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Making Sense of The Retrieval Effectiveness of Web Search Engines

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This is a review of the literature covering the retrieval effectiveness of Internet Search Engines. Literature is reviewed under appropriate headings and subheadings and includes mostly literature published from the 1990s onwards. The sources consulted for the purpose of this literature review were mostly journals though relevant websites were also accessed. The more used journals were *Information Today* and *JASIS*.

Keywords: ***Internet, Search Engines, Retrieval Effectiveness, Evaluation, Information Retrieval, Queries, Searchers.***

0 INTRODUCTION

A person venturing into the Internet will find no dearth in the number of services set to help him. The web is crawling with search sites vying to show us the way. Conservative estimates put the number of search tools at over 8000 including pure search engines, general and special interest directories and metasearchers. (Zetter and Mc Cracken, 2000). Since the Internet revolution began, frequent coverage on search tools has been found in both established computer magazines and new publications. Researchers have been comparing the retrieval effectiveness of Internet search tools for the last decade now and the number of studies is growing by the day. This is an analytical review of the literature available on the subject.

1 CHOICE OF SEARCH TOOLS

One comes across AltaVista and Lycos repeatedly on perusal of the literature. Courtois *et.al.* (1995), Chu and Rosenthal (1996), Venditto (1996), Kimmel (1996), Leighton and Srivastava ((1997), and Zetter and Mc Cracken (2000) are some of the studies that have evaluated the above two search engines (among others). A review by Su (2003) "observed an

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increasing variety of tools being evaluated in the later period compared with the early period." AltaVista, Excite, Infoseek and Lycos were the most frequently evaluated search engines with Lycos leading, Infoseek coming second and AltaVista and Excite coming third. Su found that "in addition to the general-purpose commercial search engines, other search tools began to form the foci for evaluation studies in the later period." Lawrence and Giles (1998) demonstrated the design and features of Inquirus, the NECI meta search engine and compared its sample retrieval results and efficiency with six major Web search engines. Hawking et. al.(1999) tested the effectiveness of six TREC systems against five well known but unspecified Web search engines. Special purpose tools for enhancing web searches were the objects of study for several experiments. These included Social Science Information Gateway (SOSIG) (Kuk, 1999), Yahooligans!, Ask Jeeves for Kids and Super Snooper for children (Bilal, 1999), LIBClient and LIBClient IRIS Web for legal information research (Dempsy, Vreeland and Summer and Yang, 2000). Apart from these, browsing tools such as InXight's Site Lens, a tool for creating overviews of Web sites (Brunk and Bidgood, 2000), and a relational browser for Websites on federal statistics (Marchionini *et. al.*, 2000) were objects of usability.

2 NUMBER OF SEARCH TOOLS EVALUATED

Similarities amongst the studies are found pertaining to the choice and number of search tools. The number of search tools evaluated ranges from 3(Chu and Rosenthal, 1996) to 200 (Tomaiuolo and Packer, 1996). Of course the number of queries fed to the search tools also differed in proportion to the number of search tools evaluated. Usually when more search tools were evaluated, less queries were used (Tomaiuolo and Packer, 1996 and Courtois *et.al.*- 10 search tools/3queries), and vice versa (Chu and Rosenthal, 1996). Although that was not always the case. For example, Leighton (1995) who evaluated four search engines used only eight queries.

Courtois, Baer and Stark (1995) evaluated the performances of ten different web search aids including CUI, Harvest, Lycos, OpenText, WWWWorm and Yahoo. In 1995, Leighton evaluated four search engines–InfoSeek, Lycos, WebCrawler and WWWWorm for their precision. Kimmel (1996) investigated seven search engines and two subject catalogues. Venditto (1996) in his study titled "Search Engine Showdown", tested Alta Vista, Infoseek, Lycos, Open Text, WebCrawler and WWWWorm with dozens of search terms–analyzing the first twenty

five results for relevance. Chu and Rosenthal (1996) used sample search queries that were based upon real reference questions. These queries were then structured to evaluate the abilities of three search engines – Alta Vista, Excite and Lycos. Schlichting and Nilsen (1996) compared the effectiveness of AltaVista, Excite, InfoSeek and Lycos employing the signal detection theory. Another major study is the one conducted by Leighton and Srivastava (1997) where five robot search engines (Alta Vista, Excite, Hotbot, Infoseek and Lycos) were evaluated.

In a unique study, Turner and Brackwill (1998) evaluated the effectiveness of using the HTML Meta tag to improve retrieval of World Wide Web documents through Internet search engines. Twenty documents were created in five subject areas: agriculture trade, farm business statistics, poultry statistics, vegetable statistics and cotton statistics. Four pages were created in each subject area: one with no Meta tag, one with a Meta tag using the keywords attribute and one with a Meta tag using both the keywords and description attributes. Searches were performed in AltaVista and Infoseek to find terms common to all pages as well as for each keyword term contained in the Meta tag. Analysis of the searches suggested that the use of the keyword attribute in a Meta tag substantially improves accessibility while use of the description attribute alone does not. These results suggest that HTML document authors should consider using keywords attribute Meta tags and also that more search engines should index the Meta tag to improve resource discovery.

Voorbij (1999) conducted a nationwide survey in the Netherlands among students and academics, to explore the use and perceived importance of the Internet for study or work related purposes. More specifically, the study focused on searching information resources on the World Wide Web. The user survey consisted of two parts. First, a rather detailed questionnaire was sent to 1000 members of the academic community. Second, three focus group interviews were held with experienced Internet users. Among other findings the study revealed that searching the World Wide Web is not without difficulty. The Web is being used primarily to search general factual, ephemeral or very specific information. At the moment, full text resources play only a minor role in the academic research process. The Internet may have conquered a place for itself, but it has not pushed aside traditional printed and other information sources.

The authors argued that these measures were better alternatives than precision and recall in Web search situations because of their emphasis on

the quality of ranking. Eight sets of search topics were collected from four PhD students in four different disciplines (biochemistry, industrial engineering, economics, and urban planning). Each participant was asked to provide two topics along with the corresponding query terms. Their relevance and credibility judgment of the Web pages were then used to compare the performance of the search engines using these three measures. The results show consistency among these three ranking evaluation measures, more so between "first 20 full precision" and search length than between rank correlation and the other two measures.

Thelwall (2000) conducted a survey to find sites not registered with search engines as well as those that were. The study employed a combinatorial method for finding addresses of Web sites. The survey was conducted in order to test the coverage of search engines and to decide whether their partial coverage is an obstacle to using them to calculate Web impact factors. The results indicated that search engine coverage even of large national domains is extremely uneven and would be likely to lead to misleading calculations.

"How to Stop Searching and Start Finding," is a study by Zetter and McCracken (2000) where they ran a series of queries ranging from broad to specific on twenty search engines, directories and expert sites to see which ones produced the best results. Their objective was to find out which of these search tools provided the most relevant links in the most logical ranking with the least effort. They found that while some search tools did surprisingly well while others forced them to "wade through swamps of irrelevant links," or pointed them to pages that no longer existed. They ranked Google number one among the "search superstars" because it was sleek, simple, fun to use and delivered the web's most relevant results as promised. Their overall conclusion was that search technology while far from perfect, has made great advances in helping find their way effectively through the web.

Killmer and Koppel calculated the retrieval effectiveness of 3 search engines – Google, LookSmart and Metacrawler in 2002. They had students review the first 20 sites returned by each engine. The students noted down the number of relevant sites and the total number of unique sites returned by each search engine. The exercise was given as a homework assignment, therefore the searches were not conducted simultaneously as they may have been in an in-class assignment. The retrieval effectiveness results, with 11 unique relevant sites identified among the three engines were :

Google : Precision = 9/20; Recall = 9/11

LookSmart : Precision = 3/20; Recall = 3/11

Metacrawler : Precision = 1/3; Recall = 1/11

The general consensus from students was that although many of them used search engines prior to this lesson, they did not realize that all search engines do not return the same results. Furthermore, they believed that search engines searched the entire web as it existed at the moment the search was conducted. Once students learned and witnessed the differences among search engines first hand, they found the concepts of recall and precision useful in their comparison of search engine effectiveness. Students commented that this exercise made them more information consumers. Students also commented that prior to this exercise, they were unaware of the vast number of search engines that exist. One interesting observation from this exercise was that students' calculations of recall and precision varied immensely from student to student. These differences were attributed to both the actual time the searches were conducted and each student's interpretation of relevancy when viewing individual websites. Upon completion of the hands-on exercise, students were asked to select their favourite search engine based on their findings. It was found that there was no clear favourite among the students. In choosing a favourite search engine, students used more than their calculations of recall and precision in making their selection. The initial interface, speed of the search tools, presentation of results and other criterion were also mentioned in support of their decision.

The Ziff-Davis Publishing Company (2003) ranked 14 catalogues and search engines according to usability (interface, design, overall ease of use) and effectiveness (number and precision of returned results) and summarized their opinion of each. Infoseek was ranked slightly better than several close competitors.

A study by Saikia and Chandel (2003) discussed the main features of four widely used search engines (AltaVista, Google, Yahoo and Excite) and made a comparative study of searching features available in these search engines along with their limitations. The study found that the search engines studied could not differentiate between the two mutually exclusive terms 'Apple' (as fruit) and 'Apple' (as computer) or 'Penguin' (as publisher) and 'Penguin' (as bird). They also came up with inconsistencies while searching in different modes (basic and advanced search) in the same search engine

Another finding of the study was that contrary to belief, searching through a directory did not yield better results. In fact, less records were retrieved, compared to searching directly without using a directory. The obvious reason was that the directory had not been updated.

Another interesting angle in information retrieval on the web is name recognition, matching and searching. The web is a communication and information technology that is often used for the distribution and retrieval of personal information. Many people and organizations mount Web sites containing large amounts of information on individuals particularly about celebrities. Recent studies (Jansen et.al., 2000, Spink *et.al.*, 2002) that have examined the terms submitted to web search engines suggest that personal names may form part of the low frequency terms used in Web searching.

Perfection in retrieval effectiveness is a utopian dream as of now. Visitors to the World Wide Web discover that it is a frustrating task to find specific pieces of information or digital objects despite teasing links that suggest they are only a Website away. (Casey, 1999)

According to Harris (1997), more often than not, a search for specific data can degenerate into an afternoon of dead ends, blind leads and false drops if not outright misinformation.

Too often, the searcher gives up and goes to the library stacks taking two steps at a time. Frequent visitors to the web conclude that accessing digital information is not as convenient as a person using a book; turning back and forth between two pages for comparison (once one has found the two pages) is as fast as one cares to have it and no command structure and windowing capability stand in the way (Suber, 1992).

Demas *et.al.* (1995) are of the opinion that just as a library of uncatalogued, haphazardly shelved books is of little use when searching for a specific book, the web will never be a true research tool and resource until a means of directly accessing discrete pieces of information and digital objects is developed. It is clear that the information highway will not magically sort itself out.

3 QUERIES

According to Leighton and Srivastava (1997) most published studies have had test suites that were too small for statistical usefulness. Leighton's 1995 study only had eight queries and there have been a host of minor studies that purport to judge precision based on three, two or

even one measly query. In 1995, Leighton evaluated four search engines – InfoSeek, Lycos, WebCrawler and WWWWorm for their precision. He used eight reference questions from a university library as search queries. Courtois, Baer and Stark (1995) evaluated the performances of ten different web search aids including CUI, Harvest, Lycos, OpenText, WWWWorm and Yahoo. They searched three sample search questions.

Schlichting and Nilsen(1996) compared the effectiveness of Alta Vista, Excite, InfoSeek and Lycos employing the signal detection theory. Queries were formulated according to the real needs of five users who described the information they were looking for and offered keywords

Ding and Marchionini (1996), whose study is considered the one of the best to date, for example, used only five queries. Westera (1996) also used only five queries, all dealing with wine. Chu and Rosenthal (1996) used sample search queries that were based upon real reference questions. These queries were then structured to evaluate the abilities of three search engines – AltaVista, Excite and Lycos. Another major study is the one conducted by Leighton and Srivastava (1997) where five robot search engines (AltaVista, Excite, Hotbot, Infoseek and Lycos) were evaluated. These were compared for precision on the first twenty results returned for fifteen queries. The queries used were either ones that had been asked by users at a university library reference desk or taken from another study. "How to Stop Searching and Start Finding," is a study by Zetter and McCracken (2000) where they ran a series of queries ranging from broad to specific on twenty search engines, directories and expert sites to see which ones produced the best results.

4 EVALUATION CRITERIA USED

Traditional criteria or measures for evaluation of information retrieval tools include recall, precision, coverage, overlap, search time and validity of links. In the literature available the most used evaluation criteria have been found to be relevance and precision. Studies by Leighton (1995), Chu and Rosenthal (1996), Ding and Marchionini (1996), Westera (1996), Tomaiuolo and Packer (1996), Venditto (1996), Munro and Lidsky (1996), Scoville (1996), Gauch and Wang (1996), Leighton and Srivastava (1997), Su *et. al.* (1998), Su an Chen (1999), Gordon and Pathak (1999) used either one or both of these measures.

A paper by Tang and Sun (2000), presented a study of the applicability of three user-effort-sensitive „evaluation measures" – first 20 full precision," "search length," and "rank correlation" – on four Web-based

search engines (Google, AltaVista, Excite and Metacrawler). The authors argued that these measures were better alternatives than precision and recall in Web search situations because of their emphasis on the quality of ranking. Eight sets of search topics were collected from four PhD students in four different disciplines (biochemistry, industrial engineering, economics, and urban planning). Each participant was asked to provide two topics along with the corresponding query terms. Their relevance and credibility judgment of the Web pages were then used to compare the performance of the search engines using these three measures. The results show consistency among these three ranking evaluation measures, more so between "first less frequently applied objective measures include expected search length (Agata *et. al.* 1997), recency (Lawrence and Giles, 1998), response time (Lawrence and Giles, 1998, Chignell *et. al.* 1999), search length (Chignell *et. al.* 1999), cost (Chignell *et. al.* 1999, Menczer and Belew, 2000), and accuracy (Brunk and Bidgood, 2000, Dempsy *et. al.*, 2000). Subjective measures comprise a variety of utility and user satisfaction measures (Su *et. al.*, 1998, Wang *et. al.* 1999, Kuk, 1999, Su and Chen, 1999, Marchionini *et. al.* 2000, NPD Media Service, 2000).

5 SEARCHERS

In most articles, Internet-oriented investigators have looked at the utility and/or convenience of various Internet search tools and their ability to locate information on the Internet, then offered their own subjective analysis of how easy such tools are to use. Such articles are updated as more people are introduced to the Internet and as new search tools are introduced and old ones phased out. These investigations have been carried out by writers for the particular magazines, who tested and rated the tools themselves as opposed to investigating the opinions of actual end-users. However, the writers employed by such computer journals can be assumed to have a certain amount of professionalism, with Internet knowledge somewhat advanced beyond the typical end-user, and more on a level of today's professional librarians and library students who have formal training with Internet resources (Vaughan, 1999).

Su (2003) found that in early evaluation studies, investigators or researchers served exclusively as searchers and relevance judges. During the later period, relevance judges other than investigators began to be used. Chignell *et. al.* (1999) used a consensus peer review using human judges in their study. Hawking *et. al.* (1999) employed four human judges including a research assistant and three other students from various disciplines. Gordon and Pathak (1999) enlisted experts to perform

searchers on behalf of real users but used real users as relevance judges for retrieved documents. None of the studies discussed so far investigated end-user searching and evaluation based on end-user's relevance judgements except two instances (Su et. al., 1998 and Su & Chen, 1999).

6 METHODOLOGIES USED

As large as the number of studies on the retrieval effectiveness of Internet search tools is, so large is the variety of them. These studies vary in terms of their scope and coverage. While most compare features of search tools, some provide more detailed discussions. All these works throw some light on the strengths and weaknesses of various search tools and thus help the user not only to learn about them and make appropriate use of them for retrieving information from the web (Choudhury, 1999). Articles such as those by Winship (1995), Zorn *et.al.* (1996) Machovee (1996), Falk (1997), Oppenheim (1997) and Zetter and Cracken (2000) describe the features of different search tools. Others like those by Poynder (1996) and Poulter (1997) are more evaluative and critical comparing search tools on the basis of their generic features such as database content, retrieval software and search interface. Su (2003) has found the following types of studies to be popular : reviews, experiments, naturalistic studies, surveys etc.

(*a*) Reviews of course describe the new developments or progress in the field. They provide important information on the state-of-the-art-of-Web search engines. Examples include the studies by Kassel's (1998), Garman (1999) and Hsieh-Yee (2001).

(*b*) Experiments

Two categories of experiments have been done by various researchers: controlled experiments and user-oriented experiments. The first category involves using more clearly defined criteria and methodology including control devices and statistical techniques. Studies by Agata *et. al.* (1997), Clarke and Willet (1997), Lawrence and Giles (1998), Leighton and Srivastava (1999), Hawking *et. al.* (1999), Chignell, Gwizdka and Bodner (1999), Menczer and Belew (2000) are examples.

User-oriented experiments on the other hand involve real users and their information problems in the evaluation process. Su, Chen and Dong (1998), Su and Chen (1999). Gordon and Pathak (1999), Can, Nuray and Sevdik (2003) and Griesbaum (2004), conducted these types of experiments in their studies.

(c) Naturalistic Studies, also called the qualitative method investigate user criteria or user behaviour related to web searching. The studies by Rieh and

Belkin (1998) and Kuk (1999) can be included in this category.

According to Hsieh-Yee (2001), compared with research on online search behaviour, research on Web search behaviour has become sophisticated over a shorter period of time. Many standard research methods have been used to collect data, including survey, structured self-report, interview, verbal protocol, critical incident report, transaction logs, video logs and on-site observation. Furthermore, many researchers employed multiple data-gathering methods to corroborate findings or enhance understanding of Web search behaviour.

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