A Study and Comparison of Multimedia Web Searching: 1997–2006

Dian Tjondronegoro and Amanda Spink
Faculty of Information Technology, Queensland University of Technology, GPO Box 2434, Brisbane, Queensland 4001, Australia. E-mail: {dian, ah.spink}@qut.edu.au

Bernard J. Jansen
College of Information Science and Technology, The Pennsylvania State University, State College, PA 16802. E-mail: jjansen@psu.edu

Searching for multimedia is an important activity for users of Web search engines. Studying user's interactions with Web search engine multimedia buttons, including image, audio, and video, is important for the development of multimedia Web search systems. This article provides results from a Weblog analysis study of multimedia Web searching by Dogpile users in 2006. The study analyzes the (a) duration, size, and structure of Web search queries and sessions; (b) user demographics; (c) most popular multimedia Web searching terms; and (d) use of advanced Web search techniques including Boolean and natural language. The current study findings are compared with results from previous multimedia Web searching studies. The key findings are: (a) Since 1997, image search consistently is the dominant media type searched followed by audio and video; (b) multimedia search duration is still short (>50% of searching episodes are <1 min), using few search terms; (c) many multimedia searches are for information about people, especially in audio search; and (d) multimedia search has begun to shift from entertainment to other categories such as medical, sports, and technology (based on the most repeated terms). Implications for design of Web multimedia search engines are discussed.

Introduction

Searching for multimedia is an important activity for users of Web search engines. Studying user interactions with Web search engine has potential to impact the development of more effective multimedia Web search systems. To date, the fast growth rate of multimedia over the Web has not been supported by the powerful technologies that can efficiently and accurately process the multimedia content. To handle vast amounts of multimedia information, state-of-the-art Web searching systems need to effectively index the contents and select the most relevant documents to answer users' queries that are based on the semantic or similarity perception. Content-based image, audio, and video search have been given a lot of attention by researchers due to the grand challenges in bridging the gaps between low-level audiovisual features and high-level semantics to support intuitive searching (Lew, Sebe, Djeraba, & Jain, 2006; Yoshitaka & Ichikawa, 1999).

However, despite promising research results, Web multimedia search remains problematic. The accuracy, precision, and adequately fast processing of media-specific analysis and feature extraction is yet to be fully resolved. This also is the case for a scalable and efficient index structure that can support the required searching and filtering performance over a huge volume of data.

Text-based searching is the dominant method for state-of-the-art multimedia Web search engines while query-by-example searching is supported only on more specific and narrower multimedia collection (Tjondronegoro & Spink, 2008); however, users often find it difficult to begin their Web search as most multimedia retrieval needs are often not clear as to exact query keywords or a set of sample images/sounds. For example, compromise may appear in a user's choice of result images due to difficulties in forming Web search queries (McDonald & Tait, 2003). Keyword-based Web search engines provide limited query-formulation capabilities as text descriptors are yet to be structured using a standardized dictionary that can help match terms used by searchers and annotators. Text-based search effectiveness is further limited due to gaps in the dimension and richness of contents between text, image, audio, and video (Ortiz, 2007). To improve Web searching, further focus is needed on users' searching behavior and content-based multimedia information retrieval (Lew et al., 2006). Future multimedia search

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studies need to understand users' queries, narrowing semantic gap, standardization in image description, and integration of different media (Kherfi, Ziou, & Bernardi, 2004).

Previous studies have analyzed different aspects of Web query data logs (Silverman, Henzinger, Marais, & Morris, 1999; Spink, Jansen, Wolfram, &. Saracevic, 2002) and multimedia Web search (Tjondronegoro & Spink, 2008). The study reported in this article is part of a larger, ongoing research project to investigate multimedia Web searching behavior (Ozmutlu, Spink, & Ozmutlu, 2003; Spink & Jansen, 2004, 2006; Tjondronegoro & Spink, 2008). Trend analysis is needed and important for understanding changes in multimedia Web search over time.

The study reported in this article provides an analysis of multimedia Web search using a recent Weblog and compares the findings with previous studies. In particular, the article examines the characteristics, duration, and size of the sessions and queries in multimedia Web search. In addition, the most frequently used repeated terms, the most followed-up terms, and the use of advanced query terms are examined. The article also discusses implications for the future development of multimedia Web searching technologies.

The next section outlines previous studies that have explored multimedia Web searching.

Related Studies

The study of Web search began with the development and popular use of Web search engines in the 1990s. Web search engines are the dominant technologies of digital life, for online information. Some 84% of American adult Internet users have used a search engine to seek information online (Fallows, 2005). Everyday, more than 60-million American adults query Web search engines, and after e-mail, Web search is the second most popular online activity (Rainie, 2005). Web search is now a topic of research in the social sciences, media and cultural studies, law, information science, and other related disciplines (Spink & Jansen, 2004; Spink & Zimmer, 2008) that examines social, cultural, political, legal, and informational impacts on individuals, social groups, and society.

Early Web search studies have included Jansen, Spink, and Saracevic's (2000) study of Excite search engine data and Silverstein et al.'s .(1999) analysis of 1-billion Alta Vista queries over 42 days. Recent Web search log studies have included findings on search topics, query length, Boolean operator usage, search session length, and search results page viewing (Hargittai, 2002; Spink & Jansen, 2004).

However, most Web search research has focused on general Web search and less so on multimedia Web search. Multimedia Web search has emerged to be a major area of Web research due to the users increasing demand for multimedia materials on the Web, such as music files (audio), images, and videos. The first major study of multimedia Web search behavior was conducted using Excite Web logs from 1997 to 2001 by Ozmutlu et al. (2003). They found that multimedia queries are generally longer and largely performed with multimedia interface buttons (i.e., users select a particular type of media to search). The use of radio buttons was found to have decreased in multimedia Web searches in the general collection (Ozmutlu et al., 2003); however, the researchers did not examine queries to the federated collections.

Jansen, Spink, and Pedersen (2005) compared Web searching characteristics among Web, image, audio, and video content collections on the AltaVista search engine. They reported that of the four types of multimedia, Web searching with image searching was the most complex task and that audio was the least complex, based on the mean terms per query and session lengths. The mean terms per query for image Web searching was larger (four terms) than those of the other categories of multimedia searching (<three terms). The session lengths for image searches were longer than those for any other type of multimedia searching. Another indication for the complexity of image searching was the 28% Boolean usage in image queries. Sexual or adult content terms appear more frequently in image queries. Overall, multimedia searching shifts as the content of the Web changes (Spink & Jansen, 2004).

