Query Management Techniques and their impact in Digital Libraries

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ABSTRACT: *This paper reports an investigation of the search behaviour patterns of nanoscience and nanotechnology searchers as revealed by transaction log analysis of the NANOnetBASE electronic book digital library. In particular, it examines the search and query reformulation patterns and strategies of nano searchers. The results show certain query formulation and reformulation patterns associated with searching in an emerging and interdisciplinary area of nanotechnology such as: the use of multiword and compound query terms, extensive use of search terms beginning with the prefix 'nano', hyphenated terms, spelling variations, a large number of query reformulations, and the use of acronyms.*

Keywords: Electronic records, records management, records management standards, documentation, digital information

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1. Introduction

Nanoscale science and technology has seen rapid growth and expansion in new areas in recent years. A key challenge faced by nano researchers as well as the information professionals providing related information services is to efficiently identify information resources and to carry out inclusive and effective searches in a diverse and heterogeneous range of digital libraries, web-based databases, and search engines. It is essential to understand the problems and issues of interdisciplinary searching in a strategically and commercially significant area such as nanotechnology to support and enhance researchers' scholarly productivity and innovativeness, and to inform knowledge organization and representation practices in nanotechnology-related library and information services. Kutner [1] in examining challenges and issues in searching in interdisciplinary areas, argues that although electronic bibliographic databases that provide sophisticated searching capabilities and multiple access points to the scholarly literature have been a boon to the interdisciplinary researcher, problems continue to exist in terms of lack of consistent interfaces and consistent controlled vocabularies across databases. While there exist many studies of general information seeking behaviour of interdisciplinary areas of humanities, the sciences, women studies, and social sciences, very few studies have examined the nature of queries and query formulation and reformulation strategies of interdisciplinary searchers in nanoscience and technology.

2. Related work

The literature on the information search behaviour of nanoscience and technology information searchers is scarce. Most information science studies published relating to nanoscience and technology focus on citation analysis, scientometric, and bibliometric studies of journals and publications in the field of nanoscience and technology [2], mapping and visualization of the area of nanoscience and technology [3], and identifying core journals in the area of nanotechnology [4]. Citation analysis studies have also been conducted to show the interdisciplinarity of other scientific areas such as medical and behavioural sciences [5], environmental sciences [6], and chemical engineering [7]. Bates [8] argues that studying researcher information seeking in interdisciplinary fields may tell us not only about the needs and problems of people in those fields - something we very much need to learn about - butalso about what factors, in general, contribute to ease and difficulty in scholarly

information seeking. She notes that interdisciplinary researchers constitute a significant and distinctive class of scholars, much deserving of research on their particular information needs and information -seeking behavior. Many other researchers have investigated the challenges and issues of searching in interdisciplinary areas [1, 9-11].

Transaction log analysis has been employed to study users of web search engines [12-13], OPACs [15], library websites [16], digital libraries [17-18], and electronic journals [19]. Jansen [20] presents transaction log analysis as a methodological framework along with strengths and limitations of this method in research.

The objective of the present study was to investigate the search behaviour patterns of nanoscience and technology searchers by analyzing the transaction logs of a nanoscience and technology e-book digital library. A specific objective of this study was to examine the query reformulation strategies and other search behaviours to establish if there are any certain patterns associated with interdisciplinary searching in nanoscience and technology.

3. Methodology

The methodology section provides a description of the research questions, the digital library used by the searchers, details of the transaction logs and the data analysis approach.

3.1 Research questions

The research questions addressed in this study are as follows.

• What are the search behaviour characteristics of nano searchers, including session length, query characteristics, and the use of query operators?

•What query formulation and reformulation strategies did users employ? What were the main reasons for query reformulation?

•What search strategies were adopted by the users (e.g., basic vs. advanced search features, failed and erroneous queries, and spelling issues)?

