

Applications of Thesaurus in Digital Libraries

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ABSTRACT

The purpose of this paper is to report the findings of a systematic literature review carried out to investigate the applications and potential roles of thesaurus in digital libraries. It also describes the process of systematic literature review (SLR) followed to carry out this study. 321 unique publications from Library and Information Science Abstracts (LISA) and Scopus had been subjected to SLR, and 29 papers have been analysed. Various possible applications of thesaurus in digital libraries have been identified and described. Also different approaches followed by researchers in choice of the thesaurus have been identified. Search and browse functionalities offered by thesaurus to the users of digital libraries are described. The discussion presented in this paper can play as cues for the digital library administrators in decision making towards implementing thesaurus for enhanced information retrieval. This study would allow researchers of information retrieval systems, including that of digital libraries, to proceed from more informed standpoints. Also, the discussion can be used to evaluate and improve education in library and information science.

Keywords: Thesaurus; Digital library; Digital information systems; Information retrieval; Knowledge organisation systems; Systematic literature review

1. INTRODUCTION

Research on digital libraries in last 20 years has thrived quite significantly. A title-abstract-keyword search on Scopus database (www.scopus.com) with exact phrase 'digital library' reveals a dramatic rise in the number of publications from 110 till 1995 to 5573 during 1996-2005; and to 11726 during 2005-2016 (Scopus). The major contributors to this arena are from computer science (63 per cent) and library and information science (26 per cent)¹. An important area of emphasis in digital library research, over the past decade, has been the issue of information retrieval. Recent developments in ontologies and other semantic technologies have great potential to address this issue²⁻⁶. However, in the context of information retrieval, traditionally, thesaurus has been successfully used in libraries and other information services for resource description and in providing access to resources. In recent years, implementation of thesaurus in digital libraries for enhancing information retrieval has been widely studied.

There is a growing body of literature that describes various applications of thesaurus in digital information systems, including digital libraries. However, most of the published work has been limited to local implementations. A few studies have investigated the current status of applications of thesaurus in digital repositories⁷⁻¹¹; however, they have been conducted as part of larger studies on applications of knowledge organisation systems. There has been no comprehensive study to characterise the generalised potential applications of thesaurus in digital

information systems. Moreover, other aspects associated with the application of thesaurus in digital libraries like use of other knowledge organisation/representation systems along with thesaurus, choice and availability of thesaurus, etc. have not been addressed. There has not been any comprehensive study of literature to capture and explain the potential applications of thesaurus in digital libraries; and to explain how it works in digital library architecture to assist users in information retrieval. The current study has been carried out to address the above issues related to the application of thesaurus in digital libraries.

1.1 Research Questions

The purpose of this research was to carry out a systematic literature review of the available literature on the applications of thesaurus in digital information systems with an aim to identify and to characterise its potential applications in digital libraries. Specifically, based on the evidences available in literature, it aims to explain how can the potentials of thesaurus be exploited in digital libraries. The primary research questions that drove this research are:

RQ1: How thesaurus can be used in digital libraries and what functionalities they can offer to the users?

RQ2: Whether readily available thesauri have been used in digital libraries? What other approaches have been followed by researchers in choice of the thesaurus?

RQ3: Whether other knowledge organisation / representation systems have also been used in digital libraries along with thesaurus?

1.2 Research Implications

The findings of this study should make an important contribution towards the practice of digital libraries. Administrators of digital libraries may use the findings in making more informed decisions towards implementation of thesaurus for indexing, searching and/or browsing. The findings may also enhance the understanding of the users of digital libraries about enhanced information retrieval functionalities provided by the application of thesaurus. Moreover, this study would allow researchers of information retrieval systems, including that of digital libraries, to proceed from more informed standpoints. Furthermore, the authors believe that a better understanding of above research questions may also allow educators of library and information science to improve from more informed perspective.