Tjondronegoro and Spink (2007) surveyed the multimedia search functionality for a number of major Web search engines such as Google, Yahoo, MSN, and AOL. Less than 5% of investigated retrieval systems provided content-based search methods. Tjondronegoro and Spink (2008) found that (a) few major Web search engines offer multimedia searching and that (b) multimedia Web search functionality is generally limited. They found that despite the increasing level of interest in multimedia Web search, few Web search engines offering multimedia Web search provide limited multimedia search functionality. Keywords are still the only means of multimedia retrieval while other methods such as "query by example" are offered by less than 1% of Web search engines examined.

Jansen (2008) used 587 image queries taken from a Web search engine transaction log. The researcher then investigated the structure and formation of these image queries by mapping them to three known query-classification schemes for image searching (Chen, 2001; Enser & McGregor, 1992; Jorgensen & Jorgensen, 2005). The results indicated that the features and attributes of Web image queries differ relative to the image queries from other information retrieval systems and by other user populations. Specifically, the results highlighted the need for five additional attributes (i.e., collections, pornography, presentation, URL, and cost) to more accurately classify Web image queries.

Most previous studies examining the characteristics of specialized multimedia searching (e.g., Jansen, Spink, & Pedersen, 2003, Spink & Jansen, 2006) have used AltaVista 2002 and Dogpile (www.Dogpile.com) 2005 Web logs, respectively. The study reported in this article used a Dogpile 2006 dataset. Our study is based on Web transaction logs that are commonly used for capturing characteristics of user interactions with Web search engines (Jansen, Spink, & Taksa, 2008). Web log analysis can collect data from a great number of users at a relatively inexpensive cost, and it also is the

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least obstructive data-collection method which represents the natural and unaltered behavior of searchers.

Research Aims

The major aim of the study reported here is to examine multimedia searching trends. The study includes a comparison with other major studies that have used data from different Web search engines and times. To assess Web multimedia searching trends, the findings from the current analysis are compared with findings from previous studies that were conducted on Excite 1997, 1999, and 2001 (Ozmutlu et al., 2003); Altavista 2002 (Jansen, Spink, & Pedersen, 2004); and Dogpile 2005 datasets (Spink & Jansen, 2006).

The specific aims of the study are to examine the search characteristics and differences in Web multimedia searching, including:

- *Session length:* In terms of the actual time spent, and the number of queries per session
- *Number of result pages viewed* and the lowest ranking.
- *Searchers' demographics:* In terms of the location and Web browsers used.
- *Query length:* The number of terms per query.
- *Frequent multimedia terms:* In terms of most occurring and clicked-through.
- *Categories of frequent multimedia terms.*
- *Use of advanced query-formulation strategies* such as Boolean and natural language.

Methods

Data Collection

Dogpile.com. Infospace, a market leader in the meta-search engine business, owns Dogpile. Dogpile is the only meta-search engine during the study period to incorporate the indices of the four leading Web search indices (Google, Yahoo!, MSN Live Search, and Ask) into its search results. When a searcher submits a query, Dogpile simultaneously submits the query to multiple other Web search engines, collecting the results from each Web search engine, removing duplicate results, and aggregating the remaining results into a combined ranked listing, using a proprietary algorithm. Hitwise (2005) reported that Dogpile was the 9th most popular Web search engine in 2005 as measured by number of site visits. ComScore Networks (2005) stated that in 2005, Dogpile had the industry's highest visitor-to-searcher conversion rate of 83% (i.e., 83% of the visitors to the Dogpile site executed a search).

Dogpile Web transaction logs. This study analyzed the records of searcher–system interactions in a Web transaction log that represents a portion of the searches executed on the Dogpile Web search engine on May 15, 2006. Similar to the previous Web log studies (which were done in different years), we used a Web log that is recorded during a randomly chosen day to study users' search trends. Thus, we need to assume that users' searching patterns during the 365 days in a particular year is consistent enough to be represented by 1-day (i.e., 24-hr) data. To minimize the impact of this limitation on our analysis, however, we will generalize specific terms into high-level concepts, which are less affected by temporal (or "recentness") variation, throughout our discussions. For example, the terms "Shakira" and "Paris Hilton" should be interpreted as general interest in singers and celebrities. There are some other limitations in using Web log analysis to examine Web searching trends, which will be outlined later in this article as part of the discussion on future work.

Dogpile.com uses buttons (i.e., tabs) to allow users to specify the particular media types including image, audio, and video. The original transaction log contained 1,228,330 records combined from the specialized multimedia search buttons. Each record contains nine fields:

- *Internet Protocol (IP) address:* User machine's Internet address, which can be used in combination with a cookie for identifying search sessions.
- *Cookie:* Automatically assigned by the Dogpile server to identify unique users on a particular computer. A cookie is allocated the first time a user is connected to the search engine until the user left a search session.
- *Time of Day:* The time (in hours, minutes, and seconds) that a particular query is submitted, or a result is being followed up.
- *Query terms:* The user terms entered into the query box (e.g., "Web search").
- *Vertical:* The query is being submitted to either the specialized (i.e., tabbed) images, video, or audio search, which clearly indicates users' search intention for a particular type of media.
- *Organic/Sponsored:* The number of clicks on the organic and sponsored search results (indicating that the search result is followed up by the user and may be deemed as relevant or interesting). Organic search results are naturally returned by the search engine (based on the search algorithm) while sponsored links are paid by advertisers. When both of these fields are "null," the record indicates that it is an initial query. If there is no subsequent record showing at least one organic or sponsored link being followed up in a session, then the user has not found a relevant result (i.e., he or she left the session after the initial query).
- *Rank:* The search ranking of the result being followed up (e.g., 2, 4, 6, 14, etc.), which can provide insightful information on how many search results users are willing to go through.
- *Location:* Indicates user's location.
- *Browser:* The Web browser being used by the user (e.g., Microsoft Internet Explorer 6.0).

Data Analysis

We imported into a relational database, the original flat ASCII transaction log file of 1,228,330 records. Analyses were conducted at multiple levels, using the following metrics similar to those used in other Web transaction log studies (Jansen et al., 2004; Ozmutlu et al., 2003; Spink & Jansen, 2006):

- *Terms level:* Any string of characters bounded by some delimiter such as white space.
- *Query level:* A query is a string list of one or more entered terms.