3.2 The NANOnetBASE E-book Digital Library

NANOnetBASE is an e-book database for nanotechnology and nanoscience researchers consisting of 45 titles that can be accessed in a variety of ways. Researchers can browse titles from subject lists (e.g., Biomedical Engineering, Computer Engineering, Electrical Engineering, Electrical Engineering Communications, Electronics, General, Industrial Engineering & Manufacturing, Laser & Optical Engineering, Mechanical Engineering, and Nanoscience/Nanotechnology) or search within all titles using keywords.

3.3 Transaction log dataset

The data used in this study consisted of transaction logs from the NANOnetBASE digital library between July 2004 and October 2006. The data was acquired from a large Canadian university with strong nanoscience and technology research profile where more than 140 nano researchers are currently active. They include faculty members as well as graduate students and post-doc researchers. In total, 1921 transactions were analyzed. Table 1 provides a sample of transaction logs that were analyzed in the study. The table has the following four columns:

• Date and time of activity.

• User identifier (in the form of IP address).

•Activity detail (query or book viewed).

•Activity type: book viewed, advanced search, quick search, search results viewed, or managed account information.

3.4 Data analysis

The data analysis was based on Jansen's [20] transaction data analysis method which includes term level, query level, and session level analyses. Before the transactions were analyzed, the transaction logs were converted into a spreadsheet to facilitate data manipulation.

Term level analysis: the number, nature, and frequency of user terms.

NANOnetBASE

Activity Type	Activity Detail	User Identifier	Date & Time
Book Viewed	Nano Science and Technology: Novel Structures and Phenomena	129.128.217.125	7/30/2004 4:17:50 PM
Advanced Search	Wright, Patrick	129.128.198.21	9/17/2004 11:09:14 AM
Book Viewed	Handbook of Nanoscience, Engineering, & Technology	129.128.217.4	9/17/2004/1:34:31 PM
Book Viewed	Handbook of Nanoscience, Engineering, & Technology	129.128.216.76	9/22/2004/9:20:42 PM
Book Viewed	Nanoelectromechanics in Engineering and Biology	129.128.216.76	9/27/2004/5:46:32 PM
Advanced Search	Vacuum	129.128.216.76	9/28/2004/1:47:06 AM
Quick Search	Vacuum	129.128.216.76	9/28/2004/1:47:06 AM
Search Results Viewed		129.128.216.76	9/28/2004/1:47:06 AM
Book Viewed	Nanoelectromechanics in Engineering and Biology	129.128.216.76	9/28/2004/4:33:10 AM

Table1. Snippet from a sample transaction log

Query level analysis*:* includes query characteristics as follows:

• Query formulation and reformulation (and the reasons for query reformulations),

• Query construction strategies (use of Boolean operators, quick vs. advanced search strategies etc.),

Session level analysis: includes session length and the type of interactions users had with the system (e.g., time spent on formulating and submitting a query and time spent on viewing the results).

4. Results

The results and findings presented here are based on the order of the research questions.

4.1 Session length

Jansen et al. [21] noted that a *session* is the entire series of queries submitted by a user during one interaction with the Web search engine. This definition was taken into consideration while analyzing the dataset in this study. Session length information for the dataset was only available for the years 2005 and 2006. Table 2 shows the average time spent on each search step by an individual user; the overall search session length ranged from 30 seconds to more than 6 hours. This result should be contextualized by the fact that this is in a digital library that is an electronic book digital library with more than 44 titles. Some users spent more time on consulting the content than querying. The time spend on each query averaged 2 minutes and fifty-one seconds but users spent more time looking at particular books and also viewing the results of their searches.

It is important to note the difference between the average session of 1 hour 51 minutes and the individual activities that occurred during the sessions; that is, most users performed several activities during their interaction with the system. Users who chose to limit their session to one single action normally viewed a single book. Of the 187 sessions, 161 of these involved viewing a book. This is not surprising since it reflects the nature of the digital library resources itself.

