library ontology classes may be organised into a superclass-subclass hierarchy, which is also known as a taxonomy. Subclasses specialise (are subsumed by) their superclasses. The superclass-subclass relationships (subsumption relationships) can be computed automatically by a reasoner.

Superclass Relationships

Classes can be organized in a hierarchy. Direct instances of subclass are also (indirect) instances of superclasses. In the figure, the superclass is *Digital Library Research* which has mainclass *Access*; and subclass *Access (General)*; Siblingclasses *Access Control, Open Access, Information Access, Data Access, Connection, Accessibility, Random Access, Multilingual Information Access, Internet Access, Universal Access, Multi-lingual Access, Access Methods, Wireless Access* (see Figure 6.13).

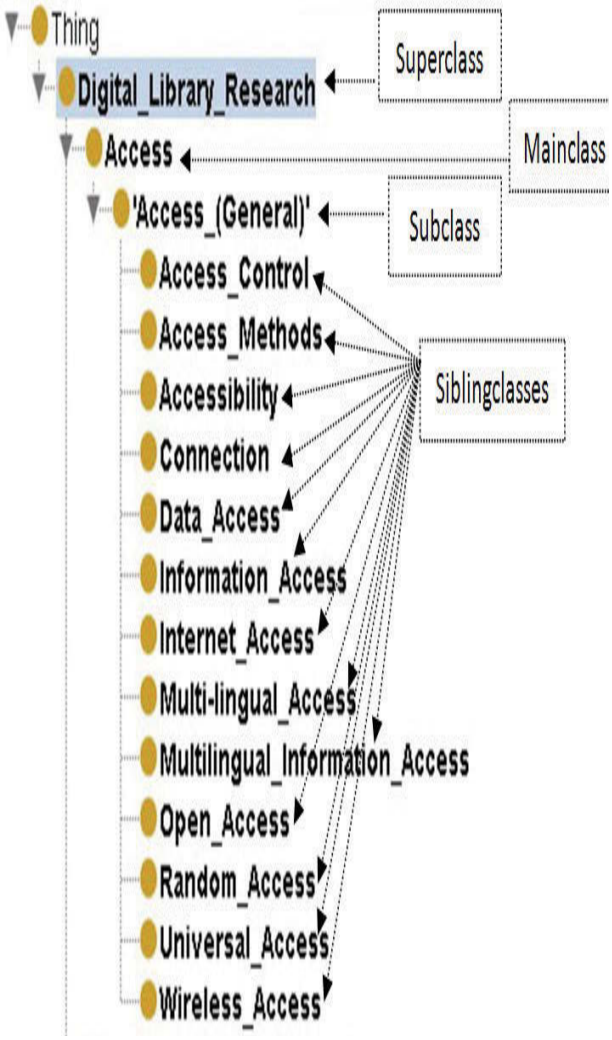

Figure 6.13: An Illustration of Superclass Relationships

Range and Domain

According to Horridge (2011), properties may have a domain and a range specified. Properties link individuals from the domain to individuals from the range. For example, *Social Web (Web 2.0), Semantic Web (Web 3.0), Mobile Technology, Virtual Technologies* are subclasses of *Architecture – Infrastructure*. In the digital library ontology, there is the domain and range for the property *HasPart* and its inverse property *IsPartOf*. The domain of *HasPart* is *Architecture – Infrastructure*, the range of *HasPart* is *Social Web (Web 2.0), Semantic Web (Web 3.0), Mobile Technology, Virtual Technologies*. The domain and range for *HasPart* are the domain and range for *IsPartOf* swapped over (see Figure 6.14 – 6.15 – 6.16 - 6.17).

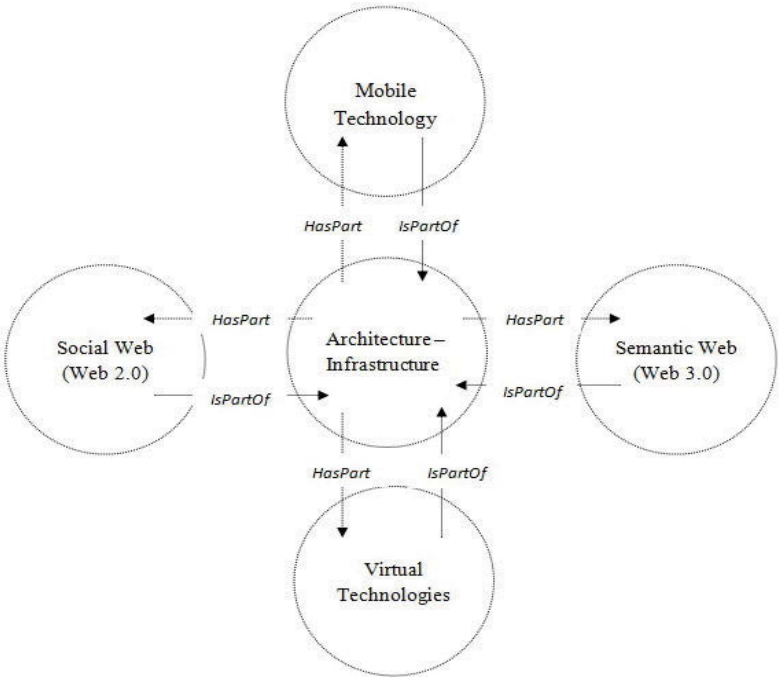

Figure 6.14: An Illustration of Range and Domain

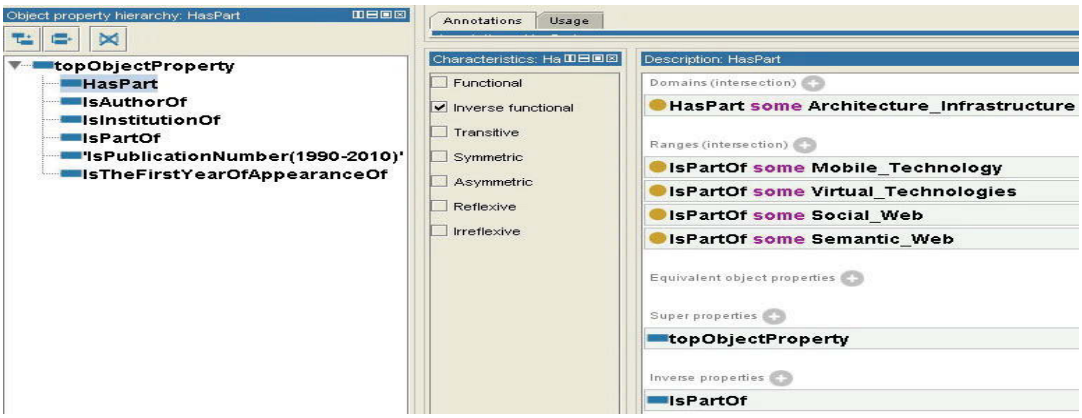

Figure 6.15: A Screenshot of Domain and Range for the Property *HasPart*

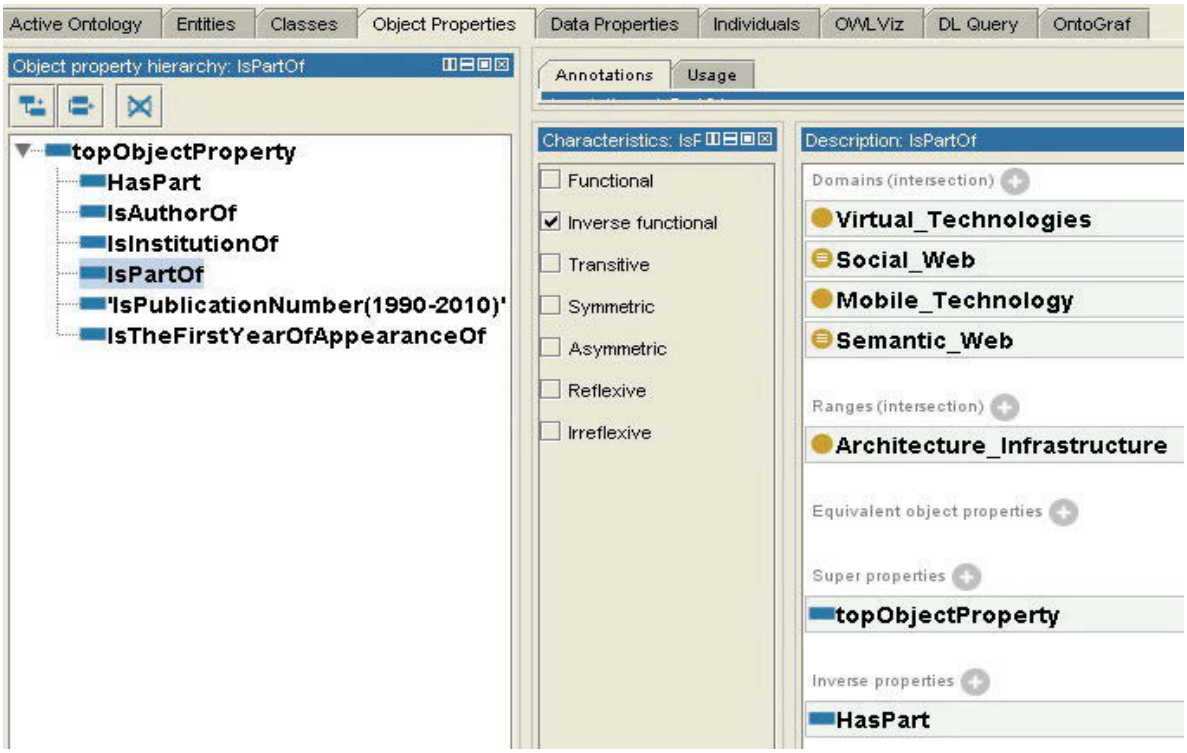

Figure 6.16: A Screenshot of Domain and Range for the Property *IsPartOf*

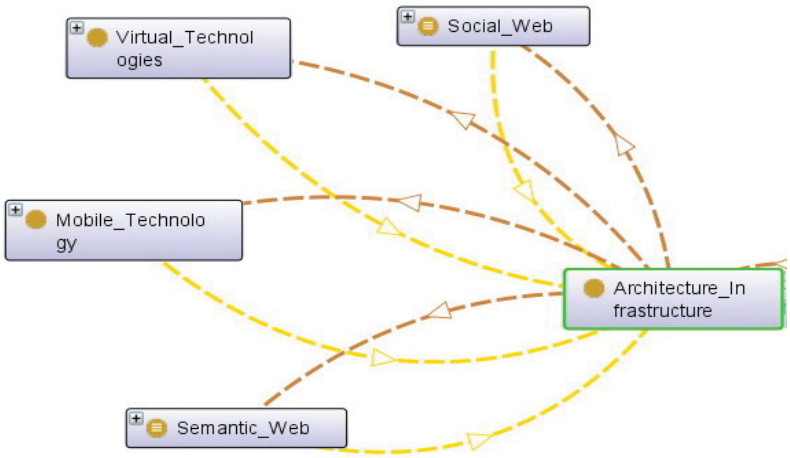

Figure 6.17: A Screenshot of Domain *Architecture – Infrastructure* and range *Social Web (Web 2.0), Semantic Web (Web 3.0), Mobile Technology, Virtual Technologies*

Class Relationships

Class Jointness: Classes can be joined by having (sharing) common individuals (instances). For example, three classes *Architecture (General), Metadata, Information Retrieval (General)* have a common individual *Interoperability* which is the intersection of the three classes (see Figure 6.18 – 6.19).

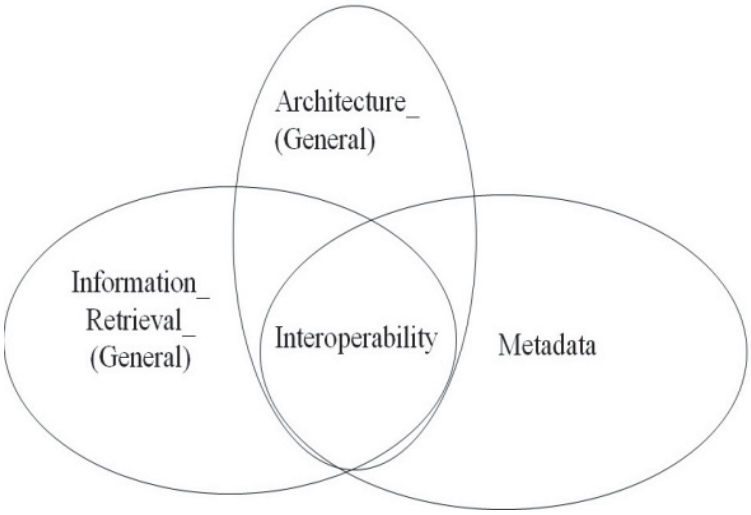

Figure 6.18: An Illustration of Class Jointness

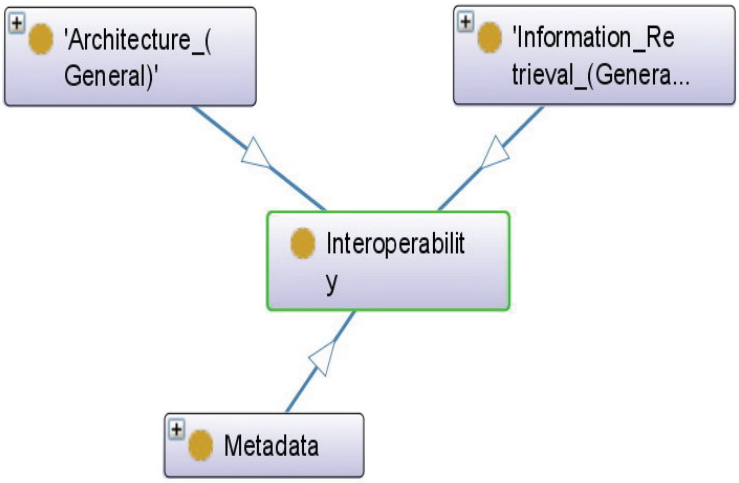

Figure 6.19: A Screenshot of Class Jointness

Class Disjointness: All classes could potentially overlap. However, in many cases, they don't share individual instances. For example, class *Architecture – Infrastructure* is disjoint with class *Information Literacy*. This is because the domain of *Architecture – Infrastructure* includes individual instances (topics) relating to technical aspects, i.e. *Computing(General); Algorithms(General); Software(General); Internet; Data Sets; Digital Objects; Fuzzy Systems,* etc. while *Information Literacy* includes individual instances (topics) relating to human and social aspects, i.e. *Information Society; Digital Divide; Information Overload; Ethics; Critical Thinking; Learning Communities; Lifelong Learning; User Education; Information Ethics; Critical Evaluation,* etc. As a result, class *Architecture – Infrastructure* is disjoint with class *Information Literacy* for not sharing individual instances (topics) (see Figure 6.20).

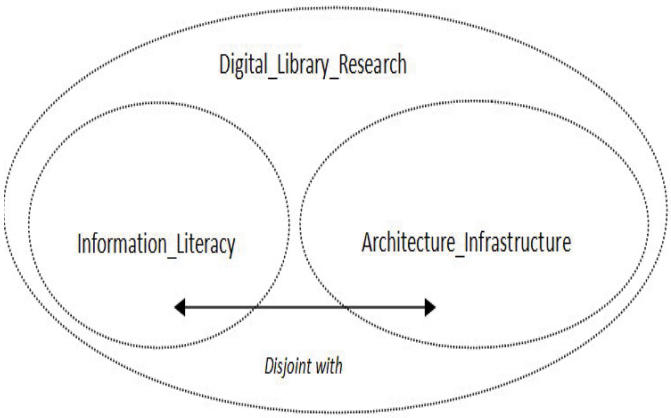

Figure 6.20: An Illustration of Class Disjointness

6.3 Summary

In conclusion, this chapter described how the digital library ontology was designed, engineered and created by using the Protégé ontology software. The main components of the digital library ontology, viz. Individuals, Properties and Classes were built to show the semantic relationships of 21 core topics and 1015 subtopics in visual forms. In the future, the structure of class organization can be re-organized and justified based on the understandings of digital library domain experts who will help to improve the knowledge sharing, applying and usages in various domain and specific contexts of user communities of the digital library ontology.

Chapter 7

Conclusions and Recommendations

7.1 Introduction

As discussed in Chapter 1 (Section 1.2), there were three main aims of this research, viz.

- to create a knowledge map of the digital library research domain,
- to analyse the current state and predict the future of research in digital libraries and
- to engineer and develop an ontology of digital libraries.

This is the first and unique study on knowledge mapping, analysis of research trends and ontology engineering in digital libraries. The research was completed in three different, but inter-related phases. First, a four-stage methodology (discussed in Chapter 3, Section 3.2.1), principles of knowledge organization methods (classification and thesaurus building) and the principle of literary warrant were used to build a knowledge map of digital libraries. The knowledge map covering 21 core topics and 1015 subtopics of digital library research provides a systematic overview of digital library research of the last two decades (1990-2010).

Second, the digital library knowledge map comprising 21 core topics and 1015 subtopics was used to analyse the trends of digital library research. Simple bibliometric techniques of counting the number of publications in each core and subtopic was used along with regression analysis (R^2) techniques to analyse the past of digital library research (1990-2010) and to predict the future of digital library domain.

Third, the library knowledge map and the Protégé software were used for creating the main components of a digital library ontology, viz. individuals, properties and classes, etc. for building the basic digital library ontology. This resulted in an ontology and a visual knowledge map of the digital library domain.

7.2 Summary and Discussions

7.2.1 The Knowledge Map of Digital Library Research

The knowledge map includes 21 core topics and 1015 subtopics of digital library research within the period of 20 years (1990-2010). The knowledge map was constructed on a sample of 7905 records within the digital library domain from SCOPUS database (the largest abstract and citation database of peer-reviewed literature) (SCOPUS, 2011). These findings are more comprehensive and up to date compared to similar other studies. For example, Pomerantz et al (2006) studied 1064 records published within 10 years (1995-2005) and identified 19 core topics and 69 subtopics; and Liew (2009) conducted her study with 557 records published within 10 years (1997-2007) and identified 5 core topics and 62 subtopics.

It may be noted that the core research topics and subtopics in digital libraries come from different disciplines including Library & Information Science (Digital Collections, Digital Preservation, Information Organization, User Studies, etc.); Computer Science (Architecture – Infrastructure, Information Retrieval, Human - Computer Interaction, etc.); Knowledge Management; Management Science (Digital Library Management); Social Sciences (Cultural, Social, Legal, Economic Aspects), etc. Also, the map shows that some subtopics may appear under more than one topic meaning that a given topic may be studied from different perspectives, e.g. the subtopic *Interoperability* appears under 3 core topics: *Architecture – Infrastructure*, *Information Retrieval*, and *Information Organization*.

The knowledge map also shows how new topics and subtopics emerged over a period of time. For example, four core topics, viz. *Social Web (Web 2.0), Semantic Web (Web 3.0), Mobile Technology, and Virtual Technology* came out of the core topic *Architecture – Infrastructure*. Other new and emerging concepts that are transforming digital libraries include *Library 2.0 (Social DLs), Library 3.0 (Semantic DLs), Virtual DLs, Mobile DLs*, etc. Thus the knowledge map will help researchers understand the trends of digital library research as a growing and evolving body of knowledge. In addition, this shows external fields/topics have come within this digital library field. For example, many topics and subtopics that had their origin in Computer Science, have now entered into the digital library research and have become important areas of research in the digital library domain.

The knowledge map also shows the increasing or decreasing interest of research in specific areas, e.g. *Architecture – Infrastructure* and *Information Organization* are the topics of huge research interests, while *Digital Library Education* and *Information Literacy* are the areas of least interest.

7.2.1.1 Applications of the Digital Library Knowledge Map

A Source for Digital Library Ontology Development

This map can be transformed into digital library ontology for semantic web development by using ontology development tools, such as: Protégé, FlexViz, DOME, Altova, ITM, etc. Such an ontology will facilitate search and retrieval of digital library topics and thus will promote digital library research and scholarship. This is discussed further in Section 7.2.3

A Robust Knowledge Platform for Digital Library Research, Education and Practices

As shown in Figure 7.1, the knowledge map can play a major role in designing and developing digital library research, curriculum and practices. First, digital library researchers and professionals can use the map to outline their research frameworks; plan their research programs according to the topics and subtopics in the map; plan staffing and employing experts against 21 core topics and 1015 subtopics; work towards connecting various disciplines (Library & Information Science, Computer Science, Knowledge Management, etc.), building interdisciplinary and collaborative programs that haven't been fully developed so far within the digital library communities, and so on.

Second, this map can be helpful for design and development of new digital library curricula. By using the topics and subtopics of the map, it is also possible to build new learning resources (text books, research papers, digital collections, etc.).

Third, the map can be used as a valuable and visual guiding tool for Chief Information Officers (CIO), Chief Knowledge Officer (CKO), leaders, managers, supervisors, librarians, technicians, etc., for understanding and mapping their various digital library activities, and also for finding gaps and improving performances, i.e. comparing their existing knowledge to the map for analysing and identifying the gap. Moreover, the map can be used as a scientific evaluation framework for assessing and measuring various research, scholarly and professional activities.

In Figure 7.1, the outwards arrow represents the order (1,2,3) as *"from thoughts to deeds"* of implementing the map and advises that the scientific order should be applied for any digital library research, education and practice activities in which (1) the researchers can use the map as a knowledgebase to guide, design and conduct their research with outputs as publications (papers, research monographs, textbooks, etc.) by which (2) the educators can design and develop their curricula and build knowledge and skills for digital librarians and researchers and (3) professionals can perform their activities using these evolving tools, technologies, standards, guides, etc.

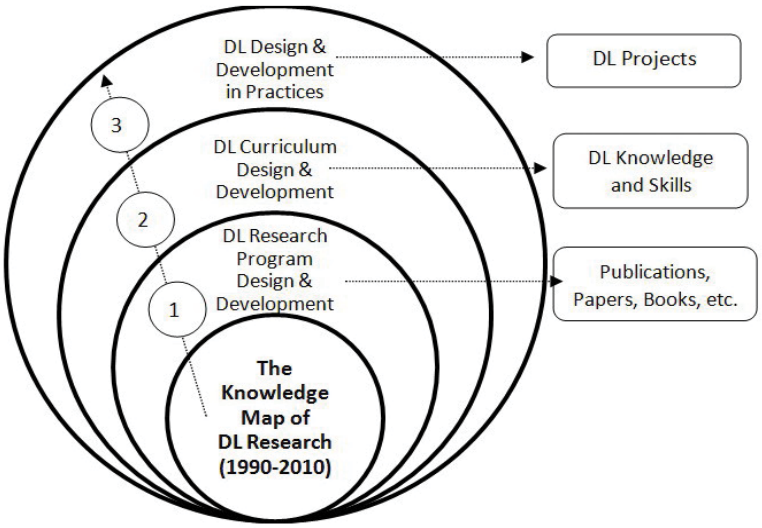

Figure 7.1: An Application Model of the Knowledge Map of Digital Library Research (1990-2010)

A Knowledge Mapping Methodology

The methods used and illustrations provided for building the digital library knowledge map can be used in other domains in order to build a knowledge map that is primarily based on the principles of literary warrant.

Knowledge Map of Digital Library Research vs. Knowledge Map of Information Science

Like the knowledge map of Information Science (Zin, 2007b, p.529), the knowledge map of digital library research (1990-2010) also covers the 3 core domains of modern Information Science, viz. Information, Technology and People but it differs in terms of structure, categorization and number of core topics and subtopics. Both the maps can play as knowledge platforms to guide, evaluate and improve the activities of research, education and practices in their fields (Appendix 3).

7.2.2 Digital Library Research Trends

As discussed in Chapter 5, overall, there is a strong increase in the total number of publications in 1015 subtopics within 21 core topics of digital library research (1990-2010) with an average future growth prediction as $R^2 = 0.836$ (very strong). Interestingly, as shown in in Table 5.2, although some core topics have the largest number of publications, viz. *Architecture – Infrastructure (15339), DL Research & Development (14220), Information Organization (6036) and Digital Collections (4593)*, they do not have the strongest growth rate. Similarly, some topics having much fewer number of publications like *User Studies (2485), Mobile Technology (359), Semantic Web (Web 3.0) (590), Social Web (Web 2.0) (298), Knowledge Management (1533)* and *Digital Preservation (2141)*, show strongest future growths in term of R^2 values. Furthermore, the core topic *DL Education* has the least number of publications as well as the least R^2 value. Therefore, it should be paid more attention so that it would enhance the activities of research, education and implementation within the digital library domain.

This research will help digital library researchers, educators, practitioners to measure and foresee the digital library research outputs for planning and managing the digital library research, education and development effectively. It should be noted that the trends shown here are based on the publication counts from the SCOPUS database only, and although the predictions are reliable because this is the largest database of its kind, some specific figures in the trend analysis could vary if one chooses to use a different database.

7.2.3 Digital Library Ontology

As discussed in Chapter 3 (section 3.4), in the methodology of the digital library ontology engineering, knowledge acquisition is the first step and in this research, it comprised a four-stage research process. Then, in order to model the knowledge map for building the digital library ontology, the Protégé software was used for creating the main components of the ontology, viz. Individuals, Properties and Classes. Furthermore the necessary data for the various classes, subclasses, etc. were coded from the SCOPUS database. The method used for the knowledge acquisition based on the principles of literary warrant (as discussed in Chapter 3) is very unique and novel. The knowledge acquisition method can be used in other domains in order to capture and build a knowledge map of any domain.

In the digital library ontology, some properties were created to describe relationships between individuals (Object Properties: *HasPart* and *IsPartOf*), describe relationships between an individual and data values (Data Properties: *IsAuthorOf, IsInstitutionOf, IsPublicationNumber(1990-2010), IsTheFirstYearOfAppearanceOf*) and add information (metadata) to classes, individuals and object/data type properties (Annotation Properties).

Because of the fact that the properties are essential for creating a frame of the digital library ontology, an ontology developer can add more properties for enriching the descriptions of relationships between individuals. In this research this was done in order to provide more information and value to the properties, such as:

- Data Properties: adding the names (of Authors, Institutions) and values (of Publication Numbers, First Year of Appearance) for all the core topics and subtopics and
- Annotation Properties: providing the domain definitions of all the core topics and subtopics.

7.2.3.1 Applications of the Digital Library Ontology

As a knowledgebase of digital library domain, the digital library ontology can be applied into following areas.

A backbone for software agents and semantic web development within the digital library domain

Suppose several different websites contain different digital library topics. If these websites share and publish the same underlying digital library ontology of the topics (terms) they all use, then computer agents can extract and aggregate information from these different sites. The agents can use this aggregated information to answer user queries or as input data to other applications (Gaševic et al, 2009). Especially, when applied to the SCOPUS or ISI Web of Knowledge databases, the ontology will easily map the digital library domain and facilitate searching publications of the domain. Future research should explore how such a digital library ontology can be integrated with online databases like SCOPUS and ISI Web of Knowledge.

A framework for knowledge management of digital library domain

According to Gaševic et al (2009), ontology can be applied in the following areas of knowledge management.

- Knowledge sharing and reuse: the digital library ontology can play an important role in knowledge management of digital library domain. From the knowledge acquisition and modelling the domain with Protégé, this process helps to build up a model of understanding in visual form describing what the digital library core topics and subtopics (concepts) are, how they are related to each other. They also specify rules for combining the topics and their relations to define extensions to the digital library domain. As a result, the digital library ontology makes the digital library domain clearly understandable, interpreted and standardised. Hence, the ontology conveys a shared understanding with unambiguous meanings of the digital library domain that is agreed between a number of individuals or agents (machine-processable common understanding of the topics). Such an agreement facilitates accurate and effective communication of meaning. This, in turn, opens up the possibility for knowledge sharing and reuse, which enables semantic interoperability between users and applications. By sharing and using the digital library ontology, the users can create new ideas and contents, and then add new concepts (topics) to the ontology to help the body of digital library knowledge tree grow.
- Knowledge collaboration: Covering 21 core topics and 1015 subtopics from Computer Science, Library and Information Science, Media and Communication, Archives and Recordkeeping, Business Management, etc., the digital library ontology provides different experts a unifying digital library knowledge skeleton that can be used as a common, shared reference for further development and participation. These people can simply talk more easily to each other when they have such a stable, consensual and visual knowledge map to rely on. Perhaps even more importantly, the digital library ontology can play the same role in collaboration between intelligent agents in terms of agent-to-agent communication. When an agent sends a message to another agent that it is communicating with, the other agent must have the same digital library domain model (i.e., the same ontology) in order to interpret the message correctly. Knowledge exchange about digital libraries between agents is much more feasible when the agents are aware of the digital library ontology that the other agents are using as a digital library domain model. Hence, the digital library ontology can help in the collaboration in the digital library domain.

- Knowledge interoperation: The digital library ontology enables the integration of information from different and disparate sources. End users typically do not show much interest in how they get their information; rather they are much more interested in getting the information they need, and getting all of it. Distributed applications may need to access several different knowledge sources in order to obtain all the information available, and those different sources may supply information in different formats and in different levels of detail. However, if all the sources recognize the same digital library ontology, data conversion and information integration are easier to do automatically and in a more natural way.

A platform for managing and conducting digital library research and education

By capturing and visualizing the whole digital library domain, the ontology can play an important role in helping researchers manage and conduct digital library research and education activities. First, by studying and analysing the digital library ontology, digital library researchers can see the body of digital library knowledge tree through a visual map, understand the evolution of the domain including the lead authors, funding institutions, etc., which can save their time and efforts in doing research and development works. Second, the digital library ontology can not only help to design and develop new digital library curricula but can also help teachers and learners communicate effectively by using the ontology, such as: structure for the minds-on part of hands-on/minds-on teaching; a systematic means for reflecting on and analysing inquiry learning; a knowledge arena for operating on ideas; tangible support for the transition from teacher-centred to student-centred classrooms; generate ideas (brainstorming, etc.); design a complex structure (long texts, hypermedia, large web sites, etc.); communicate complex ideas; aid learning by explicitly integrating new and old knowledge; and assess understanding or diagnose misunderstanding (Fisher et al, 2002; Lanzing, 1997).

7.4 Limitations and Recommendations for Further Research

7.4.1 The Knowledge Map of Digital Library Research

Because the sample used in the research was limited to 7905 bibliographic records of digital library publications published between 1990 - 2010 within the SCOPUS database which is a commercial database, open access resources could not be included in this study which is no doubt a limitation of this study. A more comprehensive study with commercial databases as

well as open access digital library publications would produce a more comprehensive knowledge map of digital libraries.

Another limitation of this study appeared because of the way in which keywords are assigned to published articles in the database. In some core topics, a significant proportion of the publications were on some general (as opposed to specific) subtopics, examples being *Information Retrieval (General)*, *Search (General)*, *Query (General)*, etc. This happened because in a substantial number of publications these rather generic subtopic names were used as keywords along with other subtopic names as keywords. However, in this research, a large number of publications appear under some generic subtopic names. A research focusing more on such generic keywords would shed new lights on this issue and this would have some useful implications for generating the knowledge map.

In the future, as the digital library domain expansion, the map will be developed and reorganized as by the same methods. Moreover, some other software can assist the method, such as: Leximancer https://www.leximancer.com/ is one of powerful computer assisted programs that helps to identify 'Concepts – Topics - Keywords' within the text, analyzing natural language text data (content analysis), automatically coding text and producing concept map, network cloud, quantitative data, concept thesaurus. Especially, this software is good at working with available fulltext, paragraphs and sentences.

7.4.2 Digital Library Research Trends

Some other limitations of this study were caused by:

- the sample that was limited to a commercial database , viz. SCOPUS , open access resources could not be included in this study. Therefore, the research trends do not include open access research publications.
- The time frames of the dataset from 1990 to 2010 (which is over three years old).

Therefore, further studies should be conducted by combining both the commercial databases, i.e. SCOPUS, ISI Web of Knowledge, LISA, etc., and open access journals and other publications, for example research reports, to increase the coverage of sample. Similarly data from 2011 to 2013 should be also included for more accurate and updated predictions of the digital library research trends in the future.

7.4.3 Digital Library Ontology

The 21 core topics and 1015 subtopics of digital library research within the period (1990 - 2010) are considered as initial and fundamental individuals for the digital library ontology. Therefore, one limitation of this study is the limited numbers of topics (concepts) included in the ontology. Topics from datasets of SCOPUS of years (2011, 2012, 2013) should be added into the ontology for more updated and comprehensive digital library domain.

Because there is a strong increase in the total number of publications in 1015 subtopics within the 21 core topics of digital library research (1990-2010) with an average future growth prediction as $R^2 = 0.836$, it can be predicted that more publications will appear in the future. Especially, there are some core topics showing their future growths in R^2 values of both numbers of publications and subtopics, such as: *User Studies*, *Mobile Technology, Semantic Web(Web 3.0), Social Web (Web 2.0), Knowledge Management,* and *Digital Preservation*. Hence, by using the same method, new topics should be captured and added to the knowledge map for the digital library ontology development. In the example of topic *Access (General)*, only some member list (individuals), viz. *Authors (top 5 authors), Institutions (top 5 institutions), Publication number within (1990-2010)* and *First year of appearance of the topic* are added into the digital library ontology. Based on this example, future ontology developers can add more individuals of each topic, such as: top 10 or 20 or more of authors and institutions; year of topic disappearing, if any; publication numbers by each year or within different periods of times; funding institutions; related digital library project, conference, workshop websites; digital library research papers and books; digital library education and research subject websites; websites of digital library research strengths on a specific topic of any institution, etc., which will help to enrich the ontology to meet various demands of digital library research, education and practices and cooperation of digital library communities around the globe.

7.4.4 Trends in Digital Library Research vs. Research Funding

This research has not studied the trends in digital library research within shorter time spans, for example in a breakdown of five-year or ten-year blocks. Such an analysis would be helpful to study whether and how digital library research ties up with the major research funding initiatives, for example, in the US or in Europe.

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Appendices

Appendix 1: Core topic and Subtopics from Chowdhury and Chowdhury (1999), Pomerantz et al (2006), Liew (2009)

Chowdhury and Chowdhury (1999)	Pomerantz et al (2006)	Liew (2009)
Goal of study: Reviewing research and development in DLs in the nineties	**Goal of study:** DL curriculum development	**Goal of study:** Studying the organizational and people issues of DLs
Core topics (16 areas) 1. Collection Development 2. Development Methodology and Design Issues 3. User Interfaces 4. Information Organisation: Classification and Indexing 5. Resource Discovery: Metadata 6. Access and File Management 7. User Studies 8. Information Retrieval 9. Legal Issues 10. Social Issues 11. Evaluation of Digital Information 12. Evaluation of Digital Libraries 13. Standards 14. Preservation 15. Implications for library managers 16. Future directions.	**Core topics (19 modules)/ Subtopics (69 related topics): CS & LIS aspects** **Module 1:** Digitization, Storage, Interchange **Module 2**: Digital Objects, Composites, Packages **Module 3**: Metadata, Cataloging, Author Submission **Module 4:** Naming, Repositories, Archives **Module 5**: Spaces (Conceptual, Geographic, 2/3D, VR) **Module 6**: Architectures (agents, buses, wrappers/mediators), Interoperability **Module 7:** Services (searching, linking, browsing, etc.) **Module 8**: Intellectual property rights management, Privacy, Protection (watermarking) **Module 9**: Archiving and preservation, Integrity **Module 10**: Multimedia Streams/ Structures, Capture/representation, Compression/coding **Module 11**: Content-based analysis, Multimedia indexing and retrieval **Module 12**: Multimedia presentation	**Core topics (5 themes)/ Subtopics (62): Social Aspect** **1. Use/usability issues:** Usability, Interface/interaction design, human computer interface/user, interface, User-centeredness, Accessibility, User needs assessment/ analysis, User education/ training, Added/ add value, Quality ssurance/quality control, User perception/ expectation, User acceptance/ acceptability, Personalise/ personalisation **2. Ethical issues:** Privacy/confidentiality, Trust, Individual rights **3. Legal issues:** Copyright, Rights management, Intellectual property rights/ regulatory, Issues/ regulations **4. Socio-cultural issues:** Multilingual, Multicultural, Cross-cultural, Social

	and rendering **Module 13**: Documents, E-publishing, Markup **Module 14**: Info. needs, Relevance, Evaluation, Effectiveness **Module 15**: Thesauri, Ontologies, Classification, Categorization **Module 16**: Bibliographic information, Bibliometrics, Citations **Module 17**: Routing, Filtering, Community filtering **Module 18:** Search & search strategy, Info seeking behavior, User modeling, Feedback **Module 19:** Information summarization, Visualization	inclusion/exclusion, Cross-lingual, Social/team empowerment, Learning/ knowledge environment **5. Organisational/ economical Issues:** Collaboration/cooperative efforts, Planning, Funding, Licensing, Collection management/ policies, Marketing, Business models, Promotion, Cost-benefit analysis, Internet/electronic commerce, Feasibility studies, Benchmark/ benchmarking, Outreach, Sustainability, Risk management, Socio-economic issues

Appendix 2: 15 core and 210 subtopics on digital library research (1997 – 2010) from 37 conference volumes: JCDL (2001-2010), ECDL (1997-2010) and ICADL (1998-2010)

The table shows the 15 core and 210 subtopics collected and organized from the 37 conference volumes: JCDL (2001-2010), ECDL (1997-2010) and ICADL (1998-2010). In the table, the conference name and the year the topic first appeared in the CFPs are indentified. e.g. *1.Digital Library Creation, 2. Digital Video Libraries, 3. OCR Text Verification (ICADL,98)*: the three topics first appeared in ICADL in 1998. All of the terms were kept originally in form of structured - table of DL core and subtopics for later research. Each group of subtopics of the same conference and year is separated by Slash sign (/)

1. Digital Collections (27 subtopics): 1.Digital Library Creation, 2. Digital Video Libraries, 3. OCR Text Verification (ICADL,98)/ 4. Arts Collection, 5. Government Information Collection, 6. Manuscripts Collection, 7. Humanities Collection, 8. Geographic Material Collection 9. Authoring, 10. Watermark, 11. Image Processing (ICADL,99)/ 12.Multimedia, 13. Agents (ICADL,99; ECDL,98;JCDL,01)/ 14.Electronic publishing, 15. Electronic journals , 16. Electronic newspapers (ICADL,00; ECDL,00; JCDL,01) / 17. EBooks (ECDL,02) / 18. Management (Collection), 19. Integration (Collection) (ECDL,03) / 20. Music Digital Libraries (JCDL,01; ECDL,04) / 21. Heterogeneous digital collections (ICADL,04)/ 22. Scholarly publishing (ICADL,05) / 23. Concepts of Digital Libraries, 24. Concepts of Digital Documents (ECDL,05) /25. Large-Scale Collections (JCDL,07)/ 26.Evaluation of Internet Resources (ICADL,98)/ 27. New Publishing (ECDL,00)/
2. Digital Preservation (16 subtopics): 1.Archives (Archiving) (ICADL,99; ECDL, 2000; JCDL,2001) / 2. Cultural Heritage Preservation (ICADL,01) / 3. Web Archiving, 4. Online Archive (ECDL,02) / 5. Digital Archives, 6. Digital Museums (ICADL,02) / 7. Preserving (ICADL,04) / 10. Digital Curation (ECDL,07; JCDL,07)/ 11. Methodological (Digital Archiving - Preservation), 12. Technical (Digital Archiving - Preservation), 13. Legal Issues (Digital Archiving - Preservation) (ECDL,07) / 14. Preservation Systems, 15. Algorithms (ICADL,2010)/ 16. Open Archives Initiative (OAI) (ECDL,04; ICADL,04)
3. Information Organization (42 subtopics): 1.Metadata, 2. Structured Documents (ECDL,97; ICADL,98; JCDL,01) / 3. Categorization (ECDL,99; ICADL,08) / 5. Text Processing, 6. Data Management (ICADL,98)/ 7. Automatic Indexing (ICADL,99; ECDL,00)/ 8. Data Mining (ICADL,98;ECDL,01) / 9. Capturing; 10. Indexing, 11. Cataloging (ECDL,00)/ 12. Harvesting, 13. Interoperability, 14. Scalability, 15. Extensibility Issues, 16. Files/ Formats Representation (ICADL,01)/ 17. Interpretation, 18. Annotation of Documents (ECDL,01)/ 19. Web Cataloguing (ICADL,02)/ 20. Personalized Classification (ECDL,02) / 21. Information Organization (ECDL,05) / 22. Semi Structured Data (ICADL,05; ECDL,09) / 23. Web-page Analysis (ICADL,05)/ 24. Taxonomy (ICADL,07)/ 25. Named Entities, 26. Links (JCDL,06)/ 27. Classification (ICADL,99; ECDL,00; JCDL,06)/ 28. Scalability; 29. Networked Resource Discovery, 30. Collaborative, 31. Distributes Authoring, 32. Resources Management (ECDL,00)/ 33. Naming Scheme (ICADL,99)/ 34. Organizing Asian Unique and Indigenous Knowledge and Culture (ICADL,04)/ 35. Information Extraction (ICADL,99; JCDL,07)/ 36. Thesaurus, 37. Summarization / 38. Personalisation, 39. Annotation (ECDL,04) / 40. Information Mining in Multilinguality (ECDL,2010)/ 41. Navigation, 42. Querying (ECDL,98; ICADL,00)/
4. Information Retrieval (16 subtopics): 1. Information Retrieval (ICADL,98; ECDL,97; JCDL,01) / 2. Multilingual Information Retrieval

(ECDL,97; ICADL,99; ECDL,00) / 3. Cross language, 4. Modelling, 5. Accessibility, 6. Connectness (ECDL,99)/ 7.Cross-Language Filtering, 8. Dissemination; 9. Multicultural (ICADL,99; ECDL,00) / 10. Information Retrieval in Asian Languages (ICADL,03) / 11.Multimedia Information Handling (ECDL,06) / 12. Searching (ICADL,01)/ 13. Access (ECDL,99; ICADL,08) / 14. Disseminating Asian Unique and Indigenous Knowledge and Culture (ICADL,04)/ 15. Distributed Access (ICADL,99; JCDL,07) / 16. Interoperability (ICADL,00)
5.Human - Computer Interaction (12 subtopics): 1.Supporting User Interaction (ECDL,97)/ 2.User Adaptation (ECDL,98) / 3.Use of Digital Video Libraries (ICADL,98)/ 4.Learning Model, 5.Instruction Model, (ICADL,99) / 6.User Interfaces (ICADL,01;ECDL,99; JCDL,01)/ 7.Evaluation, 8.Usability (ICADL,01; JCDL,01;ECDL,02)/ 9.Portals (ICADL,04)/ 10.Localization (ICADL,05)/ 11. Log Data (ECDL,09)/ 12.Visualisation (ICADL,99; JCDL,06; ECDL,2010)/ 13. Search behaviour (ICADL,00)
6.User Studies (4 subtopics): 1. User Feedback Evaluation (ICADL,99) / 2.Information Needs (ICADL,00) / 3.User's Models (ICADL,01;ECDL,99; JCDL,01)/ 4.User Communities (ICADL,02; JCDL,01; ECDL,01)/
7.Architecture - Infrastructure (13 subtopics): 1. Architectures (ECDL,97; ICADL,99; JCDL,01)/2. Cluster Computer (ICADL,98)/ 3. Network (ICADL,99)/ 4. Interoperability (ECDL,00)/ 5. Agents and tools, 6. Database design & 7. Database development (ICADL,01)/ / 8. Grids (ICADL,04; ECDL,09)/, 9. Open Source tools and systems (ICADL,08)/ 10. Time and Space (JCDL,06)/ 11. Distributing Digital Libraries (ICADL,98)/ 12. Intelligent Agent (ICADL,99; JCDL,07) / 13. Data Warehousing (ICADL,98)
8. Knowledge Management (8 subtopics): 1. Knowledge Management (ICADL,00; ECDL,01)/ 2. Ontologies, 3. Knowledge Organization Systems (JCDL,07; ECDL,09)/ 4. Knowledge sharing (ECDL,99)/ 5. Content Management, 6. Access Control (ICADL,99)/ 7. Knowledge Representation (ICADL,99;ECDL,99;JCDL,01)/ 8.Knowledge Discovery (ICADL,99; JCDL,07)
9. Digital Library Services (5 subtopics): 1.Interoperability across different services (ECDL,02)/ 2.Ontology-based Services (ICADL,02)/ 3.Personal Digital Libraries (ICADL,04; ECDL,04; JCDL,07)/ 4.Live Reference Service (ICADL,04)/ 5.Mobility Services (ICADL,04; ECDL,2010; JCDL,08)/
10. Web Development & Applications (Social Web, Semantic Web) (6 subtopics): 1.Semantic Web (ICADL,02; ECDL,09)/ 2.Ontologies, 3.Topic Maps (ICADL,04) / 4.Social Networking , 5. Web 2.0 Technologies (JCDL,07; ICADL,07; ECDL,08)/ 6.Social Media (ICADL,08)
11. Intellectual Property – Security – Privacy (7 subtopics): 1.Intellectual Property, 2.Rights Management (ECDL,00; ICADL,01; JCDL,01)/ 3.Authentication, 4. Authorization (ICADL,99)/ 5. Cryptography, 6. Compression (ICADL, 03)/ 7. Security (ICADL,99)
12. Cultural, Social, Legal , Economic Aspects (16 subtopics): 1.Social Aspects, 2.Management, 3.Policy Issues (ICADL,08; JCDL,01)/ 4. Cultural Issues, 5. Social Issues, 6. Legal Issues, 7. Economic Issues, 8.Education (ICADL,99; ECDL,06) / 9. Economic Models, 10.Terms and Conditions for Access and 11.Use (ECDL,00)/ 12.Scholarly Communication, 13.Pricing (ICADL,01)/ 14. Pedagogical Issues (ICADL,02)/ 15.Exploring a Cross-Culture Context for DL studies in Asia, 16. Social impacts of DL in Asia Technology (ICADL,04)/