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- *Query length:* Measured by counting the number of terms in the query.
- *Query complexity:* Examines the query syntax, including the advanced searching techniques such as Boolean and other query operators.
- *Session level:* The entire sequence of queries entered by a searcher with a given data-sampling method. This is similar to the definition of a unique visitor used by commercial search engines to measure Web site traffic.
- *Session length:* Measured by the number of queries per searcher as each searcher is given a unique identifier within the log; namely, the IP address.
- *Session duration:* The total time the user spent interacting with the Web search engine, measured by subtracting the time the user first submits the first query with the time the user departs the search engine for the last time (i.e., does not return).
- *Results pages viewed or Click-Through level:* A results page is the list of results returned by a search engine in response to a query, which can contain organic or sponsored search results. From a results page, a searcher may click on the URL links to visit one or more results from the results listing, a method which is often referred as page-view analysis. The result page-viewing patterns of Web searchers are analyzed through the number of results pages clicked. In our Weblog, it is denoted by the sponsored and organic field being greater than 1 (and not null).

TABLE 1. Comparison of audio, video, and images Web search sessions.

Variables	Image	Audio	Video
Total sessions	196,755 (54.4%)	113,769 (31.4%)	50,795 (14.06%)
Average duration per session (in seconds)	296.1 (4.9 min)	410.4 (6.8 min)	414.5 (6.9 min)
<5 mins	88.9%	86.9%	82.5%
5–10 mins	5.1%	5.9%	8.12%
10–15 mins	1.5%	1.7%	2.7%
15–30 mins	1.1%	1.2%	1.9%
30–60 mins	0.2%	0.3%	0.3%
1–2 hrs	2.2%	2.6%	3.3%
2–3 hrs	0.2%	0.3%	0.3%
3–4 hrs	0.08%	0.1%	0.1%
4–5 hrs	0.04%	0.09%	0.08%
>5 hrs	0.3%	0.4%	0.4%
Average queries per session	2.8	2.2	2.4
1	31.05%	28.7%	23.7%
2	41.1%	40.5%	42.2%
3	14.2%	14.6%	15.5%
4+	13.5%	16.01%	18.4%
Maximum queries per session	78	48	48
SD for queries per session	2.22	1.6	1.8

Session identification and initial filtering. We generated a unique identifier for each record. The traditional de facto standard for a session is generally 30 min without any activity on a given system. However, a recent study by Jansen, Spink, and Kathuria (2007) defined the best measure of identifying sessions by a change in terms along with IP address and cookie. Hence, we used three fields (IP address, cookie, and query) to locate the initial query and then recreate the chronological series of actions in a session. A session change is identified within the same IP address and cookie combination when the current query does not contain at least one term that has been used in the previous query.

To obtain human (not agent) sessions, all sessions with more than 101 queries submitted (in a session) were deemed to be conducted by agents. This threshold is used, as it is almost 50 times greater than the reported mean search session for human Web searchers (Ozmutlu et al., 2003). After being filtered, the study focused on 361,319 human sessions. Our study reports on: (a) analyzing the duration, size, and structure of search sessions and queries and the demographics of the users; (b) click-through analysis to study the lowest ranked results being followed up and to find the most popular multimedia Web searching terms; and (c) the use of advanced Web search techniques including Boolean and natural language.

Results

Multimedia Session-Level Analysis

Multimedia search duration. Table 1 show the characteristics of multimedia search sessions. Overall, image search dominates (i.e., 55% of multimedia sessions), 31% were audio sessions, and 14% were video queries.

Table 1 shows that based on the average Web session duration, video search was the longest at 6.9 min while audio was 6.8 min and image was 4.94 min. The top-three most common session durations for all multimedia searches indicate that 80% of the users spent less than 5 min (with 56–62% = <1 min) while only 6% and 3% users spent 5 to 10 min, or 1 to 2 hr, respectively. Table 1 shows that multimedia search was generally very short, and there were only a very small portion of users spending around 1 or 2 hr. By observing the average number of queries submitted per session, we can see that users entered more queries on image search (2.8 queries) followed by video (2.4) and audio (2.3), respectively. The most common session size was two queries (>40%), followed by one query (>23%). It shows that users generally do not spend a lot of time refining their queries.

Search result clicks. Table 2 shows the statistics on search results being followed up per session. From the total number of sessions that have at least one follow-up (per session), only 56% of them were image sessions, compared to 80% in both audio and video sessions. This percentage shows that users do not generally have to click on the results of image search, perhaps due to the visual thumbnails being sufficient for users to judge the relevance while users need to actually view the temporal information in audio and video to understand the contents. This also demonstrates that image search users are not interested in the full size of the image or reading the document that contains the image to get more complete information, and as such, they are only looking for visual

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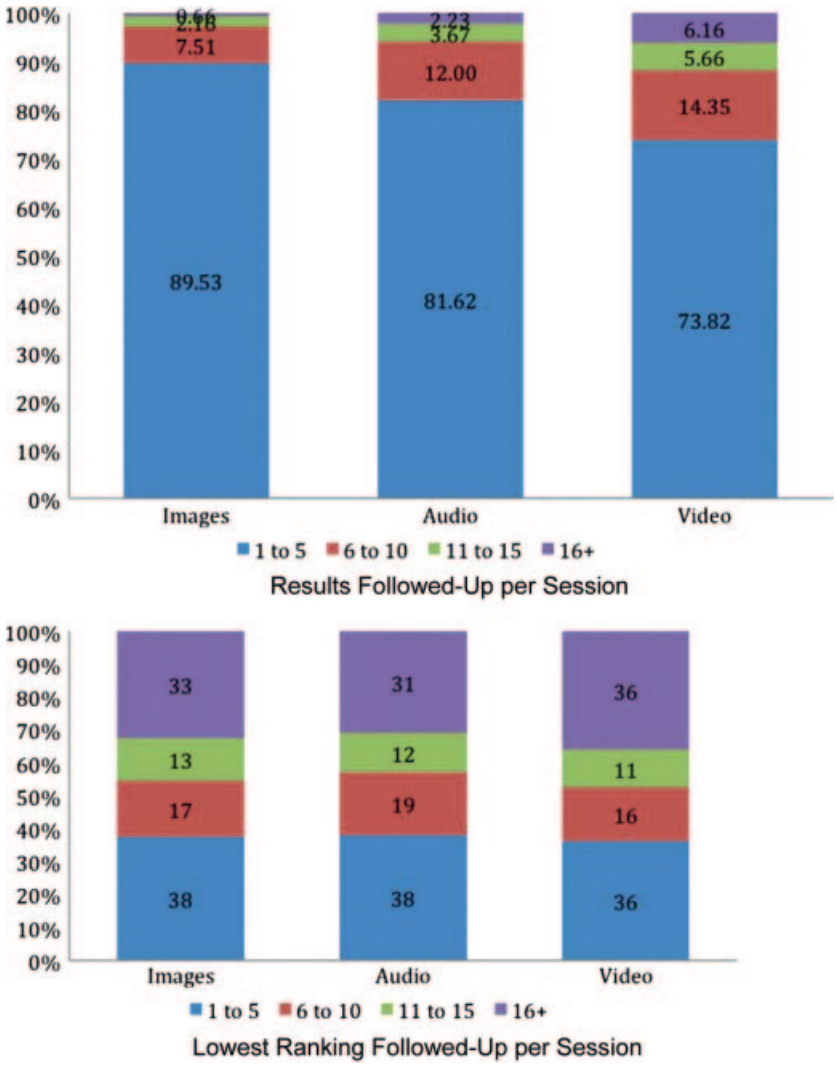

FIG. 1. Distribution of links followed up and the lowest ranks.