4.2 Query terms

The average number of terms used per query was 2.11; the maximum terms used was 8. Most users were looking for subjects

Activity type	Time spent
Average Session	1:51:00
Average Query	0:02:51
Average Book Viewed	0:08:04
Average Search Results Viewed	0:05:57

Table 2. Search session length

Number of terms used in queries	Number of Queries	Percentage of Queries
1	156	40%
2	137	35%
3	53	14%
4	19	5%
5	9	2%
6	13	3%
7	3	0.76%
8	3	0.76%
Total	393	

Table 3. Number of terms in queries

and their queries reflected looking for subjects in a direct away. For example, if someone was looking for information about how 'textiles' are used in nanotechnology, the query would be simply 'textile'. Queries with more terms tended to be searches for book titles which are usually longer than one or two words.

Table 3 shows that approximately 60% of queries consisted of two or more terms. This finding is particularly interesting when compared with previous studies that found users tend to use very short queries. This can be explained by the very specific coverage of this digital library and , based on closer examination of queries, that nano researchers tended to start with very specific but long, multi-term queries and then reformulated their queries if they were considered to be too restrictive in terms of retrieval. A hypothesis could be formulated to test whether interdisciplinary searchers tend to formulate longer queries than disciplinary searchers.

4.3 Search strategies

One advantage to using transaction logs is the ability to see the entire search process. After performing a query, the user receives search results from the NANOnetBASE with the following information: number of times the search string appears in the document and a list of documents (usually chapter titles) indicating book title, authors, and file size. Unfortunately, there is little context for the user to determine whether retrieved results are actually relevant without opening the document itself. No abstract or brief annotation is provided for any of the documents found. The search process begins with the query. During the time period of this study, most users started with a quick search easily carried out from the homepage. It is interesting to note that in 2005 the number of Advanced Searches and Quick Searches performed were almost equal (i.e., 94 Advanced Searches and 90 Quick Searches) but Quick Searches were far more popular in 2004 (almost twice as many) and 2006 (almost four times as many). It is also interesting that most users did not move from Quick Search to Advanced Search but preferred to reformulate their search within the search type they started with This may suggest that the advanced search functionality was not viewed as desirable, relevant, or intuitive to the users. NANOnetBASE has many search functions including single character, stemming, fuzzy search, phonic search, synonym search, numeric range, and variable term weighting. These search functions, however, are not well-used by users of this database. Only 22 queries out of 393 used any advanced search functions and the majority of these just used Boolean. Table 4 provides a summary of various search strategies adopted by searchers along with the frequency of those strategies in the dataset.

Although the '?' character can be used to match any single character, no queries in this dataset used it. Furthermore, there were no uses of stemming, fuzzy search, phonic search, synonym search, numeric range, or variable term weighting. Among the variety of reasons users chose not to use these functions could be a lack of understanding how they work, inaccessibility of descriptions or instructions, reliance on Quick Search where those functions can be used but are not promoted in any obvious way, the simple and easy access to free text searching, or users' frustration when advanced search features retrieve

no results. Interestingly, many consecutive searches revealed users searching for single and plural versions of the same word so the use of wildcard characters or truncation has potential timesaving benefits.

Search features	No.
Queries using advanced search functions	22
Queries using more than one advanced search function	4
Queries using 2 advanced search function	4
Queries using Boolean operators	20
Queries using AND	19
Queries using OR	1
Queries using phrase searching	4
Queries using parentheses	1
Queries using truncation	1

Table 4. Search strategies

4.4 Search for acronyms

About 10% of the queries made use of some form of acronym. This suggests that like many scientific fields, acronyms are a commonly-used and intrinsic language form within the literature of nanoscience and technology. Table 5 shows the extent of the use of acronyms in the searches.

Queries containing acronyms	% of 393 queries
Queries using acronyms	9.67
Queries using 1 acronym by itself	4.33
Queries using acronyms and full form	4.58
Queries using 2 acronyms	0.76

Table 5. Queries using acronyms

Query details	No. of queries
Number of sessions	552
Total number of queries	393
Total number of reformulated queries	155

Table 6. Number of Initial and reformulated queries

The search function of NANOnetBASE does not handle acronyms intelligently so users must know and use their full forms as well. If an acronym is entered only a small number of results are retrieved because the system does not offer simultaneous fullform and acronym searches to make the document selection process easier. To ensure that all relevant documents are retrieved, users must combine the acronym with its full-form equivalent using the Boolean operator OR.