2. METHODOLOGY

Pertaining to the aim of the study and to find answers to the stipulated research questions, it was needed to find how thesauri have been used by researchers in digital libraries or in any other digital information retrieval systems. It was premised that research publications are one of the best sources to know the various aspects related to implementation of thesaurus in digital libraries. Based on this premise, a systematic literature review (SLR) method has been adopted for the study. Systematic literature review is ‘a specific methodology for conducting reviews of literature’¹² which is different from a general literature review as it is ‘conducted in a methodical (or systematic) and unbiased manner, according to a pre-specified protocol’¹³. Besides, it also provides a greater understanding of the current developments of the topic under investigation. Systematic reviews are primarily used in the medical field, and medical librarians were among the first in the library and information science field to adopt this methodology and apply it to library research¹⁴.

2.1 Selection of Bibliographic Databases

To find how thesauri have been used in digital libraries, identification of relevant publications was essential. For this, it was warranted to identify appropriate bibliographic databases. Library and Information Science Abstracts (LISA) (<http://proquest.libguides.com/lisa>), being the most renowned and largest online abstracting and indexing platform for library and information science field, has been selected as the first choice. However, since majority of research on digital libraries are done by researchers and practitioners from computer science¹, Scopus (www.scopus.com) has also been selected as it widely covers publications in computer science.

2.2 Query Formulations

To find relevant results pertaining to the aim of the study, search terms ‘thesaurus’ and ‘digital library’ were used with Boolean operator ‘AND’ to search both the selected databases in title-abstract-keyword. To this, while Scopus returned sufficient results (248), LISA resulted very less (70). To get sufficient references from LISA, the initial query has been broadened; one more query has been formulated by replacing ‘digital library’ with ‘digital’ to search LISA. Since the number of results to this broadened query from Scopus were too large to be included in the current study; they were not included.

2.3 Searching

Table 1 displays the summary of the results for the respective queries searched on LISA and Scopus. After limiting the results to English language, record were exported in research information systems (RIS) file format so as to import and manage in Mendeley Reference Manager. Total 162 record were exported from LISA and 238 record from Scopus.

2.4 Merging and De-Duplication of Records

Records from both the exported RIS files were imported in Mendeley. After automatic de-duplication of records by Mendeley, 347 records were imported which in turn became 321 after manual de-duplication using Mendeley. Thus, 321 publications had been subjected to a screening process.

2.5 Screening

To determine the relevance of above 321 publications pertaining to the aim of the study, inclusion and exclusion criteria were developed. The criteria used for screening are presented in Table 2. Initially, ‘title’ and ‘abstract’ of each record has been reviewed in view of the stipulated criteria and 112 record were included for full-text review. After collecting full-texts of included 112 publication, they were reviewed in view of the stipulated criteria to determine its relevance to the study; and finally 29 publication were selected for data extraction and analysis.

2.6 Data Extraction and Analysis

A data collection schema, as presented in Table 3, was designed in Excel worksheet to extract data from selected publications. After extracting data from all the 29 publications, descriptive content analysis had been carried out. The findings towards answering the research questions are discussed in detail in the following section.

Table 1. Numbers of search results from LISA and Scopus

Search query	LISA			Scopus		
	Results	English	Exported	Results	English	Exported
‘Thesaurus’ AND ‘digital library’ in title-abstract-keyword	70	60	60	248	238	238
‘Thesaurus’ AND ‘digital’ in title-abstract-keyword	153	102	102	Not included	Not included	Not included

3. FINDINGS AND DISCUSSIONS

As mentioned in the introduction of this paper, this study was set out with an aim to find answers to three primary research questions. Question-wise findings with necessary discussions are presented in the following sections.

3.1 RQ1: How Thesaurus can be used in Digital Libraries and what Functionalities they can Offer to the Users?

The current study found that thesaurus can be used in three major activities/functions of digital libraries – indexing, searching and browsing. Whilst the majority of identified literature (13 paper) have used thesaurus in browsing and searching only, a significant number of literature (7 paper) have used in all three functions i.e. indexing, searching and browsing. Moreover, equally significant number of papers (6) have used thesaurus in searching only; and, three papers have used in indexing and searching both.

Potential applications of thesaurus in digital libraries are listed below. Followings sections provide description of various applications along with examples from reviewed research publications.