TABLE 2. Statistics of search results followed up in a session.

Organic links visits in a session	Images	Audio	Video
1–5	87,492	66,218	27,298
6–10	7,553	9,772	5,335
11–15	1,828	2,986	2,104
16+	1,154	2,205	2,290
Total	98,027	81,181	37,027
Sponsored links visits in a session			
15	2,725	224	141
6–10	10	0	0
11–15	2	0	0
16+	0	0	0
Total	2,737	224	141
No. of sessions with at least 1 result followed up	100,764.00	81,405.00	37,168.00
%Sessions with at least 1 follow-up	55.7	80.8	79.7

stimuli. Nevertheless, the Web logs cannot show whether the 44% (i.e., the rest) of the image sessions with no follow-up actually means browsing intention or unavailability of relevant results. Figure 1 shows that the majority of multimedia sessions (i.e., 89% of image search, 81% of audio search, and 73% of video search) followed up one to five results and that the majority of the links followed up are the organic search results.

However, given the small number of sponsored results (which are returned for a single query), we should not conclude that users do not use sponsored results. There generally is more interest in sponsored results for image search than for those of audio and video.

Table 3 shows the statistics of the lowest ranking results being followed up per session to indicate users' reliance on the ranking algorithm of the Dogpile search engine and their patience in scrolling a long list of search results.

Figure 1 shows that 38% of users are only willing to go as far as the results ranked at the fifth position; however, 31 to 36% of the users went beyond 16th-ranked results and

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TABLE 3. Statistics of lowest ranking followed up in a session.

Lowest rank followed up in a session	Images	Audio	Video
0 (not followed up)	84,612	21,753	10,279
15	41,248	35,032	14,695
6–10	18,633	17,571	6,615
11–15	14,144	11,028	4,657
16+	35,647	28,385	14,549
Total	109,672.00	92,016.00	40,516.00
%Followed up	55.7	80.8	79.7

TABLE 4. Browsers used in multimedia sessions.

Browser	Microsoft	Mozilla	Apple	Netscape	Opera	Media players	Others
Multimedia sessions	309,631	31,416	14,258	2,675	1,120	127	116

Microsoft: Microsoft Internet Explorer; Mozilla: (Firebird, Firefox, Mozilla); Apple: Safari, iCab; Media players: iTunes Media, Real Player, Web TV browser; Others: Curl, Galeon, IBM Planet, K-Meleon, LibWWW, Konqueror, WGet.

are willing to browse a long list of results, or the results are spanned across multiple pages and users only look at the first two pages. Combined with the majority of users spending less than 5 min on multimedia Web searches, there are two challenges for designing a search result interfaces: (a) support for more effective and semantic browsing (whereby users are presented with thumbnails or a summary of the multimedia contents), and (b) improve the ranking algorithm to speed the process of finding the right information or support pleasant scrolling. For example, Web browser plug-in software such as "cool iris" (cooliris.com) provides a visual browsing environment for image search.

Dogpile User Demographics

Tables 4 and 5 show the demographics of Dogpile multimedia search users (or more accurately, their computers) in 2006.

The top-three browsers used are Microsoft Internet Explorer (86%), Mozilla (9%), and Apple (4%). These statistics show that most multimedia searchers rely on Microsoft Internet Explorer due to its integration with Windows (as the most used operating systems) and the strong supports for multimedia file formats and Direct X. The top-four countries of multimedia Web search sessions are English-speaking countries—the United States (82%), the United Kingdom (9%), Canada (5%), and Australia (4%)—followed by Saudi Arabia, Germany, Singapore, India, New Zealand, and Malaysia.

Query-Level Analysis

Table 6 shows the typical length and occurrences of multimedia search queries. Figure 2 displays the distribution in a graphical diagram.

TABLE 5. Session locations.

Location	CountOfid
usa	**281,207**
gbr	**30,807**
can	**15,965**
aus	**12,969**
sau	**1,615**
deu	**1,315**
sgp	**1,299**
ind	**1,184**
nzl	**1,149**
mys	**753**
irl	751
phl	680
jpn	582
zaf	565
fra	507
mex	506
are	447
chn	389
swe	378
ita	353
nld	322
isr	316
pri	290
nor	288
esp	279
	354,916
Sampling from total sessions	98.227882

Country names based on ISO 3166-3 (Alpha 3). Boldface indicates top 10: United States, United Kingdom, Canada, Australia, Saudi Arabia, Germany, Singapore, India, New Zealand, and Malaysia.

TABLE 6. Multimedia search-query length (no. of terms).

Query length	Image queries	Image queries (%)	Audio queries	Audio queries (%)	Video queries	Video queries (%)
1	31,748	23.9	13,663	15.2	9,575	22.8
2	49,094	36.9	22,601	25.2	15,200	36.1
3	28,424	21.45	18,621	20.7	8,869	21.1
4	13,744	10.3	14,685	16.3	4,713	11.2
5	6,014	4.5	9,531	10.6	2,164	5.1
6	2,390	1.8	5,552	6.2	956	2.3
7	918	0.7	2,857	3.2	397	0.95
8	386	0.3	1,250	1.4	65	0.2
9	180	0.1	613	0.7	58	0.15
>10	135	0.1	489	0.5	55	0.1
Total	133,033	100	89,862	100	42,052	100

Query length for multimedia searching generally ranges between one to four terms, with two terms per query most commonly used. The average terms per query for audio search are slightly longer at 3.1, followed by both audio and video at 2.3 terms per query. The 2006 trends (Figure 2a) clearly show that the distribution statistics of query length in video and image search are almost equivalent.