4.5 Query reformulation

A key question of this research was to examine how users reformulated their queries and the reasons for doing so. Query reformulation can be interpreted in a variety of ways. For instance, adding terms to the initial search terms is considered to be query expansion whereas dropping any terms from the initial query terms would be considered query refinement or modification. Through the analysis of users' terms and the various ways in which they reformulated their initial queries, we identified a number of query reformulation strategies discussed in this section. Table 6 shows basic statistics about the number of total queries and the reformulated queries in the analyzed dataset. One important observation is that approximately 40% of queries were reformulated.

Table 7 shows types of reformulation strategies and the number of reformulations carried out by users. One interesting pattern was the use of phrases in searching and many reformulated queries were, in fact, the result of phrase searching. The

'major shift' category refers to a reformulation strategy where the user tries a new query related to the initial query but not by any hierarchical or semantic relationships. 'Expansion' and 'major shifts' queries constitute 37% of the 155 total reformulated queries. Also, 37% of reformulated queries were hierarchically or synonymously related to the initial queries.

Reasons for query reformulation	**No of instances**
Query changed (spelling errors)	9
Query expansion (additional terms added)	32
Major shifts	38
Query narrowed (narrower term used)	21
Query broadened (broader term used)	26
Query restructured (query terms moved around)	6
Synonymous terms used	23
Total	155

Table 7. Type and number of reformulation strategies

Figure 2 provides a graphical representation of the reasons for query reformulation and the number of instances for each reformulation reason.

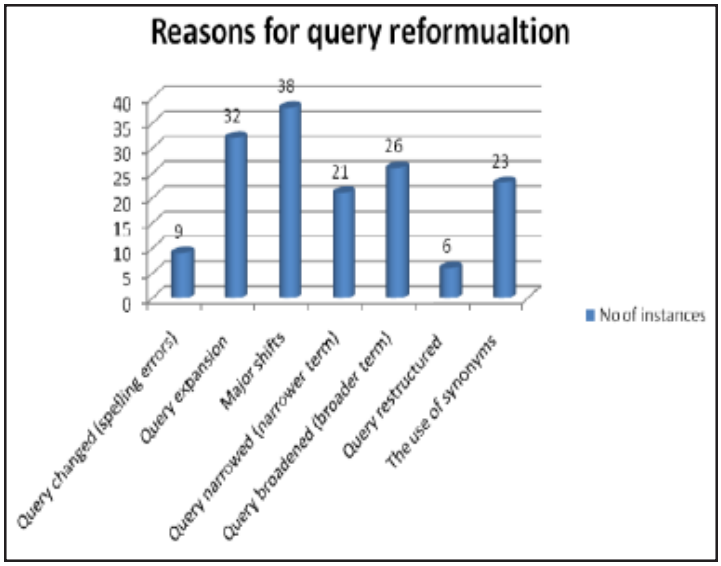

Figure 1. Query reformulation strategies

One interesting observation regarding the nature of the queries submitted by nano searchers was that of 132 terms starting with the prefix "nano," a few were very general (e.g. nanotechnogy or nanoscience) but most represented very specific query terms; for example, 'nano-onion',' nonoparticle', 'nanofabrication', 'nanotubes', and 'nanocones.' Due to a lack of consistency in the ways these terms appear in different documents (e.g. sometimes hyphenated, sometimes not), some searchers were not successful at retrieving any documents or in some cases the searcher decided to use either hyphenated or without hyphen forms.