13. Digital Library Applications (23 subtopics): 1.Digital Library Applications (ICADL,98)/ 2.Digital Libraries and Education (ICADL,99;JCDL,06; ECDL,03)/ 3.E-learning, 4.Mobile Learning (ICADL,03)/ 5.e-science (ICADL,05)/ 6.e-government (ECDL,03; ICADL,07)/ 7.Applications Libraries, 8.Museums, 9.Archives, 10. Health Care and Medicine, 11.Digital Earth/Geospatial, 12.Law, 13.Art, 14.Music,15.Humanities, 16.Culture, 17.Social Sciences, 18.News, 19.Current Affairs, 20.Information Industry, 21.Environmental Monitoring, 22.Natural Sciences, 23. E-commerce (ECDL,03)
14. International Collaboration & Development (14 subtopics): 1.Development of Universal Digital Libraries (ICADL,98)/ 2.International Collaboration (ICADL,00; ECDL,00)/ Collaboration of 3.Computer Science, 4.Information Science, 5.Librarianship, 6.Archival Science and Practice,7. Museum Studies and Practice, 8. Technology, 9. Medicine, 10.Social Sciences, 11. Humanities, 12.Academe, 13.Government, 14.Industry (JCDL,01)/
15. Digital Library Curriculum (1 subtopics): 1.Digital Library Curriculum Development (JCDL,06; ICADL,07)

Appendix 3: Knowledge Map of Digital Library Research vs. Knowledge Map of Information Science

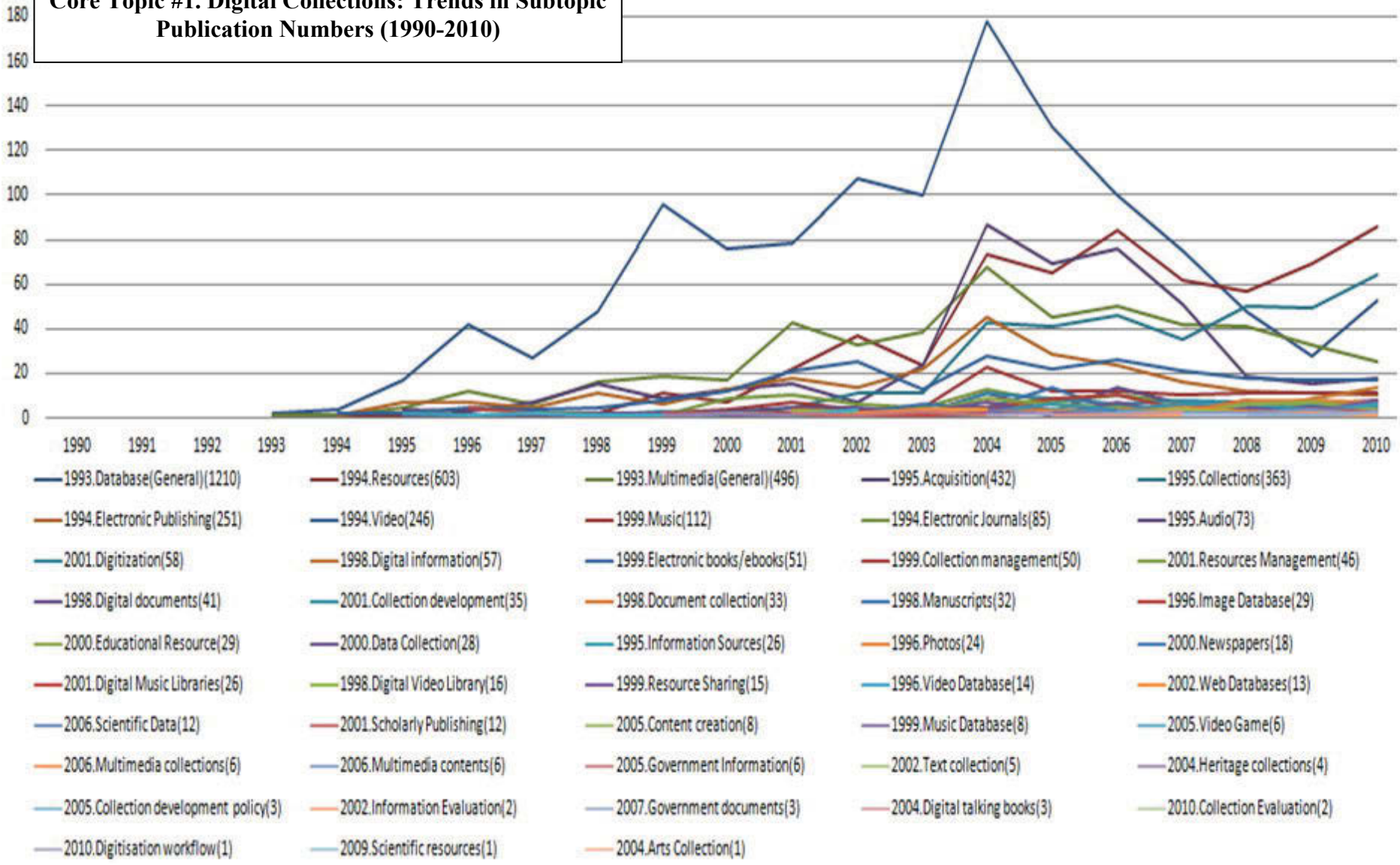
Knowledge Map of Digital Library Research (1990-2010)	**Knowledge Map of Information Science by Zins (2007b, p.529)**
Goal: Mapping the DL field in the period (1990-2010)	**Goal**: Mapping the Information Science field at the beginning of the 21st century
Method: Qualitative, Literary Warrant, Classification, Thesaurus Building	**Method:** Qualitative, Critical Delphi (facilitating critical and moderated discussions among experts)
Findings: The map has 21 core topics and 1015 subtopics structured at 3 levels (Level 1: Core Topics; Level 2: Clusters of Subtopics; Level 3: Subtopics)	**Findings:** The map has 10 basic categories structured at 3 divisions (1st division: Main Categories; 2nd division: Sub – Categories; 3rd division: Sub – Categories with examples of topics)
Applications: The map can play as a knowledge platform to guide, evaluate and improve the activities of DL research, education and practices. Moreover, it can be easily transformed into a DL ontology for various applications.	**Applications:** The map establishes the groundwork for formulating theories of Information Science, as well as developing and evaluating Information Science academic programs and bibliographic resources.

Appendix 4:

Core Topic #1. Digital Collections: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2005.Content creation(8)	0.99	1999.Music(112)	0.27	1996.Image Database(29)	0.19	2005.Collection development policy(3)	#DIV/0
1994.Resources(603)	0.84	2001.Digitization(58)	0.22	2005.Video Game(6)	0.14	2002.Information Evaluation(2)	#DIV/0
1995.Collections(363)	0.84	1995.Acquisition(432)	0.21	2006.Scientific Data(12)	0.08	2007.Government documents(3)	#DIV/0
1998.Document collection(33)	0.71	1993.Database(General) (1210)	0.20			2004.Digital talking books(3)	#DIV/0
1998.Digital information(57)	0.63	1994.Electronic Publishing(251)	0.19			2010.Collection Evaluation(2)	#DIV/0
1998.Manuscripts(32)	0.59	2001.Scholarly Publishing(12)	0.18			2010.Digitisation workflow(1)	#DIV/0
1994.Video(246)	0.57	1995.Information Sources(26)	0.17			2009.Scientific resources(1)	#DIV/0
1999.Resource Sharing(15)	0.57	1994.Electronic Journals(85)	0.14			2004.Arts Collection(1)	#DIV/0
1993.Multimedia(General)(496)	0.56	2006.Multimedia collections(6)	0.13				
2000.Educational Resource(29)	0.51	1999.Electronic books/ebooks(51)	0.11				
2006.Multimedia contents(6)	0.47	2001.Resources Management(46)	0.10				
2002.Text collection(5)	0.47	2002.Web Databases(13)	0.06				
2001.Collection development(35)	0.45	1996.Photos(24)	0.02				
2000.Data Collection(28)	0.43	2000.Newspapers(18)	0.02				
2004.Heritage collections(4)	0.40	1996.Video Database(14)	0.01				
1995.Audio(73)	0.37	2005.Government Information(6)	0.01				
2001.Digital Music Libraries(26)	0.35	1998.Digital Video Library(16)	0.00				
1998.Digital documents(41)	0.31	1999.Music Database(8)	0.00				

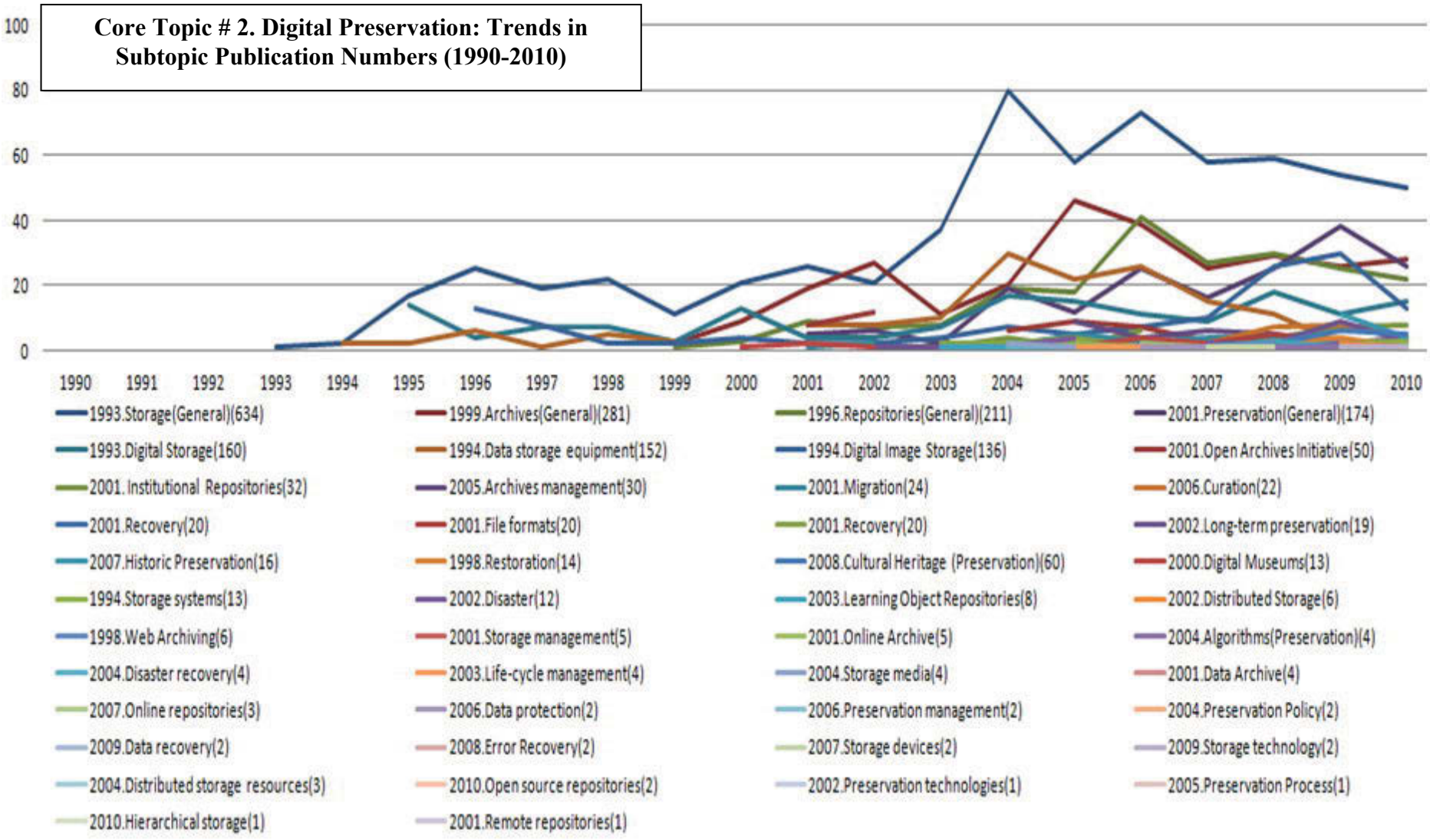
1999.Collection management(50)	0.28						

Core Topic #1. Digital Collections: Trends in Subtopic Publication Numbers (1990-2010)



Appendix 5:

Core Topic # 2. Digital Preservation: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2004.Disaster recovery(4)	0.96	2001.File formats(20)	0.26	2004.Algorithms (Preservation)(4)	0.96	2003.Life-cycle management(4)	#DIV/0
2001.Preservation (General)(174)	0.73	2007.Historic Preservation(16)	0.22	2001.Open Archives Initiative(50)	0.72	2001.Data Archive(4)	#DIV/0
2001. Institutional Repositories(32)	0.72	2003.Learning Object Repositories(8)	0.15	2005.Archives management(30)	0.52	2007.Online repositories(3)	#DIV/0
1993.Storage(General)(634)	0.70	1994.Data storage equipment(152)	0.15	2004.Storage media(4)	0.48	2006.Data protection(2)	#DIV/0
1996.Repositories (General)(211)	0.68	1998.Restoration(14)	0.12	2002.Long-term preservation(19)	0.34	2006.Preservation management(2)	#DIV/0
2008.Cultural Heritage (Preservation)(60)	0.52	2001.Migration(24)	0.11	2002.Disaster(12)	0.00	2004.Preservation Policy(2)	#DIV/0
2001.Storage management(5)	0.49	1994.Storage systems(13)	0.03			2009.Data recovery(2)	#DIV/0
2006.Curation(22)	0.39	2000.Digital Museums(13)	0.01			2008.Error Recovery(2)	#DIV/0
1999.Archives(General)(281)	0.39	2001.Recovery(20)	0.00			2007.Storage devices(2)	#DIV/0
1994.Digital Image Storage(136)	0.35	2001.Recovery(20)	0.00			2009.Storage technology(2)	#DIV/0
1993.Digital Storage(160)	0.34	2001.Online Archive(5)	0.00			2004.Distributed storage resources(3)	#DIV/0
1998.Web Archiving(6)	0.34	2002.Distributed Storage(6)	0.00			2010.Open source repositories(2)	#DIV/0
						2002.Preservation technologies(1)	#DIV/0
						2005.Preservation Process(1)	#DIV/0
						2010.Hierarchical storage(1)	#DIV/0
						2001.Remote repositories(1)	#DIV/0


Core Topic # 2. Digital Preservation: Trends in Subtopic Publication Numbers (1990-2010)
100
80
60
40
20
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
1993.Storage(General)(634)
1999.Archives(General)(281)
1996.Repositories(General)(211)
2001.Preservation(General)(174)
1993.Digital Storage(160)
1994.Data storage equipment(152)
1994.Digital Image Storage(136)
2001.Open Archives Initiative(50)
2001. Institutional Repositories(32)
2005.Archives management(30)
2001.Migration(24)
2006.Curation(22)
2001.Recovery(20)
2001.File formats(20)
2001.Recovery(20)
2002.Long-term preservation(19)
2007.Historic Preservation(16)
1998.Restoration(14)
2008.Cultural Heritage (Preservation)(60)
2000.Digital Museums(13)
1994.Storage systems(13)
2002.Disaster(12)
2003.Learning Object Repositories(8)
2002.Distributed Storage(6)
1998.Web Archiving(6)
2001.Storage management(5)
2001.Online Archive(5)
2004.Algorithms(Preservation)(4)
2004.Disaster recovery(4)
2003.Life-cycle management(4)
2004.Storage media(4)
2001.Data Archive(4)
2007.Online repositories(3)
2006.Data protection(2)
2006.Preservation management(2)
2004.Preservation Policy(2)
2009.Data recovery(2)
2008.Error Recovery(2)
2007.Storage devices(2)
2009.Storage technology(2)
2004.Distributed storage resources(3)
2010.Open source repositories(2)
2002.Preservation technologies(1)
2005.Preservation Process(1)
2010.Hierarchical storage(1)
2001.Remote repositories(1)

Appendix 6a:

Core Topic # 3. Information Organization: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2

Note: first time appearance (year) and publication number are appended to each subtopic

Subtopics (Increasing Trends)	R^2	Subtopics (Increasing Trends)	R^2	Subtopics (Increasing Trends)	R^2	Subtopics (Increasing Trends)	R^2
2007.Concept hierarchies(3)	1.00	1997.Hierarchy (General)(24)	0.50	1996.Thesaurus(44)	0.30	1995.Bibliographic data(6)	0.11
2006.Compression algorithms(3)	1.00	2003.Information Organization(General)(8)	0.49	1996.Interpretation (14)	0.27	1996.Structured Documents(14)	0.11
2007.Conceptual frameworks(5)	0.89	1999.Classification systems(15)	0.48	1997.Image Annotation(10)	0.25	2003.Text Mining(32)	0.11
2000.Discovery(84)	0.89	1998.Harvesting(44)	0.47	1995.Information analysis(263)	0.25	1995.Hierarchical systems(69)	0.11
2004.Metadata Extraction(19)	0.88	2005.Bibliographic records(11)	0.47	2002.Text Analysis(5)	0.24	1999.Personalization(63)	0.09
1995.Classification (256)	0.75	1995.Administrative data processing(29)	0.47	1995.Character recognition(101)	0.23	1996.Image compression(53)	0.07
1996.Natural language processing(124)	0.74	1996.Taxonomy(47)	0.47	2002.Web Mining(9)	0.22	2001.Bibliometric(10)	0.06
1995.Annotation (General)(125)	0.71	2002.Information Extraction(48)	0.47	2001.Controlled vocabulary(12)	0.21	2002.Automatic Classification(5)	0.06
2001.Information Discovery(11)	0.69	1999.Personalized information(12)	0.46	1995.Government data processing(25)	0.21	1999.Text Processing(145)	0.05
1996.Metadata(753)	0.69	1995.Image processing(223)	0.46	1997.OCR(25)	0.20	1995.Encoding(60)	0.04
1996.Ranking(57)	0.69	2000.Subject Headings(13)	0.45	1995.Abstracting(110)	0.18	2007.Recognition process(4)	0.04
2002.Named Entities(12)	0.66	1996.Links(83)	0.44	2000.Video recording(24)	0.18	1999.Metadata management (12)	0.03
1999.Dewey Decimal Classification(6)	0.66	2000.Conceptual design(9)	0.44	2002.Text Clustering(6)	0.17	2002.Metadata harvesting(24)	0.03
2005.Name disambiguation(19)	0.64	2001.Categorization (46)	0.44	1994.Data compression(31)	0.17	2000.RDF(14)	0.02
2001.Handwriting recognition(7)	0.62	1995.Bibliographic (161)	0.42	2000.Document Classification(16)	0.17	1999.Summarization(31)	0.02
1996.Navigation(74)	0.60	1996.Concept Space(6)	0.41	1996.Vocabulary control(24)	0.16	2002.Data Analysis(31)	0.01
2000.Hierarchical	0.59	1996.Authoring tool(9)	0.40	2001.Resource Discovery(12)	0.14	2001.Information	0.01

Structure(14)						integration(21)	
1999.Data Sharing(18)	0.58	2002.Topic maps(7)	0.38	1994.Compression (General)(87)	0.14	1996.Routing(14)	0.01
2004.Document annotation(4)	0.57	1999.Keywords(44)	0.37	2001.Data Format(9)	0.13	1996.Interoperability (metadata)(81)	0.01
1999.Dublin Core(26)	0.57	2000.Data Exploration(6)	0.36	2004.Link Analysis(9)	0.13	2000.Standardization (67)	0.01
1999.Terminologies(12)	0.55	1998.Data Mining(253)	0.35	2002.Data Exchange(10)	0.12	1997.Cataloging(30)	0.01
1994.Recognition(General)(302)	0.54	1998.Bibliographic database(26)	0.33	1999.Url(7)	0.12	1995.HTML(119)	0.00
1996.Information processing(25)	0.53	1996.Document Clustering(27)	0.33	2001.Citation Analysis(30)	0.11	2001.Video Annotation(10)	0.00
2001.Text categorization(26)	0.53	1995.Indexing(348)	0.32				
2000.Conceptual(General)(47)	0.51	1995.Markup languages(81)	0.32				

Appendix 6b:

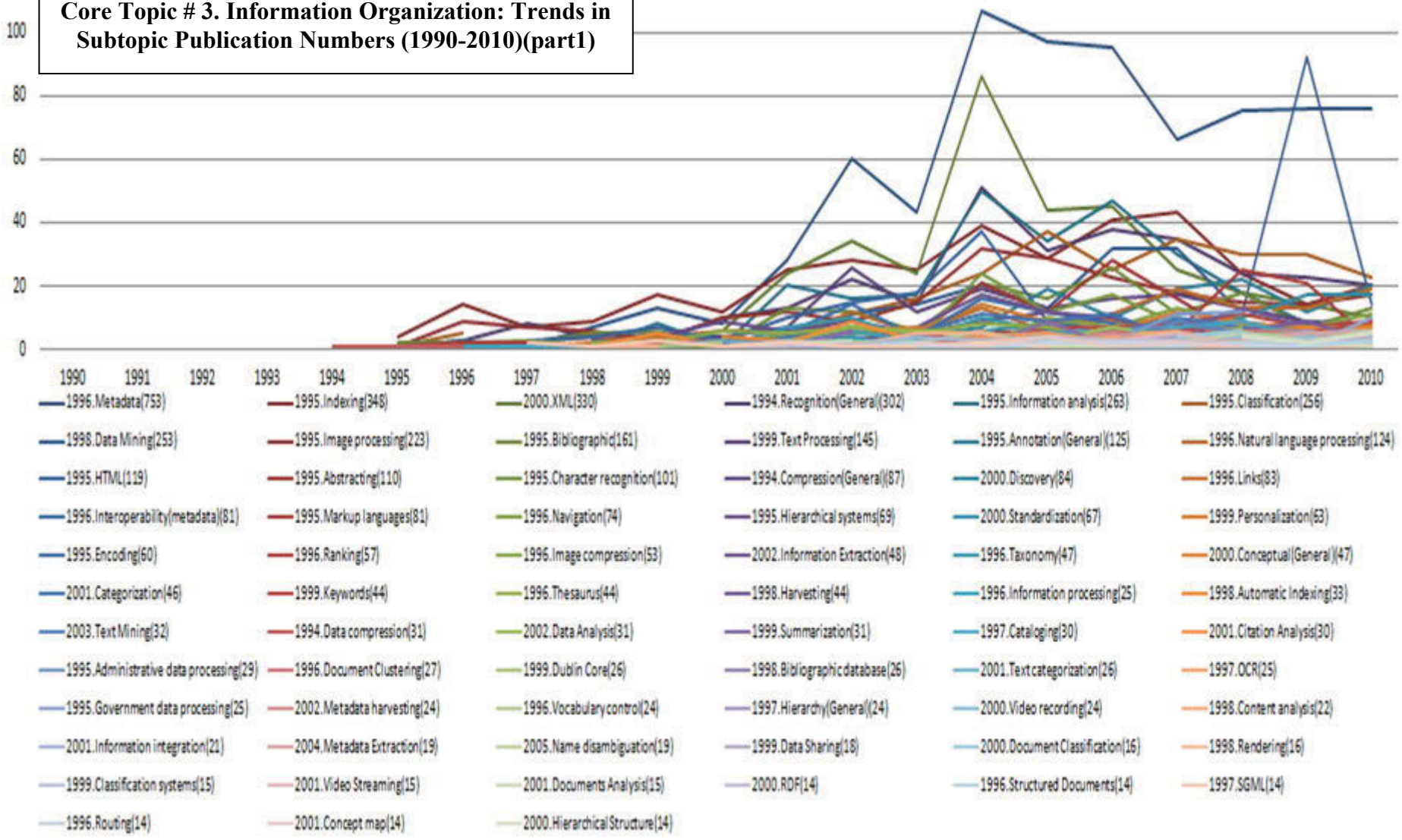
Core Topic # 3. Information Organization: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2

Note: first time appearance (year) and publication number are appended to each subtopic

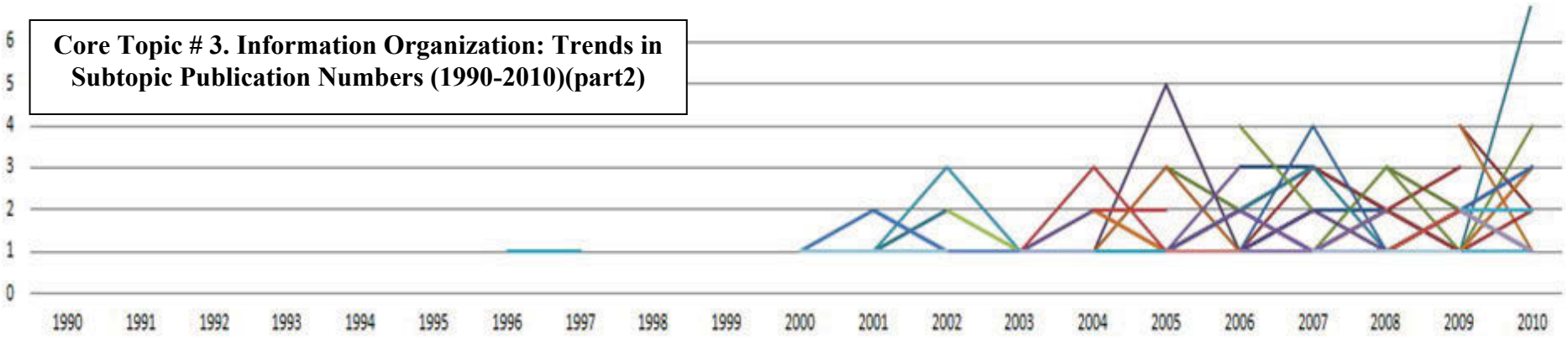
Subtopics (Decreasing Trends)	R^2	Subtopics (Not identified trends)	R^2	Subtopics (Not identified trends)	R^2
2005.Document Summarization(5)	0.96	1999.Keyphrase extraction(8)	#DIV/0	2005.Digital annotation(2)	#DIV/0
2004.Semi Structured Data(6)	0.89	1996.Text Extraction(6)	#DIV/0	2008.Visual Analysis(2)	#DIV/0
2002.Text Segmentation(5)	0.74	2003.Compression ratio(5)	#DIV/0	2007.Data interpretations(2)	#DIV/0
2002.Information Gathering(5)	0.43	2001.File Sharing(4)	#DIV/0	1999.Bibliographic control(2)	#DIV/0
2001.Object Identifier(6)	0.33	2002.Automatic categorization(4)	#DIV/0	2009.Conceptual discovery(1)	#DIV/0
2005.Metadata aggregation(6)	0.13	2001.Video editing(4)	#DIV/0		
2001.Documents Analysis(15)	0.12	2000.Streaming Media(4)	#DIV/0		
1996.Science Citation Index(6)	0.12	2001.Speech Processing(4)	#DIV/0		
2001.Concept map(14)	0.11	2001.Union Catalogs(3)	#DIV/0		
2000.Video Indexing(7)	0.10	2003.Capturing(3)	#DIV/0		
1997.SGML(14)	0.10	2001.Video processing(3)	#DIV/0		

1999.Optical Music Recognition(4)	0.08	2000.Speech Analysis(3)	#DIV/0		
1998.Automatic Indexing(33)	0.05	2006.Image Interpretation(3)	#DIV/0		
2000.XML(330)	0.02	2007.Non-structured documents(2)	#DIV/0		
1999.Video Segmentation(8)	0.02	2003.Web Cataloguing(2)	#DIV/0		
2001.Video Streaming(15)	0.01	2003.Data Gathering(2)	#DIV/0		
1998.Content analysis(22)	0.00	2006.Data Dissemination(2)	#DIV/0		
1998.Rendering(16)	0.00	2008.Conceptual graph(2)	#DIV/0		
2004.Hierarchical clustering(10)	0.00	2007.Topic hierarchy(2)	#DIV/0		
2005.Conceptual model(8)	0.00	2007.Content annotation(2)	#DIV/0		

Core Topic # 3. Information Organization: Trends in Subtopic Publication Numbers (1990-2010)(part1)



Core Topic # 3. Information Organization: Trends in Subtopic Publication Numbers (1990-2010)(part2)



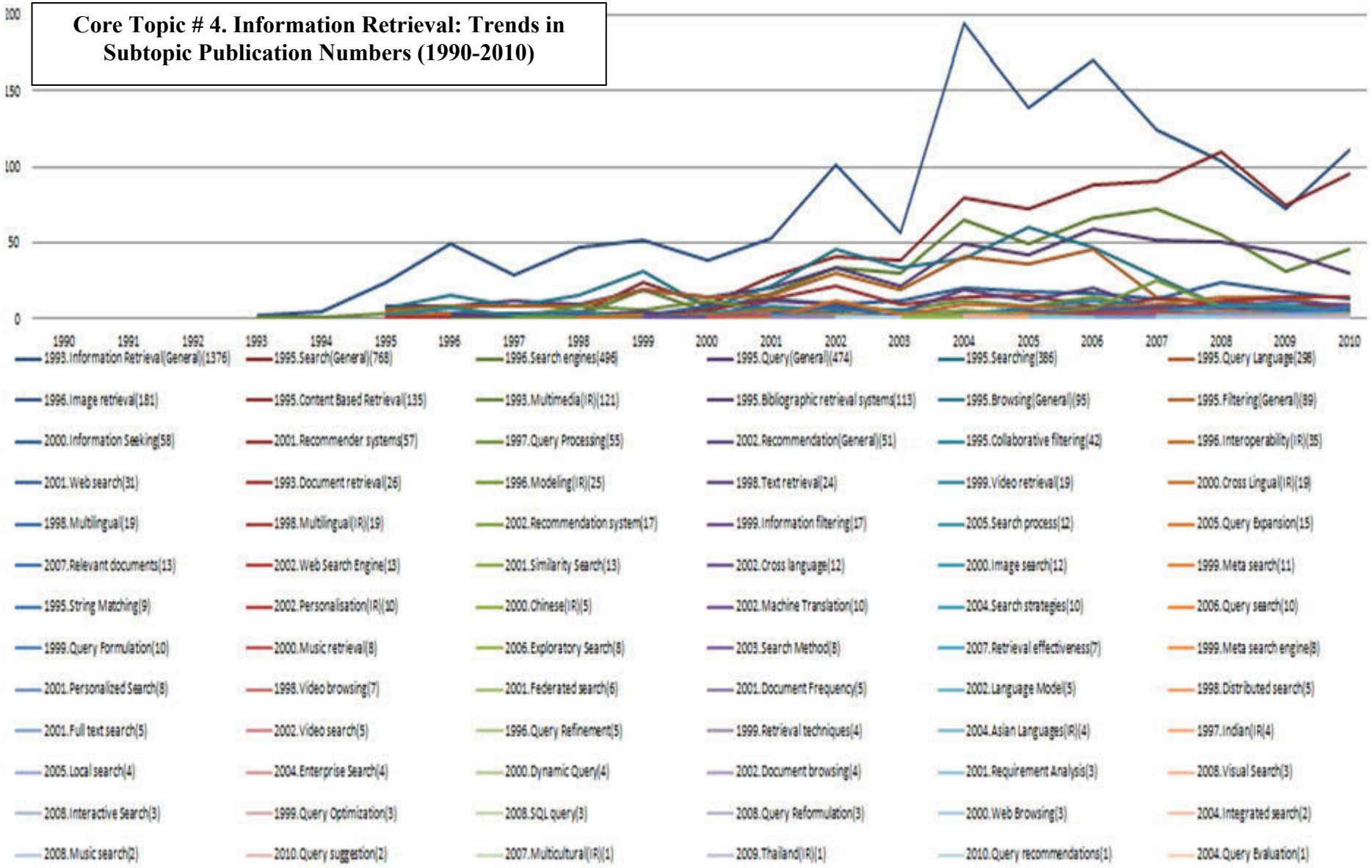
1996.Interpretation(14)
2000.Subject Headings(13)
1999.Terminologies(12)
1999.Metadata management (12)
2001.Controlled vocabulary(12)
2001.Resource Discovery(12)
2002.Named Entities(12)
1999.Personalized information(12)
2005.Bibliographic records(11)
2001.Information Discovery(11)
2001.Bibliometric(10)
2002.Data Exchange(10)
2004.Hierarchical clustering(10)
1997.Image Annotation(10)
2001.Video Annotation(10)
2002.Web Mining(9)
2000.Conceptual design(9)
2004.Link Analysis(9)
1996.Authoring tool(9)
2003.Information Organization(General)(8)
2001.Data Format(9)
2005.Conceptual model(8)
1999.Video Segmentation(8)
1999.Keyphrase extraction(8)
2000.Video Indexing(7)
1999.Url(7)
2001.Handwriting recognition(7)
2005.Metadata aggregation(6)
1999.Dewey Decimal Classification(6)
1996.Science Citation Index(6)
2001.Object Identifier(6)
2004.Semi Structured Data(6)
1995.Bibliographic data(6)
2000.Data Exploration(6)
1996.Concept Space(6)
2002.Text Clustering(6)
1996.Text Extraction(6)
2002.Topic maps(7)
2002.Information Gathering(5)
2002.Automatic Classification(5)
2007.Conceptual frameworks(5)
2003.Compression ratio(5)
2002.Text Analysis(5)
2002.Text Segmentation(5)
2005.Document Summarization(5)
2001.File Sharing(4)
2002.Automatic categorization(4)
2004.Document annotation(4)
2001.Video editing(4)
2000.Streaming Media(4)
1999.Optical Music Recognition(4)
2007.Recognition process(4)
2001.Speech Processing(4)
2001.Union Catalogs(3)
2003.Capturing(3)
2007.Concept hierarchies(3)
2006.Compression algorithms(3)
2001.Video processing(3)
2000.Speech Analysis(3)
2006.Image Interpretation(3)
2007.Non-structured documents(2)
2003.Web Cataloguing(2)
2003.Data Gathering(2)
2006.Data Dissemination(2)
2008.Conceptual graph(2)
2007.Topic hierarchy(2)
2007.Content annotation(2)
2005.Digital annotation(2)
2008.Visual Analysis(2)
2007.Data interpretations(2)
1999.Bibliographic control(2)
2009.Conceptual discovery(1)

Appendix 7:

Core Topic # 4. Information Retrieval: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2008.Visual Search(3)	1.00	2001.Similarity Search(13)	0.30	1996.Query Refinement(5)	0.96	2002.Video search(5)	#DIV/0
2008.Interactive Search(3)	1.00	1999.Meta search engine(8)	0.28	1998.Distributed search(5)	0.04	1999.Retrieval techniques(4)	#DIV/0
1999.Query Optimization(3)	1.00	1997.Query Processing(55)	0.25	1996.Interoperability(IR)(35)	0.01	2004.Asian Languages(IR)(4)	#DIV/0
1995.Search(General) (768)	0.89	2005.Query Expansion(15)	0.25	2002.Machine Translation(10)	0.00	2004.Enterprise Search(4)	#DIV/0
2001.Document Frequency(5)	0.88	2000.Information Seeking(58)	0.23	2000.Image search(12)	0.00	2000.Dynamic Query(4)	#DIV/0
2004.Search strategies(10)	0.87	2006.Exploratory Search(8)	0.23	2000.Music retrieval(8)	0.00	2002.Document browsing(4)	#DIV/0
2007.Retrieval effectiveness(7)	0.86	2000.Cross Lingual(IR)(19)	0.18	1998.Text retrieval(24)	0.00	2001.Requirement Analysis(3)	#DIV/0
2001.Web search(31)	0.81	1993.Multimedia(IR) (121)	0.17			2008.SQL query(3)	#DIV/0
2002.Recommendation(General)(51)	0.80	1997.Indian(IR)(4)	0.16			2008.Query Reformulation(3)	#DIV/0
2001.Recommender systems(57)	0.78	1995.Bibliographic retrieval systems(113)	0.15			2000.Web Browsing(3)	#DIV/0
2002.Web Search Engine(13)	0.74	1995.Content Based Retrieval(135)	0.15			2004.Integrated search(2)	#DIV/0
2007.Relevant documents(13)	0.70	1999.Video retrieval(19)	0.12			2008.Music search(2)	#DIV/0
1995.Query(General) (474)	0.68	1998.Multilingual(19)	0.12			2010.Query suggestion(2)	#DIV/0
1999.Query Formulation(10)	0.66	1998.Multilingual(IR) (19)	0.12			2007.Multicultural(IR) (1)	#DIV/0
1996.Image retrieval(181)	0.66	2001.Full text search(5)	0.11			2009.Thailand(IR)(1)	#DIV/0
1995.Filtering (General)(89)	0.64	2001.Personalized Search(8)	0.10			2010.Query recommendations(1)	#DIV/0
1996.Search engines(496)	0.63	1995.String Matching(9)	0.08			2004.Query Evaluation(1)	#DIV/0
2005.Search process(12)	0.63	1995.Query Language(298)	0.08				
2002.Recommendation system(17)	0.61	1999.Information filtering(17)	0.07				
1993.Information Retrieval(General) (1376)	0.55	1996.Modeling(IR)(25)	0.05				

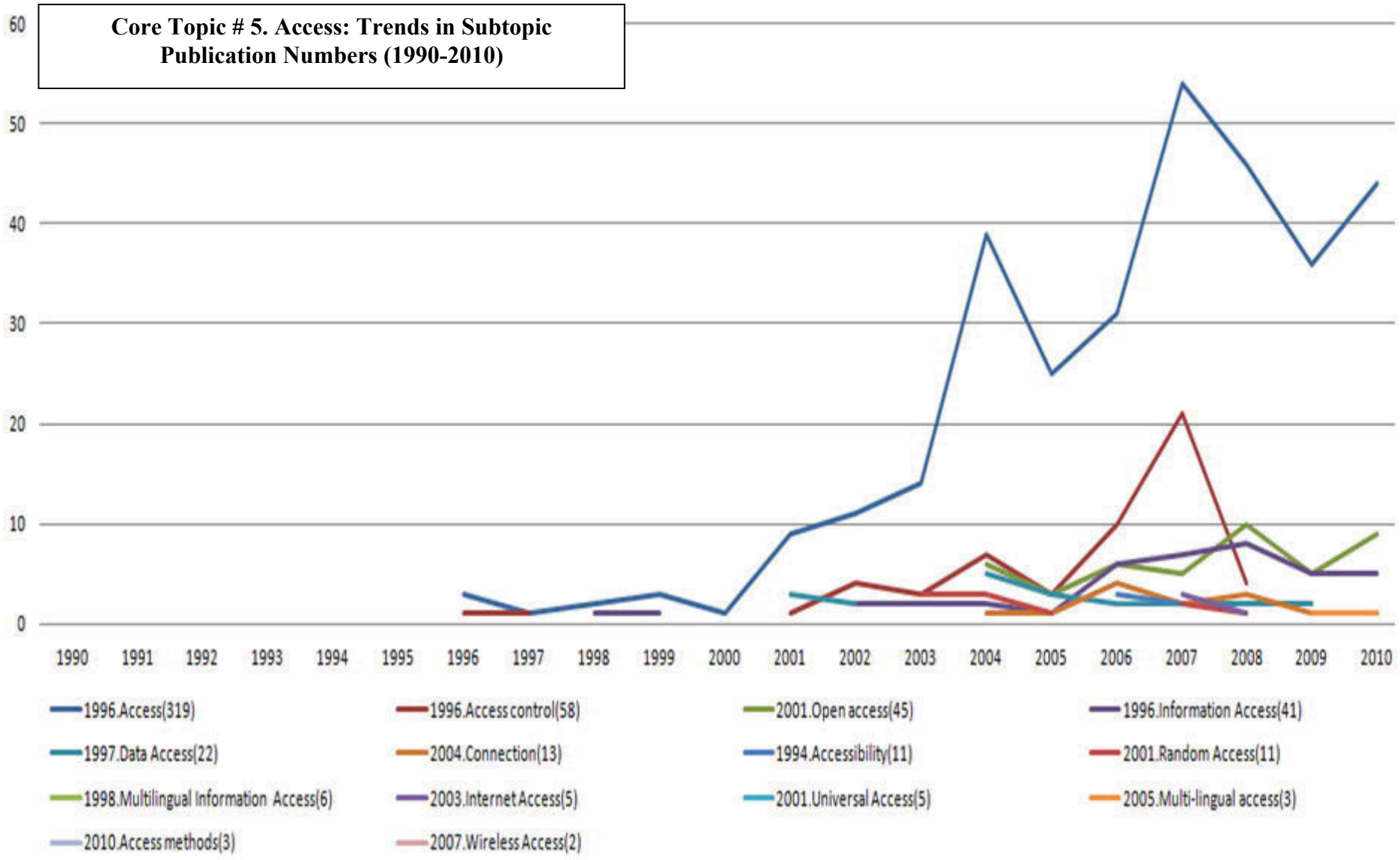
1998.Video browsing(7)	0.54	2005.Local search(4)	0.04				
2002.Language Model(5)	0.53	1995.Searching(386)	0.03				
1993.Document retrieval(26)	0.53	2002.Personalisation(IR)(10)	0.03				
2006.Query search(10)	0.42	1999.Meta search(11)	0.02				
1995.Collaborative filtering(42)	0.37	2001.Federated search(6)	0.02				
2000.Chinese(IR)(5)	0.35	2003.Search Method(8)	0.00				
1995.Browsing (General)(95)	0.33	2002.Cross language(12)	0.00				

Core Topic # 4. Information Retrieval: Trends in Subtopic Publication Numbers (1990-2010)



Appendix 8:

Core Topic # 5. Access: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*					
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
1996.Access(319)	0.82	2001.Random Access(11)	0.03	2005.Multi-lingual access(3)	#DIV/0
1996.Information Access(41)	0.60	2001.Universal Access(5)	0.02	2010.Access methods(3)	#DIV/0
2001.Open access(45)	0.56	2004.Connection(13)	0.00	2007.Wireless Access(2)	#DIV/0
1996.Access control(58)	0.21				
1998.Multilingual Information Access(6)	0.12				
2003.Internet Access(5)	0.11				
1997.Data Access(22)	0.01				
1994.Accessibility(11)	0.00				


Core Topic # 5. Access: Trends in Subtopic Publication Numbers (1990-2010)
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2006
2007
2008
2009
2010
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1996.Information Access(41)
1997.Data Access(22)
2004.Connection(13)
1994.Accessibility(11)
2001.Random Access(11)
1998.Multilingual Information Access(6)
2003.Internet Access(5)
2001.Universal Access(5)
2005.Multi-lingual access(3)
2010.Access methods(3)
2007.Wireless Access(2)