Query length of greater than or equal to six terms is rarely used for image and video searches (<2%); however, in audio search, query length of five and six terms is often used with

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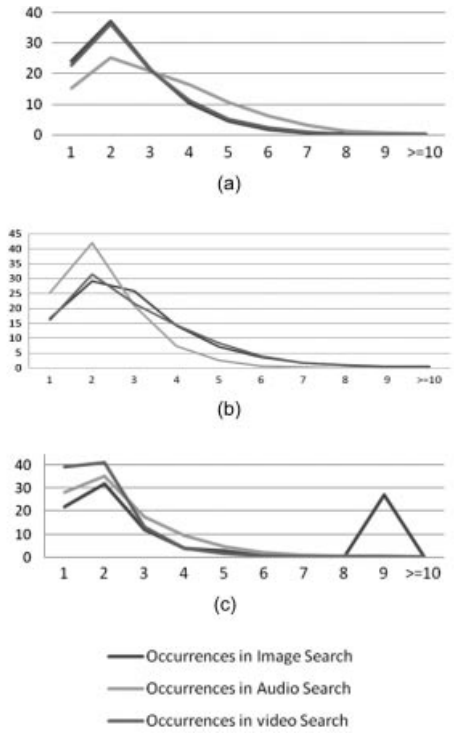

FIG. 2. Multiemedia query length distribution. (a) Dogpile 2006 (this article); (b) Dogpile 2005 (Spink & Jansen, 2004); (c) AltaVista 2002 (Wolfram et al., 2001); *y*-axis = percentage; *x*-axis = number of terms.

10.6 and 6.2%, respectively. This could be due to the fact that for audio search, users generally use the song title or artist name, or a combination of both such as "ghost riders in the sky johnny cash" and "lionel richie just for you." Compared to 2002 (Figure 2b), the query-length distribution is almost the same for image, audio, and video search. There are two notable differences between 2002 and 2006, including (a) The 2002 audio-query length was greater than or equal to five and much less than for that in 2006, and (b) the percentage of 2002 image-query length equal to nine is 27% (which was deemed as an anomaly of the data collection).

Top-25 Terms: Click-Through Analysis

Table 7 shows the top-25 terms that produced results from which users clicked on results as indicated by how many times they are entered by users (not necessarily unique) and the number of results viewed (i.e., clicked).

Almost all top-25 terms in image and video queries are sexual, except for "Paris Hilton," "Carmen Electra," and "Jessica Alba" (celebrities' names), and "anime" (Japanese movie animation). In audio queries, most queries are either a song title or an artist (or performer); "ridin dirty" is the most popular, being entered 289 times (including the shortened version), which users clicked 762 organic links. Cronin (2008) showed that pornography is a major business on the Web. The most popular performers searched for are "Shakira" and "Eminem." Sponsored links are generally not followed (i.e., clicked by users); the average is one to two clicks per session, with a maximum of five clicks. Compared to Spink, Ozmutlu, and Lorence (2004), it is quite consistent that the most frequent sexual terms in Web search are limited and mostly based on celebrities' names or "girls;" however, they are not the major proportion of all search queries.

Table 7 suggests that some query terms co-occurred in multiple Web multimedia searches. An analysis of overlap-

TABLE 7. Top-25 most frequently occurring and clicked-through multimedia query terms.

Image			Audio			Video		
Total queries	562,380		Total queries	370,890		Total queries	208,115	
Query	Frequency (%)	Links followed	Query	Frequency (%)	Links followed	Query	Frequency (%)	Links followed
pussy	0.08	498	ridin dirty	0.07	427	pussy	0.6	1371
boobs	0.04	251	ridin	0.06	335	boobs	0.3	652
sex	0.04	237	shakira	0.06	318	hentai	0.2	514
hentai	0.03	196	eminem	0.06	343	sex	0.2	468
porn	0.03	181	50 cent	0.06	362	porn	0.1	370
tits	0.02	176	dani california	0.06	266	preteen	0.1	320
paris hilton	0.02	134	temperature	0.04	231	tits	0.1	344
milf	0.02	129	panic at the disco	0.04	191	paris hilton	0.1	310
ass	0.02	122	ms new booty	0.04	197	milf	0.1	315
penis	0.02	113	sean paul	0.04	199	ass	0.1	260
thongs	0.02	107	system of a down	0.04	203	carmen electra	0.1	249
carmen electra	0.02	106	hips dont lie	0.04	253	penis	0.1	226
anime	0.01	103	chamillionaire	0.04	194	hot girls	0.1	225
jessica alba	0.01	103	chris brown	0.04	218	incest	0.1	231
lesbians	0.02	99	bad day	0.04	191	big tits	0.1	225
hot girls	0.02	99	taking back sunday	0.04	173	blowjob	0.1	210
big tits	0.01	99	slipknot	0.03	187	thongs	0.09	199
nude	0.01	92	rihanna	0.03	168	lesbians	0.09	188
preteen	0.02	92	grillz	0.03	199	upskirt	0.09	182
incest	0.01	90	panic! at the disco	0.03	152	anime	0.08	201

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TABLE 8. Overlapping query terms in multimedia searching.

	Overlapping terms		
Total unique terms	Image	Audio	Video
Image (178,399)	n/a	5,742 (3%)	12,730 (7%)
Audio (95,682)	5,742 (6%)	n/a	5,754 (6%)
Video (49,978)	12,730 (26%)	5,754 (13%)	n/a

n/a = Not applicable.

ping queries (i.e., unique terms used in multiple multimedia-type searches) is presented in Table 8. There are a total of 178,399 unique search terms in image, 94,682 in audio, and 49,978 in video. A large portion of video terms overlaps with image (26%) and audio terms (13%), respectively, which is consistent with the fact that video contains both audio and visual contents. Users prefer to search video using visual terms, as compared to audio terms. Only a small portion (6%) of audio terms overlaps with visual (i.e., image and video) terms.

Concepts (or Topics) of the Most Followed-Up Queries

We further examined the search intent for the most followed-up queries by semi-automatically categorizing the submitted search terms (used in each query). Of the most clicked-through search queries, 1,485 (of 45,578) audio, 2,818 (of 63,815) image, and 911 (of 25,216) video queries were able to be automatically classified into semantic categories using Open Calais tools (see http://www.opencalais.com/calaisAPI for the complete list of extracted entities and their definitions). We manually corrected some of the categorization results by adding new categories (viz., "sexual," "music," and "movie or game" for image and video; "song" and "sound" for audio). The corrections are particularly required as many of the *IndustryTerm* search terms were incorrect. The detection of other topic categories such as person, sports game, and country are sufficiently accurate, and we did not need to correct them.

Some examples of the categorized multimedia search terms are:

- *Holiday:* "memorial day," "labor day," and "independence day."
- *Medical condition:* "mad cow disease," "eating disorder," and "liver cancer."
- *Natural feature:* "Caribbean islands," "Australian island," and "French beach."
- *Region:* "East Africa," "Mediterranean," and "Antarctic."

Users often opted to use incomplete words from a song title and a performing artist (which can be a person's name or a group name). Hence, we actually performed the search on the Dogpile Web search engine and examined the first page of the results to predict the intended search purposes. For example, "Tater White Salad" refers to "Ron White (artist)—Tater Salad (song title)." The more difficult task is to interpret generic terms as a band group's name such as "silver chair" and "Beatles."

Moreover, an assumption that the search was in the context of audio must be made to interpret some ambiguous terms. For instance, "loud car exhaust," "bass," and "bass solo" are identified as "sound (or sound effect)" search terms. Another assumption that users are searching for the soundtrack (i.e., theme song) is made when the search terms refer to the titles of a movie, a game, an animation, and a television program. For example, "metal alchemist" refers to the soundtrack of the animation of that title. Some search terms are best described as song genre such as "metal rap" and "love metal;" however, singular terms which are too ambiguous remain in the original category. For example, "im" could refer to "I'm okay" or other song title which has the words "I'm," but without the existence of other clarifying terms, an assumption cannot be made. Hence, the industry term category in audio (as well as image and video) search still includes ambiguous and unclassified terms.

During the manual correction of image search term categories, we also focused on recategorizing the search terms which are classified as IndustryTerm; however, image search terms are more diversified, and we thus decided to avoid using too specific a category because it will not reveal a converging result. Instead, we have defined new categories, including "sexual," "movie or game," and "music," which can be easily identified. As for the rest of the incorrectly classified terms (as IndustryTerm), we determined that many of the search terms are for landscapes (e.g., "Yosemite," "Melbourne South bank") and visual objects ("food recipes," "teeth," "gas cooker," "energizer bunny").

Predicting the search intent of video terms was found to be the most challenging task because they can refer to a wide range of topics, including music video whereby audio terms such as "singer" or a band group's name and song title can be used. Moreover, movie video search can use an actor's name or a movie title. The previous assumptions for image and audio search terms cannot be used because video contains both media. For example, a search on "car" can mean the sounds of a car or video scenes which contain a car while a search on "cable car" can mean the music or video which contains "cable car." Hence, we only corrected terms which clearly belong to the existing categories, including "sexual," "person," "movie/game title," "music" (i.e., song title), and "sports." Table 9 lists the topics (or concepts) of the most clicked-through queries.

Queries for image, audio, and video are about *people*, including a singer's or a band group's name, politicians, sportspersons, and movie actors. The second and third most important categories are: *medical condition* and *sexual*, respectively, for image search; *song* and *medical condition*, respectively, for audio search; and *medical condition* and *sports game*, respectively, for video search.

Use of Advanced Web Search Features

Advanced query terms are usually combined using Boolean expressions such as "AND" (often symbolized by +, or &), "NOT" (symbolized by −, or ∼), "OR" (symbolized

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TABLE 9. Categories of most repeated queries in image, audio, and video search.

Image		Audio		Video	
Total classified queries	2,818	Total queries	1,485	Total queries	911
Query	Frequency (%)	Category	Frequency (%)	Query	Frequency (%)
Person	56.2	Person	75.7	Person	64.1
IndustryTerm	21.7	Song	8.9	IndustryTerm	13.3
MedicalCondition	7.4	MedicalCondition	2.7	MedicalCondition	5.3
Sexual	2.6	IndustryTerm	2.7	SportsGame	4.06
Country	2.5	City	1.6	Sexual	2.8
SportsGame	1.9	SportsGame	1.5	Technology	2.5
Technology	1.8	Sound	1.5	City	1.4
City	1.6	Technology	1.4	Song	1.2
Holiday	0.9	Holiday	1.2	MovieOrGame	0.9
NaturalFeature	0.8	Country	0.8	Holiday	0.9
Region	0.8	Region	0.4	Region	0.6
MovieOrGame	0.4	Currency	0.2	Country	0.6
NaturalDisaster	0.2	Organization	0.2	Organization	0.3
Currency	0.1	TV	0.2	Tutorial	0.3
Organization	0.1	Product	0.2	Currency	0.3
PhoneNumber	0.1	NaturalFeature	0.1	Facility	0.2
Product	0.1	Event	0.07	NaturalFeature	0.2
Music	0.1			NaturalDisaster	0.2
				Product	0.1
Total	100		100		100

TABLE 10. Top 10 Boolean query used in image, audio and video search.

Image			Audio			Video		
Query	No. of queries	Organic Links Followed	Query	No. of queries	Organic Links Followed	Query	No. of queries	Organic Links Followed
romeo and juliet[a]	22	24	nice and slow[a]	4	73	romeo and juliet[a]	31	34
ivy and harley	4	12	angels and airwaves[a]	53	72	round and brown	26	27
dead sea and jordan river	3	12	simple and clean[a]	37	54	dead or alive kabuki[a]	22	24
the reflecting pool and national mall	2	11	wait and bleed[a]	24	41	aladdin and sex	23	23
dead or alive[a]	7	9	coheed and cambria[a]	30	39	dead or alive[a]	17	20
mother and child	2	9	guns and roses[a]	22	33	baucis and philemon	14	19
round and brown	7	8	beauty and the beast[a]	20	29	piano and rose	11	18
chronicles of narnia the lion the witch and the wa[a]	2	8	bob and tom[a]	17	24	mac and bumble	17	17
skull and crossbones	8	7	pomp and circumstance[a]	16	24	monty python and the holy grail	16	17
hutus and tutsis	3	7	cassie me and you[a]	15	22	tarzan and jane porn	16	16

[a]Indicates that they are incidental use of Boolean (i.e., movie or song title, or a band name), which cannot be considered as advanced query.

by |), and Quotation (symbolized by "). Table 10 presents the top-10 Boolean image, audio, and video query terms which returned the most relevant results for users, as indicated by the number of click-throughs (either organic or sponsored).

At first, "round and brown" could be seen as a method by which users are trying to search images based on the shape and color (i.e., features-based query); however, after examining the search results, it is more likely to be a sexual search. All Boolean audio-query terms are song titles or artist names, which can be considered as incidental use of Boolean terms (and not the use of advanced query terms). Note that some of the top-10 Boolean video terms co-occurred in the image search, including "romeo and Juliet" and "dead or alive," which are movie and game titles, respectively (i.e., not advanced query), and "round and brown," which is sexual. Natural language often begins by "when," "how," "what," "where," "does," "do," "is," and "are." Table 11 presents the

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TABLE 11. Top-10 natural language queries in image, audio, and video search.

Image			Audio			Video		
Query	No. of queries	Links followed	Query	No. of queries	Links followed	Query	No. of queries	Links followed
how your body works	2	4	what you know[a]	77	89	how to self suck	19	19
do not enter	2	3	what hurts the most[a]	52	62	how your body works	4	6
how to have sex	2	3	do it to it[a]	22	35	do not enter	4	5
what is adequate water	2	3	when im gone[a]	22	34	what is adequate water	4	5
when hell freezes over	2	3	what you know about that[a]	23	30	how to get in shape	3	3
how to draw manga	1	3	where is the love[a]	13	28	how to tell the sex between frogs	3	3
how to draw a dog	2	2	what you know t i[a]	20	26	how to draw flames	3	3
how to get in shape	2	2	how bad do you want it[a]	4	26	how is cheese made	3	3
how to build a volcano	1	2	is this love bob[a]	2	25	how deep is a cunt	3	3
where is the plant mouth	1	2	what a wonderful world[a]	15	21	how are you feeling today	3	3

[a]Indicates that they are incidental use of natural language (i.e., song title), which cannot be considered as advanced query.

top-10 natural language query terms in multimedia search which returned the most relevant results for users, as indicated by the number of click-throughs (either organic or sponsored).

The low number of click-throughs on the results of the natural language search may be interpreted as users not finding many relevant results. Alternatively, users may have solved their information problem in the first few clicks.

Most image search queries using natural language (6 of the top 10) started with "how," and users were often looking for instructional images. The majority of image searches were for a descriptive diagram (e.g., "how does a liver cancer look like"). Thus, multimedia search engines should aggregate results on the information about the disease (text), with images that describe the different stages or types (images), and documentary videos. The natural language terms used in video search were looking for tutorials such as "how your body work," "how to get back in shape," "how to tell the sex between frogs," and "how cheese is made." Most song-title queries are in the natural language form such as "what a wonderful world," and "when I'm gone." Therefore, the number of natural language terms for audio search is higher than that for video and image queries. However, as all natural language queries for audio searching coincide with song titles and artist names, they should not be considered advanced queries.

Discussion

What are the trends in multimedia searching? Image search dominates the multimedia Web queries, with more audio searches than video searches. People Web search is the most frequent search for image, audio, and video. Medical conditions (i.e., diseases) are the second most frequent topic in all multimedia Web search types as users are looking for descriptive media to explain diseases beyond textual information. However, based on the top-25 most clicked-through multimedia Web queries, sexually related Web searches are the most frequent genre in image and video Web searches. The most frequent audio Web searching terms are music related, such as song/album title or artist. There also are many co-occurring terms in popular image and video Web searches, showing that users use similar searching strategies for defining their needs for visual information.

This study shows 12,730 overlapping queries that are used both in image and video Web searches, 5,742 in image and audio searches, and 5,754 in both video and audio. Web search engines should explore providing integrated search using a single interface to all multimedia types. Moreover, cross-media search results can be aggregated based on the semantic meaning. For example, a movie-title search can comprehensively return video clips (e.g., teaser trailers or the music video of its theme song), audio (e.g., the song or sound-effect clips from the movie), and images (e.g., on the actors and the actions).

There are not many users of natural language in image and video search, and they are commonly used for answering "how to" and "what is" questions. Boolean ("AND") search is used for image and video Web search to combine their problems such as "dead sea and jordan river" and "piano and rose." For audio Web search, the use of Boolean keywords and natural language coincides with the use of song titles as the query term. Thus, we are currently able to draw a precise analysis on users' intention in using advanced searching.

Compared to the earlier Dogpile 2005 study (Spink & Jansen, 2006), the current study shows that similar to overall Web searching, most content-collection Web searches are short and contain few terms, and that results pages are viewed except for image searches. Similarly to our findings, Spink and Jansen (2006) found that image search is the most popular (67%), followed by audio (22%), and video (11%), respectively. However, currently video search is more dominant, at the expense of (less) audio search. This slight increase could be due to the increasing proportion of users with high-bandwidth Internet connections and the increasing popularity of video as rich content types for social networking and advertising. Video and audio search in the information and entertainment genre may increase as the uptake of portable media players such as the iPod increases. Compared

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to the earlier study, the current study found that more users across image, audio, and video content collections entered two queries per session (i.e., 42% in 2006 compared to 16% in 2005) instead of only one query.

Spink and Jansen (2006) found that Dogpile searchers generally use three terms per query ($M = 2.85$) and spend less than 1 min interacting with the Web search engine. Our study confirms this finding. Users' terms per query are now slightly shorter ($M = 2.6$), and slightly more (57–62%) users spend less than 1 min per searching episode. Consistent with Spink and Jansen (2006), current multimedia queries are generally one to four terms (two terms being the most commonly used).

Unlike the Spink and Jansen (2006) study, the current study did not see audio sessions being longer, but with fewer queries per session. Video is currently the longest, with fewer queries per session than image search, but longer than audio searches. The lowest-ranked result is now being followed up in a session, and people are now willing to go beyond 16th-ranked results. The same proportion of users examined only the first results page (i.e., rank 1–5) as that in the study by Spink and Jansen (2006), where users' generally examined only the first results page and where only people seeking images examined further results pages. Considering that multimedia searchers still spend a very short period of time (i.e., <1 min) on their searches, this mounts more serious challenges for future multimedia search engines to provide a better browsing interface.

The analysis of categorized topics in the search terms shows a consistent finding with the previous results, which found that the most frequent queries were for popular people and celebrities, places, or things. We also found that sexual and pornographic queries represented a very low proportion of all queries; however, we found that the top-25 most followed-up queries in image and video search are sexual.

Compared to the multimedia search trends study of 1997 to 2001 that used the Excite Web log (Ozmutlu et al., 2003), the proportion of multimedia searching is still consistent; averaged over 3 years, 50% of multimedia search is for images, 28% for video, and 22% for audio. The mean queries per session also is quite consistent: 3.2 for images, 2.6 for video, and 2.4 for audio. For each query, the mean number of terms used is 3.4 to 4.9 for images, 3.5 to 4.1 for video, and 4.1 to 4.4 for audio). The most frequently used terms for music search are "music," "mp3," "sound," and "songs" while the popular terms in video search are "video," "movie," "free," and "MPEG." For image search, "free," "art," and "pics" are most frequently used. However, note that the Weblog used for this study was prior to the use of separate buttons for each multimedia type. The analysis for image, audio, and video searching depends on the detection of some typical terms such as "mp3" for music. Hence, the results of their analysis cannot be directly compared with this study.

Jansen et al. (2004) examined the effect of specialized multimedia-searching buttons using AltaVista 2002 data. They found that the most dominant session size is one query, which is still consistent with our study. However, they found that the mean terms per query for image searching was notably larger (3.21 terms) than that for the other categories of searching, which were less than three terms (audio: 1.62; video: 1.09). In contrast, our study found that two terms per query is mostly used for all image, audio, and video searches, demonstrating that users have incorporated longer search terms per query in audio and video searching.