- (i) Indexing: achieving consistency in metadata creation;
- (ii) Enhanced browsing: browsing digital library collections through thesaurus terms;
- (iii) Enhanced searching: query formulations using thesaurus terms for high precision information retrieval;
- (iv) Search term recommendation (STR) system; and
- (v) Automatic query expansion.

3.1.1 Role of Thesaurus in Indexing

Digital libraries describe its resources by using metadata schemes like Dublin Core (DC) Metadata Scheme ([http://](http://dublincore.org)

dublincore.org), Electronic Theses and Dissertations – Metadata Scheme (ETDMS) (<http://www.ndltd.org/standards/metadata>), etc. Each metadata scheme necessarily provides element to describe subject contents/keywords. For example, both DC and ETDMS have element ‘dc.subject’. The current study found that thesauri have been used to achieve consistency in metadata creation; primarily for subject/keyword description. For example, Shirii¹⁵, *et al.* used UNESCO thesaurus in their High Level Thesaurus (HILT) project; Binding and Tudhope¹⁶ used Art and Architecture Thesaurus (AAT) to index an extract of the UK National Museum of Science and Industry (NMSI) collections in their project. Torres and Reis¹⁷ used a textual thesaurus in their conceptual image retrieval system for representing the conceptual information; and Petrič¹⁸, *et al.* used three thesauri to represent the institutional program, ranking keywords and user profiles for their retrieval system. Moreover, thesauri have also been used to create consistent place names. For example, Getty’s Thesaurus of Geographic Names (TGN) has been used by Dalmau¹⁹, *et al.* for place names. Thesauri have also been used to describe both subject and place names in the same system. For example, Soo²⁰, *et al.* used Mandarin Chinese Thesaurus for describing names of historical figures, articles, locations, countries, etc.

3.1.2 Role of Thesaurus in Browsing

Perhaps, the most noteworthy finding of this study is that thesaurus can greatly enhance browsing experience in digital libraries. Thesaurus terms may be displayed on the interface to assist users in directly retrieving documents, in query formulation and also in query refinement/expansion. In this context, the current study identified two different approaches of presenting thesaurus terms on the interface for

Table 2. Inclusion/exclusion criteria for selecting publications for full-text review

Include	Exclude
<ul style="list-style-type: none"> • Publications that describe practical implementation of thesaurus in digital library/environment. • Publications that describe development of prototype or model for implementing thesaurus in digital library/environment. • Publications that propose model for implementing thesaurus in digital library/environment. 	<ul style="list-style-type: none"> • Publications that only focus on development of thesaurus. • Publications that describe on only the process of automatic development of thesaurus. • Publications that focus only on interoperability or mapping of thesaurus. • Publications that do not describe application of thesaurus in digital library/environment

Table 3. Data extraction schema

Fields	Description
Identifier (citation) of Publication	Proper citation of publication with detailed reference at other place
Implementation Status	Whether thesaurus has been implemented; or prototype developed; or model developed or proposed
Choice of thesaurus	Whether readily available thesaurus has been used; or available thesaurus has been modified; or new thesaurus has been developed; or thesaurus has been automatically developed
More than one thesaurus	Whether more than one thesaurus have been used
Name/s of thesaurus	It refers to name/s of thesaurus used
Purpose/Role of thesaurus	What is the purpose of thesaurus in digital libraries?
Where does it fit and how does it work on the user interface?	Where does thesaurus fit in the digital library or digital information system? It refers to the functionalities offered by thesaurus to the end users
Application of other KOS?	Whether any other knowledge organisation system (KOS) has been used along with thesaurus. If yes, how?

browsing the resources. In first approach, thesaurus terms are not displayed on the interface in the first instance, rather they are presented along with the results in relation to the search query. Users can either go to the results or can browse through related terms of the thesaurus displayed as suggested terms on the interface²¹⁻²⁶. In second approach, in addition to what is achieved in the first approach, thesaurus terms are displayed on the interface along with a search window; users can either start retrieval process by clicking on thesaurus terms or they can enter a query in search window^{15-19,27-34}. With respect to the implementation of thesaurus in enhanced browsing, it was found that a representation of thesaurus terms may be presented as hyperlinks or nodes on the interface^{27,34}; users can see the associated resources by clicking on a node. These nodes can also be used to show levels of hierarchy by showing the term's classification²⁷. Moreover, thesaurus can also be used to design visual interfaces for browsing digital collections^{17,32,33}.

3.1.3 Role of Thesaurus in Searching

Another significant finding of the study is that thesaurus can be used to significantly improve searching mechanism of a digital library. In this context, two important approaches have been identified during the analytic process - 'search term recommendation' system and 'automatic query expansion' which are described below separately.

3.1.3.1 Thesaurus in Search Term Recommendation System

As mentioned in the previous section, thesaurus terms can be displayed on the screen before or after a query has been entered in the search box; users can choose the thesaurus terms and, in turn, associated results are displayed. Apart from this, it is also possible to suggest relevant thesaurus terms for users' consideration in refining a query³⁵; this is known as search term recommendation (STR). STR is used for query formulation or query expansion by the users. Gordon²⁸ developed a browsing-based photograph retrieval system where thesaurus terms are presented on the interface so that users can browse the collection. Nakashima³⁰, *et al.* used thesaurus for document arrangement to assist users by suggesting which documents are worth examining. Digital libraries may also provide its users an option to formulate queries by consulting thesaurus; and can also suggest alternatives from thesaurus if users do not use thesaurus in query formulation and if their search term do not match with thesaurus²⁵. Thesauri have also been used to identify and display other documents relevant to the query in context³⁶. Moreover, other statistical tools have also been used in thesaurus-enhance information retrieval. For example, Shiri and Revie²⁴ have developed a system which shows 'exact match' in response to the initial query if user's term exactly matches thesaurus term, or shows 'permuted index match' if there is partial match and if there is no match then shows 'statistical match' through statistical analysis.

3.1.3.2 Thesaurus in Automatic Query Expansion

In this approach, thesaurus terms are not displayed on the screen rather they are used behind the interface to expand the query automatically. While searching, related thesaurus

terms are identified for each query term and are added to the query terms before searching the database³⁷. In this context, while use of narrower terms (NT) has been found to be more common among researchers^{19,25,29,38}, use of broader term (BT) and associative thesaurus relationships (RT)³⁵ have also been found. In addition to using thesaurus in automatic query expansion, few researchers have also applied other techniques related to search algorithms like stemming, vector space model, Jaccard similarity measure, etc. For example, Bakar and Rahman³⁷ have used an in-house developed thesaurus together with stemming technique. Lüke²², *et al.* have used a thesaurus to process the queries and Jaccard similarity measure to rank the results. Along similar lines, Da Silveira³⁸, *et al.* have used the classic vector space model for ranking results along with a judicial thesaurus in query processing. Their system maps the query into the terms of the thesaurus and automatically retrieves narrower terms (NT) before searching the database; vector space model is later applied in ranking of results.

3.2 RQ2: Whether Readily available Thesauri have been used in Digital Libraries?

The current study found that readily available thesauri like UNESCO thesaurus, Getty Art and Architecture Thesaurus (AAT), ERIC Thesaurus, AGROVOC, etc. have been used in digital libraries. Majority of researchers (16 papers) have used readily available thesaurus; however, other approaches in choice and selection of thesaurus have also been identified. Instances have been found of using in-house development of thesaurus (4 papers); automatic development of thesaurus (3 papers); and modifying the available thesaurus (3 papers). Moreover, the review also found that there are nine instances where more than one thesauri have been used^{15-19,26,27,35,39,40}, out of which two^{16,39} have implemented both readily available thesaurus and in-house developed thesaurus in single digital information system.

3.3 RQ3: Whether other Knowledge Organisation /Representation Systems can also be used in Digital Libraries along with Thesaurus?

Ten instances have been found where thesaurus has been used along with other knowledge organisation/representation systems. Thesaurus has been used along with other traditional knowledge organisation systems like 'authority files', 'taxonomy', 'classification scheme', 'subject heading lists'; and also with relatively modern knowledge representation systems like 'ontology' and 'semantic web (tools)'.

3.3.1 Thesaurus with other Traditional Knowledge Organisation Systems

Thesaurus and other traditional knowledge organisation systems have been used by different researchers in different ways and for different purposes. Few of them have used traditional KOSs for its simplest possible application in digital information systems. For example, Dalmau¹⁹, *et al.* have used Library of Congress Name Authority file for personal and corporate names and Getty's Thesaurus of Geographic Names (TGN) for place names. Petric¹⁸, *et al.* used Universal Decimal Classification system to systematically arrange documents and

the pages of a pilot web library and more than one thesaurus to organize data in the database. Moreover, a couple of researchers have also used these KOSs in automatic processing of query. For example, a classification system – ‘classification of social sciences’ and a thesaurus – ‘TheSoz’ have been used together by Lüke²², *et al.* to automatically create discipline specific document sets. Along similar lines, Nakashima³⁰, *et al.* have used ACM Computing Classification System (CCS), Medical Subject Headings and ASIS Thesaurus of information science for query and document processing during automatic query processing. Apart from above approaches, Shirii¹⁵, *et al.* have used Dewey Decimal Classification and Library of Congress Subject Headings along with two thesauri - the UNESCO thesaurus and the MeSH thesaurus - for searching and browsing across digital collections.

3.3.2 Thesaurus with Modern Knowledge Organisation/Representation Systems

The current study found a couple of distinctive usage of thesaurus in ontology building and in developing automatic semantic processes for digital information systems. For example, Alani³⁵, *et al.* have developed an ontology by linking Getty AAT and TGN thesauri for thematic descriptors and for spatial data respectively. Feki⁴¹, *et al.* have used thesaurus to develop an automatic semantic process to extract different meanings for a given text query in an image retrieval system. Feki⁴¹, *et al.* have also developed another semantic process which creates a dynamic list of concepts based on earlier queries entered in to the search system.

4. CONCLUSIONS

This study was set out to systematically review the available information on the applications of thesaurus in digital information systems in order to identify and characterise the potential applications of thesaurus in digital libraries. The systematic review provided evidences for successful implementation of thesaurus in various types digital information systems.

The study has identified three primary applications of thesaurus in digital libraries – achieving consistency in indexing digital resources; providing thesaurus based browsing; and thesaurus enhanced searching. Thesaurus based browsing and searching generally goes side by side. Two distinctive and significant concepts related to the application of thesaurus have been identified – search term recommendation and automatic query expansion. Whilst, thesauri have been used to develop text-based browsing interfaces for digital libraries, it has also been used to create visual interfaces for browsing. The study also found that readily available thesauri like UNESCO thesaurus, Getty Art and Architecture Thesaurus, ERIC Thesaurus, AGROVOC, etc. have been used in digital libraries. Moreover, to suit requirements of individual systems, available thesauri may be modified; or a new thesaurus may be developed; or it can also be generated automatically. Thesaurus, on one hand, can be used along with other traditional knowledge organisation systems like taxonomy, subject heading lists, etc.; and on the other hand, with modern knowledge representation systems like ontology and semantic (web) tools. Moreover,

thesaurus can also be used to develop ontology to be used in digital information systems.

The evidences found in this study suggest that thesaurus is equally effective in digital information retrieval systems. It has great potential to effectively describe and organise digital resources; and to provide better browsing and searching mechanisms to the users of digital libraries. These findings have significant implications for digital library administrators in deciding to exploit the potentials of thesaurus for enhanced information retrieval. Moreover, it can also serve as cues for improving education of library and information science.

While the findings of this research provide insights into what is known about the implementation and applications of thesaurus in digital libraries, it would be interesting to assess the current status of its applications in existing open access repositories. What is now needed is a cross-national study involving administrators of digital repositories to assess the current status of its applications in practice. Also, it would be interesting to carry out another systematic review on evaluating the effectiveness of thesaurus.

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In the current study, the systematic review of literature has been carried out by him.

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