5. Discussion

Interdisciplinary searching in the area of nanotechnology is an interesting topic as it sheds light on the ways in which knowledge organization systems, digital libraries, portals, and other web services can be developed. Session length indicates

the level of users' engagement and also their interaction with the system. Jones et al. [17] suggest that over half (54.34%) of user sessions they studied had a duration of five or fewer minutes while two thirds (66.43%) had a duration of ten minutes or less. Marchionini [22] reported that many researchers use 30 minutes as a sensible idle time interval for a session delimiter. Spink and Jansen [23] noted that the mean session time associated with an identifier was more than two hours for some search engine datasets but most sessions lasted less than 15 min. Wolfram [24] found that users were more likely to engage in extensive searching using the OPAC and specialized search system as compared to search engines and bibliographic databases. In the present study, session length was found to be in line with those from Wolfram and Spink & Jansen; the average session lasted for an hour and fifty-one minutes. This finding should be viewed in light of users interacting with an electronic book digital library so a significant amount of time was spent viewing individual electronic books. It can be argued that, in the context of electronic book libraries, users generally spend more time compared to OPAC searches, search engine use, and bibliographic databases consultation.

Number of terms per query and query length represent search behaviour characteristic of interest to researchers. Jansen et al. [21] reported 2.35 average number of terms per query for Altavista search engine users. Wolfram [24] found that query length varies in different web-based information retrieval environments; users tend to formulate shorter queries in bibliographic databanks or specialized search services (1.81 and 1.78 terms per query respectively) and longer queries when using OPACs or search engines (3.66 and 2.62 terms per query respectively). In the present study the average number of terms per query was 2.11. An interesting observation in this study was that approximately 24% of queries had three or more terms. This can be explained by users carrying out searches in an electronic book collection specific to the area of nanoscience and technology where uses could formulate very specific but sometimes long and hyphenated queries. This that some queries formulated by nano researchers are multifaceted and are more sophisticated compared to queries submitted to general search engines.

In total, 22 queries made use of Boolean operators but it must be noted that the interface does not explicitly provide search options using Boolean operators, thus partly explaining the limited use. Gerhard et al. [25] note that despite keyword, Boolean, and other sophisticated search techniques making it easier to access interdisciplinary and newly emerging bodies of literature, poorly constructed keyword searching still results in the retrieval of much irrelevant material. In this study query reformulations and consecutive searches were related to the poor performance of keyword searching. A close examination of users' queries showed that approximately 10% of their queries included some form of acronym. Because nanotechnology queries may represent multifaceted and interdisciplinary search terms, the use of acronyms should be considered one search strategies that digital libraries in this field must support. In the present study, users showed variability in their use of search terms, including American and British spellings. The matching algorithm and the interface should be designed to support users by providing cross references for variant spelling forms and acronyms, particularly the disambiguation of homographic acronyms such as 'PVD' to distinguish between *Physical Vapour Deposition* and *Peripheral Vascular Disease.*

One key search strategy that can be used to infer users' search patterns and behaviours is query reformulation. The analyzed data showed that approximately 40% (155 of 393) of the queries were subject to reformulations. Some of the reasons for query reformulations were spelling errors, hyphenated and combined words, narrowing the search, broadening the search, restructuring the query, and use of phrase searching and synonyms. The reformulation reasons noted earlier indicate that nanotechnology information searchers require terminological support to carry out successful reformulations and to explore the conceptual structure of the collection. The use of multiword search terms and the order of the terms pose a challenge to nanotechnology searchers in terms of formulating queries. It is of particular importance that the interface and the search system be flexible enough to guide the user throughout the search process. Interactive term suggestion facilities based on the document collection can alleviate this problem.

Braun et al. [26] analyzed the early growth of nanoscience research during 1986-1995 and counted the occurrence of nano-prefix terms in the title of journal papers; they found 4152 such papers during 1985-1995 which indicated a fast growth rate. Schummer [27] measured the growth of "nano-titlepapers" in terms of annual growth rate and doubling times in different bibliographic databases and various disciplines. In the present study, approximately 132 of the search terms used had the prefix 'nano,' thus stressing the importance of incorporating ways to handle these terms by the search system.