Furthermore, based on the most occurring terms, their study noted that the shift in Web searching trends (from entertainment to commercial content and an increased variety of topics) had not happened yet in multimedia searching, which is mostly for entertainment and many of the terms are sexual related. We noted a difference in our study on the most repeated terms (shown in Table 5), which used a more recent Weblog (i.e., Dogpile 2006). We found that some multimedia-searching users have started to shift (from entertainment) into other categories such as medical, sports, and technology.

Moreover, more Web search providers are now moving towards a "federated" search interface to enable users to search for information without worrying about the type of media in which it is represented (i.e., media-agnostic searching). For example, when general users search for a movie (based on the title or its main actors' names), they would be interested in images (e.g., photos of actors and snapshots from key scenes), audio (e.g., soundtrack from the movie), and video (e.g., the teaser or key video segments). As a future work, when portable devices become more popular, we should benefit from a specialized study on multimedia searching from mobile devices that generally have a small screen size, thereby presenting users with a more effective interface, and more requirements for contextualized and personalized search results.

Users' terms per query is now even slightly shorter ($M = 2.60$), and there are slightly more (57–62%) users spending less than 1 min searching. Combined with the fact the most users are willing to follow up only the first five results of the first and second pages, future multimedia search interfaces need to be more effective (a) for query formulation, (b) for browsing the search results (to determine the relevant ones), and (c) to view the multimedia document which caters the spatial and temporal dimensions in text, audio, and video. Given that there are still some proportion of users (although small) who would spend more than 10 min in a search session, there are two types of users in multimedia search: (a) those users who know precisely what they need (i.e., only willing to spend <1 min to decide whether the search results provide what they need and exit) and (b) those users who know their search topic and are willing to browse for more information to decide what they actually want.

Implications

To support the first type of users (i.e., specific and "on-the-go"), the search interface should enable these users to narrow the results, thus improving the ranking based on the context, interests (e.g., user profile or search history), and particular searching purpose at that time. For example, the system should allow users to start their image search for "Paris"

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using the keyword and let users select the pictures/keywords that represent "Eiffel Tower" to filter other pictures such as "Paris Hilton" (using image-similarity algorithms). To support the second type of users (i.e., generalists and browsers), the search interface should provide users with more relevant (and still interesting) results with their initial query while providing a fun and intuitive interface to browse results. For example, query expansion based on concept mapping can be used to bring more results to a specific query and allow users to see more related results which are still conceptually related.

Most image, audio, and video queries are seeking information on a *person*; including a singer's or band group's name, politicians, sportspersons, and movie actors. Hence, the improvement of face detection (from the computer vision field) may provide faster and more accurate results. More visually relevant search results are important for image and video Web search; however, manual annotation for people's appearance in images and videos is an expensive and tedious task. Moreover, music annotation should at least include the name of the singer(s) and song composer(s) or producer(s) to allow users to get more relevant music from their current favorite artist. The other most important categories are *medical condition* and *sexual* for image search, *song* and *medical condition* for audio search, and *medical condition* and *sports game* for video search.

To support more precise medical-related searches in image and video, Web search engines can benefit from the advancements in medical imaging (from the computer vision field) to semi-automatically annotate visual information with the types of disease or anomaly in medical images, which include external organs (e.g., skin and hair images) and internal organs (e.g., x-ray images). Moreover, amid all the ethical issues, there is potential in allowing expert users (preferably doctors and experienced practitioners) to annotate medical-related images so that users can search and learn from more examples of a particular disease or condition, particularly for educational purposes.

Finally, sports-related video search will benefit from richly annotated and content-based segmented video segments. For example, many users in the (arguably) most popular video-sharing portal Youtube.com have contributed in the creation of video compilations on "the top ten goals of a particular player," "most memorable match of a particular team," and "highlights of a particular sport game." Note that Youtube.com video collections are indexed and searched by Google.com; thus, Dogpile.com search (which combines the results from Google) should return more results from such richly annotated sports-related video to improve the relevant search results.

Limitations

While examining the characteristics of specialized multimedia searching, we have compared the current results (based on the Dogpile 2006 dataset) with previous studies that have used Excite 1997–2001, AltaVista 2002, and Dogpile 2005 Web logs (Jansen et al., 2003; Ozmutlu et al., 2003; Spink & Jansen, 2006). As such, our comparative analysis to study the trends from 1997 to 2006 assumes that multimedia Web searching users consistently share the same interests regardless of the search engines used. In addition to this variant, we have used a new method for session identification (by adding a change in query term from the initial term as an indication for a session change within the same IP and cookie) and an additional calculation method for session duration (by using the timestamp field incorporated within the latest Web log data).

There are some limitations in using Web log analysis to accurately calculate session duration and the time spent for browsing/viewing search results. The timestamp for each query (within a session) is recorded when a user submits the query; thus, there is a possibility that users may leave the computer to conduct other activities (e.g., resting) between submitting two subsequent queries. Moreover, Web log data cannot be used to determine when a user leaves the current search session, as there is only a record of the last query being submitted. Hence, the calculation of session duration in this study does not take into account the viewing time (of the last search results) prior to leaving the session. The problem with the current method in identifying a user's session in a particular computer (i.e., via cookie and IP address) is the inability to learn whether a user opens multiple browser windows to submit each query. As a result, a study of multitasking search cannot be conducted.

Without other user data, such as that from questionnaire or observation, we cannot determine successful searching, including: (a) whether a user is satisfied with the results prior to leaving a search session, and (b) whether a query with zero (number of) click-through means that users are satisfied with their image/video search after browsing the visual thumbnails or that they did not find any relevant result. Furthermore, a Web log cannot indicate the reasoning process behind the initial and subsequent query terms [to reach the original or updated search goal(s)]. As such, a study of users' search-intent evolvement while searching for multimedia is limited. Finally, automatic classification of query terms cannot accurately determine the intended concepts or topics (being searched) while a fully manual process of classification (that would still not avoid false detections) is tedious, lengthy, and inaccurate, especially when the query is too short and without any clarifying terms.

Conclusion and Further Research

Our current study has provided insights into the current state and trends in multimedia Web searching. We are currently conducting further research into multimedia Web searching by investigating users' genre interests and searching for personal names. For example, the personal names can be for music, sports, politics, and movie or games. Using larger scale data and other data-analysis techniques, we also need to study multitasking during multimedia Web search sessions. Effective user models are needed to help provide users with better search support.

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