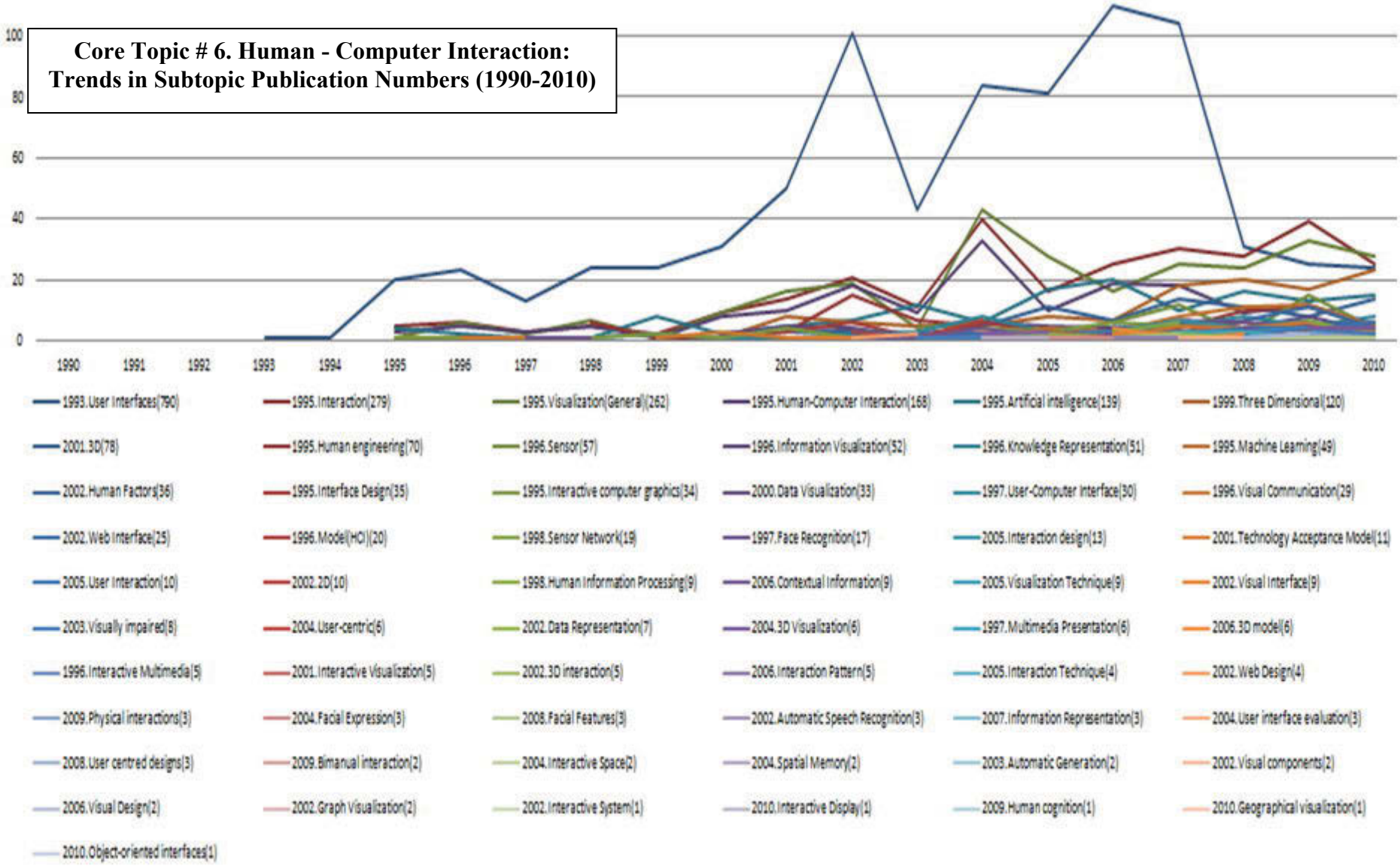
Appendix 9:

Core Topic # 6. Human - Computer Interaction: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2

Note: first time appearance (year) and publication number are appended to each subtopic

Subtopics (Increasing Trends)	R^2	Subtopics (Increasing Trends)	R^2	Subtopics (Decreasing Trends)	R^2	Subtopics (Not identified trends)	R^2
2002.Automatic Speech Recognition(3)	1.00	1996.Sensor(57)	0.34	2009.Physical interactions(3)	1.00	1997.Multimedia Presentation(6)	#DIV/0
2008.User centred designs(3)	1.00	1997.User-Computer Interface(30)	0.34	2007.Information Representation(3)	1.00	1996.Interactive Multimedia(5)	#DIV/0
2006.Contextual Information(9)	0.94	1996.Information Visualization(52)	0.31	2004.3D Visualization(6)	0.43	2004.Facial Expression(3)	#DIV/0
1999.Three Dimensional(120)	0.80	1995.Interactive computer graphics(34)	0.30	2002.Data Representation(7)	0.32	2008.Facial Features(3)	#DIV/0
2006.3D model(6)	0.77	1993.User Interfaces(790)	0.28	2005.Visualization Technique(9)	0.25	2004.User interface evaluation(3)	#DIV/0
1995.Interaction(279)	0.69	1996.Visual Communication(29)	0.26	2002.Web Design(4)	0.13	2009.Bimanual interaction(2)	#DIV/0
2000.Data Visualization(33)	0.69	2002.Human Factors(36)	0.25	2001.Interactive Visualization(5)	0.08	2004.Interactive Space(2)	#DIV/0
2001.3D(78)	0.67	1998.Sensor Network(19)	0.24	2002.Visual Interface(9)	0.01	2004.Spatial Memory(2)	#DIV/0
1995.Artificial intelligence(139)	0.66	2003.Visually impaired(8)	0.22	2002.2D(10)	0.00	2003.Automatic Generation(2)	#DIV/0
1996.Knowledge Representation(51)	0.63	1995.Human-Computer Interaction(168)	0.18			2002.Visual components(2)	#DIV/0
1995.Visualization(General) (262)	0.60	1995.Human engineering(70)	0.15			2006.Visual Design(2)	#DIV/0
2006.Interaction Pattern(5)	0.60	1996.Model(HCI)(20)	0.14			2002.Graph Visualization(2)	#DIV/0
2004.User-centric(6)	0.57	2005.Interaction design(13)	0.13			2002.Interactive System(1)	#DIV/0
1995.Machine Learning(49)	0.49	2005.User Interaction(10)	0.10			2010.Interactive Display(1)	#DIV/0
2005.Interaction Technique(4)	0.48	1997.Face Recognition(17)	0.07			2009.Human cognition(1)	#DIV/0
2002.Web Interface(25)	0.41	2001.Technology Acceptance Model(11)	0.06			2010.Geographical visualization(1)	#DIV/0
1998.Human Information Processing(9)	0.41	1995.Interface Design(35)	0.02			2010.Object-oriented interfaces(1)	#DIV/0

2002.3D interaction(5)	0.38						


Core Topic # 6. Human - Computer Interaction:
Trends in Subtopic Publication Numbers (1990-2010)
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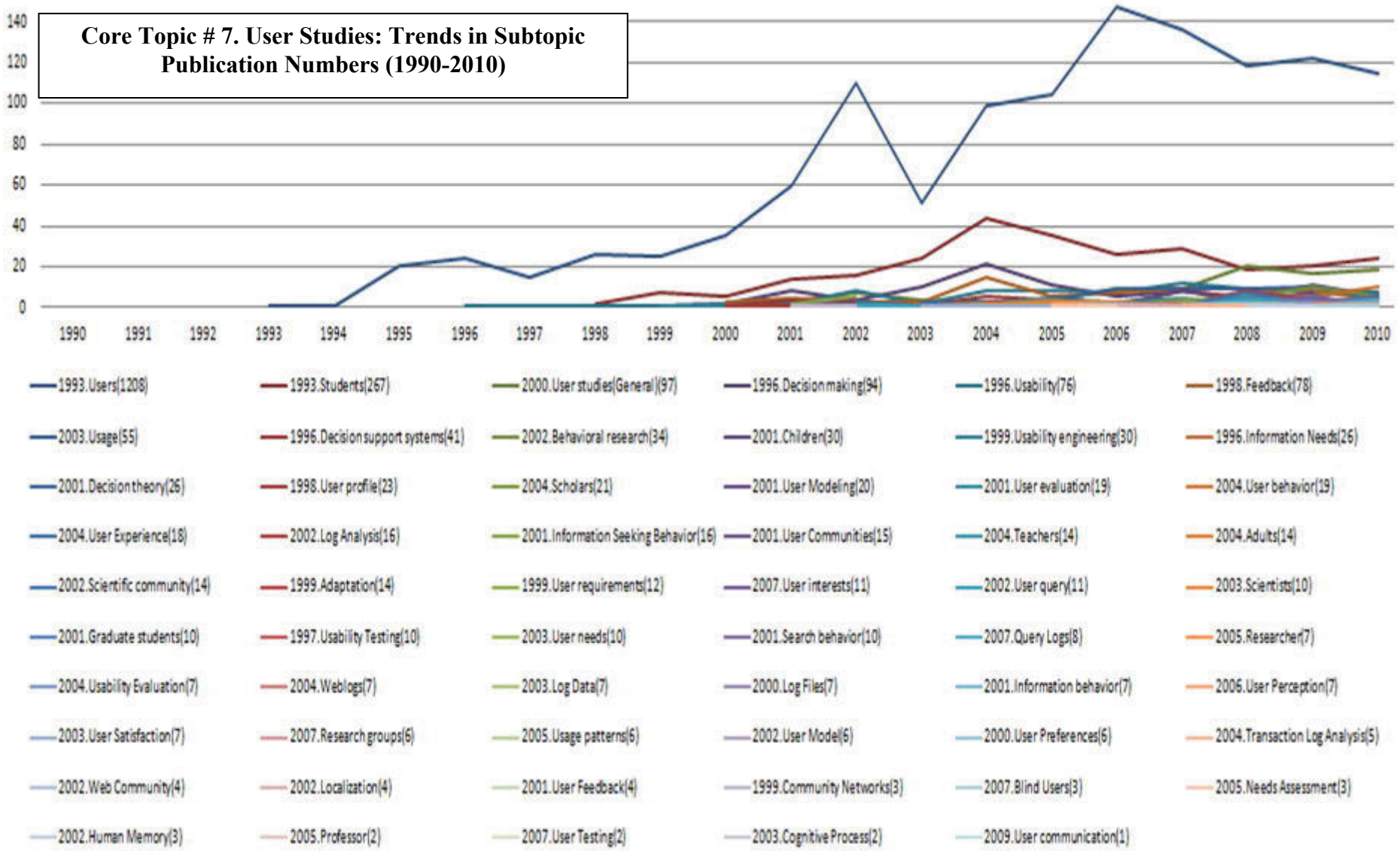
2006
2007
2008
2009
2010
1993.User Interfaces(790)
1995.Interaction(279)
1995.Visualization(General)(262)
1995.Human-Computer Interaction(168)
1995.Artificial intelligence(139)
1999.Three Dimensional(120)
2001.3D(78)
1995.Human engineering(70)
1996.Sensor(57)
1996.Information Visualization(52)
1996.Knowledge Representation(51)
1995.Machine Learning(49)
2002.Human Factors(36)
1995.Interface Design(35)
1995.Interactive computer graphics(34)
2000.Data Visualization(33)
1997.User-Computer Interface(30)
1996.Visual Communication(29)
2002.Web Interface(25)
1996.Model(HCI)(20)
1998.Sensor Network(19)
1997.Face Recognition(17)
2005.Interaction design(13)
2001.Technology Acceptance Model(11)
2005.User Interaction(10)
2002.2D(10)
1998.Human Information Processing(9)
2006.Contextual Information(9)
2005.Visualization Technique(9)
2002.Visual Interface(9)
2003.Visually impaired(8)
2004.User-centric(6)
2002.Data Representation(7)
2004.3D Visualization(6)
1997.Multimedia Presentation(6)
2006.3D model(6)
1996.Interactive Multimedia(5)
2001.Interactive Visualization(5)
2002.3D interaction(5)
2006.Interaction Pattern(5)
2005.Interaction Technique(4)
2002.Web Design(4)
2009.Physical interactions(3)
2004.Facial Expression(3)
2008.Facial Features(3)
2002.Automatic Speech Recognition(3)
2007.Information Representation(3)
2004.User interface evaluation(3)
2008.User centred designs(3)
2009.Bimanual interaction(2)
2004.Interactive Space(2)
2004.Spatial Memory(2)
2003.Automatic Generation(2)
2002.Visual components(2)
2006.Visual Design(2)
2002.Graph Visualization(2)
2002.Interactive System(1)
2010.Interactive Display(1)
2009.Human cognition(1)
2010.Geographical visualization(1)
2010.Object-oriented interfaces(1)

Appendix 10:

Core Topic # 7. User Studies: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2006.User Perception(7)	0.96	1996.Information Needs(26)	0.42	2005.Researcher(7)	0.49	2004.Transaction Log Analysis(5)	#DIV/0
2001.User Feedback(4)	0.92	2004.User Experience(18)	0.41	2001.Information Seeking Behavior(16)	0.15	2002.Web Community(4)	#DIV/0
2001.Search behavior(10)	0.91	2003.Log Data(7)	0.40	2004.Adults(14)	0.01	2002.Localization(4)	#DIV/0
1993.Users(1208)	0.85	2000.Log Files(7)	0.38			1999.Community Networks(3)	#DIV/0
2004.Weblogs(7)	0.85	1998.User profile(23)	0.31			2007.Blind Users(3)	#DIV/0
2000.User studies(General)(97)	0.76	2007.Query Logs(8)	0.30			2005.Needs Assessment(3)	#DIV/0
2002.User Model(6)	0.76	2002.Log Analysis(16)	0.29			2002.Human Memory(3)	#DIV/0
2004.User behavior(19)	0.75	2000.User Preferences(6)	0.25			2005.Professor(2)	#DIV/0
2004.Usability Evaluation(7)	0.70	2001.User Modeling(20)	0.23			2007.User Testing(2)	#DIV/0
1996.Usability(76)	0.65	1998.Feedback(78)	0.22			2003.Cognitive Process(2)	#DIV/0
2002.Scientific community(14)	0.63	1999.User requirements(12)	0.21			2009.User communication(1)	#DIV/0
2004.Teachers(14)	0.58	1996.Decision support systems(41)	0.19				
2002.User query(11)	0.54	2003.User Satisfaction(7)	0.17				
2003.User needs(10)	0.53	1996.Decision making(94)	0.16				
2002.Behavioral research(34)	0.52	2003.Scientists(10)	0.15				
2001.Children(30)	0.51	1997.Usability Testing(10)	0.13				
1999.Adaptation(14)	0.51	2005.Usage patterns(6)	0.13				
2001.User Communities(15)	0.49	2001.Information behavior(7)	0.02				
1993.Students(267)	0.46	2004.Scholars(21)	0.01				
2001.Graduate students(10)	0.44	2007.User interests(11)	0.00				
2001.User evaluation(19)	0.43	2001.Decision theory(26)	0.00				
1999.Usability engineering(30)	0.42	2007.Research groups(6)	0.00				
2003.Usage(55)	0.42						


Core Topic # 7. User Studies: Trends in Subtopic Publication Numbers (1990-2010)
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1993.Students(267)
2000.User studies(General)(97)
1996.Decision making(94)
1996.Usability(76)
1998.Feedback(78)
2003.Usage(55)
1996.Decision support systems(41)
2002.Behavioral research(34)
2001.Children(30)
1999.Usability engineering(30)
1996.Information Needs(26)
2001.Decision theory(26)
1998.User profile(23)
2004.Scholars(21)
2001.User Modeling(20)
2001.User evaluation(19)
2004.User behavior(19)
2004.User Experience(18)
2002.Log Analysis(16)
2001.Information Seeking Behavior(16)
2001.User Communities(15)
2004.Teachers(14)
2004.Adults(14)
2002.Scientific community(14)
1999.Adaptation(14)
1999.User requirements(12)
2007.User interests(11)
2002.User query(11)
2003.Scientists(10)
2001.Graduate students(10)
1997.Usability Testing(10)
2003.User needs(10)
2001.Search behavior(10)
2007.Query Logs(8)
2005.Researcher(7)
2004.Usability Evaluation(7)
2004.Weblogs(7)
2003.Log Data(7)
2000.Log Files(7)
2001.Information behavior(7)
2006.User Perception(7)
2003.User Satisfaction(7)
2007.Research groups(6)
2005.Usage patterns(6)
2002.User Model(6)
2000.User Preferences(6)
2004.Transaction Log Analysis(5)
2002.Web Community(4)
2002.Localization(4)
2001.User Feedback(4)
1999.Community Networks(3)
2007.Blind Users(3)
2005.Needs Assessment(3)
2002.Human Memory(3)
2005.Professor(2)
2007.User Testing(2)
2003.Cognitive Process(2)
2009.User communication(1)

Appendix 11a:

Core Topic # 8. Architecture – Infrastructure: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Increasing Trends)**	**R^2**
2009.Fuzzy linguistic(9)	1	2007.Web 2.0(33)	0.52	2001.Distributed Data(9)	0.26	1993.Data structures(305)	0.12
2007.Design Principle(6)	1	1996.Heterogeneous (General)(53)	0.52	1993.Protocols(265)	0.25	2001.Peer to peer(50)	0.12
1995.Tools(256)	0.85	1993.Architecture (General)(472)	0.51	2000.Learning Object(41)	0.24	2004.Data Grid(24)	0.12
2003.Design and Development(7)	0.84	2002.Software Tool(17)	0.50	1993.Distributed systems(22)	0.23	1998.Multi agent systems(50)	0.12
2001.Semantic Web(137)	0.83	1999.Vector spaces(30)	0.50	1996.Interoperability (Architecture)(184)	0.23	1998.Hardware(138)	0.11
2000.Open Source(95)	0.82	2004.Schema Mapping(6)	0.50	1995.Computer simulation(350)	0.22	2001.Computer games(7)	0.11
2003.Intelligent systems(20)	0.79	1995.Algorithms (General)(895)	0.49	2004.Computational tools(5)	0.21	2001.Controllers(29)	0.10
1995.Clustering (136)	0.78	1996.Open systems(50)	0.49	2000.Embedded systems(110)	0.20	1997.Operating systems(129)	0.09
2002.Web Technology(28)	0.76	1993.Software (General)(1203)	0.43	2001.Software Design(38)	0.19	2000.Ubiquitous computing(90)	0.08
1994.Web(1441)	0.75	2004.Fuzzy logic(14)	0.42	2001.Parallel programming(33)	0.19	1999.Middleware(80)	0.08
1993.Network(875)	0.74	2003.Probabilistic Model(11)	0.41	1995.Multimedia systems(402)	0.18	1996.Computational methods(127)	0.08
1993.Information systems(393)	0.72	2000.Clustering Method(11)	0.41	1995.Distributed computer systems(236)	0.18	1997.Digital Library Architecture(11)	0.07
1996.Learning Algorithm(53)	0.68	1994.Internet(699)	0.41	2004.Software infrastructure(5)	0.18	1993.Database systems(1047)	0.07
1995.Digital Objects(83)	0.68	1996.Optimization (317)	0.41	2002.Computer engineering(9)	0.18	1999.Portals(127)	0.05
2001.Information Model(6)	0.67	2004.Service-oriented architecture(27)	0.41	2000.Software architecture(36)	0.17	2001.Distributed Computing(18)	0.04
1994.Infrastructure (General)(95)	0.67	1997.Spatial Data(22)	0.39	1999.Digital library integration(12)	0.17	1996.Heterogeneous information(5)	0.03
1995.Artificial intelligence(139)	0.66	1997.Data Model(29)	0.39	1995.Mathematical Model(457)	0.16	1996.Groupware(14)	0.02
1997.Platform(70)	0.66	1999.Linear Algebra(34)	0.39	1995.Software engineering (367)	0.16	1999.Information architecture(11)	0.02

1993.Computing (General)(509)	0.65	2002.Data Center(4)	0.37	1993.Object oriented(213)	0.16	2005.Classification Algorithm(9)	0.02
2004.Hardware architecture(4)	0.64	1995.Web servers(30)	0.37	2004.Cyberinfrastructure (10)	0.15	2003.Application software(6)	0.01
1993.Digital library systems(88)	0.64	2002.Open Source Software(20)	0.36	2002.Heterogeneous systems(8)	0.15	1995.Client server(84)	0.00
1998.Data sets(80)	0.62	1999.Integration systems(7)	0.36	1997.Digital library software(28)	0.15	2006.Network architecture(20)	0.00
1997.Integration (General)(148)	0.56	2004.Heterogeneous data(7)	0.34	1993.Object oriented programming(196)	0.14	2002.Content management system(12)	0.00
2001.System Design(28)	0.55	1995.Agents(General) (165)	0.31	1996.Scalability(27)	0.14	2005.Simulation model(6)	0.00
1993.Large scale systems(52)	0.54	1999.Software Component(15)	0.29	2003.Hybrid System(5)	0.14		
2002.Fuzzy systems(9)	0.54	1995.Neural Network(69)	0.27	1994.Information Infrastructure(20)	0.14		
2004.Digital library federation(5)	0.54	2002.Grid computing(153)	0.26	1993.Computer architecture(208)	0.13		

Appendix 11b:

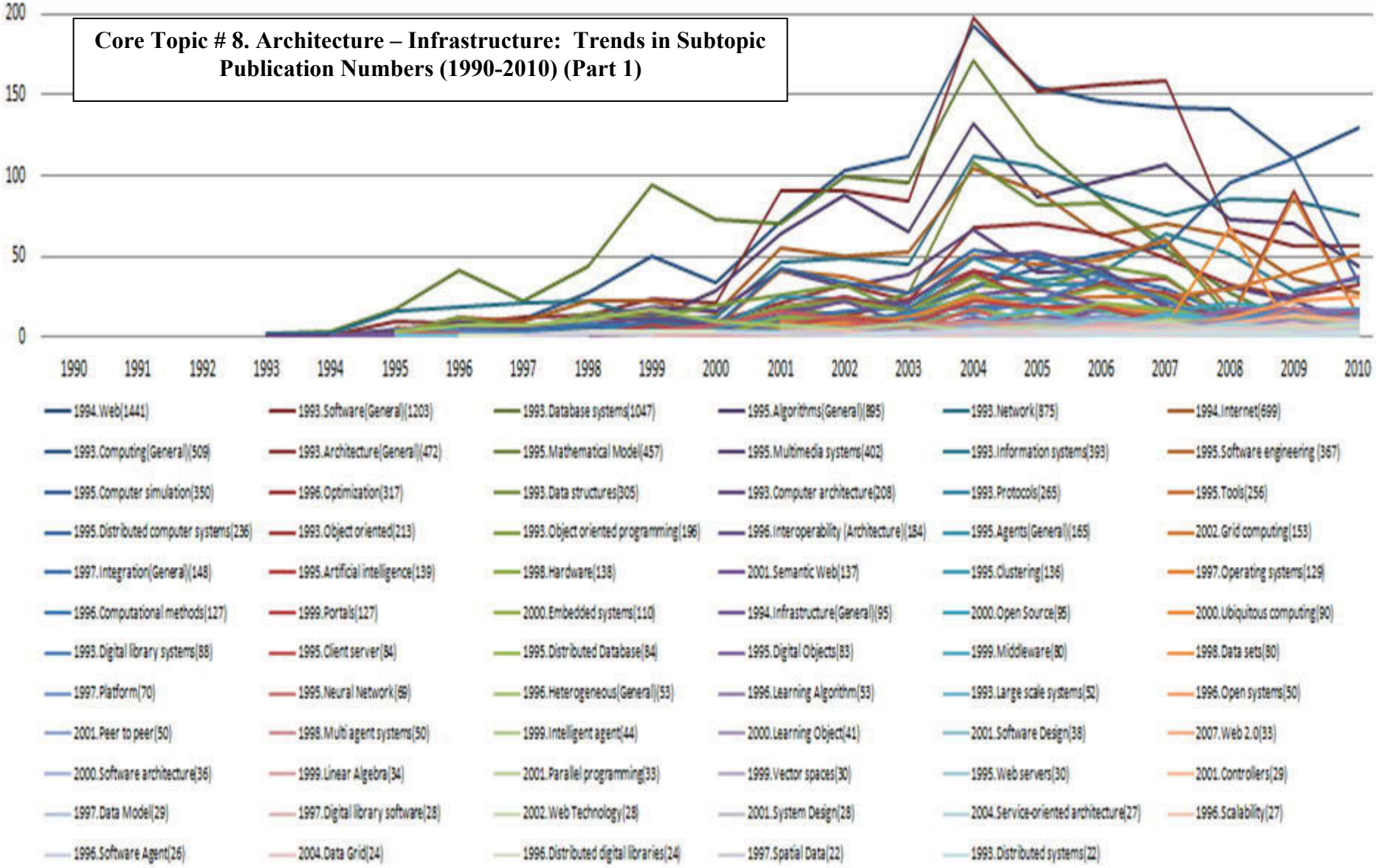
Core Topic # 8. Architecture – Infrastructure: Trends in Subtopic Publication Numbers (1990-2010) measured by R2

Note: first time appearance (year) and publication number are appended to each subtopic

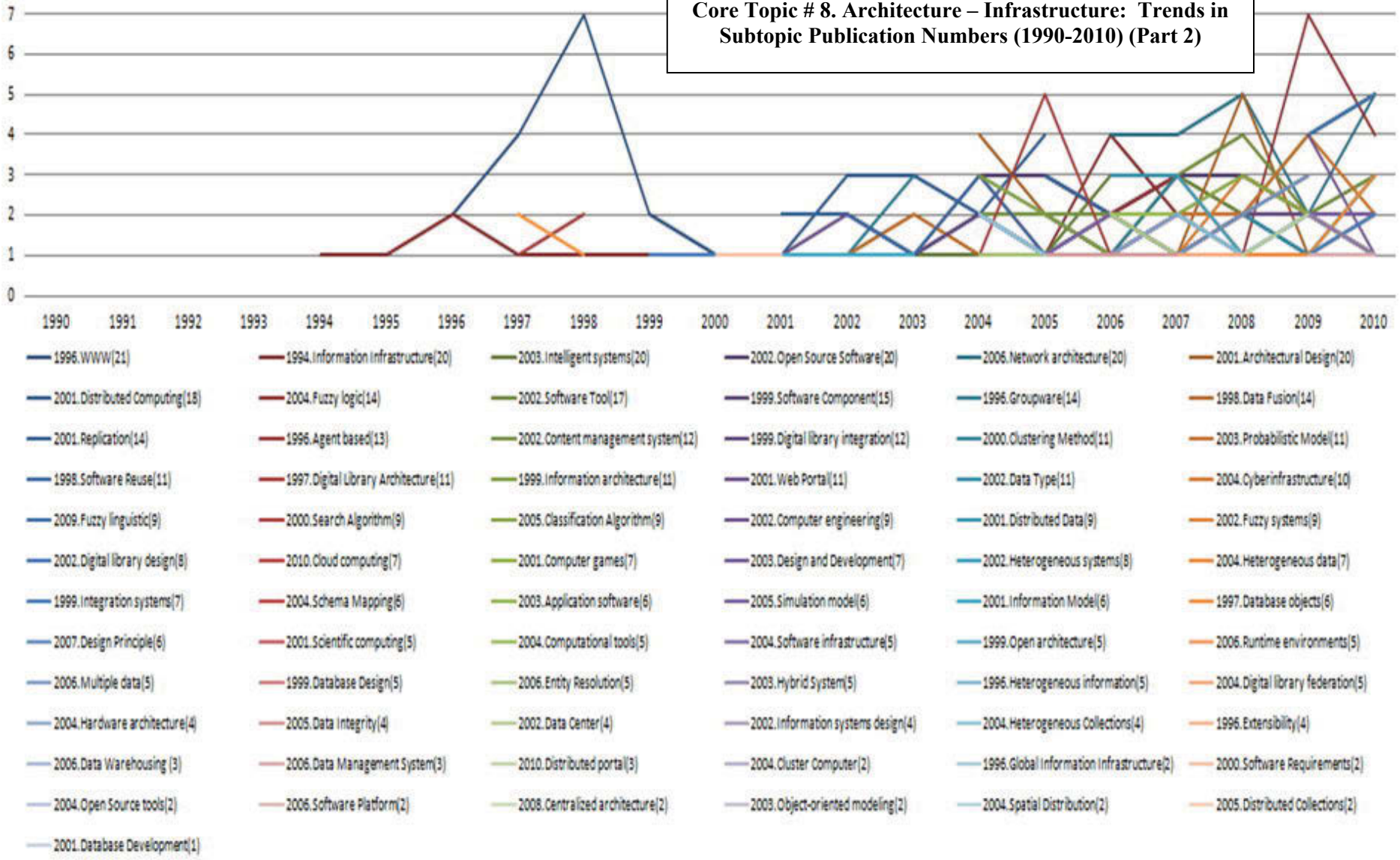
Subtopics (Decreasing Trends)	R^2	Subtopics (Not identified trends)	R^2
2006.Data Warehousing (3)	1.00	2010.Cloud computing(7)	#DIV/0
2001.Scientific computing(5)	0.89	1999.Open architecture(5)	#DIV/0
2006.Runtime environments(5)	0.75	1999.Database Design(5)	#DIV/0
2006.Entity Resolution(5)	0.47	2005.Data Integrity(4)	#DIV/0
2004.Heterogeneous Collections(4)	0.43	2002.Information systems design(4)	#DIV/0
1995.Distributed Database(84)	0.40	1996.Extensibility(4)	#DIV/0
2001.Replication(14)	0.32	2006.Data Management System(3)	#DIV/0
1997.Database objects(6)	0.31	2010.Distributed portal(3)	#DIV/0
1996.WWW(21)	0.28	2004.Cluster Computer(2)	#DIV/0
2002.Digital library design(8)	0.12	1996.Global Information Infrastructure(2)	#DIV/0
1999.Intelligent agent(44)	0.11	2000.Software Requirements(2)	#DIV/0
2006.Multiple data(5)	0.09	2004.Open Source tools(2)	#DIV/0
1996.Distributed digital libraries(24)	0.04	2006.Software Platform(2)	#DIV/0

2000.Search Algorithm(9)	0.04	2008.Centralized architecture(2)	#DIV/0
2001.Architectural Design(20)	0.03	2003.Object-oriented modeling(2)	#DIV/0
1996.Software Agent(26)	0.02	2004.Spatial Distribution(2)	#DIV/0
1996.Agent based(13)	0.02	2005.Distributed Collections(2)	#DIV/0
2002.Data Type(11)	0.01	2001.Database Development(1)	#DIV/0
2001.Web Portal(11)	0.00		
1998.Data Fusion(14)	0.00		
1998.Software Reuse(11)	0.00		

Core Topic # 8. Architecture – Infrastructure: Trends in Subtopic Publication Numbers (1990-2010) (Part 1)



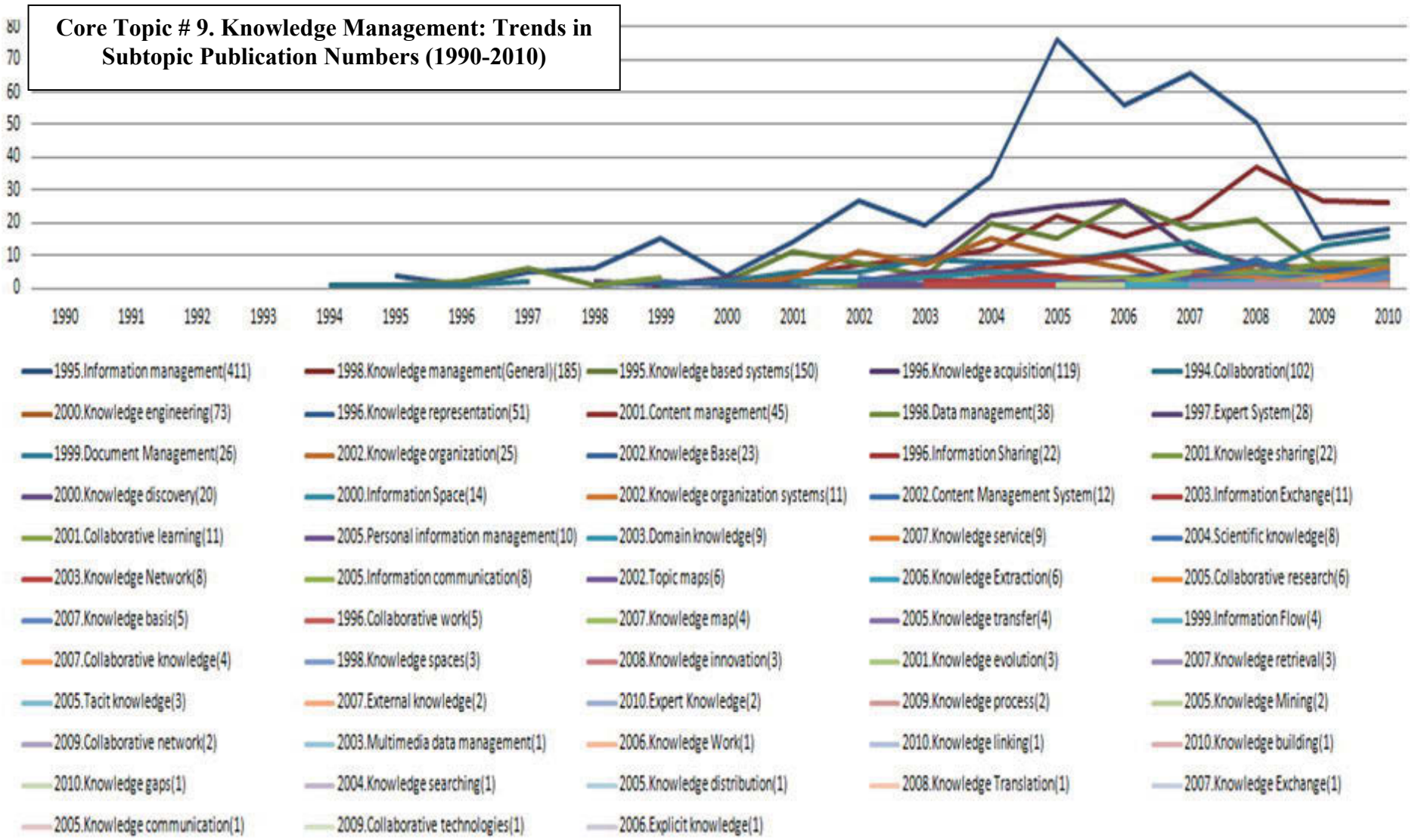
Core Topic # 8. Architecture – Infrastructure: Trends in Subtopic Publication Numbers (1990-2010) (Part 2)



Appendix 12:

Core Topic # 9. Knowledge Management: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2007.Knowledge service(9)	0.84	2001.Content management(45)	0.03	2008.Knowledge innovation(3)	1.00	1996.Collaborative work(5)	#DIV/0
2005.Collaborative research(6)	0.84	1997.Expert System(28)	0.03	2001.Knowledge evolution(3)	1.00	1999.Information Flow(4)	#DIV/0
1998.Knowledge management(General)(185)	0.83	2000.Knowledge engineering(73)	0.00	2005.Knowledge transfer(4)	0.84	2007.Collaborative knowledge(4)	#DIV/0
1994.Collaboration(102)	0.78	2002.Content Management System(12)	0.00	2002.Knowledge organization systems(11)	0.16	1998.Knowledge spaces(3)	#DIV/0
2007.Knowledge map(4)	0.75	2005.Information communication(8)	0.00	1999.Document Management(26)	0.03	2007.Knowledge retrieval(3)	#DIV/0
2000.Knowledge discovery(20)	0.66	2006.Knowledge Extraction(6)	0.00	2003.Information Exchange(11)	0.00	2005.Tacit knowledge(3)	#DIV/0
1996.Knowledge representation(51)	0.63					2007.External knowledge(2)	#DIV/0
2007.Knowledge basis(5)	0.57					2010.Expert Knowledge(2)	#DIV/0
1998.Data management(38)	0.47					2009.Knowledge process(2)	#DIV/0
2003.Domain knowledge(9)	0.46					2005.Knowledge Mining(2)	#DIV/0
1996.Information Sharing(22)	0.45					2009.Collaborative network(2)	#DIV/0
1995.Knowledge based systems(150)	0.39					2003.Multimedia data management(1)	#DIV/0
1995.Information management(411)	0.39					2006.Knowledge Work(1)	#DIV/0
2002.Topic maps(6)	0.38					2010.Knowledge linking(1)	#DIV/0
2002.Knowledge organization(25)	0.37					2010.Knowledge building(1)	#DIV/0
2005.Personal information management(10)	0.35					2010.Knowledge gaps(1)	#DIV/0
2001.Knowledge sharing(22)	0.34					2004.Knowledge searching(1)	#DIV/0
2004.Scientific knowledge(8)	0.18					2005.Knowledge distribution(1)	#DIV/0
1996.Knowledge acquisition(119)	0.16					2008.Knowledge Translation(1)	#DIV/0

2003.Knowledge Network(8)	0.15					2007.Knowledge Exchange(1)	#DIV/0
2001.Collaborative learning(11)	0.12					2005.Knowledge communication(1)	#DIV/0
2002.Knowledge Base(23)	0.12					2009.Collaborative technologies(1)	#DIV/0
2000.Information Space(14)	0.09					2006.Explicit knowledge(1)	#DIV/0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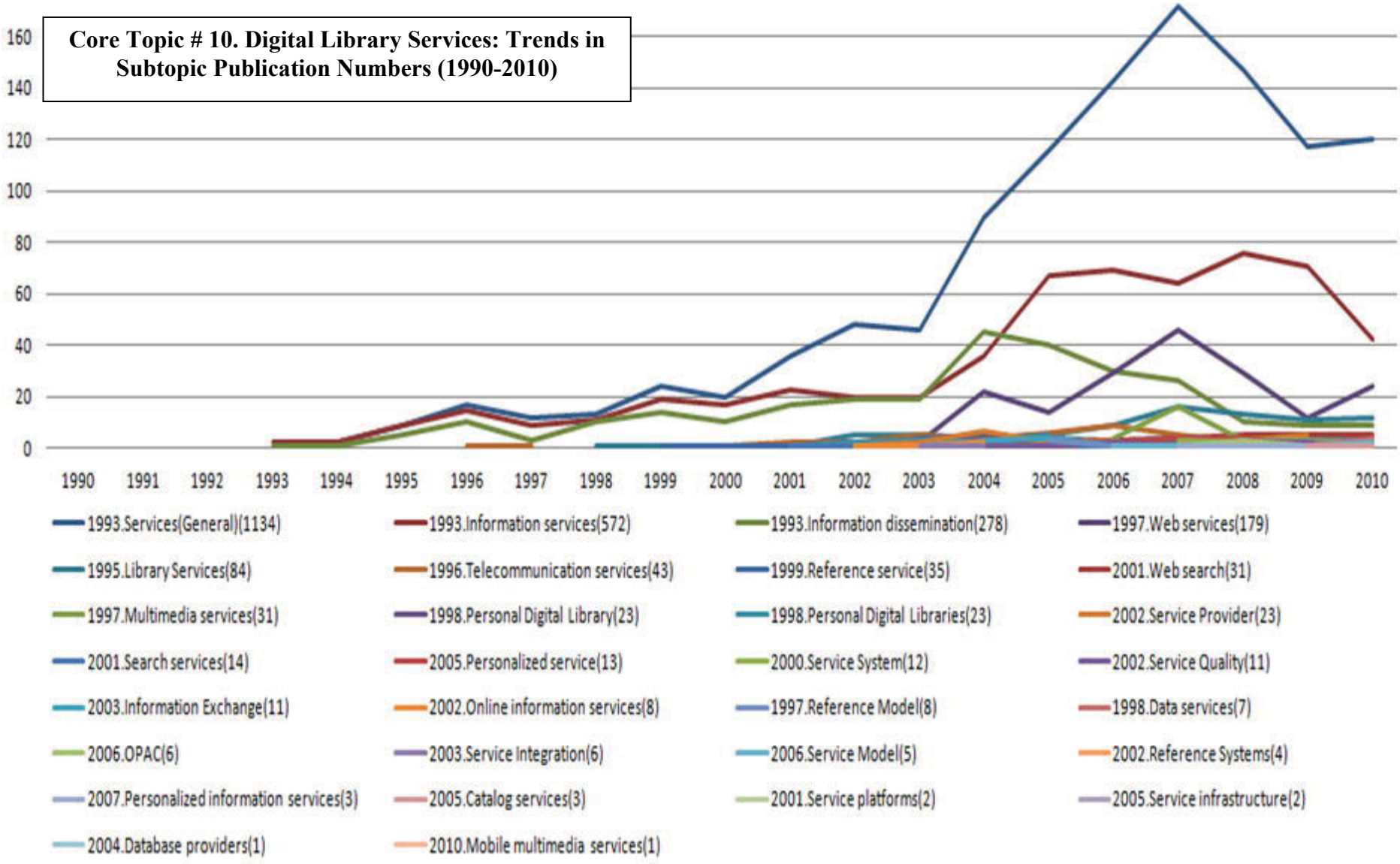
1995.Information management(411)
1998.Knowledge management(General)(185)
1995.Knowledge based systems(150)
1996.Knowledge acquisition(119)
1994.Collaboration(102)
2000.Knowledge engineering(73)
1996.Knowledge representation(51)
2001.Content management(45)
1998.Data management(38)
1997.Expert System(28)
1999.Document Management(26)
2002.Knowledge organization(25)
2002.Knowledge Base(23)
1996.Information Sharing(22)
2001.Knowledge sharing(22)
2000.Knowledge discovery(20)
2000.Information Space(14)
2002.Knowledge organization systems(11)
2002.Content Management System(12)
2003.Information Exchange(11)
2001.Collaborative learning(11)
2005.Personal information management(10)
2003.Domain knowledge(9)
2007.Knowledge service(9)
2004.Scientific knowledge(8)
2003.Knowledge Network(8)
2005.Information communication(8)
2002.Topic maps(6)
2006.Knowledge Extraction(6)
2005.Collaborative research(6)
2007.Knowledge basis(5)
1996.Collaborative work(5)
2007.Knowledge map(4)
2005.Knowledge transfer(4)
1999.Information Flow(4)
2007.Collaborative knowledge(4)
1998.Knowledge spaces(3)
2008.Knowledge innovation(3)
2001.Knowledge evolution(3)
2007.Knowledge retrieval(3)
2005.Tacit knowledge(3)
2007.External knowledge(2)
2010.Expert Knowledge(2)
2009.Knowledge process(2)
2005.Knowledge Mining(2)
2009.Collaborative network(2)
2003.Multimedia data management(1)
2006.Knowledge Work(1)
2010.Knowledge linking(1)
2010.Knowledge building(1)
2010.Knowledge gaps(1)
2004.Knowledge searching(1)
2005.Knowledge distribution(1)
2008.Knowledge Translation(1)
2007.Knowledge Exchange(1)
2005.Knowledge communication(1)
2009.Collaborative technologies(1)
2006.Explicit knowledge(1)

Appendix 13

Core Topic # 10. Digital Library Services: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
1993.Services (General)(1134)	0.82	1997.Web services(179)	0.34	2005.Personalized service(13)	0.01	2002.Reference Systems(4)	#DIV/0
2001.Web search(31)	0.81	2002.Online information services(8)	0.30	2003.Information Exchange(11)	0.00	2007.Personalized information services(3)	#DIV/0
1993.Information services(572)	0.77	1993.Information dissemination(278)	0.24			2005.Catalog services(3)	#DIV/0
1995.Library Services(84)	0.75	1996.Telecommunication services(43)	0.18			2001.Service platforms(2)	#DIV/0
2001.Search services(14)	0.65	2002.Service Quality(11)	0.16			2005.Service infrastructure(2)	#DIV/0
2000.Service System(12)	0.56	2002.Service Provider(23)	0.13			2004.Database providers(1)	#DIV/0
2006.Service Model(5)	0.53	1998.Personal Digital Libraries(23)	0.10			2010.Mobile multimedia services(1)	#DIV/0
2003.Service Integration(6)	0.49	2006.OPAC(6)	0.07				
1999.Reference service(35)	0.46	1997.Multimedia services(31)	0.06				
1998.Data services(7)	0.39	1997.Reference Model(8)	0.00				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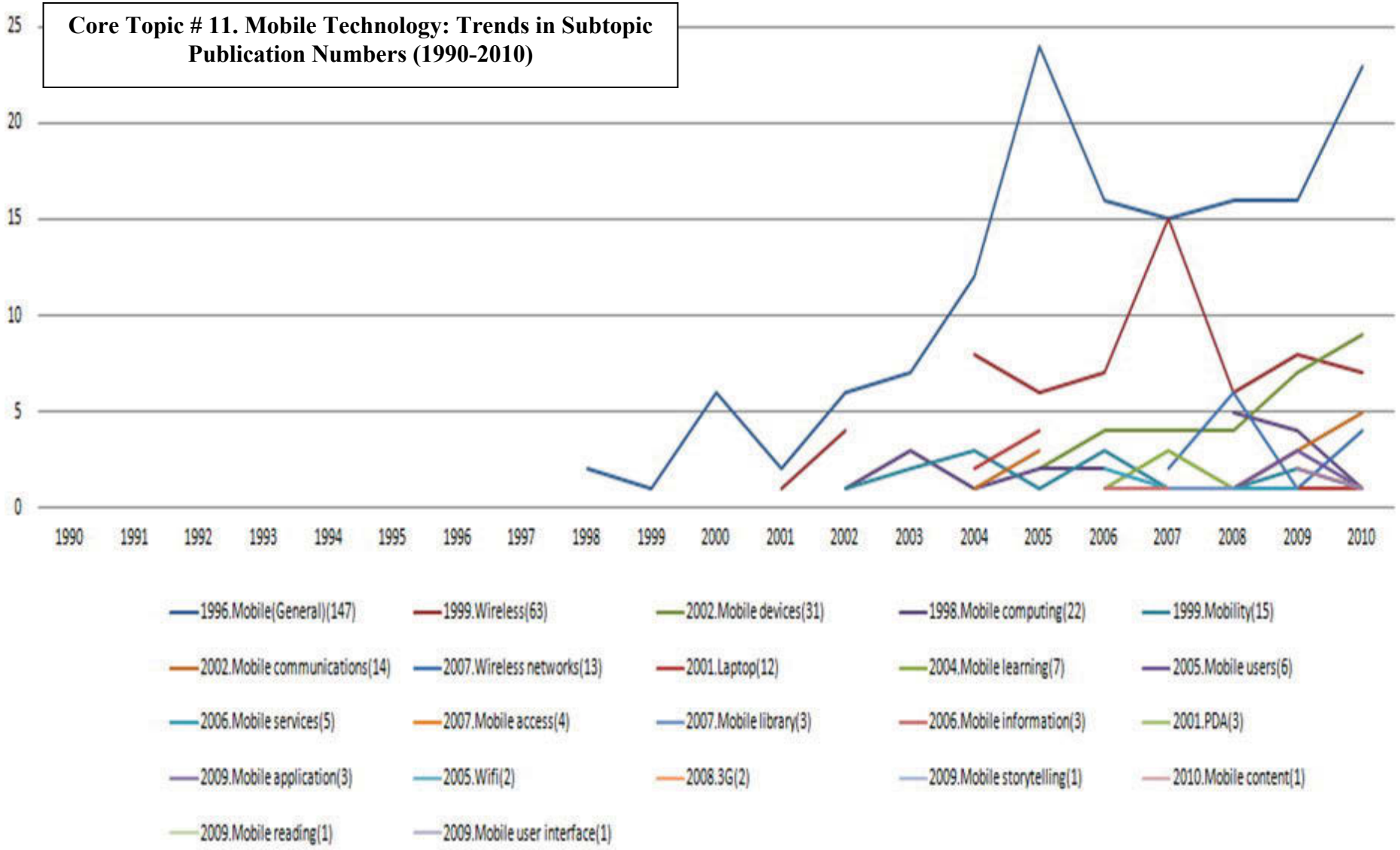
1997.Web services(179)
1995.Library Services(84)
1996.Telecommunication services(43)
1999.Reference service(35)
2001.Web search(31)
1997.Multimedia services(31)
1998.Personal Digital Library(23)
1998.Personal Digital Libraries(23)
2002.Service Provider(23)
2001.Search services(14)
2005.Personalized service(13)
2000.Service System(12)
2002.Service Quality(11)
2003.Information Exchange(11)
2002.Online information services(8)
1997.Reference Model(8)
1998.Data services(7)
2006.OPAC(6)
2003.Service Integration(6)
2006.Service Model(5)
2002.Reference Systems(4)
2007.Personalized information services(3)
2005.Catalog services(3)
2001.Service platforms(2)
2005.Service infrastructure(2)
2004.Database providers(1)
2010.Mobile multimedia services(1)

Appendix 14:

Core Topic # 11. Mobile Technology: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*					
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2009.Mobile application(3)	1.00	2006.Mobile services(5)	0.60	2007.Mobile library(3)	#DIV/0
2002.Mobile devices(31)	0.84	2001.Laptop(12)	0.30	2006.Mobile information(3)	#DIV/0
1996.Mobile(General)(147)	0.77			2001.PDA(3)	#DIV/0
2002.Mobile communications(14)	0.46			2005.Wifi(2)	#DIV/0
1999.Wireless(63)	0.44			2008.3G(2)	#DIV/0
1998.Mobile computing(22)	0.20			2009.Mobile storytelling(1)	#DIV/0
2005.Mobile users(6)	0.10			2010.Mobile content(1)	#DIV/0
2007.Mobile access(4)	0.04			2009.Mobile reading(1)	#DIV/0
1999.Mobility(15)	0.02			2009.Mobile user interface(1)	#DIV/0
2007.Wireless networks(13)	0.00				
2004.Mobile learning(7)	0.00				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2010
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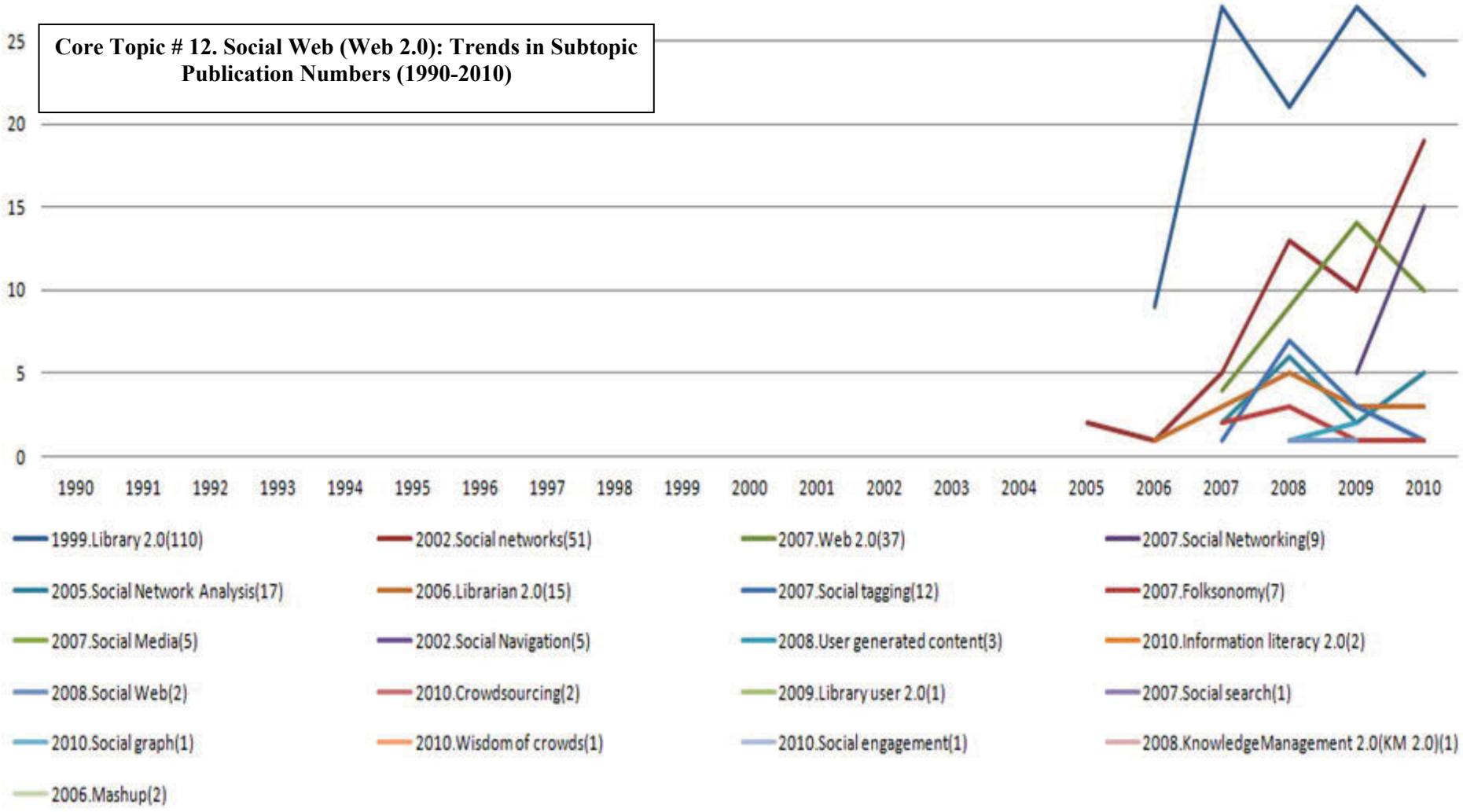
1999.Wireless(63)
2002.Mobile devices(31)
1998.Mobile computing(22)
1999.Mobility(15)
2002.Mobile communications(14)
2007.Wireless networks(13)
2001.Laptop(12)
2004.Mobile learning(7)
2005.Mobile users(6)
2006.Mobile services(5)
2007.Mobile access(4)
2007.Mobile library(3)
2006.Mobile information(3)
2001.PDA(3)
2009.Mobile application(3)
2005.Wifi(2)
2008.3G(2)
2009.Mobile storytelling(1)
2010.Mobile content(1)
2009.Mobile reading(1)
2009.Mobile user interface(1)

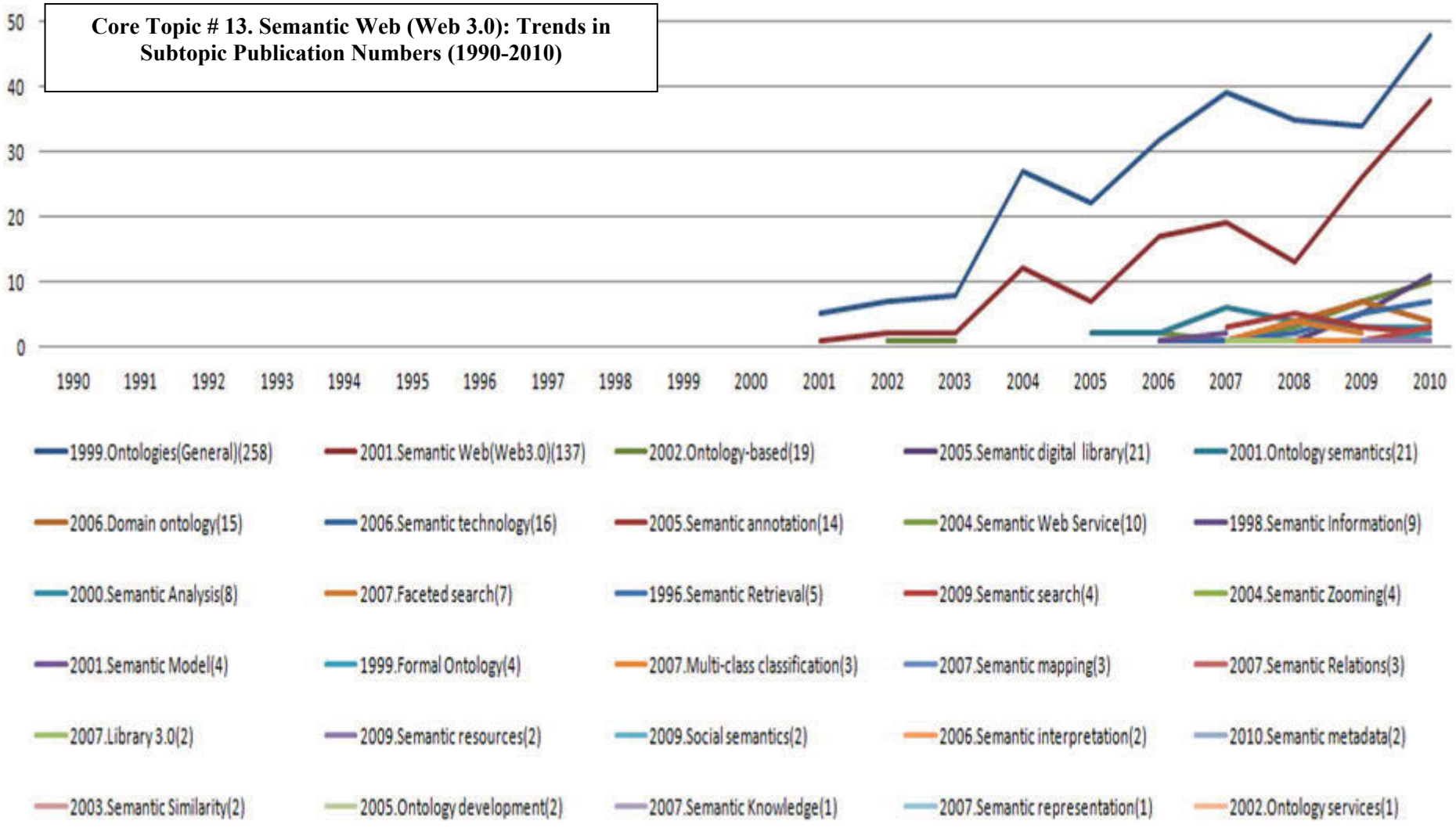
Appendix 15:

Core Topic # 12. Social Web (Web 2.0): Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*					
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2007.Social Media(5)	1.00	2007.Folksonomy(7)	0.45	2010.Information literacy 2.0(2)	#DIV/0
2008.User generated content(3)	1.00	2007.Social tagging(12)	0.03	2008.Social Web(2)	#DIV/0
2007.Social Networking(9)	0.82			2010.Crowdsourcing(2)	#DIV/0
1999.Library 2.0(110)	0.76			2009.Library user 2.0(1)	#DIV/0
2002.Social networks(51)	0.71			2007.Social search(1)	#DIV/0
2002.Social Navigation(5)	0.63			2010.Social graph(1)	#DIV/0
2007.Web 2.0(37)	0.52			2010.Wisdom of crowds(1)	#DIV/0
2005.Social Network Analysis(17)	0.24			2010.Social engagement(1)	#DIV/0
2006.Librarian 2.0(15)	0.20			2008.KnowledgeManagement 2.0(KM 2.0)(1)	#DIV/0
				2006.Mashup(2)	#DIV/0


Core Topic # 12. Social Web (Web 2.0): Trends in Subtopic Publication Numbers (1990-2010)
25
20
15
10
5
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
1999.Library 2.0(110)
2002.Social networks(51)
2007.Web 2.0(37)
2007.Social Networking(9)
2005.Social Network Analysis(17)
2006.Librarian 2.0(15)
2007.Social tagging(12)
2007.Folksonomy(7)
2007.Social Media(5)
2002.Social Navigation(5)
2008.User generated content(3)
2010.Information literacy 2.0(2)
2008.Social Web(2)
2010.Crowdsourcing(2)
2009.Library user 2.0(1)
2007.Social search(1)
2010.Social graph(1)
2010.Wisdom of crowds(1)
2010.Social engagement(1)
2008.KnowledgeManagement 2.0(KM 2.0)(1)
2006.Mashup(2)

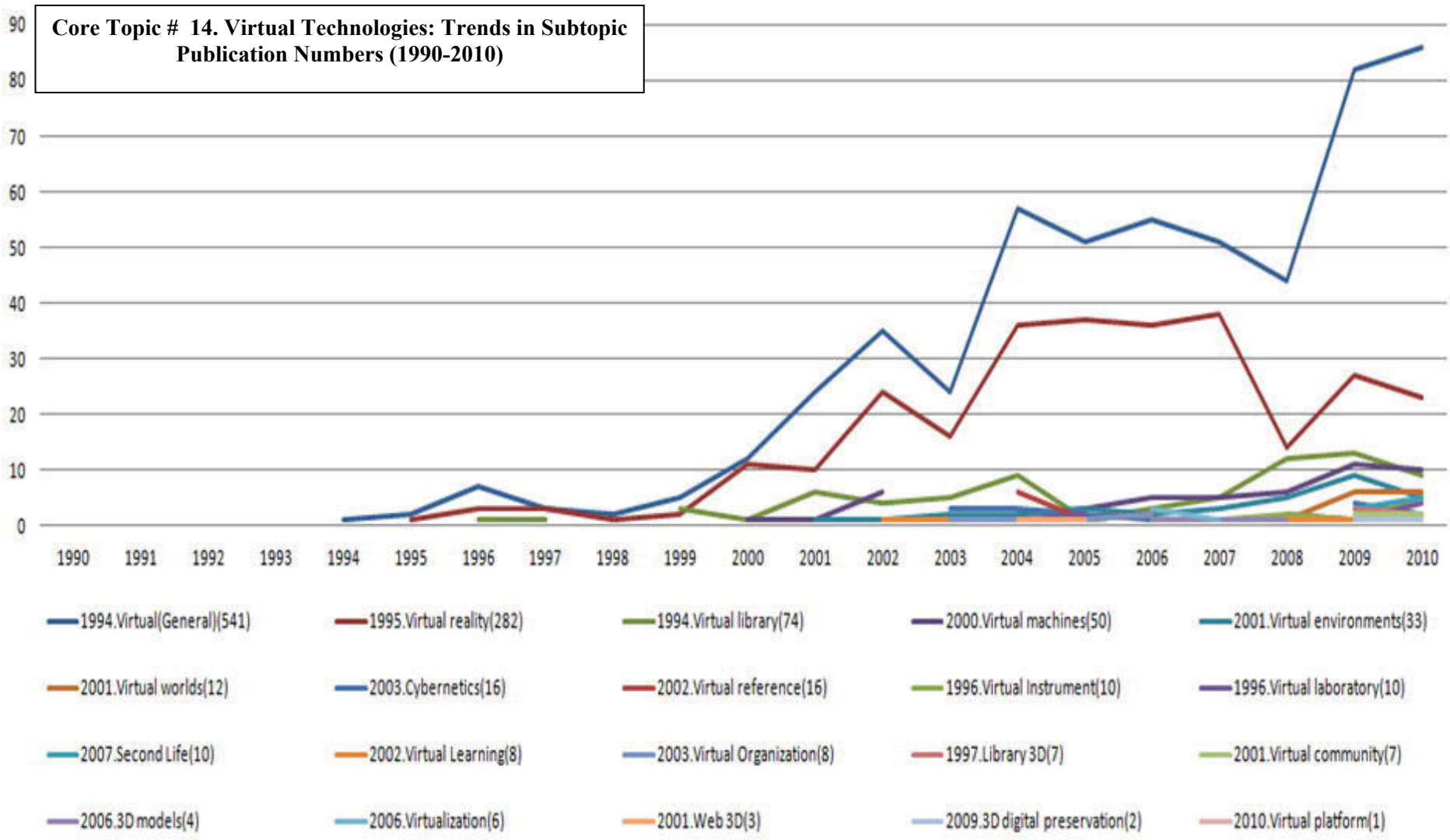
Appendix 16:

Core Topic # 13. Semantic Web (Web 3.0): Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*					
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2009.Semantic search(4)	1.00	2004.Semantic Web Service(10)	0.57	2004.Semantic Zooming(4)	#DIV/0
1999.Ontologies(General)(258)	0.90			2007.Multi-class classification(3)	#DIV/0
2006.Semantic technology(16)	0.89			2007.Semantic mapping(3)	#DIV/0
2001.Semantic Web(Web3.0)(137)	0.83			2007.Semantic Relations(3)	#DIV/0
2001.Semantic Model(4)	0.64			2007.Library 3.0(2)	#DIV/0
2002.Ontology-based(19)	0.62			2009.Semantic resources(2)	#DIV/0
2006.Domain ontology(15)	0.57			2009.Social semantics(2)	#DIV/0
1998.Semantic Information(9)	0.51			2006.Semantic interpretation(2)	#DIV/0
1999.Formal Ontology(4)	0.45			2010.Semantic metadata(2)	#DIV/0
2005.Semantic digital library(21)	0.44			2003.Semantic Similarity(2)	#DIV/0
2000.Semantic Analysis(8)	0.35			2005.Ontology development(2)	#DIV/0
2001.Ontology semantics(21)	0.30			2007.Semantic Knowledge(1)	#DIV/0
1996.Semantic Retrieval(5)	0.25			2007.Semantic representation(1)	#DIV/0
2005.Semantic annotation(14)	0.11			2002.Ontology services(1)	#DIV/0
2007.Faceted search(7)	0.11				


Core Topic # 13. Semantic Web (Web 3.0): Trends in Subtopic Publication Numbers (1990-2010)
50
40
30
20
10
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
1999.Ontologies(General)(258)
2001.Semantic Web(Web3.0)(137)
2002.Ontology-based(19)
2005.Semantic digital library(21)
2001.Ontology semantics(21)
2006.Domain ontology(15)
2006.Semantic technology(16)
2005.Semantic annotation(14)
2004.Semantic Web Service(10)
1998.Semantic Information(9)
2000.Semantic Analysis(8)
2007.Faceted search(7)
1996.Semantic Retrieval(5)
2009.Semantic search(4)
2004.Semantic Zooming(4)
2001.Semantic Model(4)
1999.Formal Ontology(4)
2007.Multi-class classification(3)
2007.Semantic mapping(3)
2007.Semantic Relations(3)
2007.Library 3.0(2)
2009.Semantic resources(2)
2009.Social semantics(2)
2006.Semantic interpretation(2)
2010.Semantic metadata(2)
2003.Semantic Similarity(2)
2005.Ontology development(2)
2007.Semantic Knowledge(1)
2007.Semantic representation(1)
2002.Ontology services(1)

Appendix 17:

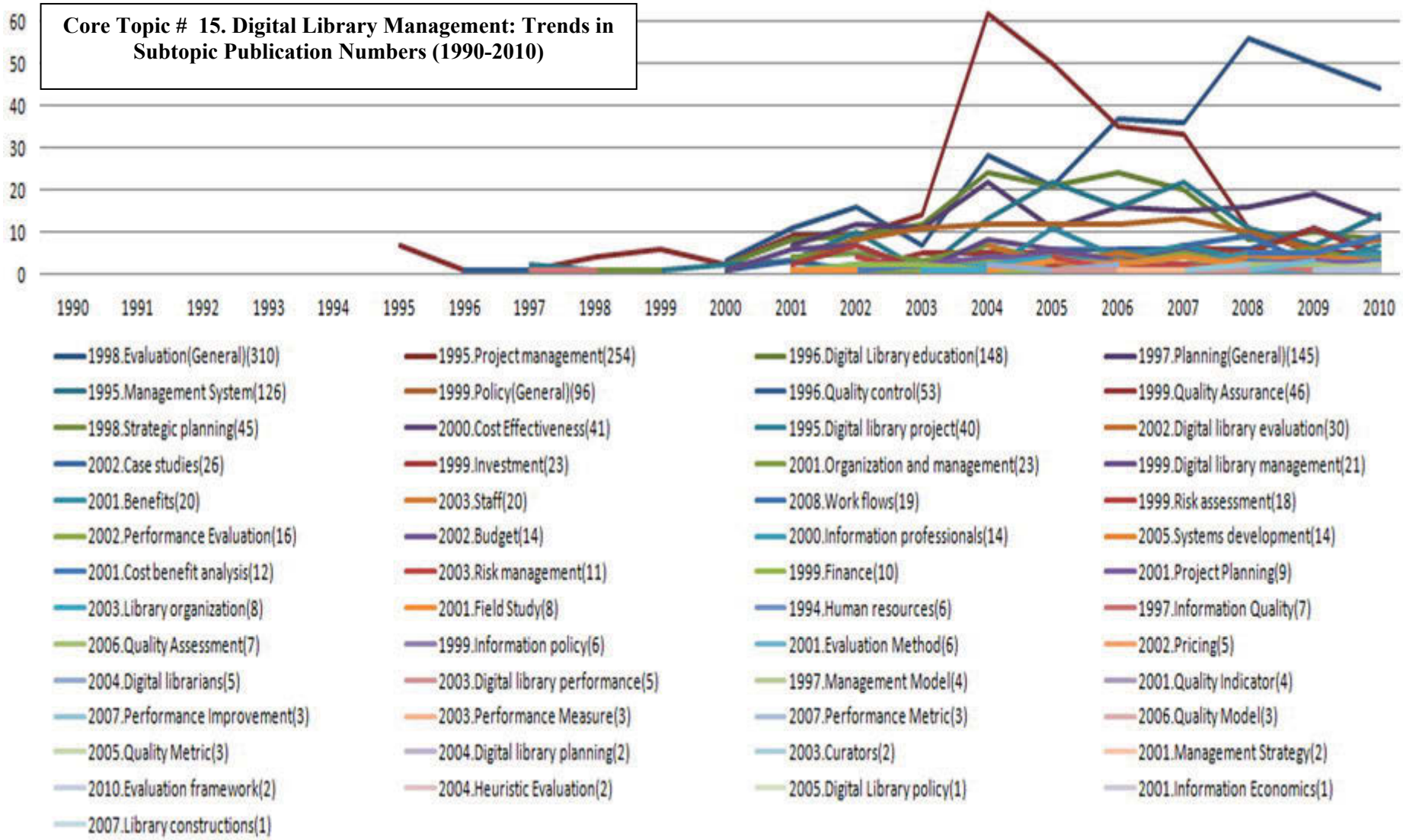
Core Topic # 14. Virtual Technologies: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2003.Virtual Organization(8)	0.90	1994.Virtual library(74)	0.55	2006.Virtualization(6)	0.53	2001.Web 3D(3)	#DIV/0
1994.Virtual(General)(541)	0.87	2001.Virtual worlds(12)	0.52	2002.Virtual reference(16)	0.04	2009.3D digital preservation(2)	#DIV/0
2007.Second Life(10)	0.86	1997.Library 3D(7)	0.39	2003.Cybernetics(16)	0.00	2010.Virtual platform(1)	#DIV/0
2006.3D models(4)	0.77	1996.Virtual laboratory(10)	0.22				
2000.Virtual machines(50)	0.68	1996.Virtual Instrument(10)	0.21				
2001.Virtual environments(33)	0.67	2002.Virtual Learning(8)	0.02				
1995.Virtual reality(282)	0.58	2001.Virtual community(7)	0.01				


Core Topic # 14. Virtual Technologies: Trends in Subtopic Publication Numbers (1990-2010)
90
80
70
60
50
40
30
20
10
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
1994.Virtual(General)(541)
1995.Virtual reality(282)
1994.Virtual library(74)
2000.Virtual machines(50)
2001.Virtual environments(33)
2001.Virtual worlds(12)
2003.Cybernetics(16)
2002.Virtual reference(16)
1996.Virtual Instrument(10)
1996.Virtual laboratory(10)
2007.Second Life(10)
2002.Virtual Learning(8)
2003.Virtual Organization(8)
1997.Library 3D(7)
2001.Virtual community(7)
2006.3D models(4)
2006.Virtualization(6)
2001.Web 3D(3)
2009.3D digital preservation(2)
2010.Virtual platform(1)

Appendix 18:

Core Topic # 15. Digital Library Management: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2001.Quality Indicator(4)	1.00	2005.Systems development(14)	0.18	2006.Quality Model(3)	1.00	2003.Digital library performance(5)	#DIV/0
2007.Performance Improvement(3)	1.00	1999.Finance(10)	0.16	2002.Digital library evaluation(30)	0.11	2003.Performance Measure(3)	#DIV/0
1998.Evaluation(General)(310)	0.86	1998.Strategic planning(45)	0.16	1999.Information policy(6)	0.06	2007.Performance Metric(3)	#DIV/0
2008.Work flows(19)	0.75	1996.Digital Library education(148)	0.16	2000.Cost Effectiveness(41)	0.04	2005.Quality Metric(3)	#DIV/0
2001.Cost benefit analysis(12)	0.73	1995.Project management(254)	0.14	2002.Budget(14)	0.02	2004.Digital library planning(2)	#DIV/0
1996.Quality control(53)	0.69	2003.Library organization(8)	0.14	1999.Investment(23)	0.00	2003.Curators(2)	#DIV/0
1997.Planning(General)(145)	0.66	2000.Information professionals(14)	0.11	2003.Risk management(11)	0.00	2001.Management Strategy(2)	#DIV/0
2001.Benefits(20)	0.65	1994.Human resources(6)	0.10			2010.Evaluation framework(2)	#DIV/0
2001.Project Planning(9)	0.62	2006.Quality Assessment(7)	0.08			2004.Heuristic Evaluation(2)	#DIV/0
1995.Management System(126)	0.49	2002.Pricing(5)	0.04			2005.Digital Library policy(1)	#DIV/0
1997.Information Quality(7)	0.44	1999.Risk assessment(18)	0.02			2001.Information Economics(1)	#DIV/0
1999.Quality Assurance(46)	0.39	2001.Evaluation Method(6)	0.01			2007.Library constructions(1)	#DIV/0
2001.Organization and management(23)	0.36	2002.Performance Evaluation(16)	0.01				
2003.Staff(20)	0.34	2002.Case studies(26)	0.00				
1997.Management Model(4)	0.31	1999.Digital library management(21)	0.00				

1995.Digital library project(40)	0.23	2001.Field Study(8)	0.00				
1999.Policy(General) (96)	0.22	2004.Digital librarians(5)	0.00				

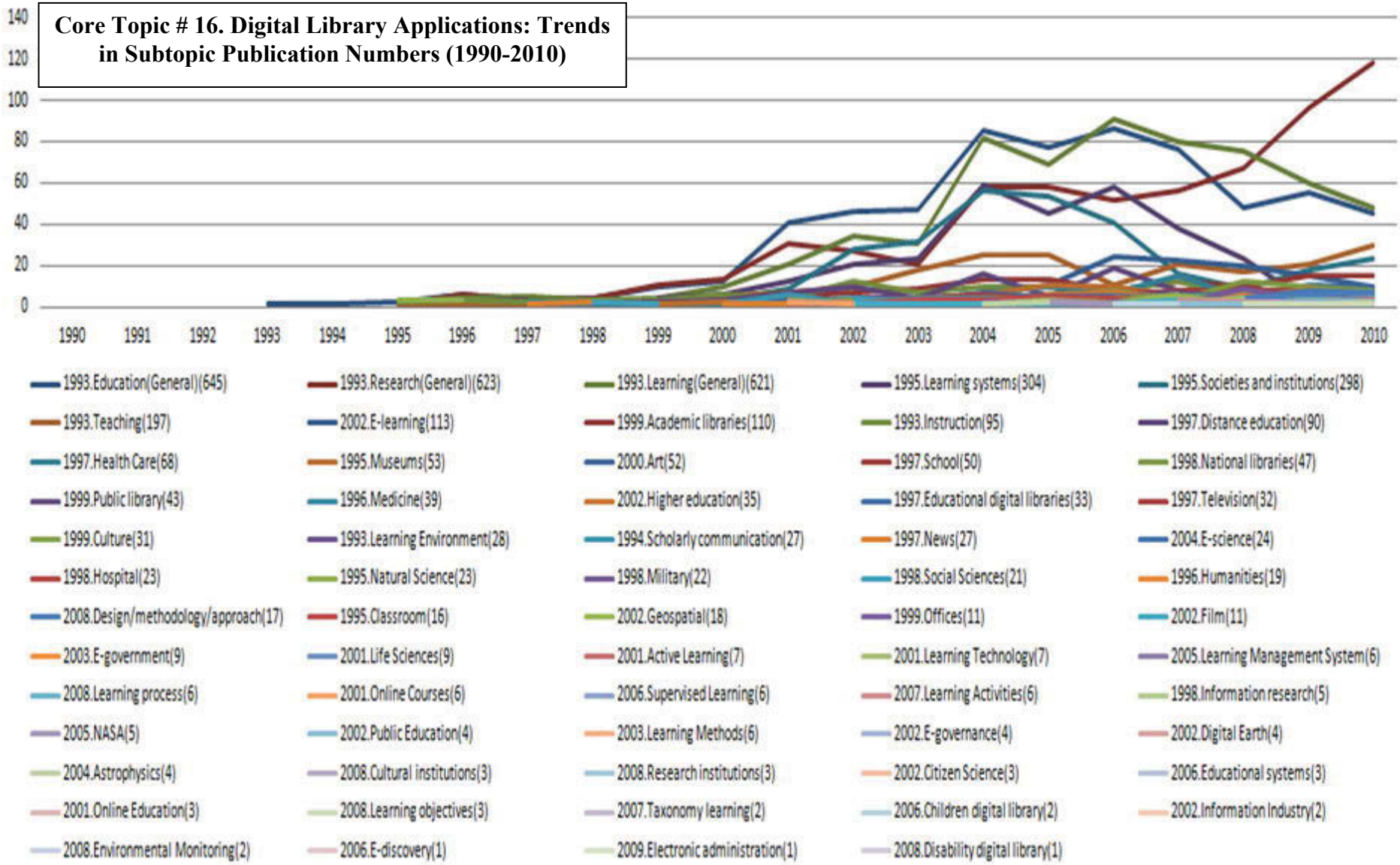

Core Topic # 15. Digital Library Management: Trends in Subtopic Publication Numbers (1990-2010)
60
50
40
30
20
10
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
1998.Evaluation(General)(310)
1995.Project management(254)
1996.Digital Library education(148)
1997.Planning(General)(145)
1995.Management System(126)
1999.Policy(General)(96)
1996.Quality control(53)
1999.Quality Assurance(46)
1998.Strategic planning(45)
2000.Cost Effectiveness(41)
1995.Digital library project(40)
2002.Digital library evaluation(30)
2002.Case studies(26)
1999.Investment(23)
2001.Organization and management(23)
1999.Digital library management(21)
2001.Benefits(20)
2003.Staff(20)
2008.Work flows(19)
1999.Risk assessment(18)
2002.Performance Evaluation(16)
2002.Budget(14)
2000.Information professionals(14)
2005.Systems development(14)
2001.Cost benefit analysis(12)
2003.Risk management(11)
1999.Finance(10)
2001.Project Planning(9)
2003.Library organization(8)
2001.Field Study(8)
1994.Human resources(6)
1997.Information Quality(7)
2006.Quality Assessment(7)
1999.Information policy(6)
2001.Evaluation Method(6)
2002.Pricing(5)
2004.Digital librarians(5)
2003.Digital library performance(5)
1997.Management Model(4)
2001.Quality Indicator(4)
2007.Performance Improvement(3)
2003.Performance Measure(3)
2007.Performance Metric(3)
2006.Quality Model(3)
2005.Quality Metric(3)
2004.Digital library planning(2)
2003.Curators(2)
2001.Management Strategy(2)
2010.Evaluation framework(2)
2004.Heuristic Evaluation(2)
2005.Digital Library policy(1)
2001.Information Economics(1)
2007.Library constructions(1)

Appendix 19:

Core Topic # 16. Digital Library Applications: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2008.Research institutions(3)	1.00	2002.Higher education(35)	0.29	2007.Learning Activities(6)	1.00	2002.Public Education(4)	#DIV/0
2008.Design/methodology/approach(17)	0.96	2001.Learning Technology(7)	0.29	2002.Citizen Science(3)	1.00	2003.Learning Methods(6)	#DIV/0
1993.Research(General)(623)	0.85	2001.Active Learning(7)	0.28	2003.E-government(9)	0.41	2008.Cultural institutions(3)	#DIV/0
1997.School(50)	0.81	1995.Societies and institutions(298)	0.28	2005.Learning Management System(6)	0.41	2006.Educational systems(3)	#DIV/0
1993.Teaching(197)	0.77	1993.Instruction(95)	0.26	2005.NASA(5)	0.38	2001.Online Education(3)	#DIV/0
2004.E-science(24)	0.77	2002.Film(11)	0.26	2001.Online Courses(6)	0.36	2008.Learning objectives(3)	#DIV/0
1999.Academic libraries(110)	0.75	2008.Learning process(6)	0.25	2002.Digital Earth(4)	0.08	2007.Taxonomy learning(2)	#DIV/0
1993.Learning(General)(621)	0.71	1995.Museums(53)	0.20	2004.Astrophysics(4)	0.04	2006.Children digital library(2)	#DIV/0
1993.Education(General)(645)	0.67	1995.Learning systems(304)	0.18	1999.Offices(11)	0.00	2002.Information Industry(2)	#DIV/0
1996.Medicine(39)	0.65	1999.Public library(43)	0.18			2008.Environmental Monitoring(2)	#DIV/0
2000.Art(52)	0.63	1997.Distance education(90)	0.12			2006.E-discovery(1)	#DIV/0
1998.National libraries(47)	0.54	1998.Military(22)	0.12			2009.Electronic administration(1)	#DIV/0
1999.Culture(31)	0.48	2002.Geospatial(18)	0.06			2008.Disability digital library(1)	#DIV/0
2001.Life Sciences(9)	0.40	1998.Social Sciences(21)	0.05				
1997.Health Care(68)	0.38	1997.Television(32)	0.04				
1997.Educational digital libraries(33)	0.38	1998.Hospital(23)	0.04				
2002.E-learning(113)	0.36	1995.Natural Science(23)	0.04				
1996.Humanities(19)	0.35	2006.Supervised Learning(6)	0.03				
1993.Learning	0.32	1997.News(27)	0.02				

Environment(28)							
1995.Classroom(16)	0.31	1994.Scholarly communication(27)	0.02				
1998.Information research(5)	0.30	2002.E-governance(4)	0.01				

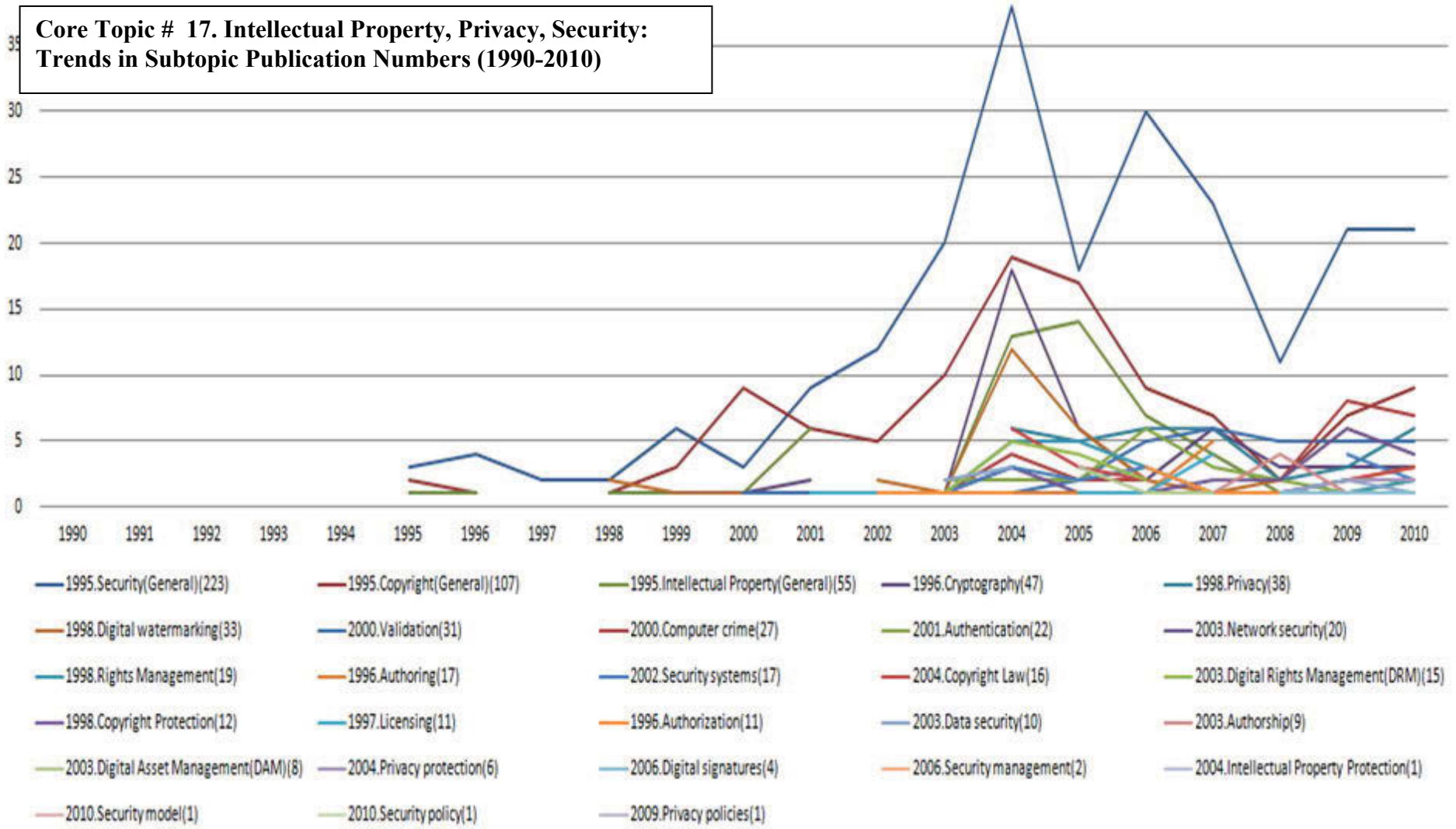
Core Topic # 16. Digital Library Applications: Trends in Subtopic Publication Numbers (1990-2010)



Appendix 20:

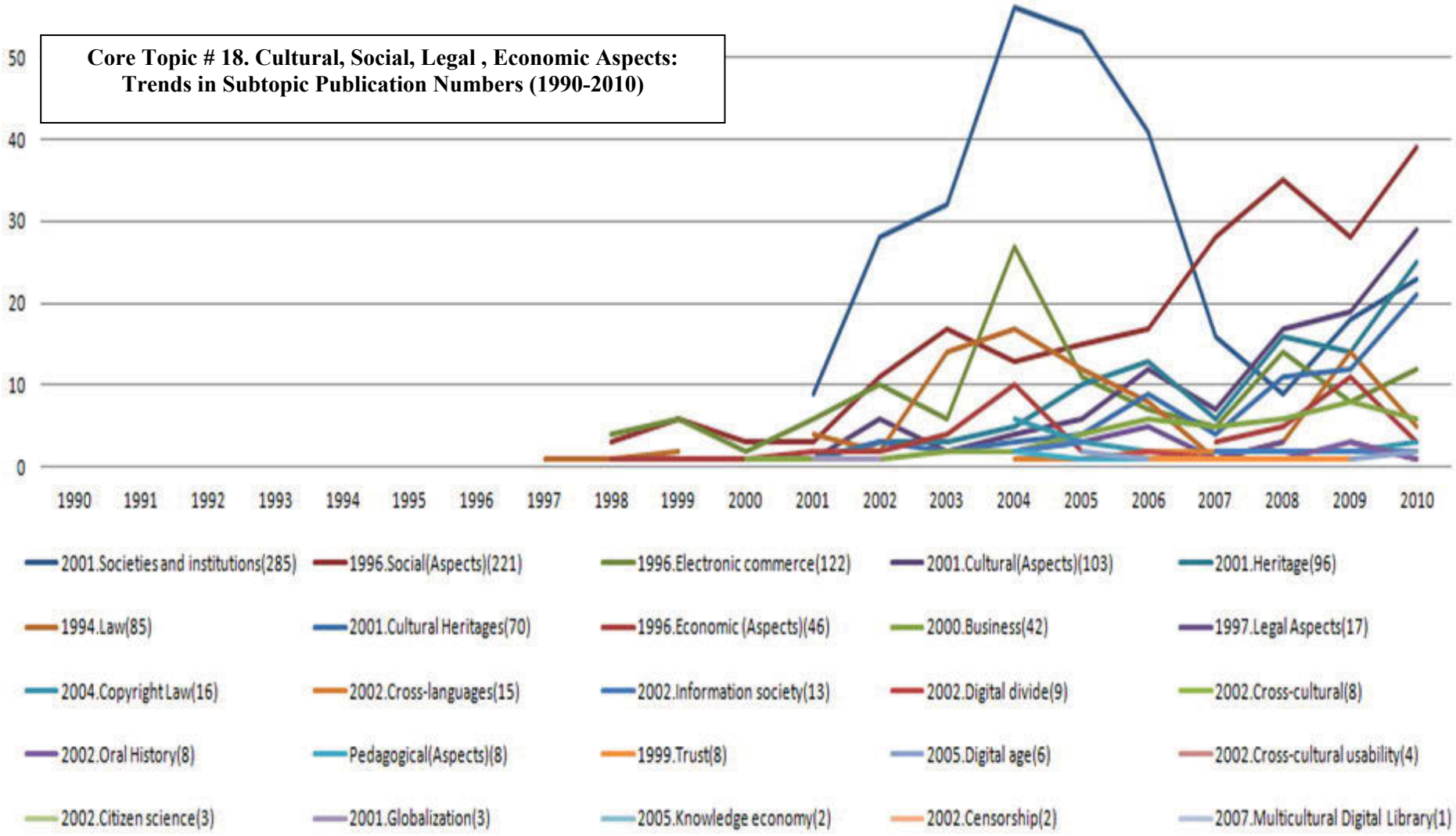
Core Topic # 17. Intellectual Property, Privacy, Security: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2004.Privacy protection(6)	0.89	1995.Copyright(General)(107)	0.19	2003.Data security(10)	0.34	2006.Digital signatures(4)	#DIV/0
2000.Validation(31)	0.73	1998.Copyright Protection(12)	0.11	2004.Copyright Law(16)	0.33	2006.Security management(2)	#DIV/0
2000.Computer crime(27)	0.55	1995.Intellectual Property(General)(55)	0.07	2003.Digital Rights Management(DRM) (15)	0.30	2004.Intellectual Property Protection(1)	#DIV/0
1995.Security(General)(223)	0.51	1997.Licensing(11)	0.05	1996.Authorization (11)	0.06	2010.Security model(1)	#DIV/0
2003.Network security(20)	0.43	1996.Cryptography(47)	0.05	2001.Authentication(22)	0.00	2010.Security policy(1)	#DIV/0
1998.Privacy(38)	0.35	2003.Authorship(9)	0.04	1998.Rights Management(19)	0.00	2009.Privacy policies(1)	#DIV/0
1996.Authoring(17)	0.21	2003.Digital Asset Management(DAM)(8)	0.02				
2002.Security systems(17)	0.21	1998.Digital watermarking(33)	0.02				

Core Topic # 17. Intellectual Property, Privacy, Security: Trends in Subtopic Publication Numbers (1990-2010)



Appendix 21:

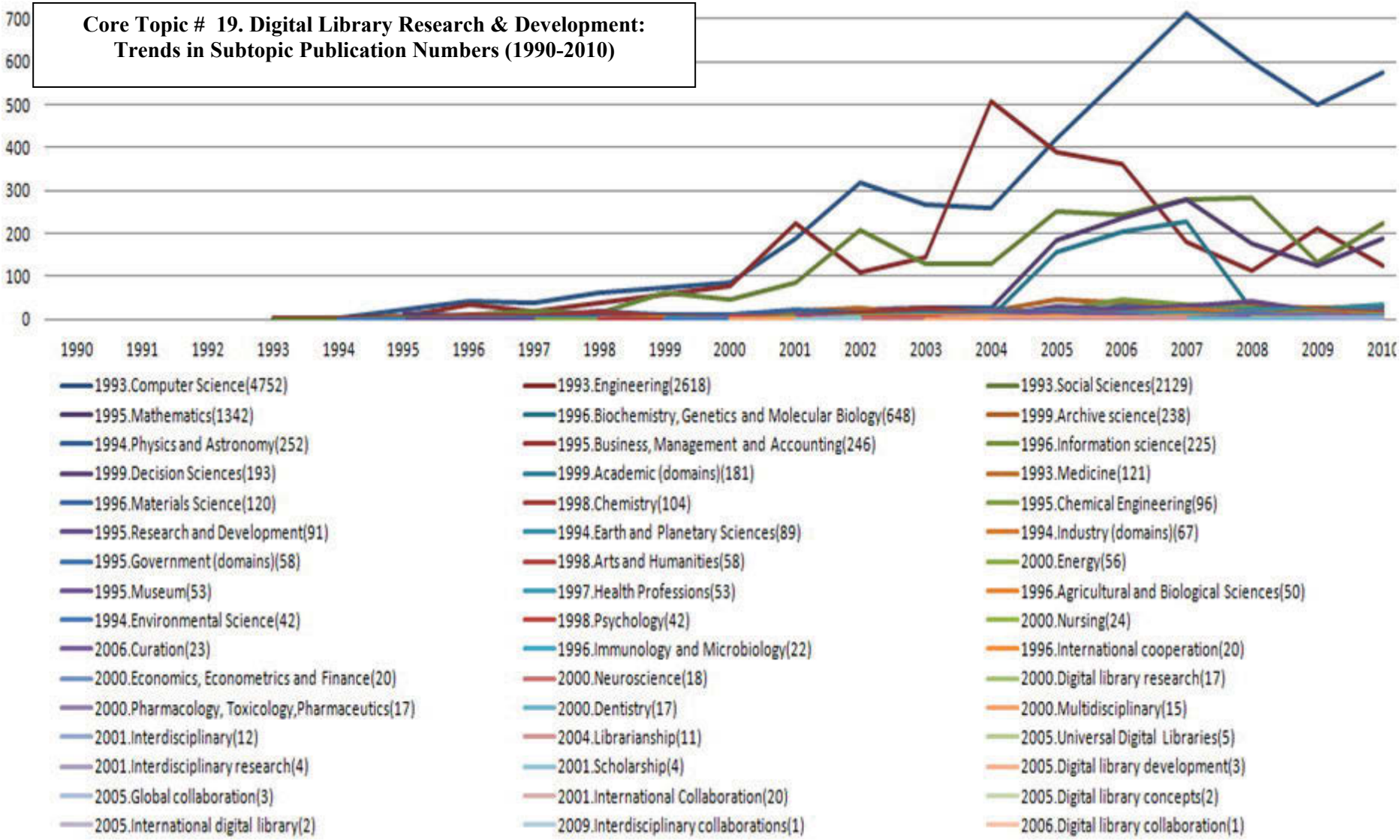
Core Topic # 18. Cultural, Social, Legal , Economic Aspects: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2000.Business(42)	0.87	1994.Law(85)	0.19	2002.Citizen science(3)	1.00	1999.Trust(8)	#DIV/0
1996.Social(Aspects)(221)	0.86	1996.Electronic commerce(122)	0.16	2002.Cross-cultural usability(4)	0.92	2001.Globalization (3)	#DIV/0
2001.Heritage(96)	0.80	Pedagogical(Aspects)(8)	0.15	2004.Copyright Law(16)	0.33	2005.Knowledge economy(2)	#DIV/0
2001.Cultural(Aspects) (103)	0.79	2002.Digital divide(9)	0.14	2002.Information society(13)	0.21	2002.Censorship(2)	#DIV/0
2001.Cultural Heritages(70)	0.75	1997.Legal Aspects(17)	0.07	2001.Societies and institutions(285)	0.04	2007.Multicultural Digital Library(1)	#DIV/0
2002.Cross-cultural(8)	0.43	2002.Oral History(8)	0.07	2002.Cross-languages(15)	0.00		
1996.Economic (Aspects)(46)	0.34	2005.Digital age(6)	0.00				


Core Topic # 18. Cultural, Social, Legal , Economic Aspects:
Trends in Subtopic Publication Numbers (1990-2010)
50
40
30
20
10
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2001.Societies and institutions(285)
1996.Social(Aspects)(221)
1996.Electronic commerce(122)
2001.Cultural(Aspects)(103)
2001.Heritage(96)
1994.Law(85)
2001.Cultural Heritages(70)
1996.Economic (Aspects)(46)
2000.Business(42)
1997.Legal Aspects(17)
2004.Copyright Law(16)
2002.Cross-languages(15)
2002.Information society(13)
2002.Digital divide(9)
2002.Cross-cultural(8)
2002.Oral History(8)
Pedagogical(Aspects)(8)
1999.Trust(8)
2005.Digital age(6)
2002.Cross-cultural usability(4)
2002.Citizen science(3)
2001.Globalization(3)
2005.Knowledge economy(2)
2002.Censorship(2)
2007.Multicultural Digital Library(1)

Appendix 22:

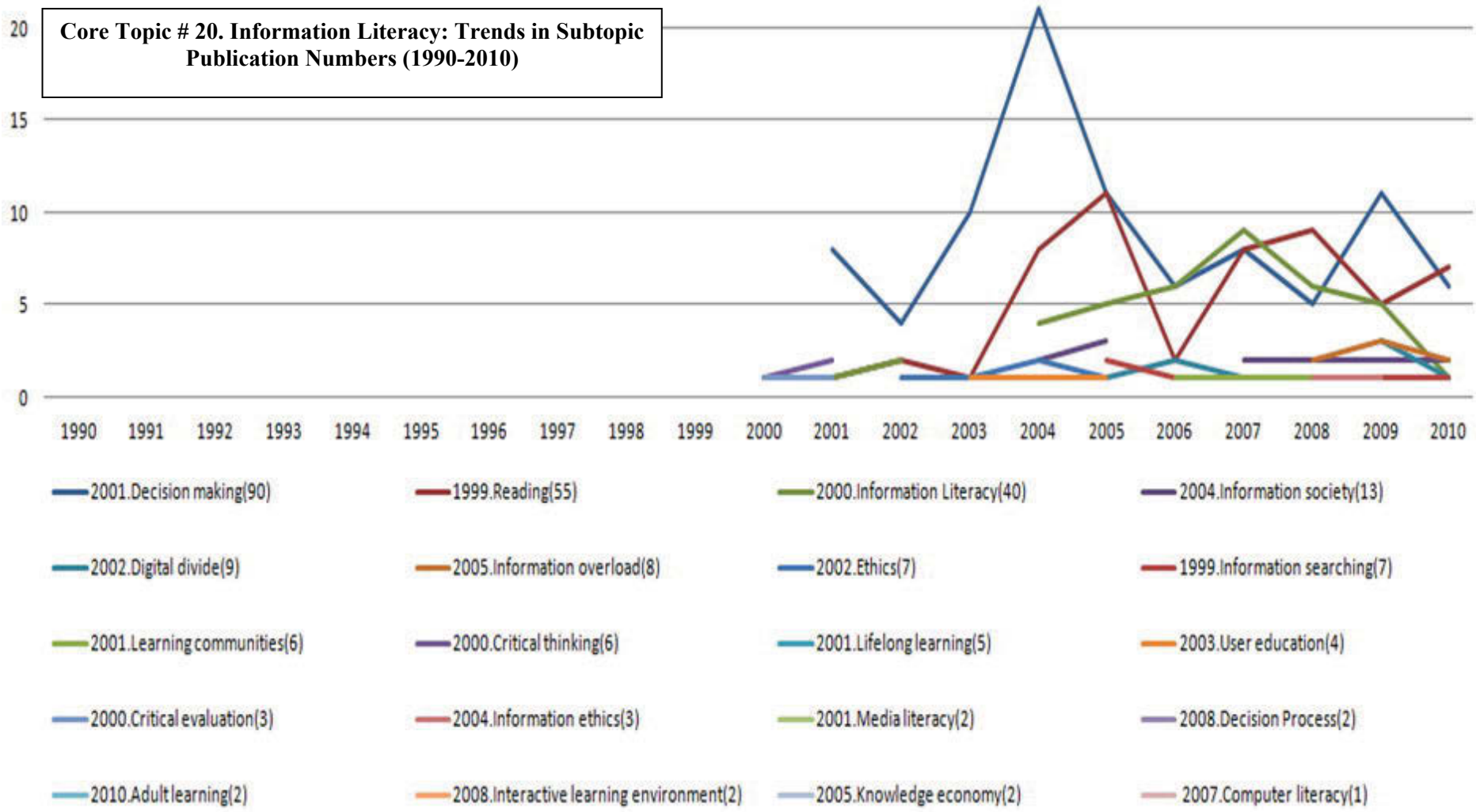
Core Topic # 19. Digital Library Research & Development: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*							
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Increasing Trends)**	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2001.Interdisciplinary research(4)	0.99	1995.Business, Management and Accounting(246)	0.45	2005.Digital library development(3)	1.00	2005.Universal Digital Libraries(5)	#DIV/0
1999.Academic (domains)(181)	0.93	2000.Energy(56)	0.45	2005.Global collaboration(3)	1.00	2001.International Collaboration(20)	#DIV/0
1993.Computer Science(4752)	0.87	1996.Agricultural and Biological Sciences(50)	0.41	2001.Scholarship(4)	0.13	2005.Digital library concepts(2)	#DIV/0
1993.Social Sciences(2129)	0.77	1999.Archive science(238)	0.41	1998.Psychology(42)	0.04	2005.International digital library(2)	#DIV/0
1993.Medicine(121)	0.73	1996.Immunology and Microbiology(22)	0.38			2009.Interdisciplinary collaborations(1)	#DIV/0
1994.Environmental Science(42)	0.70	1993.Engineering(2618)	0.37			2006.Digital library collaboration(1)	#DIV/0
1995.Chemical Engineering(96)	0.70	1994.Physics and Astronomy(252)	0.37				
1999.Decision Sciences(193)	0.69	1998.Arts and Humanities(58)	0.26				
1998.Chemistry(104)	0.68	2001.Interdisciplinary(12)	0.23				
2000.Economics, Econometrics and Finance(20)	0.66	2000.Multidisciplinary(15)	0.22				
1996.Materials Science(120)	0.63	1995.Museum(53)	0.20				
1995.Mathematics(1342)	0.62	2000.Dentistry(17)	0.19				
1996.Information science(225)	0.60	2000.Neuroscience(18)	0.14				
1994.Industry (domains)(67)	0.60	1996.Biochemistry, Genetics and Molecular Biology(648)	0.13				
1997.Health Professions(53)	0.59	2000.Nursing(24)	0.10				
2000.Pharmacology, Toxicology,Pharmaceutics(17)	0.57	1996.International cooperation(20)	0.07				
2006.Curation(23)	0.53	2004.Librarianship(11)	0.05				

1994.Earth and Planetary Sciences(89)	0.50	1995.Research and Development(91)	0.05				
1995.Government (domains)(58)	0.48	2000.Digital library research(17)	0.03				


Core Topic # 19. Digital Library Research & Development:
Trends in Subtopic Publication Numbers (1990-2010)
700
600
500
400
300
200
100
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
1993.Computer Science(4752)
1993.Engineering(2618)
1993.Social Sciences(2129)
1995.Mathematics(1342)
1996.Biochemistry, Genetics and Molecular Biology(648)
1999.Archive science(238)
1994.Physics and Astronomy(252)
1995.Business, Management and Accounting(246)
1996.Information science(225)
1999.Decision Sciences(193)
1999.Academic (domains)(181)
1993.Medicine(121)
1996.Materials Science(120)
1998.Chemistry(104)
1995.Chemical Engineering(96)
1995.Research and Development(91)
1994.Earth and Planetary Sciences(89)
1994.Industry (domains)(67)
1995.Government (domains)(58)
1998.Arts and Humanities(58)
2000.Energy(56)
1995.Museum(53)
1997.Health Professions(53)
1996.Agricultural and Biological Sciences(50)
1994.Environmental Science(42)
1998.Psychology(42)
2000.Nursing(24)
2006.Curation(23)
1996.Immunology and Microbiology(22)
1996.International cooperation(20)
2000.Economics, Econometrics and Finance(20)
2000.Neuroscience(18)
2000.Digital library research(17)
2000.Pharmacology, Toxicology,Pharmaceutics(17)
2000.Dentistry(17)
2000.Multidisciplinary(15)
2001.Interdisciplinary(12)
2004.Librarianship(11)
2005.Universal Digital Libraries(5)
2001.Interdisciplinary research(4)
2001.Scholarship(4)
2005.Digital library development(3)
2005.Global collaboration(3)
2001.International Collaboration(20)
2005.Digital library concepts(2)
2005.International digital library(2)
2009.Interdisciplinary collaborations(1)
2006.Digital library collaboration(1)

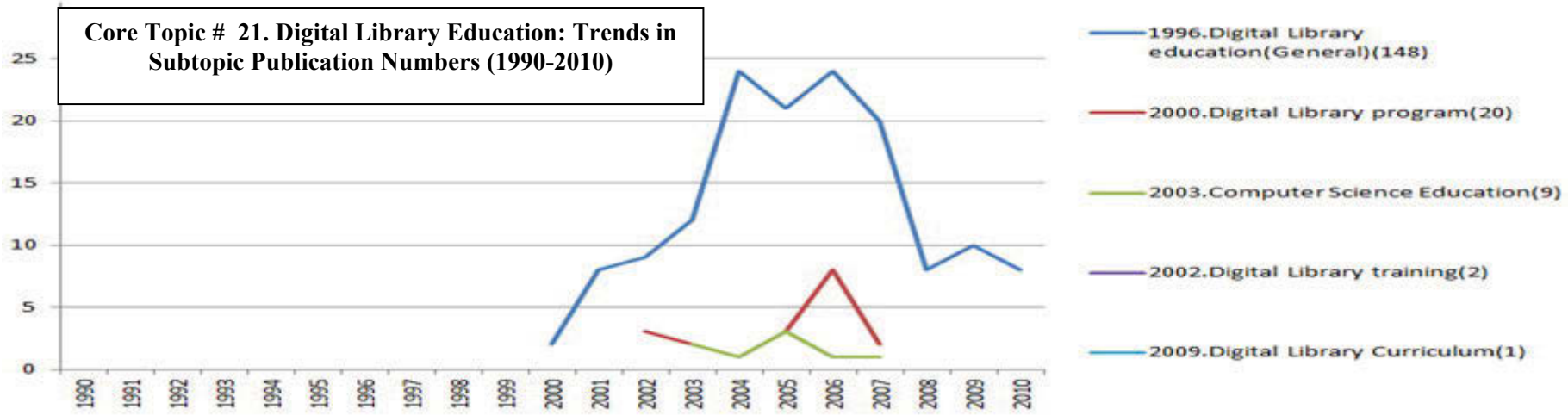
Appendix 23:

Core Topic # 20. Information Literacy: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*					
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
2005.Information overload(8)	0.57	2001.Learning communities(6)	0.87	2003.User education(4)	#DIV/0
1999.Reading(55)	0.37	2001.Lifelong learning(5)	0.78	2000.Critical evaluation(3)	#DIV/0
2000.Information Literacy(40)	0.23	2004.Information society(13)	0.21	2004.Information ethics(3)	#DIV/0
2002.Digital divide(9)	0.14	2002.Ethics(7)	0.04	2001.Media literacy(2)	#DIV/0
2000.Critical thinking(6)	0.06	2001.Decision making(90)	0.02	2008.Decision Process(2)	#DIV/0
		1999.Information searching(7)	0.02	2010.Adult learning(2)	#DIV/0
				2008.Interactive learning environment(2)	#DIV/0
				2005.Knowledge economy(2)	#DIV/0
				2007.Computer literacy(1)	#DIV/0

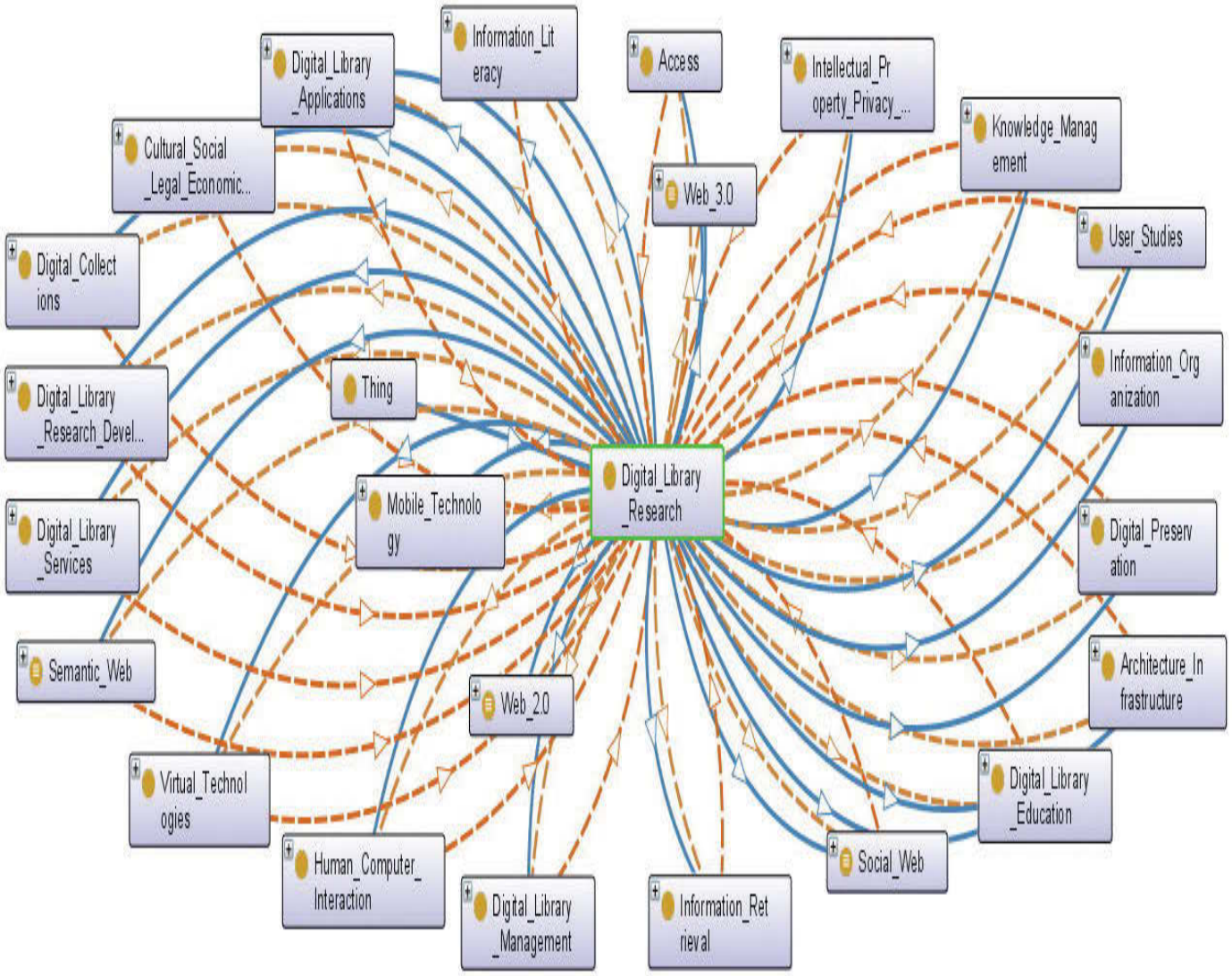

Core Topic # 20. Information Literacy: Trends in Subtopic Publication Numbers (1990-2010)
20
15
10
5
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
2001.Decision making(90)
1999.Reading(55)
2000.Information Literacy(40)
2004.Information society(13)
2002.Digital divide(9)
2005.Information overload(8)
2002.Ethics(7)
1999.Information searching(7)
2001.Learning communities(6)
2000.Critical thinking(6)
2001.Lifelong learning(5)
2003.User education(4)
2000.Critical evaluation(3)
2004.Information ethics(3)
2001.Media literacy(2)
2008.Decision Process(2)
2010.Adult learning(2)
2008.Interactive learning environment(2)
2005.Knowledge economy(2)
2007.Computer literacy(1)

Appendix 24:

Core Topic # 21. Digital Library Education: Trends in Subtopic Publication Numbers (1990-2010) measured by R^2 *Note: first time appearance (year) and publication number are appended to each subtopic*					
Subtopics (Increasing Trends)	**R^2**	**Subtopics (Decreasing Trends)**	**R^2**	**Subtopics (Not identified trends)**	**R^2**
1996.Digital Library education(General)(148)	0.16	2003.Computer Science Education(9)	0.20	2002.Digital Library training(2)	#DIV/0
2000.Digital Library program(20)	0.16			2009.Digital Library Curriculum(1)	#DIV/0

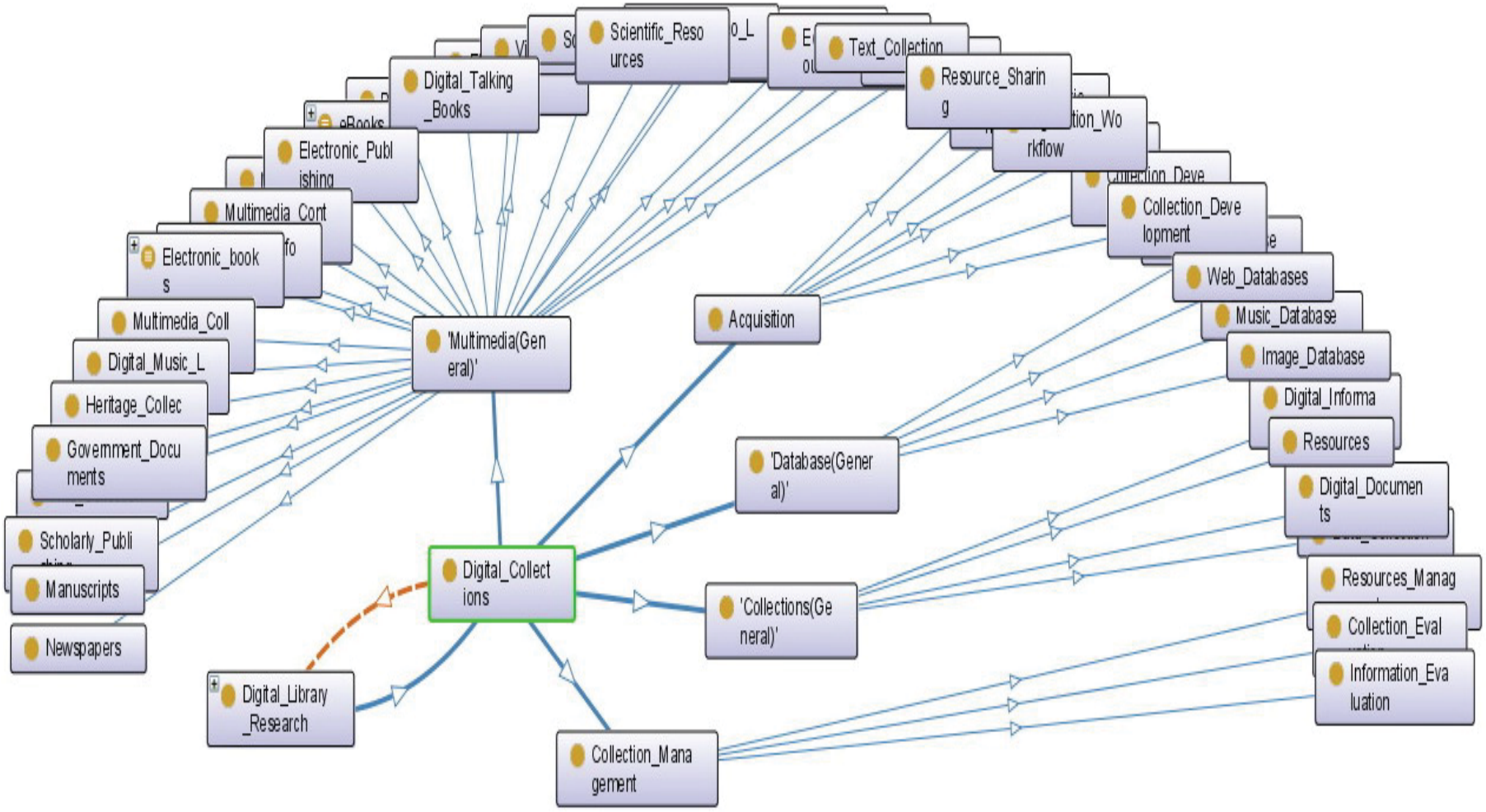


Appendix 25: An ontology visualization of relationships between Digital Library Research and its 21 core topics.

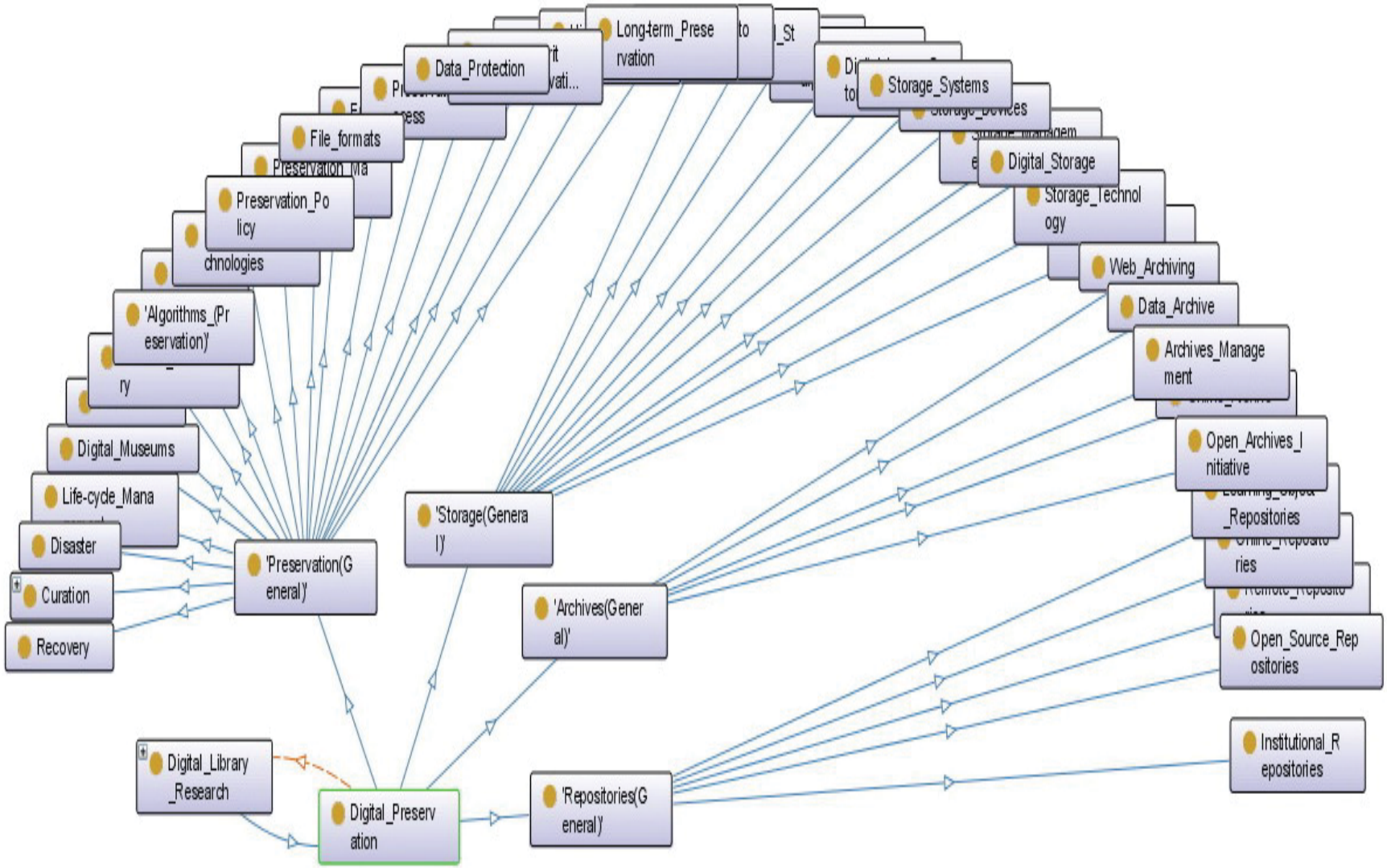


Note: Types of relationships in colours

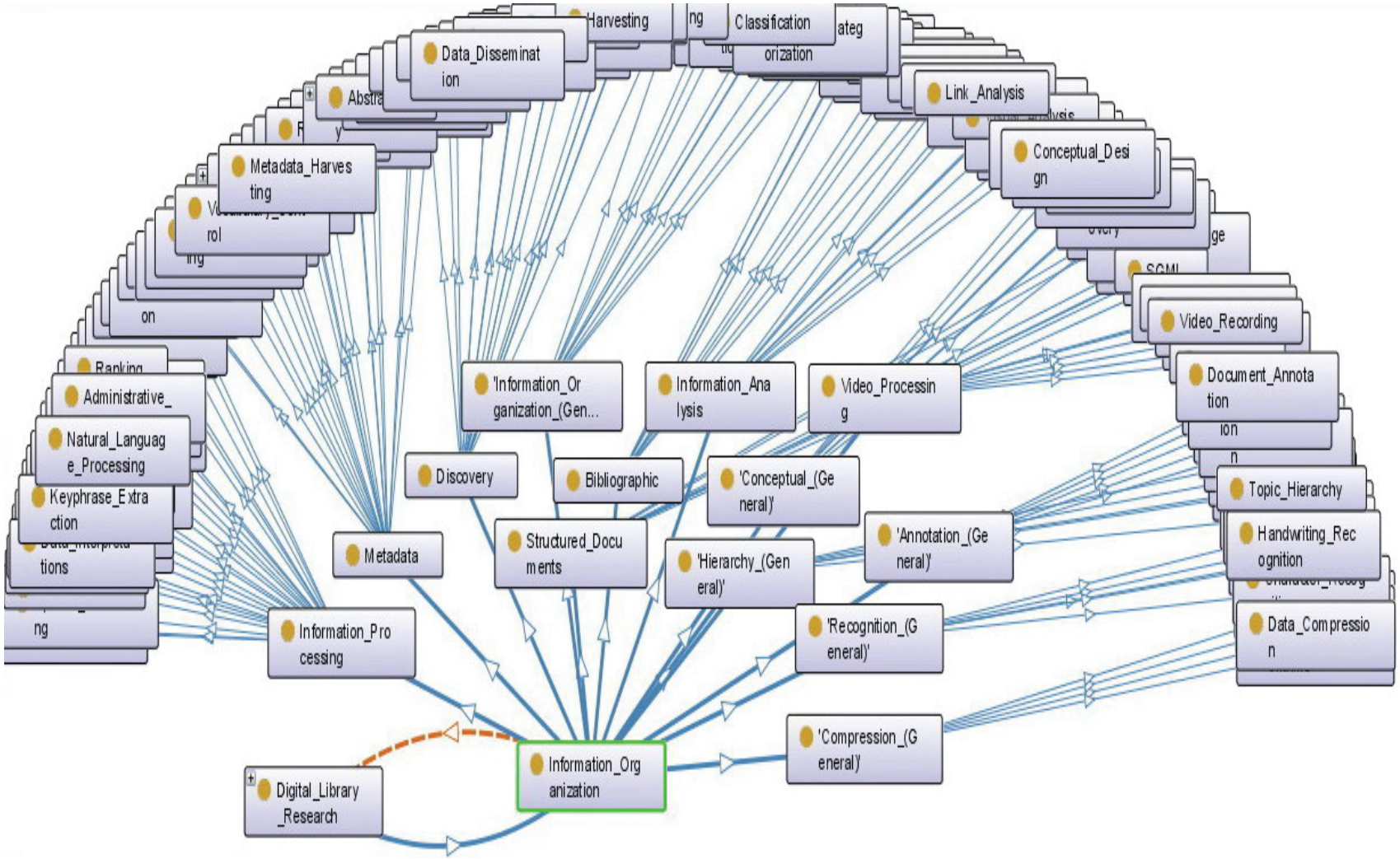
Appendix 26: A screenshot of ontology visualization of core topic Digital Collection



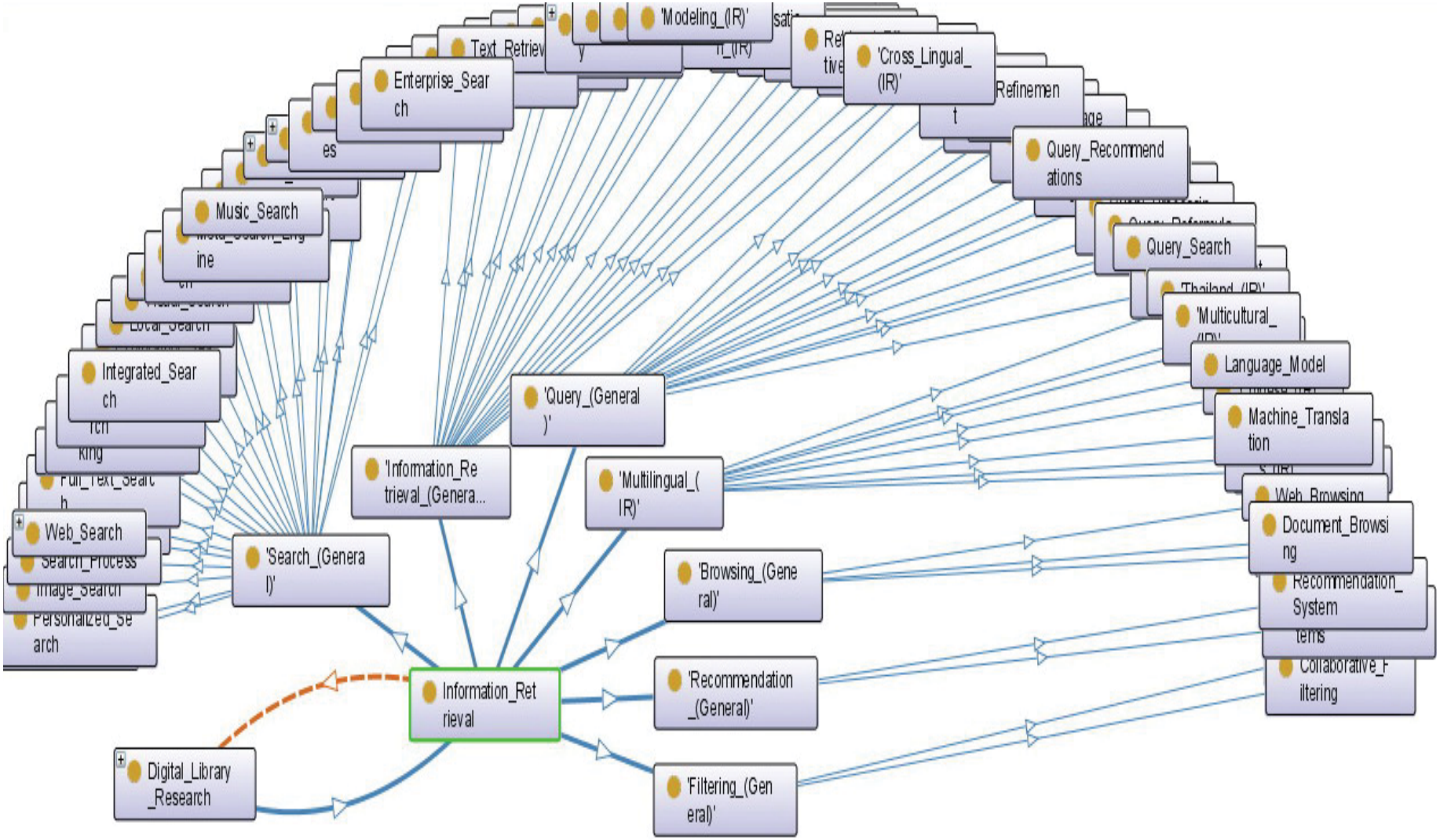
Appendix 27: A screenshot of ontology visualization of core topic Digital Preservation



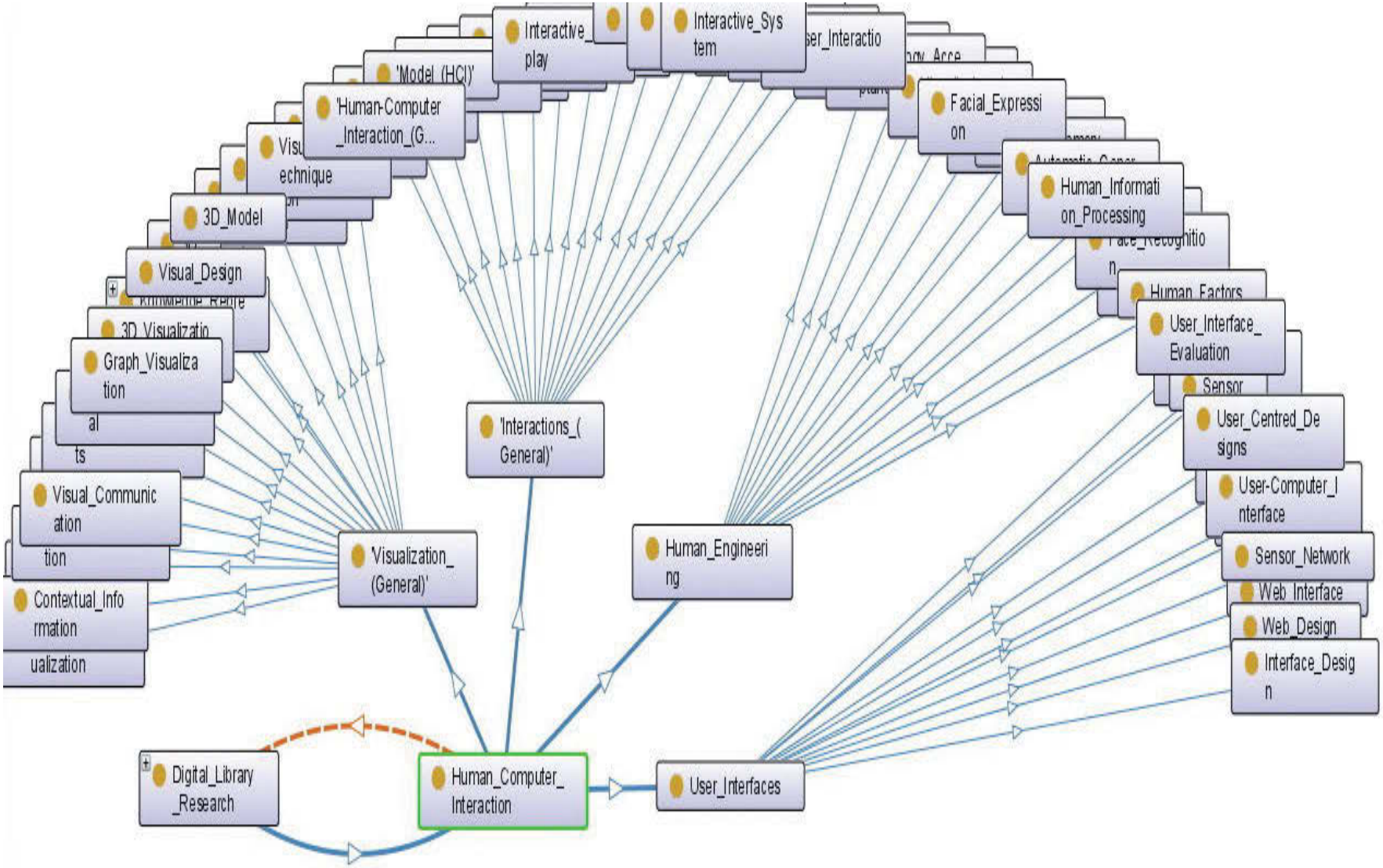
Appendix 28: **A screenshot of ontology visualization of core topic Information Organization**



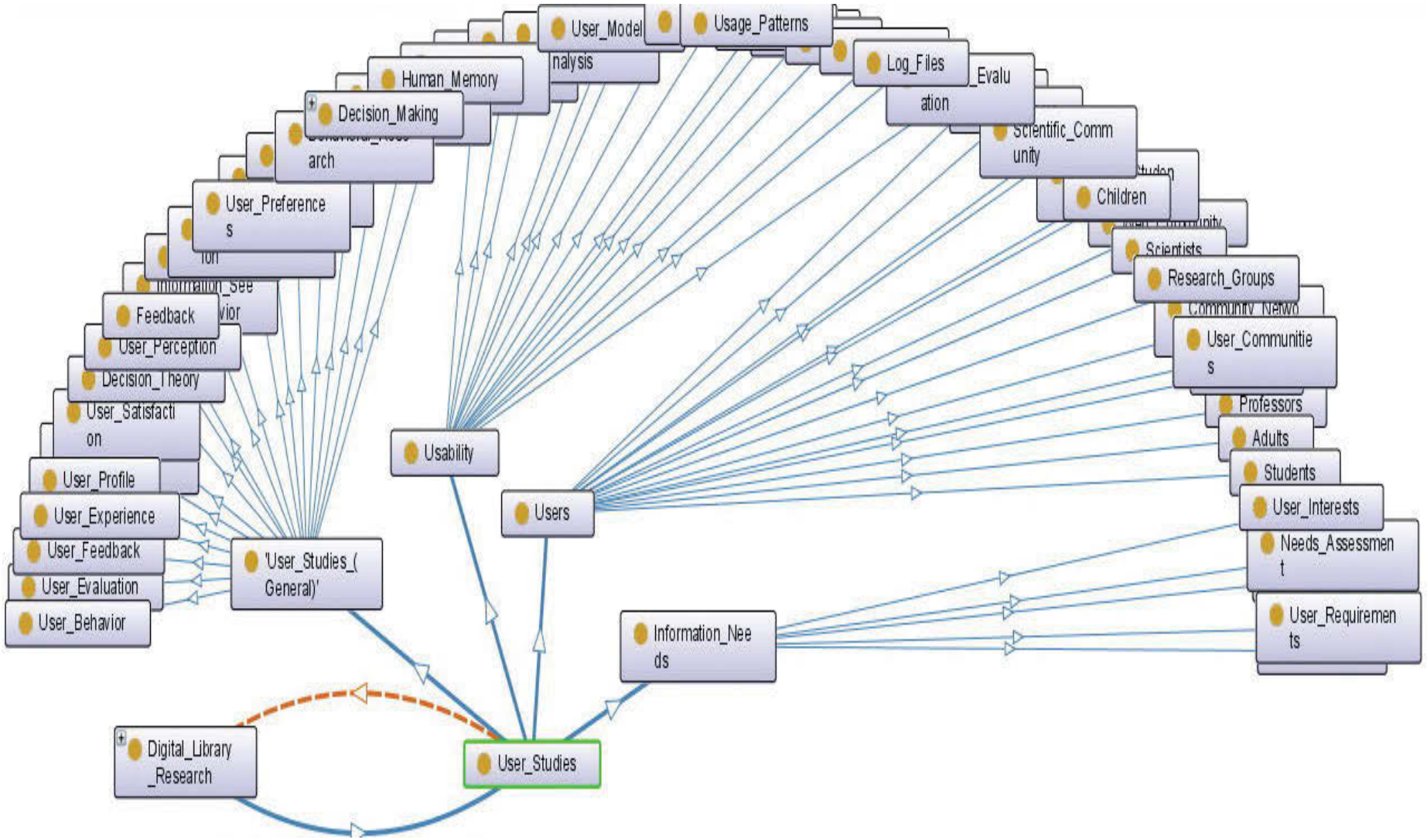
Appendix 29: **A screenshot of ontology visualization of core topic Information Retrieval**



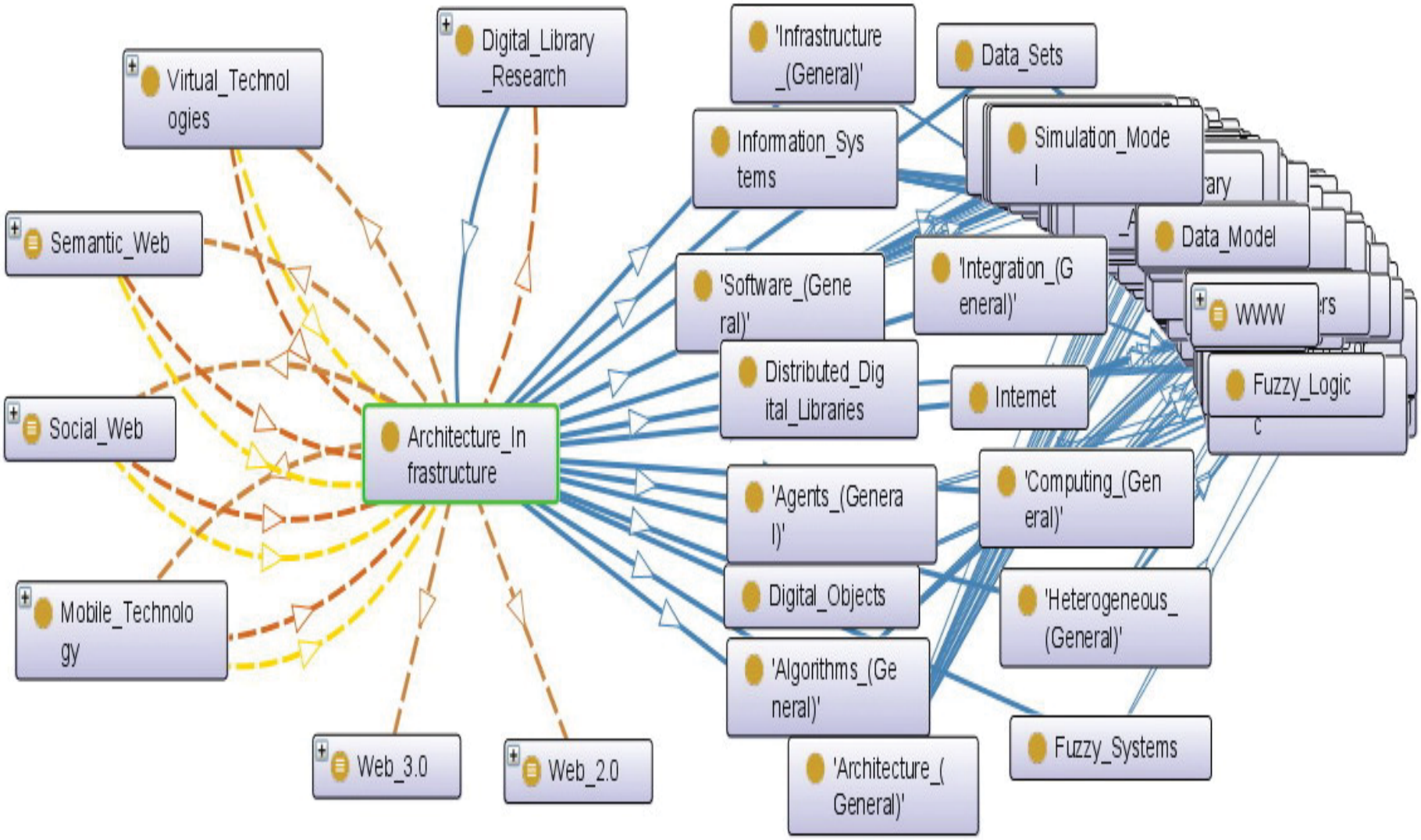
Appendix 30: **A screenshot of ontology visualization of core topic Human Computer Interaction**



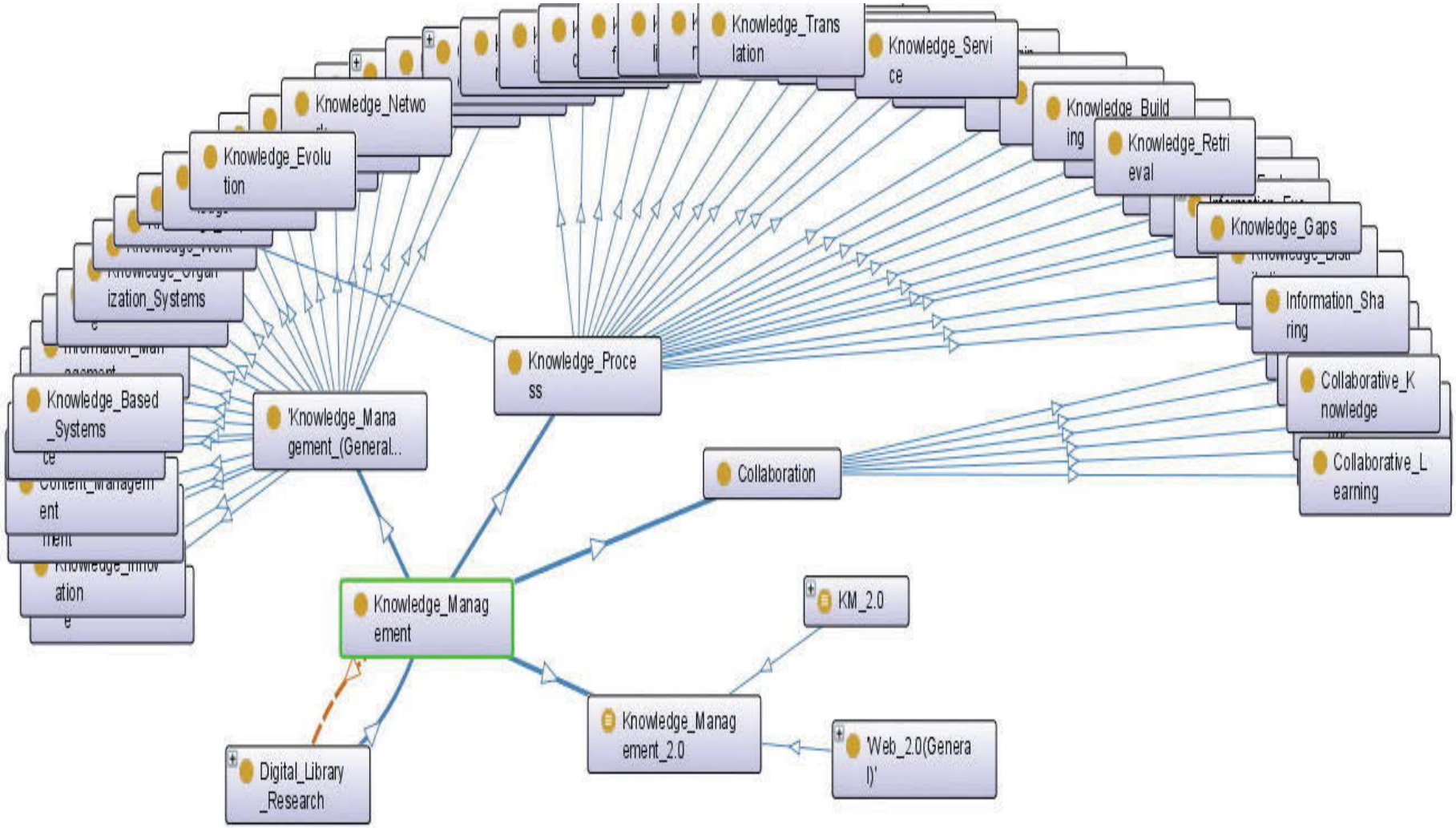
Appendix 31: **A screenshot of ontology visualization of core topic User Studies**



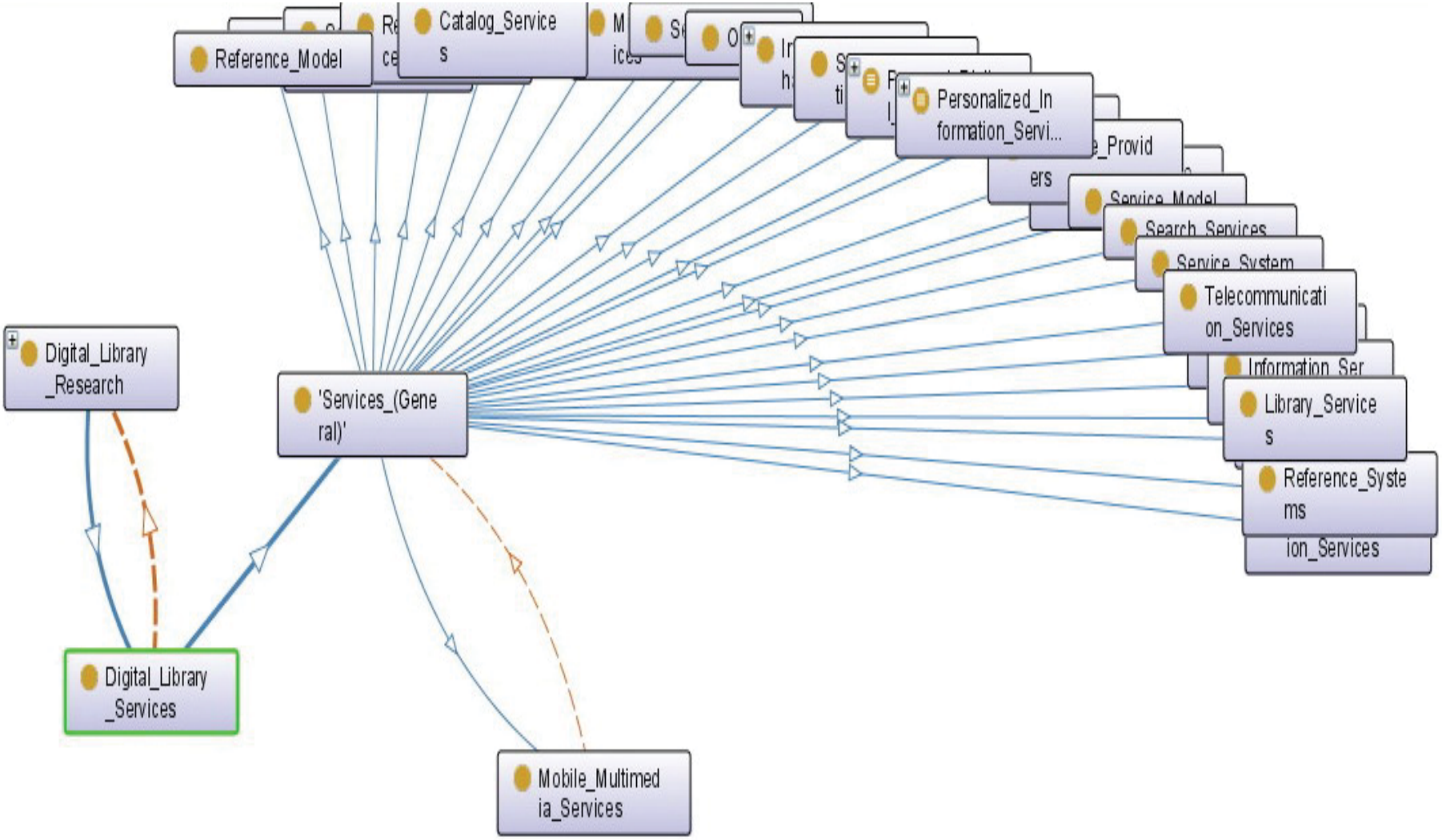
Appendix 32: **A screenshot of ontology visualization of core topic Architecture - Infrastructure**



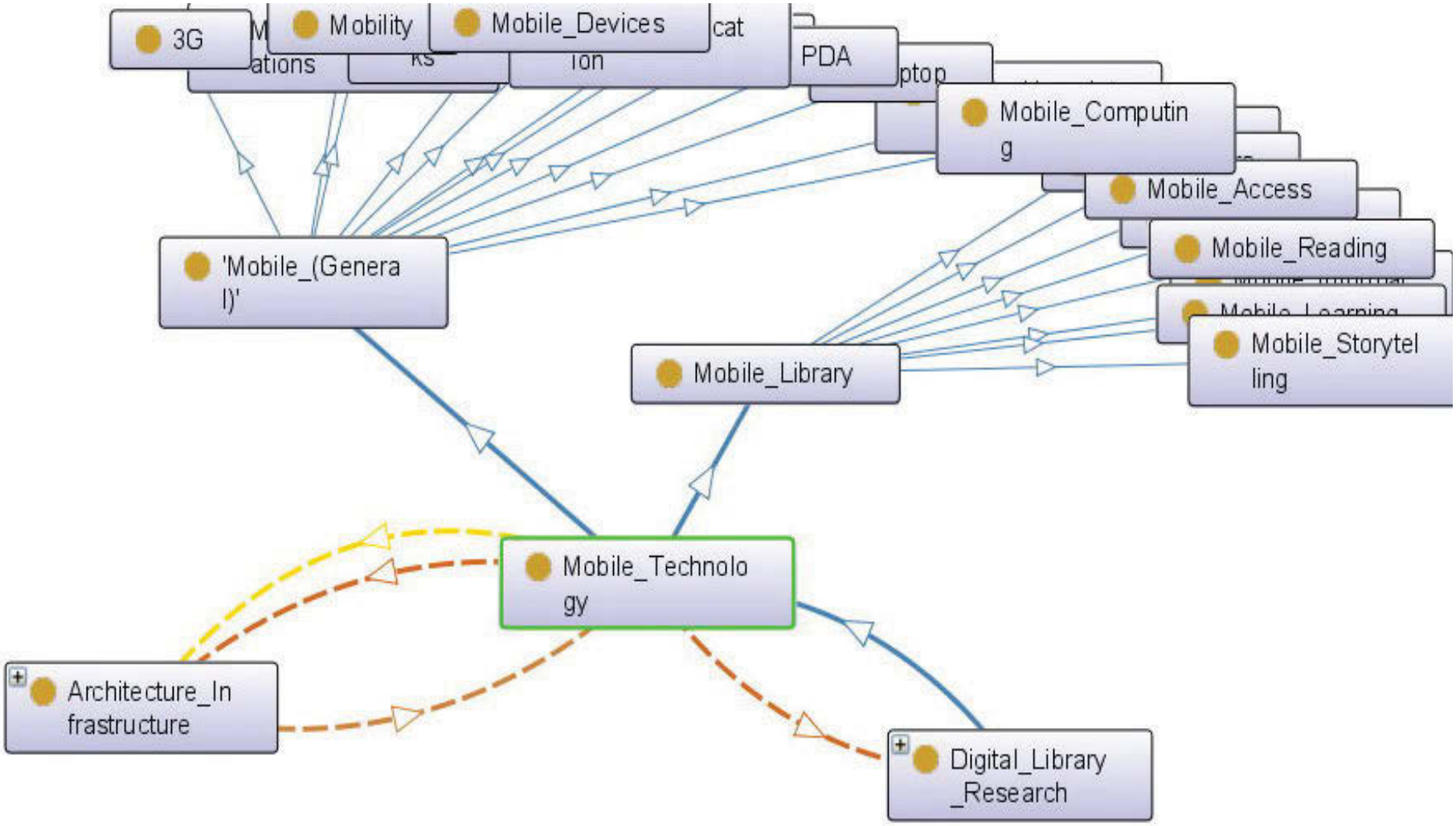
Appendix 33: A screenshot of ontology visualization of core topic Knowledge Management



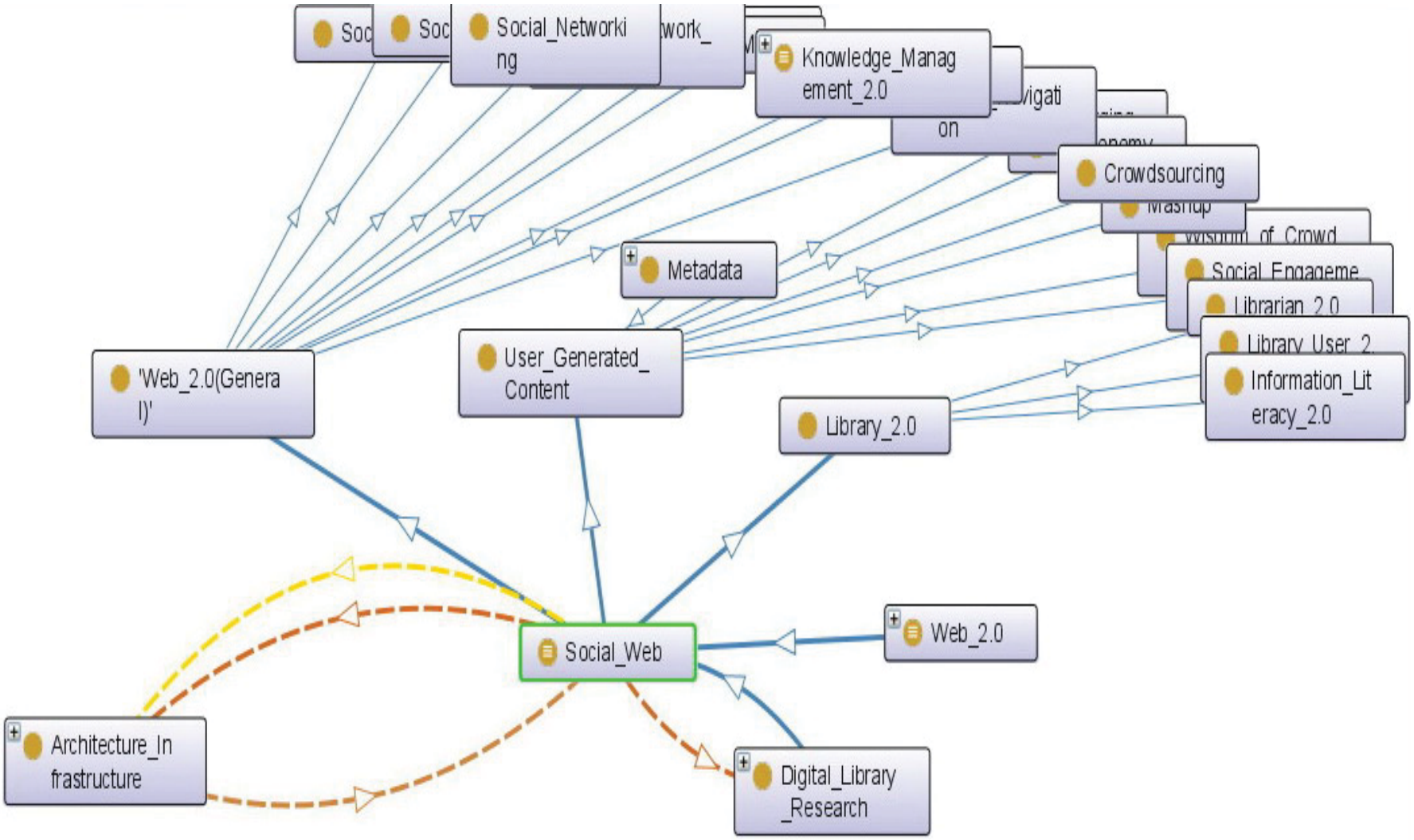
Appendix 34: **A screenshot of ontology visualization of core topic Digital Library Services**



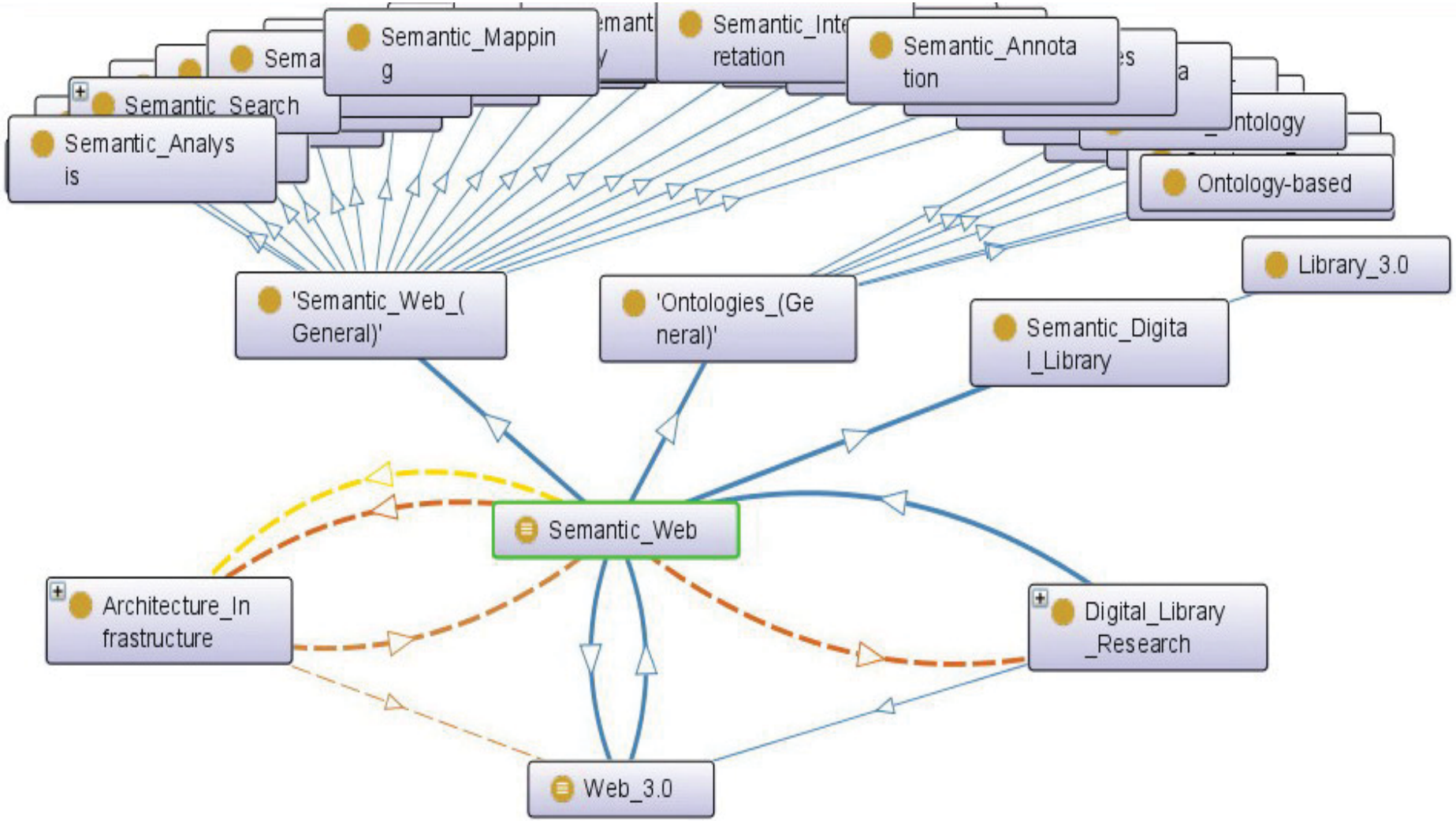
Appendix 35: A screenshot of ontology visualization of core topic Mobile Technology



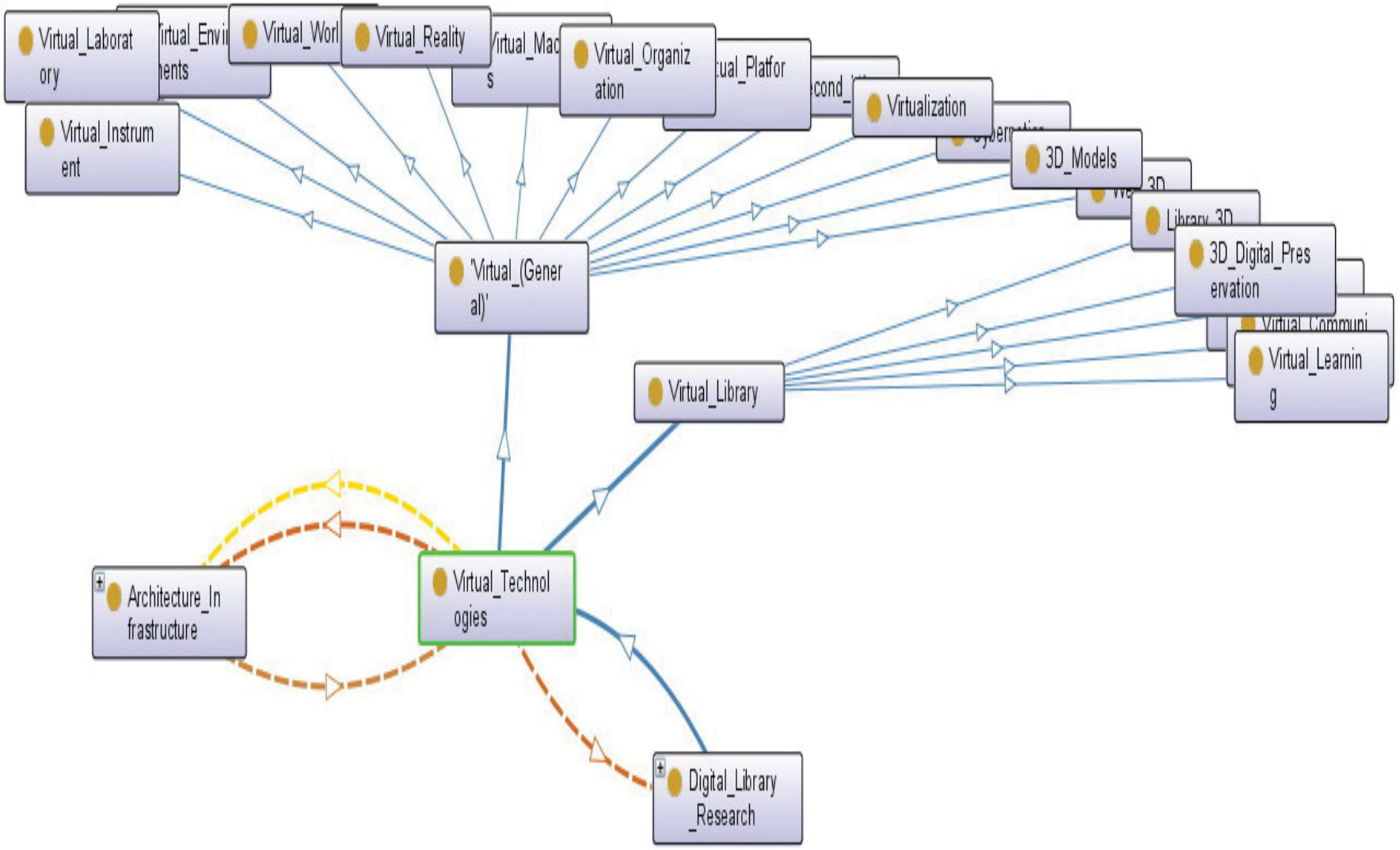
Appendix 36: A screenshot of ontology visualization of core topic Social Web



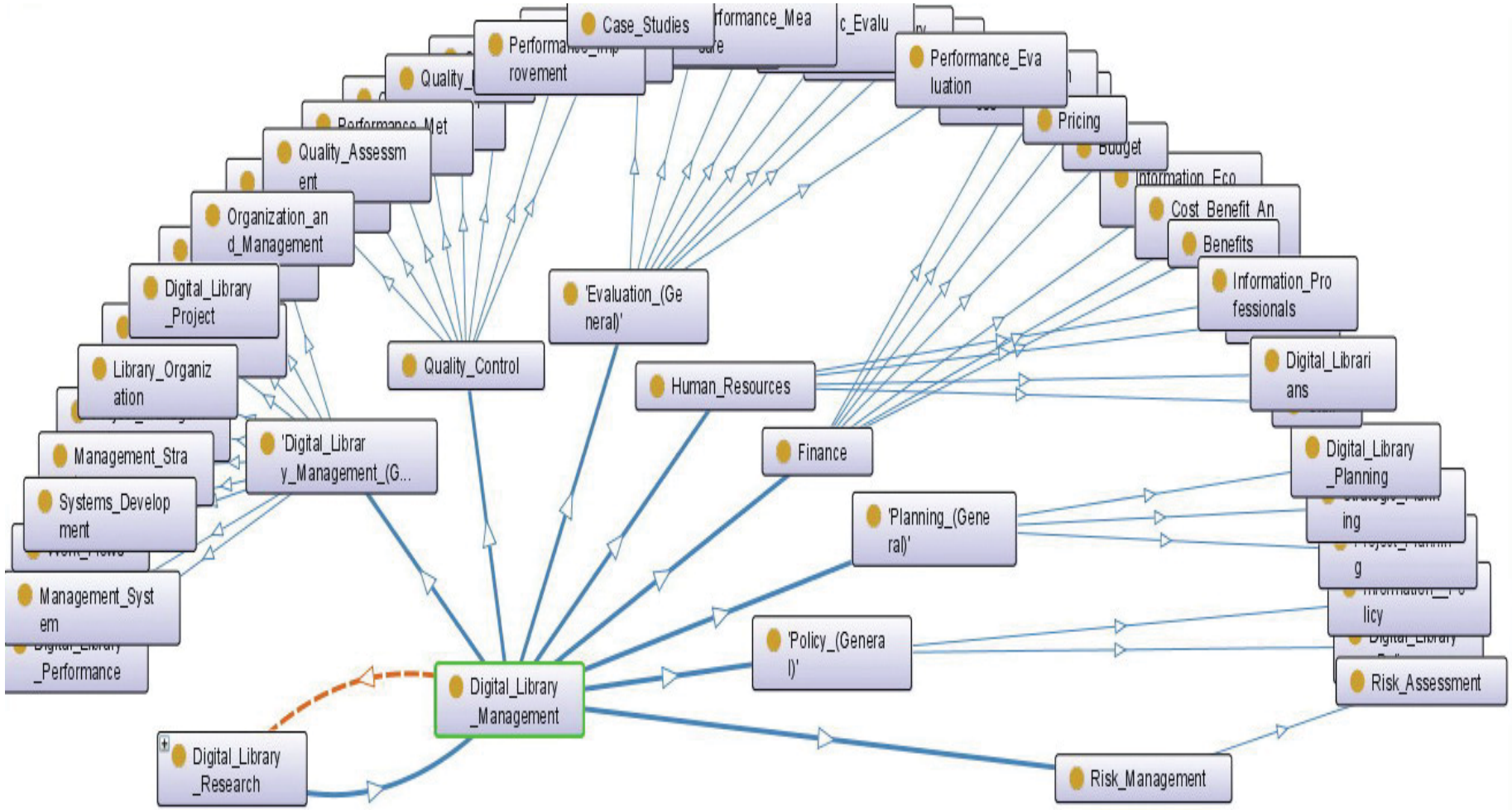
Appendix 37: A screenshot of ontology visualization of core topic Semantic Web



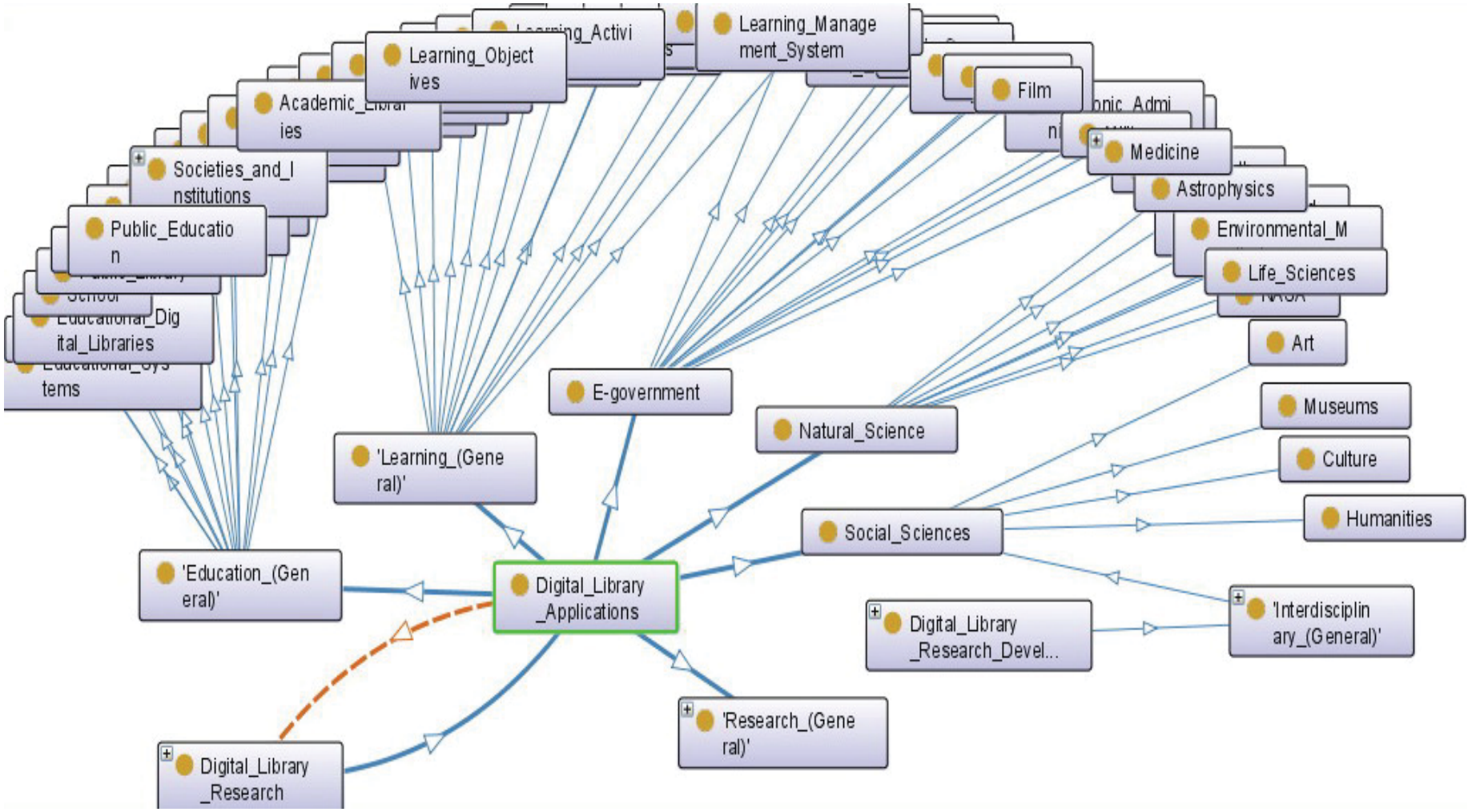
Appendix 38: A screenshot of ontology visualization of core topic Virtual Technologies



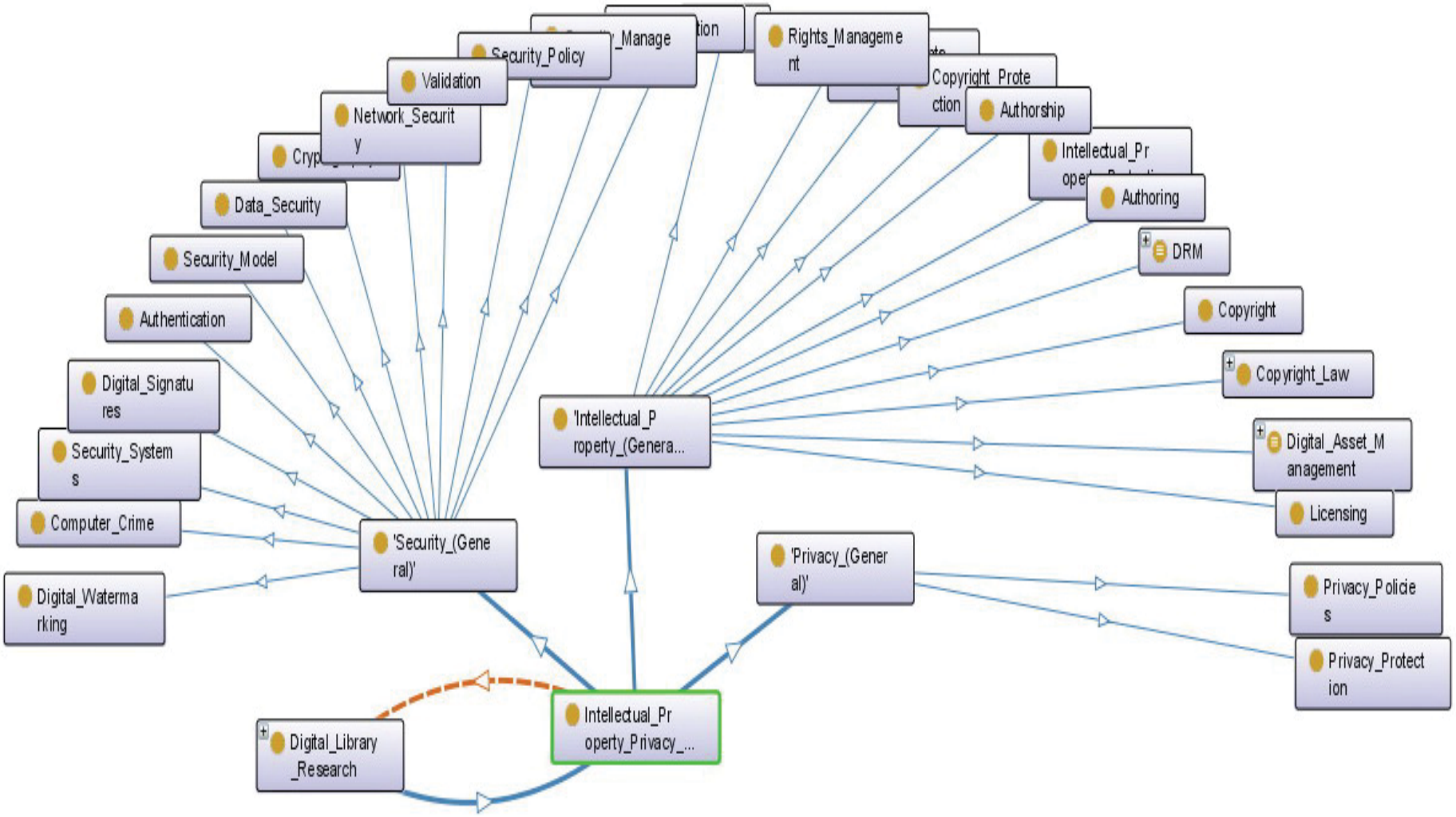
Appendix 39: A screenshot of ontology visualization of core topic Digital Library Management



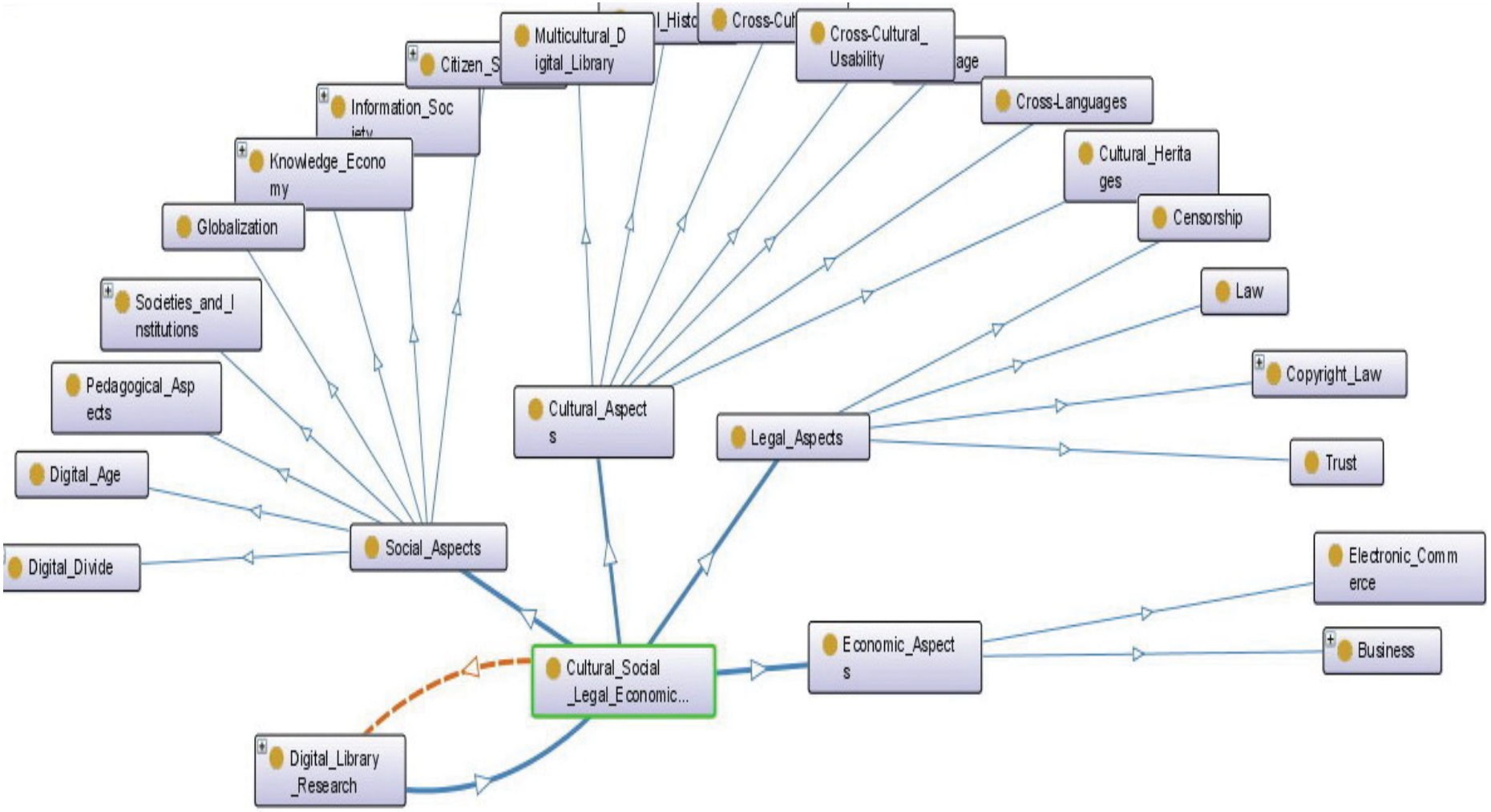
Appendix 40: A screenshot of ontology visualization of core topic Digital Library Applications



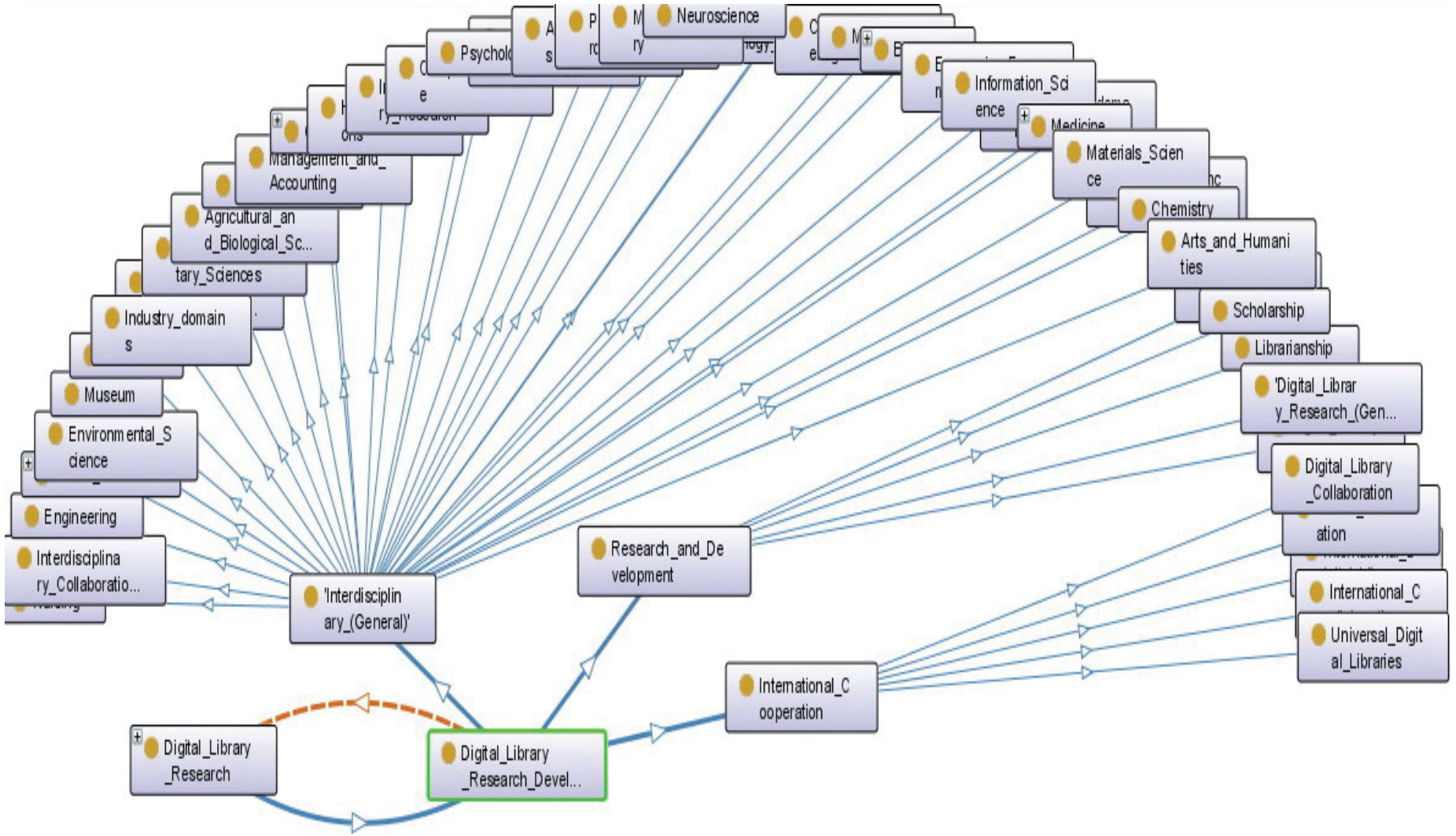
Appendix 41: A screenshot of ontology visualization of core topic Intellectual Property Privacy



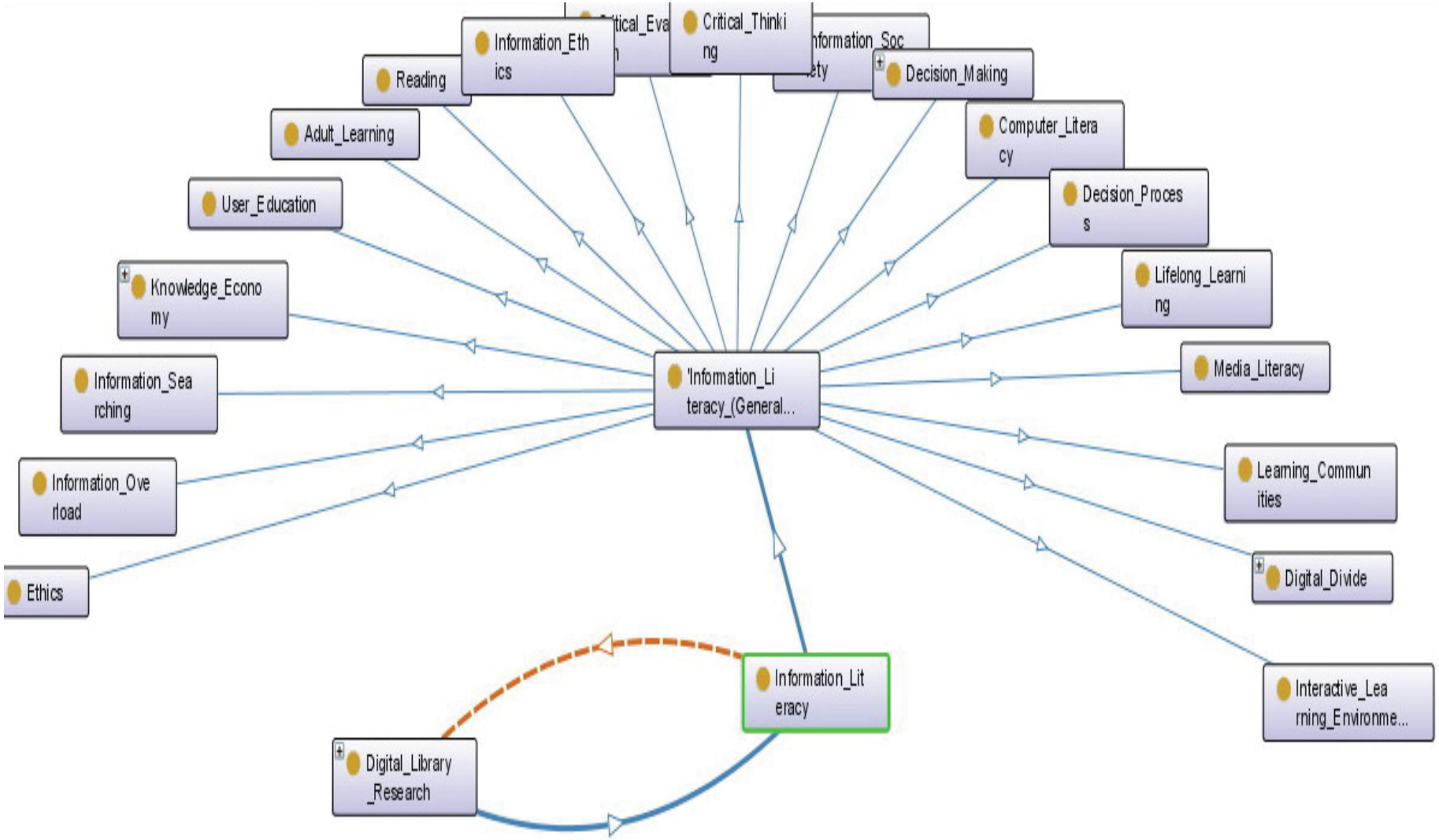
Appendix 42: A screenshot of ontology visualization of core topic Cultural Social Legal Economic Aspects



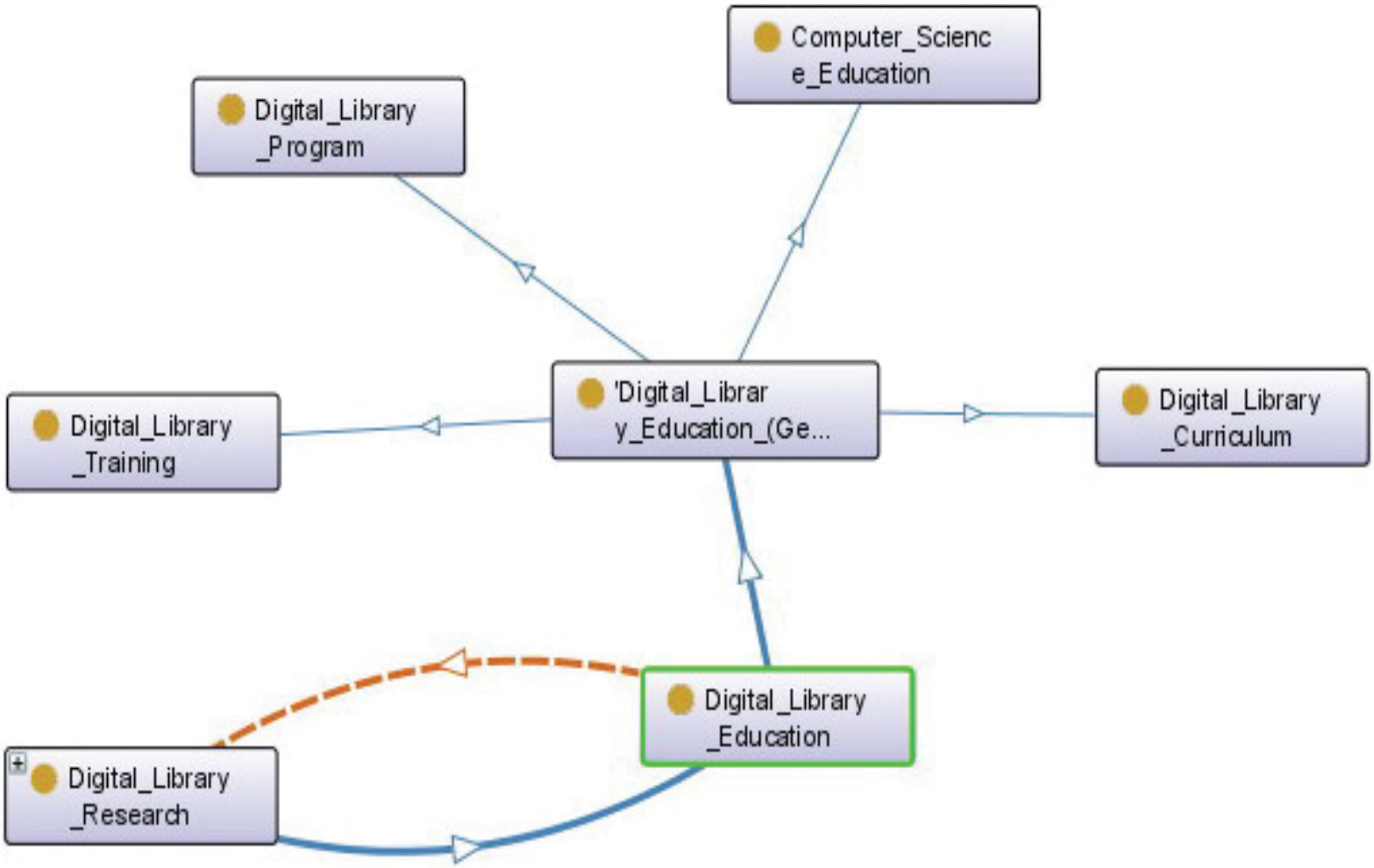
Appendix 43: **A screenshot of ontology visualization of core topic Digital Library Research Development**



Appendix 44: **A screenshot of ontology visualization of core topic Information Literacy**



Appendix 45: A screenshot of ontology visualization of core topic Digital Library Education



Appendix 46: Core Topic #1. Digital Collections (48 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1993.Database(General)(1210)				2	4	17	42	27	48	96	76	78	107	100	178	131	100	75	48	28	53	**1210**
1994.Resources(603)					1	1	1	1	2	11	7	22	37	24	73	65	84	62	57	69	86	**603**
1993.Multimedia(General)(496)				1	1	5	12	6	16	19	17	43	33	39	68	45	50	42	41	33	25	**496**
1995.Acquisition(432)						4	3	7	15	9	13	15	7	24	87	69	76	51	19	15	18	**432**
1995.Collections(363)						2	1		1	3	1	5	11	11	43	41	46	35	50	49	64	**363**
1994.Electronic Publishing(251)					1	7	7	5	11	6	13	18	14	22	45	29	24	16	12	11	10	**251**
1994.Video(246)					2	2	5	4	5	8	12	21	25	13	28	22	26	21	18	17	17	**246**
1999.Music(112)										2	4	7	4	5	23	12	12	10	11	11	11	**112**
1994.Electronic Journals(85)					1		1	2	2	1	9	10	6	5	13	7	10	7	4	2	5	**85**
1995.Audio(73)						1	1	1	2	2	3	5	5	2	11	3	14	6	3	6	8	**73**
2001.Digitization(58)												1	3	1	11	9	6	8	7	6	6	**58**
1998.Digital information(57)									1	1		4	3		7	4	4	6	4	9	14	**57**
1999.Electronic books/ebooks(51)										1	2	1	2	6	5	14	3	1	6	7	3	**51**
1999.Collection management(50)										1			1	2	5	9	10	4	8	2	8	**50**
2001.Resources Management(46)												2	2	3	9	6	5	5	1	8	5	**46**
1998.Digital documents(41)									1			3	1	3	7	1	7	2	5	5	6	**41**
2001.Collection development(35)												1			3	6	4	6	6	4	5	**35**
1998.Document collection(33)									1	1					1		4	3	8	8	7	**33**
1998.Manuscripts(32)									1			1	3	2	2	3	3	4	2	4	7	**32**
1996.Image Database(29)							5	2		2	2	2	3	1	2	4		1	1	2	2	**29**
2000.Educational Resource(29)											2	1	2		3		2	2	6	7	4	**29**
2000.Data Collection(28)											1	1	1		5	1	3	2	3	3	8	**28**
1995.Information Sources(26)						2	1			2			2	1	1	4	2	1	1	3	6	**26**
1996.Photos(24)							1				1		1		3	3	2	5	3	2	3	**24**
2000.Newspapers(18)											1			2	3	2	3	2	1	1	3	**18**

2001.Digital Music Libraries(26)												2	1	1	2		2		1	4	3	**16**
1998.Digital Video Library(16)									1			3	3				2	4	2	1		**16**
1999.Resource Sharing(15)										1					2	2	2		2		6	**15**
1996.Video Database(14)							1	2	1	1		1	4		1		2	1				**14**
2002.Web Databases(13)													2	4	4		3					**13**
2006.Scientific Data(12)																	3	2	2	4	1	**12**
2001.Scholarly Publishing(12)												2	1	3	1		1		4			**12**
2005.Content creation(8)																1			3		4	**8**
1999.Music Database(8)										1	2	1				1			2		1	**8**
2005.Video Game(6)																1	2	1		1	1	**6**
2006.Multimedia collections(6)																	1	1	1	2	1	**6**
2006.Multimedia contents(6)																	1		1	1	3	**6**
2005.Government Information(6)																1	1	3		1		**6**
2002.Text collection(5)													1				1		1		2	**5**
2004.Heritage collections(4)															1	2					2	**5**
2005.Collection development policy(3)																1			1		1	**3**
2002.Information Evaluation(2)													1						1		1	**3**
2007.Government documents(3)																		1	1		1	**3**
2004.Digital talking books(3)															1		1			1		**3**
2010.Collection Evaluation(2)																					2	**2**
2010.Digitisation workflow(1)																					1	**1**
2009.Scientific resources(1)																				1		**1**
2004.Arts Collection(1)															1							**1**
				3	10	41	81	57	108	168	166	250	286	274	649	499	522	390	347	328	414	**4593**

Appendix 47: Core Topic #2. Digital Preservation (46 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1993.Storage(General)(634)				1	2	17	25	19	22	11	21	26	21	37	80	58	73	58	59	54	50	**634**
1999.Archives(General)(281)										2	9	19	27	11	20	46	39	25	29	26	28	**281**
1996.Repositories(General)(211)							1			1	3	9	7	8	19	18	41	27	30	25	22	**211**
2001.Preservation(General)(174)												5	6	2	19	12	25	16	25	38	26	**174**
1993.Digital Storage(160)				1		14	4	7	7	3	13	4	4	7	17	15	11	9	18	11	15	**160**
1994.Data storage equipment(152)					2	2	6	1	5	3		8	8	10	30	22	26	15	11	2	1	**152**
1994.Digital Image Storage(136)					1		13	8	2	2	4	2	2	4	7	5	7	10	26	30	13	**136**
2001.Open Archives Initiative(50)												8	12		6	9	7	3	1	2	2	**50**
2001. Institutional Repositories(32)												1		1	4	1	6		4	7	8	**32**
2005.Archives management(30)																9	4	6	5	2	4	**30**
2001.Migration(24)												1	2		1	5	3	4	4	2	2	**24**
2006.Curation(22)																	1	2	7	8	4	**22**
2001.Recovery(20)												2		2	2	4	1	2	2	3	2	**20**
2001.File formats(20)												1		2	2	3		2	5	3	2	**20**
2001.Recovery(20)												2		2	2	4	1	2	2	3	2	**20**
2002.Long-term preservation(19)													1	1			1	2	2	9	3	**19**
2007.Historic Preservation(16)																		1		11	4	**16**
1998.Restoration(14)									1			2			1		1	1	3	4	1	**14**
2008.Cultural Heritage (Preservation)(60)																			2	6	5	**13**
2000.Digital Museums(13)											1	2	1			1	4	2	1	1		**13**
1994.Storage systems(13)					2							1			1	2	1		1	2	3	**13**
2002.Disaster(12)													1		1	4		2	1	2	1	**12**
2003.Learning Object Repositories(8)														1	1		1	1	3	1		**8**
2002.Distributed Storage(6)													1		1	1				2	1	**6**
1998.Web Archiving(6)									1				1		1			1	2			**6**

2001.Storage management(5)												1			1				1		2	**5**
2001.Online Archive(5)												1					2	1		1		**5**
2004.Algorithms(Preservation)(4)															2				1	1		**4**
2004.Disaster recovery(4)															1	1				2		**4**
2003.Life-cycle management(4)														1		1	1				1	**4**
2004.Storage media(4)															2	1			1			**4**
2001.Data Archive(4)												1					1			1	1	**4**
2007.Online repositories(3)																		1		1	1	**3**
2006.Data protection(2)																	1	1				**2**
2006.Preservation management(2)																	1				1	**2**
2004.Preservation Policy(2)															1					1		**2**
2009.Data recovery(2)																				2		**2**
2008.Error Recovery(2)																			2			**2**
2007.Storage devices(2)																		1	1			**2**
2009.Storage technology(2)																				1	1	**2**
2004.Distributed storage resources(3)															1						1	**2**
2010.Open source repositories(2)																					2	**2**
2002.Preservation technologies(1)													1									**1**
2005.Preservation Process(1)																1						**1**
2010.Hierarchical storage(1)																					1	**1**
2001.Remote repositories(1)												1										**1**
				2	7	33	49	35	38	22	51	97	95	89	223	223	259	195	249	264	210	**2141**

Appendix 48: Core Topic #3. Information Organization (141 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1996.Metadata(753)							1	1	7	13	8	28	60	43	107	97	95	66	75	76	76	**753**
1995.Indexing(348)						4	14	7	9	17	12	25	28	25	39	29	41	43	24	14	17	**348**
2000.XML(330)											6	24	34	24	86	44	45	25	18	14	10	**330**
1994.Recognition(General)(302)					1	1	3	8	4	3	10	13	22	15	51	31	38	35	24	23	20	**302**
1995.Information analysis(263)						1	3	1	1	8	1	20	16	17	50	34	47	30	18	8	8	**263**
1995.Classification(256)						1	5		3	4	6	6	11	16	24	37	25	35	30	30	23	**256**
1998.Data Mining(253)									3	5	4	2	11	14	20	13	32	32	11	92	14	**253**
1995.Image processing(223)						1	9	7	6	3	10	12	9	15	32	29	23	18	15	14	20	**223**
1995.Bibliographic(161)						2	2	2	5	6	1	13	12	6	21	16	26	11	18	7	13	**161**
1999.Text Processing(145)										1	4	7	26	12	19	13	16	17	13	9	8	**145**
1995.Annotation(General)(125)						1		2		1		3	5	4	7	19	10	19	22	12	20	**125**
1996.Natural language processing(124)							1	2	4	3		3	12	5	13	6	11	19	13	13	19	**124**
1995.HTML(119)						1		3	4	7	3	10	15	18	37	9	5		2	2	3	**119**
1995.Abstracting(110)						1	1		2		1	3	7	4	21	12	28	16	4	6	4	**110**
1995.Character recognition(101)						1	2	3	1		1	4	6	3	24	12	17	8	4	7	8	**101**
1994.Compression(General)(87)					1	1	2		3	4	9	6	9	5	9	12	9	8	1	3	5	**87**
2000.Discovery(84)											1	2	4	1	6	8	9	9	10	17	17	**84**
1996.Links(83)							2	1	2	4	1	2	6	6	14	9	9	6	5	7	9	**83**
1996.Interoperability(metadata)(81)							1					5	14	4	16	12	8	4	7	5	5	**81**
1995.Markup languages(81)						1	2	2			3		2	2	5	6	3	6	25	21	3	**81**
1996.Navigation(74)							1			1	1	5	6	3	1	10	7	13	8	7	11	**74**
1995.Hierarchical systems(69)						1			1	1	2	2	2	7	17	12	10	4	4	4	2	**69**
2000.Standardization(67)											1	7	10	3	10	6	6	5	9	6	4	**67**
1999.Personalization(63)										1		2	6	7	4	4	6	12	9	4	8	**63**
1995.Encoding(60)						1			1		1	4	7	5	11	9	11	3	4	1	2	**60**
1996.Ranking(57)							1							5	2	7	7	8	11	7	9	**57**

1996.Image compression(53)							1		2	2	6	5	7	5	8	7	3	5			2	**53**
2002.Information Extraction(48)													2		4	5	4	6	13	7	7	**48**
1996.Taxonomy(47)							1			1		2	6	3	2	5	6	2	8	5	6	**47**
2000.Conceptual(General)(47)											4	3	2	1	1	3	7	4	8	7	7	**47**
2001.Categorization(46)												2	3	2	3	4	5	10	7	4	6	**46**
1999.Keywords(44)										3			3	2	6	1	4	7	4	5	9	**44**
1996.Thesaurus(44)							1		1	1		3	7	6	5	3	3	2	7		5	**44**
1998.Harvesting(44)									1	1		1	6		3	4	5	5	6	9	3	**44**
1996.Information processing(25)							1	1	1		1	1	1		3	4	6	7	9	4	3	**42**
1998.Automatic Indexing(33)									1	5	1	2	9	3		2	2	2	3	2	1	**33**
2003.Text Mining(32)														2	3	3	2	9	5	6	2	**32**
1994.Data compression(31)					1	1	1		1	2	3	1	2		1	2	6	5	1	2	2	**31**
2002.Data Analysis(31)													3	1	3	3	7	4	6	3	1	**31**
1999.Summarization(31)										1		1	6		1	9	1	3	2	4	3	**31**
1997.Cataloging(30)								2		1	3	1	3	3	4	5	2	3		1	2	**30**
2001.Citation Analysis(30)												2	1	2	4	5	2	5	4	2	3	**30**
1995.Administrative data processing(29)						1					1					1	3	11	12			**29**
1996.Document Clustering(27)							1					2	1	2	2		4	1	6	6	2	**27**
1999.Dublin Core(26)										1	2					3	4	1	4	5	6	**26**
1998.Bibliographic database(26)									1	1			1		5	2	4	1	4	4	3	**26**
2001.Text categorization(26)												2	1	1	2	2	3	4	5	3	3	**26**
1997.OCR(25)								1					1		3	3	4	6	1	3	3	**25**
1995.Government data processing(25)						1						1		4		1	1	1	5	1	10	**25**
2002.Metadata harvesting(24)													3		2	2	5	2	3	5	2	**24**
1996.Vocabulary control(24)							1						2	2	6	1	1	4		2	5	**24**
1997.Hierarchy(General)(24)								1			1		1	1	1	2	2	4	2	6	3	**24**
2000.Video recording(24)											1	3	1		3	3	1	2	4	4	2	**24**
1998.Content analysis(22)									1	1		2	1	5	5	1	1	1	1	1	2	**22**

2001.Information integration(21)												1	1	4	3	4	2		1	1	4	**21**
2004.Metadata Extraction(19)															1	1	1	2	3	5	6	**19**
2005.Name disambiguation(19)																2	1	2	5	3	6	**19**
1999.Data Sharing(18)										1		1	2		2	1	1	3		3	4	**18**
2000.Document Classification(16)											2				1	1		4	6		2	**16**
1998.Rendering(16)									1		1	2		1	2	4	2		1	1	1	**16**
1999.Classification systems(15)										1			1	1		3		2	2	3	2	**15**
2001.Video Streaming(15)												3		1	1		3	5	1		1	**15**
2001.Documents Analysis(15)												2	3		2	1	1	3		2	1	**15**
2000.RDF(14)											1	1				4	3	3	1		1	**14**
1996.Structured Documents(14)							1					2	1	2			1	1	2	1	3	**14**
1997.SGML(14)								2	1	3	1	2	1	1	2	1						**14**
1996.Routing(14)							1			2		1		1	1	2	2	2	1	1		**14**
2001.Concept map(14)												2		2	1	4	1	2	1		1	**14**
2000.Hierarchical Structure(14)											1					2			4	2	5	**14**
1996.Interpretation(14)							1							1			3	3	2	1	3	**14**
2000.Subject Headings(13)											1					1	2	3		4	2	**13**
1999.Terminologies(12)										1		1				3	2		3	2		**12**
1999.Metadata management (12)										1			1		1	5	1		1		2	**12**
2001.Controlled vocabulary(12)												1	2						1	1	7	**12**
2001.Resource Discovery(12)												1	1		1	3	1		1	2	2	**12**
2002.Named Entities(12)													1		1		1	2	2		5	**12**
1999.Personalized information(12)										1					1	1	1	3	2	3		**12**
2005.Bibliographic records(11)																1	1	1	3	1	4	**11**
2001.Information Discovery(11)												1			1	1	1	2		2	3	**11**
2001.Bibliometric(10)												1		1		1	2	3	1	1		**10**
2002.Data Exchange(10)													1		2	1		1		4	1	**10**
2004.Hierarchical clustering(10)															1	1	1	4	1	1	1	**10**
1997.Image Annotation(10)								1						1		1	1	1	2	1	2	**10**

2001.Video Annotation(10)												1		1			4	2		1	1	**10**
2002.Web Mining(9)													1	1	2			2	1		2	**9**
2000.Conceptual design(9)											1			1			2		1	2	2	**9**
2004.Link Analysis(9)															2	1	1	1		1	3	**9**
1996.Authoring tool(9)							1							1			1	1		2	3	**9**
2003.Information Organization(General)(8)														1	1			1	1		4	**8**
2001.Data Format(9)												1		1	1	1		1	2		1	**8**
2005.Conceptual model(8)																1	2	1	1	2	1	**8**
1999.Video Segmentation(8)										1		1	3	1	1				1			**8**
1999.Keyphrase extraction(8)										1		1	1	1	1		1			1	1	**8**
2000.Video Indexing(7)											1	2	1	1	1						1	**7**
1999.Url(7)										1			1	1	3	1						**7**
2001.Handwriting recognition(7)												1	1		1			1			3	**7**
2005.Metadata aggregation(6)																1	3		1	1		**6**
1999.Dewey Decimal Classification(6)										1			1	1		1				2		**6**
1996.Science Citation Index(6)							1					2							1	1	1	**6**
2001.Object Identifier(6)												2	1		1				1		1	**6**
2004.Semi Structured Data(6)															2	2			1		1	**6**
1995.Bibliographic data(6)						1										1			1	2	1	**6**
2000.Data Exploration(6)											1						2	1		2		**6**
1996.Concept Space(6)							1	1							1	1			2			**6**
2002.Text Clustering(6)													1			1		1		2	1	**6**
1996.Text Extraction(6)							1		1				1					1	1	1		**6**
2002.Topic maps(7)													1			1	1		1	2		**6**
2002.Information Gathering(5)													2	1				1		1		**5**
2002.Automatic Classification(5)													1					1	2		1	**5**
2007.Conceptual frameworks(5)																		1		2	2	**5**
2003.Compression ratio(5)														1		1			1	1	1	**5**

2002.Text Analysis(5)													1	1							2	1	**5**
2002.Text Segmentation(5)													2				1	1				1	**5**
2005.Document Summarization(5)																3					1	1	**5**
2001.File Sharing(4)												1			1		1	1					**4**
2002.Automatic categorization(4)													1				1				1	1	**4**
2004.Document annotation(4)															1					1		2	**4**
2001.Video editing(4)												1		1			1				1		**4**
2000.Streaming Media(4)											1		1			1	1						**4**
1999.Optical Music Recognition(4)										1		2						1					**4**
2007.Recognition process(4)																		1		2	1		**4**
2001.Speech Processing(4)												1		1		1			1				**4**
2001.Union Catalogs(3)												1			1							1	**3**
2003.Capturing(3)														1	1		1						**3**
2007.Concept hierarchies(3)																		1				2	**3**
2006.Compression algorithms(3)																	1					2	**3**
2001.Video processing(3)												1	1							1			**3**
2000.Speech Analysis(3)											1	1	1										**3**
2006.Image Interpretation(3)																	1			1	1		**3**
2007.Non-structured documents(2)																		1	1				**2**
2003.Web Cataloguing(2)														2									**2**
2003.Data Gathering(2)														1							1		**2**
2006.Data Dissemination(2)																	1				1		**2**
2008.Conceptual graph(2)																			1	1			**2**
2007.Topic hierarchy(2)																		1				1	**2**
2007.Content annotation(2)																		1				1	**2**
2005.Digital annotation(2)																2							**2**
2008.Visual Analysis(2)																			1			1	**2**
2007.Data interpretations(2)																		2					**2**
1999.Bibliographic control(2)										1													**1**

2009.Conceptual discovery(1)																				1		**1**
					3	22	64	48	68	118	121	283	451	350	771	651	703	647	587	593	556	**6036**

Appendix 49: Core Topic #4. Information Retrieval (78 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1993.Information Retrieval(General)(1376)				2	5	24	50	29	47	52	39	53	102	57	195	139	171	124	104	72	111	**1376**
1995.Search(General)(768)						2	4	3	4	24	10	28	41	39	80	73	88	91	110	75	96	**768**
1996.Search engines(496)							1	1	2	19	5	17	34	30	65	50	67	72	56	31	46	**496**
1995.Query(General)(474)						8	8	12	10	19	15	20	34	22	49	42	59	52	51	43	30	**474**
1995.Searching(386)						7	16	8	16	32	7	22	46	34	40	61	47	28	8	6	8	**386**
1995.Query Language(298)						6	8	9	8	19	15	16	30	19	41	36	46	14	11	14	6	**298**
1996.Image retrieval(181)							4	3	5	2	9	13	10	12	20	18	17	13	24	18	13	**181**
1995.Content Based Retrieval(135)						1				1	6	13	22	10	15	16	9	13	11	8	10	**135**
1993.Multimedia(IR)(121)				1	1	4	8	1	9	6	12	6	7	6	12	9	15	7	8	3	6	**121**
1995.Bibliographic retrieval systems(113)						1	2	2	2	5	1	12	10	5	19	12	20	6	10	1	5	**113**
1995.Browsing(General)(95)						2	7	2	5	1	4	8	6	6	4	7	12	9	9	9	4	**95**
1995.Filtering(General)(89)						1	3			1	2	6	4	2	10	8	7	10	14	14	7	**89**
2000.Information Seeking(58)											1	4	9	1	3	5	7	6	11	5	6	**58**
2001.Recommender systems(57)												1	2		1	5	2	6	12	14	14	**57**
1997.Query Processing(55)								1	1	2		1	1	1	2	2	7	25	8		4	**55**
2002.Recommendation(General)(51)													1	2	5	2	5	8	7	12	9	**51**
1995.Collaborative filtering(42)						1							4		3	4	3	5	9	10	3	**42**
1996.Interoperability(IR)(35)							2		1	2		1	12	3	4	3	3		1	2	1	**35**
2001.Web search(31)												1	1	1	4	2	3	4	5	5	5	**31**
1993.Document retrieval(26)				1		1	1							1	2	2	5	2	4	4	3	**26**
1996.Modeling(IR)(25)							1					2	2	1	6	2	1	2	4	2	2	**25**
1998.Text retrieval(24)									3			2	4	1	1	1	1	3	3	2	3	**24**
1999.Video retrieval(19)										1		2	1		2	1	3	2	4	2	1	**19**

2000.Cross Lingual(IR)(19)											1		1	1	2	2	2	3	2	1	4	**19**
1998.Multilingual(19)									1				3		1	2	3	3	1	2	3	**19**
1998.Multilingual(IR)(19)									1				3		1	2	3	3	1	2	3	**19**
2002.Recommendation system(17)													1	1	2		1	3	2	4	3	**17**
1999.Information filtering(17)										1	1	2				3	1	4	2	2	1	**17**
2005.Search process(12)																1	1	3	3	2	4	**14**
2005.Query Expansion(15)																1	1	2	5	3	2	**14**
2007.Relevant documents(13)																		1	1	2	9	**13**
2002.Web Search Engine(13)													1				1	2	3	3	3	**13**
2001.Similarity Search(13)												1				2	1	2	2	1	4	**13**
2002.Cross language(12)													2		1		2	2	2	1	2	**12**
2000.Image search(12)											2		2		1		1	1	1	1	3	**12**
1999.Meta search(11)										2		1			2	1		1		1	3	**11**
1995.String Matching(9)						1									2	1		1	2	2	1	**10**
2002.Personalisation(IR)(10)													1	1			1	5	1		1	**10**
2000.Chinese(IR)(5)											1	1	2	1	1	2					2	**10**
2002.Machine Translation(10)													2		2	1	1	2	2			**10**
2004.Search strategies(10)															1	1	1		2	2	3	**10**
2006.Query search(10)																	1	1	2	4	2	**10**
1999.Query Formulation(10)										1									2	4	3	**10**
2000.Music retrieval(8)											1	2			1			1	1	2		**8**
2006.Exploratory Search(8)																	1		3	2	2	**8**
2003.Search Method(8)														1			2		3	1	1	**8**
2007.Retrieval effectiveness(7)																		1		2	4	**7**
1999.Meta search engine(8)										1					1	1		1		1	2	**7**
2001.Personalized Search(8)												1					1	1	3	1		**7**
1998.Video browsing(7)									1			1	1			1	1				2	**7**
2001.Federated search(6)												1			1		3				1	**6**
2001.Document Frequency(5)												1	1		1					2		**5**

2002.Language Model(5)													1		1				1		2	**5**
1998.Distributed search(5)									1			3						1				**5**
2001.Full text search(5)												1							1	2	1	**5**
2002.Video search(5)													1				1		1	1	1	**5**
1996.Query Refinement(5)							2											1		1	1	**5**
1999.Retrieval techniques(4)										1						1		1			1	**4**
2004.Asian Languages(IR)(4)															1	1	1				1	**4**
1997.Indian(IR(4)								1							2	1						**4**
2005.Local search(4)																1		2	1			**4**
2004.Enterprise Search(4)															1				1	1	1	**4**
2000.Dynamic Query(4)											1				1				1		1	**4**
2002.Document browsing(4)													1				1			1	1	**4**
2001.Requirement Analysis(3)												1						1	1			**3**
2008.Visual Search(3)																			1		2	**3**
2008.Interactive Search(3)																			1		2	**3**
1999.Query Optimization(3)										1									2			**3**
2008.SQL query(3)																			1	1	1	**3**
2008.Query Reformulation(3)																			1	1	1	**3**
2000.Web Browsing(3)											1		1	1								**3**
2004.Integrated search(2)															1			1				**2**
2008.Music search(2)																			1		1	**2**
2010.Query suggestion(2)																					2	**2**
2007.Multicultural(IR)(1)																		1				**1**
2009.Thailand(IR)(1)																				1		**1**
2010.Query recommendations(1)																					1	**1**
2004.Query Evaluation(1)															1							**1**

Appendix 50: Core Topic #5. Access (14 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1996.Access(319)							3	1	2	3	1	9	11	14	39	25	31	54	46	36	44	**319**
1996.Access control(58)							1	1				1	4	3	7	3	10	21	4		3	**58**
2001.Open access(45)												1			6	3	6	5	10	5	9	**45**
1996.Information Access(41)							1		1	1			2	2	2	1	6	7	8	5	5	**41**
1997.Data Access(22)								1				3	2		5	3	2	2	2	2		**22**
2004.Connection(13)															1	1	4	2	3	1	1	**13**
1994.Accessibility(11)					1										3		3	2		1	1	**11**
2001.Random Access(11)												1		3	3	1		2	1			**11**
1998.Multilingual Information Access(6)									1				1					3			1	**6**
2003.Internet Access(5)														1				3	1			**5**
2001.Universal Access(5)												1				2		1			1	**5**
2005.Multi-lingual access(3)																1				1	1	**3**
2010.Access methods(3)																					3	**3**
2007.Wireless Access(2)																		1			1	**2**

Appendix 51: Core Topic#6. Human - Computer Interaction (61 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1993.User Interfaces(790)				1	1	20	23	13	24	24	31	50	101	43	84	81	110	104	31	25	24	**790**
1995.Interaction(279)						5	6	3	5	2	9	14	21	11	40	16	25	30	28	39	25	**279**
1995.Visualization(General)(262)						1	6	2	7	1	9	16	19	4	43	28	16	25	24	33	28	**262**
1995.Human-Computer Interaction(168)						3	5	3	5	1	8	10	18	9	33	10	19	18	9	12	5	**168**
1995.Artificial intelligence(139)						4	2	1	1	8	2	5	7	12	6	17	20	10	16	13	15	**139**
1999.Three Dimensional(120)										2	1	8	6	5	5	8	7	18	20	17	23	**120**
2001.3D(78)												3	3	2	5	11	7	14	11	8	14	**78**
1995.Human engineering(70)						1			6	1	1	3	15	7	5		1	4	10	11	5	**70**
1996.Sensor(57)							1		2		1	1		4	7	2	6	12	2	15	4	**57**
1996.Information Visualization(52)							2		2		2	5	4	1	6	5	4	6	4	8	3	**52**
1996.Knowledge Representation(51)							1		1	2	1	1	2	3	8	3	3	5	8	5	8	**51**
1995.Machine Learning(49)						1							1	2	2	4	3	8	11	12	5	**49**
2002.Human Factors(36)													1		6		5	2	7	11	4	**36**
1995.Interface Design(35)						2		1				3	6	1	6	2	1	3	6	3	1	**35**
1995.Interactive computer graphics(34)						1	1	1	1	2	1	4	1		4	3	6	5		1	3	**34**
2000.Data Visualization(33)											1		2		1	2	3	7	6	5	6	**33**
1997.User-Computer Interface(30)								1	1			1		1	2	2	3	7	4	7	1	**30**
1996.Visual Communication(29)							1	1		1	3	1		1	3	1	1	5	4	6	1	**29**
2002.Web Interface(25)													3	2	2	1	1	2	4	4	6	**25**
1996.Model(HCI)(20)							1		1				3	1	7		1	2		4		**20**
1998.Sensor Network(19)									1					1			3	6		7	1	**19**
1997.Face Recognition(17)								1	1				1	1	4	1	2		4	1	1	**17**
2005.Interaction design(13)																1	1	3	3	4	1	**13**
2001.Technology Acceptance Model(11)												1	1				2	2		1	4	**11**
2005.User Interaction(10)																2			2	4	2	**10**
2002.2D(10)													1		1	3	1	2	1	1		**10**

1998.Human Information Processing(9)									1						1	2	1	2			2	**9**
2006.Contextual Information(9)																	1			4	4	**9**
2005.Visualization Technique(9)																2		2	3	1	1	**9**
2002.Visual Interface(9)													2				4	1	2			**9**
2003.Visually impaired(8)														1	1	1		1		3	1	**8**
2004.User-centric(6)															1				1		6	**8**
2002.Data Representation(7)													2			1		2	1		1	**7**
2004.3D Visualization(6)															2	3		1				**6**
1997.Multimedia Presentation(6)								1					1			1	1	1	1			**6**
2006.3D model(6)																	1	1	1		3	**6**
1996.Interactive Multimedia(5)							1		1						1	1					1	**5**
2001.Interactive Visualization(5)												1			2				1		1	**5**
2002.3D interaction(5)													1			1	1	2				**5**
2006.Interaction Pattern(5)																	1	1	1	2		**5**
2005.Interaction Technique(4)																1			1	2		**4**
2002.Web Design(4)													1	2					1			**4**
2009.Physical interactions(3)																				2	1	**3**
2004.Facial Expression(3)															1	1	1					**3**
2008.Facial Features(3)																			1	1	1	**3**
2002.Automatic Speech Recognition(3)													1		2							**3**
2007.Information Representation(3)																		2		1		**3**
2004.User interface evaluation(3)															1			1	1			**3**
2008.User centred designs(3)																			1	2		**3**
2009.Bimanual interaction(2)																				2		**2**
2004.Interactive Space(2)															1		1					**2**
2004.Spatial Memory(2)															1	1						**2**
2003.Automatic Generation(2)														1						1		**2**
2002.Visual components(2)													1							1		**2**

2006.Visual Design(2)																	2					**2**
2002.Graph Visualization(2)													1								1	**2**
2002.Interactive System(1)													1									**1**
2010.Interactive Display(1)																					1	**1**
2009.Human cognition(1)																				1		**1**
2010.Geographical visualization(1)																					1	**1**
2010.Object-oriented interfaces(1)																					1	**1**

Appendix 52: Core Topic #7. User Studies (59 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1993.Users(1208)				1	1	20	24	15	26	25	35	60	110	51	99	104	147	136	118	122	115	**1209**
1993.Students(267)				1					2	7	6	14	16	24	44	35	26	29	19	20	24	**267**
2000.User studies(General)(97)											2	3	7	4	3	4	9	9	20	17	19	**97**
1996.Decision making(94)							1			1	2	8	4	10	21	11	6	8	5	11	6	**94**
1996.Usability(76)							1	1	1	1	2	2	8	2	8	8	7	12	9	7	7	**76**
1998.Feedback(78)									1		3	5	3	3	15	6	7	9	9	8	4	**73**
2003.Usage(55)														2	3	4	9	9	9	10	5	**51**
1996.Decision support systems(41)							1				1	4	3	1	6	4	1	8	5	5	2	**41**
2002.Behavioral research(34)													2		2	4	3	2	5	10	6	**34**
2001.Children(30)												1	2	1	1	5	2	8	3	7		**30**
1999.Usability engineering(30)										1	1		3	1	3	4	3	5	2	3	4	**30**
1996.Information Needs(26)							1								1		1	1	6	6	10	**26**
2001.Decision theory(26)												3		3	2	5	1	2	3	5	2	**26**
1998.User profile(23)									1		1	1				1	3	2	8	4	2	**23**
2004.Scholars(21)															2	4	1	4	5	3	2	**21**
2001.User Modeling(20)												2	1		3	1	2	2	3	4	2	**20**
2001.User evaluation(19)												1			1		2	1	6	2	6	**19**

2004.User behavior(19)															1	3	3		4	4	4	**19**
2004.User Experience(18)															1		1	1	7	2	6	**18**
2002.Log Analysis(16)													1		3	1	1	1	3	2	4	**16**
2001.Information Seeking Behavior(16)												2	6		1		1	2	2		2	**16**
2001.User Communities(15)												1	2			1	1		2	3	5	**15**
2004.Teachers(14)															1	1	2	1	1	4	4	**14**
2004.Adults(14)															2	3	3	1	3	2		**14**
2002.Scientific community(14)													1					1	4	4	4	**14**
1999.Adaptation(14)										1		1	1	1			2	2	1	3	2	**14**
1999.User requirements(12)										1				1		1	1	1	3	3	1	**12**
2007.User interests(11)																		2	2	6	1	**11**
2002.User query(11)													1	1		1		1	4	3		**11**
2003.Scientists(10)														1	2		2	1	2	2		**10**
2001.Graduate students(10)												1			1		1		1	2	4	**10**
1997.Usability Testing(10)								1				1		1	1		1	1	1	2	1	**10**
2003.User needs(10)														1			1	1	1	3	3	**10**
2001.Search behavior(10)												1	1						2	3	3	**10**
2007.Query Logs(8)																		2	1	1	4	**8**
2005.Researcher(7)																2	2			2	1	**7**
2004.Usability Evaluation(7)															1	1		1	2	2		**7**
2004.Weblogs(7)															1		1	2		3		**7**
2003.Log Data(7)														1		1	1	1		1	2	**7**
2000.Log Files(7)											1						1		1		4	**7**
2001.Information behavior(7)												1	1			1	2	1			1	**7**
2006.User Perception(7)																	1		2		4	**7**
2003.User Satisfaction(7)														1	1	1		1	2	1		**7**
2007.Research groups(6)																		2	1	1	2	**6**
2005.Usage patterns(6)																1	1	1	2	1		**6**

2002.User Model(6)													1			1		2		2		**6**
2000.User Preferences(6)											1					1	1	1	2			**6**
2004.Transaction Log Analysis(5)															1		1	1	1		1	**5**
2002.Web Community(4)													1			1	1			1		**4**
2002.Localization(4)													1			1	1	1				**4**
2001.User Feedback(4)												1		1					2			**4**
1999.Community Networks(3)										1		1	1									**3**
2007.Blind Users(3)																		1		1	1	**3**
2005.Needs Assessment(3)																1	1		1			**3**
2002.Human Memory(3)													1						1	1		**3**
2005.Professor(2)																1		1				**2**
2007.User Testing(2)																		1			1	**2**
2003.Cognitive Process(2)														1						1		**2**
2009.User communication(1)																				1		**1**

Appendix 53: Core Topic #8. Architecture – Infrastructure (144 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1994.Web(1441)					1	5	8	11	27	50	34	72	103	112	193	155	146	142	141	111	130	**1441**
1993.Software(General)(1203)				1	1	10	9	13	14	24	21	91	91	84	197	152	156	158	67	57	57	**1203**
1993.Database systems(1047)				2	4	17	42	23	44	94	73	71	99	95	171	118	85	54	28	9	18	**1047**
1995.Algorithms(General)(895)						2	10	3	13	11	29	64	88	65	132	87	97	107	73	70	44	**895**
1993.Network(875)				2	2	16	19	21	23	11	12	47	49	45	112	106	88	76	86	84	76	**875**
1994.Internet(699)					1	2	13	10	23	23	15	55	50	53	104	91	63	70	63	36	27	**699**
1993.Computing(General)(509)				1		4	8	2	9	2	2	17	25	17	31	43	51	56	96	111	34	**509**
1993.Architecture(General)(472)				1	1	4	7	6	11	15	10	21	32	22	68	71	64	49	32	25	33	**472**
1995.Mathematical Model(457)						1	2	6	5	9	8	19	14	28	108	82	83	59	13	11	9	**457**
1995.Multimedia systems(402)						2	4	4	13	19	16	41	31	39	67	40	42	21	31	23	9	**402**
1993.Information systems(393)				1		4	6	3	7	14	9	12	24	17	40	35	40	64	52	29	36	**393**
1995.Software engineering (367)						6	2	4	2	8	6	42	38	28	50	45	48	60	18	6	4	**367**
1995.Computer simulation(350)						1	2	3	5	10	8	43	34	27	54	49	39	30	14	16	15	**350**
1996.Optimization(317)							2	1	1	4	3	10	13	24	42	33	34	36	11	91	12	**317**
1993.Data structures(305)				1		2	13	5	15	13	20	26	33	14	33	29	44	38	9	5	5	**305**
1993.Computer architecture(208)				1	1	4	5	6	8	13	8	16	22	21	49	53	43	19	2	3	4	**278**
1993.Protocols(265)				1		3	5	3	9	2	6	25	24	18	49	33	32	16	17	13	9	**265**
1995.Tools(256)						2	2				2	6	13	12	23	24	25	25	30	40	52	**256**
1995.Distributed computer systems(236)						5	1	3	7	7	3	11	16	19	30	52	33	25	8	6	10	**236**
1993.Object oriented(213)				1		3	2	2	2	6	4	19	25	16	40	22	32	27	7	3	2	**213**
1993.Object oriented programming(196)				1		2	2	1	2	4	5	19	22	16	37	21	31	25	6	1	1	**196**
1996.Interoperability (Architecture)(184)							5	2	2	6	3	14	22	8	26	30	20	11	12	11	12	**184**
1995.Agents(General)(165)						2	3	2	4	5	6	12	10	15	25	24	16	13	7	13	8	**165**
2002.Grid computing(153)													4	1	4	13	12	10	10	87	12	**153**
1997.Integration(General)(148)								2		2	1	7	6	16	19	19	20	9	15	16	16	**148**
1995.Artificial intelligence(139)						4	2	1	1	8	2	5	7	12	6	17	20	10	16	13	15	**139**

1998.Hardware(138)									3	2	1	13	13	10	28	13	18	10	5	10	12	**138**
2001.Semantic Web(137)												1	2	2	12	7	17	19	13	26	38	**137**
1995.Clustering(136)						1	2		1		3	4	6	6	8	19	17	16	21	18	14	**136**
1997.Operating systems(129)								1	1	3		10	9	13	25	18	19	15	6	6	3	**129**
1996.Computational methods(127)							3			1	2	3	2	11	15	22	38	22	5	1	2	**127**
1999.Portals(127)										1		8	12	9	23	19	19	9	5	6	16	**127**
2000.Embedded systems(110)											1	5	5	6	17	11	21	17	10	10	7	**110**
1994.Infrastructure(General)(95)					1	1	2	2	1	3	1	3	3	1	8	12	13	7	6	13	18	**95**
2000.Open Source(95)											3	4	3	1	6	11	8	15	11	16	17	**95**
2000.Ubiquitous computing(90)											1	1				2	6	8	68	1	3	**90**
1993.Digital library systems(88)				1		1	4	2	2	4	2	2	2	1	3	8	9	10	12	16	9	**88**
1995.Client server(84)						2	2		4	3	7	16	11	3	17	4	5	7		1	2	**84**
1995.Distributed Database(84)						4	8	8	11	17	10	7	6	1	4	1	1	2	1		3	**84**
1995.Digital Objects(83)						1	1			2		3	2	1	4	6	7	6	17	17	16	**83**
1999.Middleware(80)										1		4	6	3	10	17	8	14	10	3	4	**80**
1998.Data sets(80)									1		1	2	1	1	5	1	2	6	12	23	25	**80**
1997.Platform(70)								1				2	2	1	5	6	14	9	6	11	13	**70**
1995.Neural Network(69)						1	1	1		1	2	3	6	7	10	4	5	1	5	19	3	**69**
1996.Heterogeneous(General)(53)							1				1		5		8	3	3	11	7	12	7	**58**
1996.Learning Algorithm(53)							1	1				2	2	3	3	3	4	8	10	10	6	**53**
1993.Large scale systems(52)				1		1	1		1		2	3	1	3	9	10	8	8	4			**52**
1996.Open systems(50)							1	1			2	2	2	4	3	11	6	8	4	6		**50**
2001.Peer to peer(50)												1	1	2	8	10	9	5	5	5	4	**50**
1998.Multi agent systems(50)									1		1	2	3	4	10	7	6	3	3	9	1	**50**
1999.Intelligent agent(44)										1		7	5	9	4	7	5	3		1	2	**44**
2000.Learning Object(41)											1	1	3	4	4	6	7	3	5	3	4	**41**
2001.Software Design(38)												1	1	1	1	4	11	9	2	2	6	**38**
2007.Web 2.0(33)																		4	9	14	10	**37**
2000.Software architecture(36)											1				6	2	5	9	5	2	6	**36**

1999.Linear Algebra(34)										1	1	2	4	1	4	2	9	7	3			**34**
2001.Parallel programming(33)												1	4		5	6	5	10	2			**33**
1999.Vector spaces(30)										1		1		2	2	1	2	4	6	2	9	**30**
1995.Web servers(30)						1						2	2	1	2		2	2	9	5	4	**30**
2001.Controllers(29)												4	3	1	1	3	2	2	1	8	4	**29**
1997.Data Model(29)								1	1			2	1		1	2	3	2	1	5	10	**29**
1997.Digital library software(28)								1		1	2	1			1	3	6	7	3	2	1	**28**
2002.Web Technology(28)													1	2	2	1	3	3	3	6	7	**28**
2001.System Design(28)												3	2		2	2	3	4	3	4	5	**28**
2004.Service-oriented architecture(27)															1	3	4	5	6	4	4	**27**
1996.Scalability(27)							2			1				3		4	5	3	5	2	2	**27**
1996.Software Agent(26)							1	1		3	3	2		2	5	2	3	1	1	1	1	**26**
2004.Data Grid(24)															2	4	2	1	4	9	2	**24**
1996.Distributed digital libraries(24)							1	1	4	4	3					2	1	2	2	2	2	**24**
1997.Spatial Data(22)								1	2	1		2	1	1	2	1	1	3		4	3	**22**
1993.Distributed systems(22)				1				1			1		1	3		4	1	2	4	1	3	**22**
1996.WWW(21)							2	4	7	2	1		1		2	1			1			**21**
1994.Information Infrastructure(20)					1	1	2	1	1	1		2			1	1	4	2	1		2	**20**
2003.Intelligent systems(20)														1	1	1	3	3	2	4	5	**20**
2002.Open Source Software(20)													2	1	3	3	2	3	3		3	**20**
2006.Network architecture(20)																	4	4	5	2	5	**20**
2001.Architectural Design(20)												2	2		4	2	2	1	5	1	1	**20**
2001.Distributed Computing(18)												1	3	3	2	4			3	2		**18**
2004.Fuzzy logic(14)															1		2	3	1	7	4	**18**
2002.Software Tool(17)													1	1		2	1	3	4	2	3	**17**
1999.Software Component(15)										1	1	1	1	1	2	2	1	1	1		3	**15**
1996.Groupware(14)							2				1		1	3		1	1	3			2	**14**
1998.Data Fusion(14)									2				1	2	1	1	2	2		1	2	**14**

2001.Replication(14)												2	2			3	2	1	2	1	1	**14**
1996.Agent based(13)							2						2		3	1	1	2			2	**13**
2002.Content management system(12)													1		2	2	2	2	2		1	**12**
1999.Digital library integration(12)										1		1		1	2	1	1		2	2	1	**12**
2000.Clustering Method(11)											1		1			1	2		2	1	3	**11**
2003.Probabilistic Model(11)														1				2	2	4	2	**11**
1998.Software Reuse(11)									1		1		2	1	3	1		1		1		**11**
1997.Digital Library Architecture(11)								1	2				1		1	5	1					**11**
1999.Information architecture(11)										1					3	2	1		3		1	**11**
2001.Web Portal(11)												1	2		1	1	1	1	1	2	1	**11**
2002.Data Type(11)													1		2		3	3		1	1	**11**
2004.Cyberinfrastructure(10)															1	1	1	1	3	2	1	**10**
2009.Fuzzy linguistic(9)																				4	5	**9**
2000.Search Algorithm(9)											1		1		3			1	1	1	1	**9**
2005.Classification Algorithm(9)																1		2	3	2	1	**9**
2002.Computer engineering(9)													1				1	2		4	1	**9**
2001.Distributed Data(9)												1	1				2		1	1	3	**9**
2002.Fuzzy systems(9)													1		1		1	1	2	3		**9**
2002.Digital library design(8)													1		2	1	1	1	1	1		**8**
2010.Cloud computing(7)																					7	**7**
2001.Computer games(7)												1			1	1		1	2		1	**7**
2003.Design and Development(7)														1		1	1			2	2	**7**
2002.Heterogeneous systems(8)													1					3	1	2		**7**
2004.Heterogeneous data(7)															1			1	1	1	3	**7**
1999.Integration systems(7)										1	1	1					1			1	2	**7**
2004.Schema Mapping(6)															1	1	1	1	2			**6**
2003.Application software(6)														1			2	2		1		**6**
2005.Simulation model(6)																1	2			2	1	**6**

2001.Information Model(6)												1	1	1			1			2		**6**
1997.Database objects(6)								2	1				1		1						1	**6**
2007.Design Principle(6)																		1	2	3		**6**
2001.Scientific computing(5)												3				1		1				**5**
2004.Computational tools(5)															1	1				2	1	**5**
2004.Software infrastructure(5)															1		1			2	1	**5**
1999.Open architecture(5)										1		1			1		1			1		**5**
2006.Runtime environments(5)																	2		2		1	**5**
2006.Multiple data(5)																	1	2	1		1	**5**
1999.Database Design(5)										1		1				1		1	1			**5**
2006.Entity Resolution(5)																	2	1	1		1	**5**
2003.Hybrid System(5)														1		1		2	1			**5**
1996.Heterogeneous information(5)							1											2	1		1	**5**
2004.Digital library federation(5)															1			1	1		2	**5**
2004.Hardware architecture(4)															1			1		2		**4**
2005.Data Integrity(4)																1	1	1		1		**4**
2002.Data Center(4)													1						1	2		**4**
2002.Information systems design(4)													1		1		1		1			**4**
2004.Heterogeneous Collections(4)															2	1				1		**4**
1996.Extensibility(4)							2						2									**4**
2006.Data Warehousing (3)																	2		1			**3**
2006.Data Management System(3)																	1			1	1	**3**
2010.Distributed portal(3)																					3	**3**
2004.Cluster Computer(2)															1			1				**2**
1996.Global Information Infrastructure(2)							1														1	**2**
2000.Software Requirements(2)											1	1										**2**
2004.Open Source tools(2)															1						1	**2**
2006.Software Platform(2)																	1				1	**2**

2008.Centralized architecture(2)																			1		1	**2**
2003.Object-oriented modeling(2)														1						1		**2**
2004.Spatial Distribution(2)															1				1			**2**
2005.Distributed Collections(2)																1			1			**2**
2001.Database Development(1)												1										**1**
				16	13	115	217	168	294	420	366	916	1064	967	2052	1777	1770	1599	1257	1282	1046	**15339**

Appendix 54: Core Topic #9. Knowledge Management (58 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1995.Information management(411)						4	1	5	6	15	4	14	27	19	34	76	56	66	51	15	18	**411**
1998.Knowledge management(General)(185)									2		1	4	7	9	12	22	16	22	37	27	26	**185**
1995.Knowledge based systems(150)						1	2	6	1		2	11	8	4	20	15	26	18	21	6	9	**150**
1996.Knowledge acquisition(119)							1		2	1	3	2		7	22	25	27	12	7	5	5	**119**
1994.Collaboration(102)					1	1	1	2		1	2	5	5	9	8	8	11	14	5	13	16	**102**
2000.Knowledge engineering(73)											1	3	11	7	15	10	6	2	7	6	5	**73**
1996.Knowledge representation(51)							1		1	2	1	1	2	3	8	3	3	5	8	5	8	**51**
2001.Content management(45)												2	2	3	6	8	10	2	5	3	4	**45**
1998.Data management(38)									1	3		2	1	5		1	2	4	4	8	7	**38**
1997.Expert System(28)								1		1		2	2	5	5	2	2	1	2	3	2	**28**
1999.Document Management(26)										3		2	2	3	5	4	1	1		2	3	**26**
2002.Knowledge organization(25)													3		1	2	1	5	4	3	6	**25**
2002.Knowledge Base(23)													3	1	1		2	2	9	1	4	**23**
1996.Information Sharing(22)							1			1		1		2	2	3	2	2	1	4	3	**22**
2001.Knowledge sharing(22)												2			3		2	3	5	4	3	**22**
2000.Knowledge discovery(20)											1		1	1	1	1	2	4	3	3	3	**20**
2000.Information Space(14)											1				1	3		2	4	2	1	**14**
2002.Knowledge organization systems(11)													3				1	2	3	1	2	**12**

2002.Content Management System(12)													1		2	2	2	2	2		1	**12**
2003.Information Exchange(11)														1	3	4	1				2	**11**
2001.Collaborative learning(11)												1		1	1	1	3	1	1	2		**11**
2005.Personal information management(10)																1	2		2	1	4	**10**
2003.Domain knowledge(9)														1	1			2	1	4		**9**
2007.Knowledge service(9)																		1	1	3	4	**9**
2004.Scientific knowledge(8)															2					1	5	**8**
2003.Knowledge Network(8)														1	1	1			4		1	**8**
2005.Information communication(8)																1	1	5			1	**8**
2002.Topic maps(6)													1			1	1		1	2		**6**
2006.Knowledge Extraction(6)																	1	1	2	1	1	**6**
2005.Collaborative research(6)																1		1			4	**6**
2007.Knowledge basis(5)																		1		1	3	**5**
1996.Collaborative work(5)							1							1				1		1	1	**5**
2007.Knowledge map(4)																		1	1	2		**4**
2005.Knowledge transfer(4)																2			1		1	**4**
1999.Information Flow(4)										1		1						1		1		**4**
2007.Collaborative knowledge(4)																		2			2	**4**
1998.Knowledge spaces(3)									1									1			1	**3**
2008.Knowledge innovation(3)																			2	1		**3**
2001.Knowledge evolution(3)												2									1	**3**
2007.Knowledge retrieval(3)																		1	1	1		**3**
2005.Tacit knowledge(3)																1	1				1	**3**
2007.External knowledge(2)																		1			1	**2**
2010.Expert Knowledge(2)																					2	**2**
2009.Knowledge process(2)																				1	1	**2**
2005.Knowledge Mining(2)																1	1					**2**
2009.Collaborative network(2)																				2		**2**

2003.Multimedia data management(1)														1								**1**
2006.Knowledge Work(1)																	1					**1**
2010.Knowledge linking(1)																					1	**1**
2010.Knowledge building(1)																					1	**1**
2010.Knowledge gaps(1)																					1	**1**
2004.Knowledge searching(1)															1							**1**
2005.Knowledge distribution(1)																1						**1**
2008.Knowledge Translation(1)																			1			**1**
2007.Knowledge Exchange(1)																		1				**1**
2005.Knowledge communication(1)																1						**1**
2009.Collaborative technologies(1)																				1		**1**
2006.Explicit knowledge(1)																	1					**1**

Appendix 55:Core Topic #10. Digital Library Services (30 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1993.Services(General)(1134)				2	2	9	17	12	13	24	20	36	48	46	90	116	143	172	147	117	120	**1134**
1993.Information services(572)				2	2	9	15	9	11	19	17	23	20	20	36	67	69	64	76	71	42	**572**
1993.Information dissemination(278)				1	1	5	10	3	10	14	10	17	19	19	45	40	30	26	10	9	9	**278**
1997.Web services(179)								1						2	22	14	29	46	29	12	24	**179**
1995.Library Services(84)						1			1	1		1	5	5	4	5	9	16	13	11	12	**84**
1996.Telecommunication services(43)							1	1			1	2	2	5	4	6	9	5	2	1	4	**43**
1999.Reference service(35)										1	1	1	1	4	5	4	3	4	4	4	3	**35**
2001.Web search(31)												1	1	1	4	2	3	4	5	5	5	**31**
1997.Multimedia services(31)								1					1	1			4	16	3	1	2	**29**
1998.Personal Digital Library(23)									1			1	2	3	2	5		2	3	1	3	**23**
1998.Personal Digital Libraries(23)									1			1	2	3	2	5		2	3	1	3	**23**

2002.Service Provider(23)													1	2	7	2	3		3	5		**23**
2001.Search services(14)												1	1			1	1	2	3	2	3	**14**
2005.Personalized service(13)																1	2	4	4	1	1	**13**
2000.Service System(12)											1			1				3	2	3	2	**12**
2002.Service Quality(11)													1		1	1	2	1	2	2	1	**11**
2003.Information Exchange(11)														1	3	4	1				2	**11**
2002.Online information services(8)													1	1	2					1	3	**8**
1997.Reference Model(8)								1						1		3	1		1	1		**8**
1998.Data services(7)									1		1									1	4	**7**
2006.OPAC(6)																	1	1	3	1		**6**
2003.Service Integration(6)														1	1			1	1		2	**6**
2006.Service Model(5)																	1	1		1	2	**5**
2002.Reference Systems(4)													1		1			1			1	**4**
2007.Personalized information services(3)																		1	1	1		**3**
2005.Catalog services(3)																1				1	1	**3**
2001.Service platforms(2)												1								1		**2**
2005.Service infrastructure(2)																1					1	**2**
2004.Database providers(1)															1							**1**
2010.Mobile multimedia services(1)																					1	**1**

Appendix 56:Core Topic #11. Mobile Technology (22 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1996.Mobile(General)(147)							1		2	1	6	2	6	7	12	24	16	15	16	16	23	**147**
1999.Wireless(63)										1		1	4		8	6	7	15	6	8	7	**63**
2002.Mobile devices(31)													1			2	4	4	4	7	9	**31**
1998.Mobile computing(22)									1		2		1	3	1	2	2		5	4	1	**22**
1999.Mobility(15)										1			1	2	3	1	3	1	1	2		**15**
2002.Mobile communications(14)													1		1	3			1	3	5	**14**

2007.Wireless networks(13)																		2	6	1	4	**13**
2001.Laptop(12)												2			2	4		1	1	1	1	**12**
2004.Mobile learning(7)															1		1	3	1		1	**7**
2005.Mobile users(6)																1			1	3	1	**6**
2006.Mobile services(5)																	2	1	1	1		**5**
2007.Mobile access(4)																		1		2	1	**4**
2007.Mobile library(3)																		1	1		1	**3**
2006.Mobile information(3)																	1	1			1	**3**
2001.PDA(3)												1		1				1				**3**
2009.Mobile application(3)																				2	1	**3**
2005.Wifi(2)																1					1	**2**
2008.3G(2)																			1		1	**2**
2009.Mobile storytelling(1)																				1		**1**
2010.Mobile content(1)																					1	**1**
2009.Mobile reading(1)																				1		**1**
2009.Mobile user interface(1)																				1		**1**

Appendix 57: Core Topic #12. Social Web (Web 2.0) (21 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1999.Library 2.0(110)										1		1			1		9	27	21	27	23	**110**
2002.Social networks(51)													1			2	1	5	13	10	19	**51**
2007.Web 2.0(37)																		4	9	14	10	**37**
2007.Social Networking(9)																		1		5	15	**21**
2005.Social Network Analysis(17)																2		2	6	2	5	**17**
2006.Librarian 2.0(15)																	1	3	5	3	3	**15**
2007.Social tagging(12)																		1	7	3	1	**12**
2007.Folksonomy(7)																		2	3	1	1	**7**
2007.Social Media(5)																		1			5	**6**

2002.Social Navigation(5)													1			1		1			2	**5**
2008.User generated content(3)																			1	2		**3**
2010.Information literacy 2.0(2)																					2	**2**
2008.Social Web(2)																			1	1		**2**
2010.Crowdsourcing(2)																					2	**2**
2009.Library user 2.0(1)																				1		**1**
2007.Social search(1)																		1				**1**
2010.Social graph(1)																					1	**1**
2010.Wisdom of crowds(1)																					1	**1**
2010.Social engagement(1)																					1	**1**
2008.KnowledgeManagement 2.0(KM 2.0)(1)																			1			**1**
2006.Mashup(2)																	1			1		**2**

Appendix 58: Core Topic #13. Semantic Web (Web 3.0) (30 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1999.Ontologies(General)(258)										1		5	7	8	27	22	32	39	35	34	48	**258**
2001.Semantic Web(Web3.0)(137)												1	2	2	12	7	17	19	13	26	38	**137**
2002.Ontology-based(19)													1	1			2	1	3	7	10	**25**
2005.Semantic digital library(21)																3		1	1	5	11	**21**
2001.Ontology semantics(21)												1				2	2	6	4	3	3	**21**
2006.Domain ontology(15)																	1	1	4	7	4	**17**
2006.Semantic technology(16)																	1	1	2	5	7	**16**
2005.Semantic annotation(14)																1		3	5	3	2	**14**
2004.Semantic Web Service(10)															6		2				2	**10**
1998.Semantic Information(9)									1								1	2			5	**9**
2000.Semantic Analysis(8)											1		1			1		2		1	2	**8**
2007.Faceted search(7)																		1	4	2		**7**

1996.Semantic Retrieval(5)							1											1	1		2	**5**
2009.Semantic search(4)																				1	3	**4**
2004.Semantic Zooming(4)															1				1	1	1	**4**
2001.Semantic Model(4)												1			1		2					**4**
1999.Formal Ontology(4)										1							1		2			**4**
2007.Multi-class classification(3)																		1	1	1		**3**
2007.Semantic mapping(3)																		1		1	1	**3**
2007.Semantic Relations(3)																		1	1		1	**3**
2007.Library 3.0(2)																		1	1			**2**
2009.Semantic resources(2)																				1	1	**2**
2009.Social semantics(2)																				2		**2**
2006.Semantic interpretation(2)																1					1	**2**
2010.Semantic metadata(2)																					2	**2**
2003.Semantic Similarity(2)														1			1					**2**
2005.Ontology development(2)																1				1		**2**
2007.Semantic Knowledge(1)																		1				**1**
2007.Semantic representation(1)																		1				**1**
2002.Ontology services(1)													1									**1**

Appendix 59: Core Topic #14. Virtual Technologies (20 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1994.Virtual(General)(541)					1	2	7	3	2	5	12	24	35	24	57	51	55	51	44	82	86	**541**
1995.Virtual reality(282)						1	3	3	1	2	11	10	24	16	36	37	36	38	14	27	23	**282**
1994.Virtual library(74)					1		1	1		3	1	6	4	5	9	1	3	5	12	13	9	**74**
2000.Virtual machines(50)											1	1	6		2	3	5	5	6	11	10	**50**
2001.Virtual environments(33)												1	1	2	2	3	2	3	5	9	5	**33**
2001.Virtual worlds(12)												1			1		1		1	6	6	**16**
2003.Cybernetics(16)														3	3	2	1	1		4	2	**16**

2002.Virtual reference(16)													1		6	1	2		2	1	2	**15**
1996.Virtual Instrument(10)							1											1	2	1	5	**10**
1996.Virtual laboratory(10)							1								1	2		1		1	4	**10**
2007.Second Life(10)																		2		3	5	**10**
2002.Virtual Learning(8)													1	1	1	1	2		1	1		**8**
2003.Virtual Organization(8)														1	1	1	2			3		**8**
1997.Library 3D(7)								1										1		3	2	**7**
2001.Virtual community(7)												2					1			2	2	**7**
2006.3D models(4)																	1	1	1		3	**6**
2006.Virtualization(6)																	3	1		1	1	**6**
2001.Web 3D(3)												1			1	1						**3**
2009.3D digital preservation(2)																				1	1	**2**
2010.Virtual platform(1)																					1	**1**

Appendix 60: Core Topic #15. Digital Library Management (53 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1998.Evaluation(General)(310)									1		3	11	16	7	28	21	37	36	56	50	44	**310**
1995.Project management(254)						7	1	1	4	6	2	9	9	14	62	50	35	33	11	5	5	**254**
1996.Digital Library education(148)							2				2	8	9	12	24	21	24	20	8	10	8	**148**
1997.Planning(General)(145)								1	1	1		7	12	11	22	11	16	15	16	19	13	**145**
1995.Management System(126)						1		2	1	1	2	3	10	1	13	22	16	22	11	7	14	**126**
1999.Policy(General)(96)										1		3	8	11	12	12	12	13	10	6	8	**96**
1996.Quality control(53)							1	1	1		1	3	1	2	3	6	6	6	6	11	5	**53**
1999.Quality Assurance(46)										1			1	5	5	5	2	7	5	11	4	**46**
1998.Strategic planning(45)									1	1		4	5	3	7	3	5	4	4	6	2	**45**
2000.Cost Effectiveness(41)											1	6	7	1	8	6	3	6	2	1		**41**
1995.Digital library project(40)						1		2			1		1		1	11	4	7	3	2	7	**40**
2002.Digital library evaluation(30)													4		7	2	5	2	5	1	4	**30**

2002.Case studies(26)													3			3		7	9	2	2	**26**
1999.Investment(23)										1		2	7	1	3	2	3		2	2		**23**
2001.Organization and management(23)												1	1	1	1	4	2	5	2	2	4	**23**
1999.Digital library management(21)										1			2	1	2	6	3	2	1	1	2	**21**
2001.Benefits(20)												1	2	2				2	5	3	5	**20**
2003.Staff(20)														2	2	1	3	1	4	4	3	**20**
2008.Work flows(19)																			5	5	9	**19**
1999.Risk assessment(18)										1			4	1	1	4	2	2	1	3		**19**
2002.Performance Evaluation(16)													2	1	3	1	2	4	1		2	**16**
2002.Budget(14)													1	2	4	4	2			1		**14**
2000.Information professionals(14)											1			1	2	4	2			2	2	**14**
2005.Systems development(14)																3	2	4	2		3	**14**
2001.Cost benefit analysis(12)												1	1	2					3	2	3	**12**
2003.Risk management(11)														1		4	1	2	1		2	**11**
1999.Finance(10)										1		1	2	2	1	1				2		**10**
2001.Project Planning(9)												1				1			2	3	2	**9**
2003.Library organization(8)														1	1		2		1	1	2	**8**
2001.Field Study(8)												1	1		1	3			1		1	**8**
1994.Human resources(6)					1								1					1	1	2	1	**7**
1997.Information Quality(7)								1	1										2	1	2	**7**
2006.Quality Assessment(7)																	1	1	2	2	1	**7**
1999.Information policy(6)										1			3			1		1				**6**
2001.Evaluation Method(6)												2							1	3		**6**
2002.Pricing(5)													2		1				2			**5**
2004.Digital librarians(5)															2	1	2					**5**
2003.Digital library performance(5)														1		1	1	1	1			**5**
1997.Management Model(4)								1												1	2	**4**
2001.Quality Indicator(4)												1								3		**4**

2007.Performance Improvement(3)																		1	2			**3**
2003.Performance Measure(3)													1			1	1					**3**
2007.Performance Metric(3)																	1		1	1		**3**
2006.Quality Model(3)																2				1		**3**
2005.Quality Metric(3)															1		1		1			**3**
2004.Digital library planning(2)														2								**2**
2003.Curators(2)													1					1				**2**
2001.Management Strategy(2)											1								1			**2**
2010.Evaluation framework(2)																				2		**2**
2004.Heuristic Evaluation(2)														1						1		**2**
2005.Digital Library policy(1)															1							**1**
2001.Information Economics(1)											1											**1**
2007.Library constructions(1)																	1					**1**

Appendix 61: Core Topic #16. Digital Library Applications (64 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1993.Education(General)(645)				1	1	2	6	3	4	10	12	41	46	47	85	77	86	76	48	55	45	**645**
1993.Research(General)(623)				1		1	6	3	4	11	13	31	27	21	58	58	52	56	67	96	118	**623**
1993.Learning(General)(621)				2		2	4	5	3	4	10	21	34	31	82	69	91	80	75	60	48	**621**
1995.Learning systems(304)						2	2	3		4	6	12	21	23	59	45	58	38	23	2	6	**304**
1995.Societies and institutions(298)						1	2	1	3	3	3	9	28	32	56	53	41	16	9	18	23	**298**
1993.Teaching(197)				1		1	1	1	1	2	5	7	10	18	25	25	11	21	17	21	30	**197**
2002.E-learning(113)													1	4	6	11	24	22	20	15	10	**113**
1999.Academic libraries(110)										2	1	5	7	9	13	13	8	12	10	15	15	**110**
1993.Instruction(95)				1		2	3	2	3	3	6	4	12	7	10	10	8	12	3	5	4	**95**
1997.Distance education(90)								1	1	2	3	7	10	4	16	5	19	8	5	4	5	**90**
1997.Health Care(68)								2	1	1	1	2	4	3	7	10	7	15	4	5	6	**68**

1995.Museums(53)						1				1	2	2	1	3	6	11	10	5	5	4	2	**53**
2000.Art(52)											1	3	1	1	7	4	6	4	4	11	10	**52**
1997.School(50)								1				1		1	5	4	6	8	8	8	8	**50**
1998.National libraries(47)									1						1	4	8	3	12	10	8	**47**
1999.Public library(43)										3			4	4	2	4	5	7	4	7	3	**43**
1996.Medicine(39)							1		1		1	1		2	2	5	5	5	6	7	3	**39**
2002.Higher education(35)													1	1	1	6	7	4	3	9	3	**35**
1997.Educational digital libraries(33)								1				1	1		4	5	5	4	1	7	4	**33**
1997.Television(32)								1		1		3	2	4	6	2	3	2	4	3	1	**32**
1999.Culture(31)										1		1	3		4	2	4	5	4	4	3	**31**
1993.Learning Environment(28)				1									4	1	1	2	2	2	3	7	5	**28**
1994.Scholarly communication(27)					1			1			1	6	1	4	4	2	1		1	1	4	**27**
1997.News(27)								1	2		1	1	2		2	1	2	2	6	4	3	**27**
2004.E-science(24)															1	1	2	1	4	8	7	**24**
1998.Hospital(23)									1		1		1	1	3	5	4	3	2	1	1	**23**
1995.Natural Science(23)						3	3					3	1		2	3	2	6				**23**
1998.Military(22)									1			2	1		1	1	2	1	9	3	1	**22**
1998.Social Sciences(21)									2	1			4	2	1	1	1	4	2	3		**21**
1996.Humanities(19)							1					2			1	3	1	2	3	2	4	**19**
2008.Design/methodology/approach(17)																			4	6	7	**17**
1995.Classroom(16)						1				1			1	3	3	4	1				3	**17**
2002.Geospatial(18)													1	1	1	3	1	5	1	3	1	**17**
1999.Offices(11)										1			2		2	1	1	1		2	1	**11**
2002.Film(11)													1	1	1	1	1	3	1	2		**11**
2003.E-government(9)														3		1		1	2	1	1	**9**
2001.Life Sciences(9)												1					1		1	2	4	**9**
2001.Active Learning(7)												1			1				1	1	3	**7**
2001.Learning Technology(7)												1					1	1	4			**7**
2005.Learning Management System(6)																2	1	1	1		1	**6**

2008.Learning process(6)																			1	3	2	**6**
2001.Online Courses(6)												2	1		1			1		1		**6**
2006.Supervised Learning(6)																	1		2	2	1	**6**
2007.Learning Activities(6)																		3	2	1		**6**
1998.Information research(5)									1							1				1	2	**5**
2005.NASA(5)																2	1	1			1	**5**
2002.Public Education(4)													1					1	1		1	**4**
2003.Learning Methods(6)														1			1		1		1	**4**
2002.E-governance(4)													1			2		1				**4**
2002.Digital Earth(4)													1		2						1	**4**
2004.Astrophysics(4)															1	2		1				**4**
2008.Cultural institutions(3)																			1	1	1	**3**
2008.Research institutions(3)																			1		2	**3**
2002.Citizen Science(3)													2								1	**3**
2006.Educational systems(3)																	1	1		1		**3**
2001.Online Education(3)												1			1		1					**3**
2008.Learning objectives(3)																			1	1	1	**3**
2007.Taxonomy learning(2)																		1			1	**2**
2006.Children digital library(2)																	1	1				**2**
2002.Information Industry(2)													1						1			**2**
2008.Environmental Monitoring(2)																			2			**2**
2006.E-discovery(1)																	1					**1**
2009.Electronic administration(1)																				1		**1**
2008.Disability digital library(1)																			1			**1**

Appendix 62 :Core Topic #17. Intellectual Property, Privacy, Security (28 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1995.Security(General)(223)						3	4	2	2	6	3	9	12	20	38	18	30	23	11	21	21	**223**

1995.Copyright(General)(107)						2	1		1	3	9	6	5	10	19	17	9	7	2	7	9	**107**
1995.Intellectual Property(General)(55)						1	1		1	1	1	6		1	13	14	7	4	1	2	2	**55**
1996.Cryptography(47)							1			1	1	2		1	18	6	2	6	3	3	3	**47**
1998.Privacy(38)									1		1		2		6	5	6	6	2	3	6	**38**
1998.Digital watermarking(33)									2	1	1		2	1	12	6	2	1	2		3	**33**
2000.Validation(31)											1	1			1	2	5	6	5	5	5	**31**
2000.Computer crime(27)											1			1	4	2	2		2	8	7	**27**
2001.Authentication(22)												2		2	2	2	6	3	2	1	2	**22**
2003.Network security(20)														1	3	1	1	2	2	6	4	**20**
1998.Rights Management(19)									1					1	5	5	3		1	1	2	**19**
1996.Authoring(17)							1					2		1	1	1	1	5		2	3	**17**
2002.Security systems(17)													1	1	3	2	3	1		4	2	**17**
2004.Copyright Law(16)															6	3	2			2	3	**16**
2003.Digital Rights Management(DRM)(15)														1	5	4	2		1	1	1	**15**
1998.Copyright Protection(12)									1			1	1		3			1	1	2	2	**12**
1997.Licensing(11)								1				1	1			1	1	4		1	1	**11**
1996.Authorization(11)							2						1	1	1		3	1	1		1	**11**
2003.Data security(10)														2	3		1		1	2	1	**10**
2003.Authorship(9)														1		1		1	4	1	1	**9**
2003.Digital Asset Management(DAM)(8)														1		3	1	1			2	**8**
2004.Privacy protection(6)															1		1			2	2	**6**
2006.Digital signatures(4)																	1		1	1	1	**4**
2006.Security management(2)																	1				1	**2**
2004.Intellectual Property Protection(1)															1							**1**
2010.Security model(1)																					1	**1**
2010.Security policy(1)																					1	**1**
2009.Privacy policies(1)																				1		**1**

Appendix 63: Core Topic #18. Cultural, Social, Legal , Economic Aspects (25 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
2001.Societies and institutions(285)												9	28	32	56	53	41	16	9	18	23	**285**
1996.Social(Aspects)(221)							3		3	6	3	3	11	17	13	15	17	28	35	28	39	**221**
1996.Electronic commerce(122)							4		4	6	2	6	10	6	27	11	7	5	14	8	12	**122**
2001.Cultural(Aspects)(103)												1	6	2	4	6	12	7	17	19	29	**103**
2001.Heritage(96)												1	3	3	5	10	13	6	16	14	25	**96**
1994.Law(85)					1			1	1	2		4	2	14	17	12	8	1	3	14	5	**85**
2001.Cultural Heritages(70)												1	3	2	3	4	9	4	11	12	21	**70**
1996.Economic (Aspects)(46)							1		1	1	1	2	2	4	10	2		3	5	11	3	**46**
2000.Business(42)											1	1	1	2	2	4	6	5	6	8	6	**42**
1997.Legal Aspects(17)								1				1			2	3	5	1	3		1	**17**
2004.Copyright Law(16)															6	3	2			2	3	**16**
2002.Cross-languages(15)													3		1	1	2	2	2	2	2	**15**
2002.Information society(13)															2	3		2	2	2	2	**13**
2002.Digital divide(9)													1			1	2	1		3	1	**9**
2002.Cross-cultural(8)													2		1			2		3		**8**
2002.Oral History(8)													1				2		1	3	1	**8**
Pedagogical(Aspects)(8)											1				2	1	1	1			2	**8**
1999.Trust(8)										1		1	1		1		1	1	1	1		**8**
2005.Digital age(6)																2	1			1	2	**6**
2002.Cross-cultural usability(4)													2					1		1		**4**
2002.Citizen science(3)													2								1	**3**
2001.Globalization(3)												1	1					1				**3**
2005.Knowledge economy(2)																1				1		**2**
2002.Censorship(2)													1		1							**2**
2007.Multicultural Digital Library(1)																		1				**1**

Appendix 64: Core Topic #19. Digital Library Research & Development (48 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1993.Computer Science(4752)				1	5	23	42	37	64	75	88	188	320	267	261	423	566	714	599	502	577	**4752**
1993.Engineering(2618)				2	3	9	33	19	39	59	79	225	110	146	510	390	362	179	115	212	126	**2618**
1993.Social Sciences(2129)				1	1	2	12	19	16	61	46	87	208	128	130	252	245	281	283	132	225	**2129**
1995.Mathematics(1342)						15	6	5	17	5	13	18	22	26	26	184	237	278	177	125	188	**1342**
1996.Biochemistry, Genetics and Molecular Biology(648)							1	1			1	1	1	5	6	158	204	227	25	8	10	**648**
1999.Archive science(238)										2	9	19	27	11	20	46	39	25	29	26	30	**283**
1994.Physics and Astronomy(252)					1		6	7	18	11	12	23	15	18	28	13	29	23	10	19	19	**252**
1995.Business, Management and Accounting(246)						1	11	7	21	9	4	8	14	26	16	19	24	12	29	13	32	**246**
1996.Information science(225)							1	2	1	5	1	7	9	11	19	19	48	33	27	13	29	**225**
1999.Decision Sciences(193)										1	1	2	1	4	6	30	25	31	43	20	29	**193**
1999.Academic (domains)(181)										3	2	5	7	12	17	19	17	21	23	22	33	**181**
1993.Medicine(121)				1				3	1	1	3	4	3	5	5	12	14	22	16	13	18	**121**
1996.Materials Science(120)							2	5	3		2	5	4	2	13	10	17	11	7	21	18	**120**
1998.Chemistry(104)									2		2	5	1	5	5	7	17	15	9	22	14	**104**
1995.Chemical Engineering(96)						1	2	1	1	1	3	5	8	6	6	7	10	10	6	19	10	**96**
1995.Research and Development(91)						1	4	1		3		11	4	7	18	17	10	5	5	1	4	**91**
1994.Earth and Planetary Sciences(89)					1				4		2	4	5	4	10	4	14	15	5	9	12	**89**
1994.Industry (domains)(67)					1				1	3		3	5	4	8	6	3	3	11	10	9	**67**
1995.Government (domains)(58)						1						3		4	4	4	4	8	14	4	12	**58**
1998.Arts and Humanities(58)									3	1	5	3	5	3	2	4	2	1	2	15	12	**58**
2000.Energy(56)											1	4	5	3	6	4	7	6	2	8	10	**56**
1995.Museum(53)						1				1	2	2	1	3	6	11	10	5	5	4	2	**53**
1997.Health Professions(53)								1			2	3	3	3	3	5	5	5	6	12	5	**53**
1996.Agricultural and Biological Sciences(50)							1			1	1	2	3	7	6	5	5	8	3	3	5	**50**
1994.Environmental Science(42)					1	1				1	1	2	3	2	5	3	2	5	4	6	6	**42**

1998.Psychology(42)									1		9	4	3	4	4	3	2	3	1	6	2	**42**
2000.Nursing(24)											1	2		1	2	5	4	1	3	3	2	**24**
2006.Curation(23)																	1	2	7	8	5	**23**
1996.Immunology and Microbiology(22)							1				1	1		1	2	3	2	4	1	2	4	**22**
1996.International cooperation(20)							1						2		1	7	1	2		4	2	**20**
2000.Economics, Econometrics and Finance(20)											1	1		1	2	3	2	4		3	3	**20**
2000.Neuroscience(18)											1	1	1	1	2	3	3	1	1	2	2	**18**
2000.Digital library research(17)											1	1	1		1	4	5		2	1	1	**17**
2000.Pharmacology, Toxicology,Pharmaceutics(17)											1	1		1	2	3	2	2		2	3	**17**
2000.Dentistry(17)											1	1		1	2	3	2	1	1	3	2	**17**
2000.Multidisciplinary(15)											1	1		1	2	3	2	1		2	2	**15**
2001.Interdisciplinary(12)												1	2		1		1	1		3	2	**11**
2004.Librarianship(11)															1	1	1	5		1		**9**
2005.Universal Digital Libraries(5)																5						**5**
2001.Interdisciplinary research(4)												1	1							2		**4**
2001.Scholarship(4)												1	2					1				**4**
2005.Digital library development(3)																2		1				**3**
2005.Global collaboration(3)																2				1		**3**
2001.International Collaboration(20)												1				1			1			**3**
2005.Digital library concepts(2)																1		1				**2**
2005.International digital library(2)																1				1		**2**
2009.Interdisciplinary collaborations(1)																				1		**1**
2006.Digital library collaboration(1)																	1					**1**

Appendix 65: Core Topic #20. Information Literacy (20 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
2001.Decision making(90)												8	4	10	21	11	6	8	5	11	6	**90**
1999.Reading(55)										1		1	2	1	8	11	2	8	9	5	7	**55**
2000.Information Literacy(40)											1	1	2		4	5	6	9	6	5	1	**40**
2004.Information society(13)															2	3		2	2	2	2	**13**
2002.Digital divide(9)													1			1	2	1		3	1	**9**
2005.Information overload(8)																1			2	3	2	**8**
2002.Ethics(7)													1	1	2	1			1	1		**7**
1999.Information searching(7)										1						2	1	1		1	1	**7**
2001.Learning communities(6)												2					1	1	1	1		**6**
2000.Critical thinking(6)											1	2						1			2	**6**
2001.Lifelong learning(5)												2				1			1	1		**5**
2003.User education(4)														1	1	1					1	**4**
2000.Critical evaluation(3)											1	1									1	**3**
2004.Information ethics(3)															1				1	1		**3**
2001.Media literacy(2)												1									1	**2**
2008.Decision Process(2)																			1		1	**2**
2010.Adult learning(2)																					2	**2**
2008.Interactive learning environment(2)																			1		1	**2**
2005.Knowledge economy(2)																1				1		**2**
2007.Computer literacy(1)																		1				**1**

Appendix 66: Core Topic #21. Digital Library Education (5 subtopics) – Table of Publication Numbers by Years

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
1996.Digital Library education(General)(148)							2				2	8	9	12	24	21	24	20	8	10	8	**148**
2000.Digital Library program(20)											2		3	2		3	8	2				**20**
2003.Computer Science Education(9)														2	1	3	1	1		1		**9**
2002.Digital Library training(2)													1			1						**2**
2009.Digital Library Curriculum(1)																				1		**1**