6. Conclusion

This study was based on an analysis of transaction logs from an electronic book digital library in the area of nanoscience and technology. The results show that there are certain patterns associated with searching in an emerging and interdisciplinary

area of nanotechnology. Examples of these patterns are the use of multiword and compound query terms, hyphenated terms, spelling variations, query reformulation, and the use of acronyms. One hypothesis that can be formulated based on this study is that interdisciplinary searchers tend to carry out more query reformulation and modification compared with disciplinary searchers. This hypothesis should be tested through user-centred studies. Other findings suggest that the use of acronyms and full form of terms should be accommodated to allow users to disambiguate their search terms; the user interface/system should provide opportunities to use either hyphenated or non-hyphenated words without penalizing the user by zero hits. The NANOnetBASE user interface does not provide query reformulation or modification facilities. Interdisciplinary digital library services should offer interactive query reformulation support such as term suggestions or a document collection map as well as ranking algorithms that account for the importance of query terms in various disciplinary or interdisciplinary documents. This area also calls for revisiting information organization and representation strategies based on the notion of disciplinarity. For instance, subject terms can be categorized, contextualized, and presented based on their relevance and importance in different disciplines. If we can prove that some queries are more interdisciplinary than others, then it should be possible to design algorithms that match terms to documents based on disciplinary or interdisciplinary focus. The interface could then categorize and display the retrieved results based on the degree of interdisciplinarity or the dominant disciplines that have a higher degree of association with the terms searched. This study was limited to transaction log analysis and did not involve real users. Further research should examine the interdisciplinary search behaviour of real users and their perceptions and impressions of their research topics, search terms, and vocabulary problems.

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Case Studies in Digital Libraries. The Impact of ICT on Library Services for the Visually Impaired Young Sook Lee . . . 44. An Asian Study of Healthcare Web Portals: Implications for Healthcare Digital Libraries. Yin-Leng Theng, Eng-Soon Soh . . .Â Ontologies and Content Management in Digital Libraries. A Standards-Based Approach for Supporting Dynamic Access Policies for a Federated Digital Library. K. Bhoopalam, K. Maly, F. McCown, R. Mukkamala, M. Zubair . . . .Â Evaluating the Eectiveness of a Collaborative Querying Environment Lin Fu, Dion Hoe-Lian Goh, Schubert Shou-Boon Foo . . . 342. Opinion Leader Based Filtering Hyeonjae Cheon, Hongchul Lee . . . This growing focus on the accessibility of digital resources will undoubtedly impact the role of library professionals. Librarians will be challenged to â€œlearn new skills to be able to implement the new technologies for learning, research and information for their patronsâ€.Â Innovations will also lead to advancements in digital data management that will result in more accurate subject search results and citations while enabling libraries to more effectively curate and display relevant resources. These new innovations will significantly improve the way patrons discover content, making it more accessible and relevant to them. Re-thinking library spaces. The Horizon Report also identifies a shift in how students now use their libraries. uments and their contents using XQuery. The proposed.Â Historical queries represent an excellent example of the. ability of digital libraries to enhance content delivery ser-. vices well beyond those of traditional libraries. Our ICAP.Â The project libraries will have the same beneficial impact on data analytics that scientific libraries such as PETSc, MPI and ScaLAPACK have had for supercomputer simulations. These libraries will be implemented to be scalable and interoperable across a range of computing systems including clouds, clusters and supercomputers. [more].Â In this paper, we present e-cient techniques for man- aging multiversion document histories and supporting powerful [Show full abstract] temporal queries on such documents. Creating a digital library takes time, effort, and resources, but the tools are available, thanks to the popularity of the digital movement. In this panel discussion, three experts in the field of librarianship will share their views on the role of the librarian in providing tools and guidance to create and manage a digital library. 4. Introducing Our Panel. A Climate of Demand: The shift from traditional print collections to the emergence of eBooks and demand-driven acquisitions. Laura Costello, Head of Research & Emerging Technologies Stony Brook University. Altmetrics and Research Support: