

Deciphering Mobile Search Patterns: A Study of Yahoo! Mobile Search Queries

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ABSTRACT

In this paper we study the characteristics of search queries submitted from mobile devices using various Yahoo! *mobile oneSearch* applications during a 2 months period in the second half of 2007, and report the query patterns derived from 20 million English sample queries submitted by users in US, Canada, Europe, and Asia. We examine the query distribution and topical categories the queries belong to in order to find new trends. We compare and contrast the search patterns between US vs international queries, and between queries from various search interfaces (XHTML/WAP, java widgets, and SMS). We also compare our results with previous studies wherever possible, either to confirm previous findings, or to find interesting differences in the query distribution and pattern.

Categories and Subject Descriptors

H.3.3 [Information Storage and Retrieval]: Information Search and Retrieval—*Internet search*; H.3.0 [Information Storage and Retrieval]: General—*Web search*; A.1 [General Literature]: introductory and survey

Keywords

Mobile query analysis, mobile search, query analysis, query log analysis, mobile applications, wireless devices, mobile devices, cell phones, personal devices

1. INTRODUCTION

The number of wireless subscribers is growing rapidly, from under 200 million in June 2005 to over 243 million in June 2007 in the US, a growth rate of almost 2 million users per month¹. The world-wide growth is projected to be at an even more impressive rate: over 4 billion by 2010 from 2.7 billion at the end of 2006.

With the growing population of mobile subscribers, it is anticipated that the access to the internet through their

wireless devices is to grow, too. In fact, we might have already entered into the early stage of the massive adoption of internet access through wireless handheld devices. The use of popular internet applications, including email and maps, has been growing at a very high rate lately.² Further, in most emerging markets, like India and Eastern European countries, majority of users are projected to start experiencing the internet through their mobile devices than through desktop computers³. And there would be tremendous market opportunity on the wireless services, especially for advertising business, as wireless device becomes the third screen after TV and computer monitors. Mobile search may play a major role in facilitating and accelerating the internet data access through the mobile devices, just as the majority of internet users use a desktop search application as a gateway to the internet services.

It is a paramount importance to understand users' information needs and demands for mobile data access in order to better serve them. And it would be very helpful to understand the usage patterns and the user intent of search queries to learn their wireless information needs and to decipher the trends.

We have studied search query log data of various Yahoo! mobile search applications. Yahoo! *Mobile oneSearch*⁴ is a federated mobile search service with three distinct search application interfaces built on top of it: a XHTML/WAP browser interface (<http://m.yahoo.com>), a java application interface (Yahoo! Go), and an SMS text messaging interface (Yahoo! Mobile SMS).

The goal of this study is two-fold:

- to explore the search characteristics of the sample data and to discover notable patterns in the queries
- to supplement and complement prior studies on mobile query pattern analysis by relaxing various restrictions put on the previous studies and by exploring a new set of data

We intended to primarily focus our analysis on areas where prior work is not available, or has not explored comprehensively. The followings are the major focus areas of our study:

²<http://www.reuters.com/article/marketsNews/idUKN2120622020070822?rpc=44&pageNumber=1>

³By desktop computers, we refer to both desktop and notebook computers.

⁴<http://mobile.yahoo.com>

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¹According to the CTIA (the International Association for the Wireless Telecommunication estimation. http://www.ctia.org/media/industry_info/index.cfm/AID/10323

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WWW 2008, April 21–25, 2008, Beijing, China.
ACM 978-1-60558-085-2/08/04.



Figure 1: Sample Search Results of Yahoo! oneSearch

- comparison of underlying query distribution and characteristics to find new trends
- comparison between the US and international query patterns
- analysis of mobile queries from various types of mobile application interfaces

The data set for our analysis consists of a random sample of 20 million queries submitted from US, Europe, and Asia by the 3 Yahoo! mobile search applications during a 2 months period in 2007. Only English queries were included in the study in order to eliminate language specific idiosyncrasy and to maintain consistency in the analysis. The cross comparison of the query patterns among various language and culture is beyond the scope of this paper. All of the sample data is completely anonymous. No data to match a user's identity is maintained or used in our study, and we report only aggregate statistics.

For the study, we first surveyed empirical observations drawn from the sample data sets. We apply first-order analysis on the sample queries and examine the statistics such as the length of an individual query, the number of words per query, and the query distribution and repetition pattern. We have conducted research on the topical categories and application specific query patterns.

Major contributions of this paper include the followings:

- It is by far the largest scale mobile query log analysis for English queries. It is more than an order of magnitude larger than the previous studies on mobile query data[10, 9].
- It reports inter-regional and inter-national mobile search patterns in large scale including the US, Europe, and Asian countries.
- It includes the results of comprehensive analysis of various types of mobile application interfaces.

The rest of this paper is structured as follows. In the next section, we briefly introduce Yahoo's mobile search services and applications. Section 3 describes the sample data sets used for the study. Section 4, the main section of this paper, consists of three major parts: section 4.1 is for the first-order analysis and the results, section 4.2 for the mobile query



Figure 2: Yahoo! oneSearch Front Page Interface

categorization and the results, and section 4.3 for mobile search application specific issues. We provide an overview of related work and the comparison with our work in section 5, and conclude in section 6 with discussion and plan for the future work.

2. YAHOO! MOBILE SEARCH SERVICE AND APPLICATION INTERFACES

Yahoo!'s **Mobile oneSearch** is a federated search service optimized for mobile devices and users. For a given user query, it, first, analyses the *concept* and the *intent* of the query. Second, it produces and executes a search execution plan, optimized for the *concept*- and *intent*- of the query, against a large array of vertical back-end including the Web, news, images, finance information, wikipedia, user-generated contents such as Yahoo! Answers, and so on. Lastly, it aggregates the search results of the verticals and blends the results in a manner optimal to the query, and to the rendering on the mobile device.

The goal of **oneSearch** is to provide better search results and user experience by providing immediate answers to user queries, not just links to the target pages, and by minimizing the number of clicks for search and browsing interactions in order to minimize the number of round trip requests to the servers over the slow wireless data network. The search results of vertical back-ends are grouped by verticals and blended for optimal user experience by taking account of various factors, including the concept and the intent of the query, the content relevance and rank of the search results, and other query independent factors, such as mobile device types. See Figure 1 for a few samples of the search results.

Mobile oneSearch servers process all mobile search queries coming from 3 different Yahoo! search application interfaces for mobile devices: an XHTML/WAP browser interface, a java application interface for Yahoo! Go, and an SMS text messaging interface for Yahoo! Mobile SMS. The rest of this section provides a brief introduction to the three Yahoo! mobile search product offerings.

2.1 Mobile oneSearch XHTML/WAP Interface

Figure 2 shows oneSearch XHTML/WAP front page interface available at <http://m.yahoo.com>. The page has a

search box and a list of links to various mobile applications such as email and calendar, and links to other verticals such as news, finance, and flickr.

The most distinctive feature of **Mobile oneSearch** SERP (Search Engine Results Page) is the grouping of the search results by the source verticals of the results. Currently, first, the federated search results are blended and ranked in an optimal ordering of the verticals. Result pages of a vertical source is ranked optimally within the vertical. Figure 1 shows search results of a few sample queries

2.2 Yahoo! Go for Mobile 2.0

Yahoo! Go (downloadable from <http://m.yahoo.com>) is a broad array of customizable mobile offerings under a single downloadable java-based application, optimized for the small screen of a mobile phone. At the core of the interface is the *carousel* users can scroll through, comprising currently nine widgets including the made-for-mobile **oneSearch** as well as other popular mobile applications, such as email, local info and maps, news, sports, finance, entertainment, weather, and Flickr photos.

With the advanced caching and background loading technology, **Go** widget content is automatically and continuously *pushed* to the user's phone, so it is readily available when it is needed.

2.3 Yahoo! SMS Search

The SMS Search application provides an interface that a search query is submitted by an SMS text messaging. A SMS text message with the search query is sent to the server (short code: 92466), and the result is delivered by one or more text messages. Each result message may contain the search results directly, instead of search result page links, at least for certain types of information (such as business listings), thus minimizing the need of additional click. This is a very useful service for users whose device is not equipped with data access capability.

3. SAMPLE DATA SET

We use two query samples from Yahoo! mobile query logs during the period of August and September 2007:

1. US sample queries: 20 million page views with non-empty US English queries were randomly selected, with 10 million samples each from August and September, respectively.
2. International sample queries: 20 million page views with non-empty English queries during the same period were randomly sampled in the same manner. This query data set consists of queries from Australia, Canada, India, New Zealand, and the UK.

Both are limited to English queries only. The countries selected for the study are those in Asia, Europe, and North America that Yahoo! receives English queries predominantly from.

4. ANALYSIS OF MOBILE QUERIES

In this section, we present the results of various analyses on mobile queries. Section 4.1 reports the results of various first-order analysis applied on individual queries from the sample data sets. Section 4.2 describes the mobile query

Table 1: Query Distribution

		US	International
Total # of queries		20M	20M
# of unique queries		4.49M	3.7M
Avg. # of query repetition		4.46	5.41
# words per query			
All Queries	Avg	2.35	2.1
	Median	2	2
	StdDev	1.16	1.09
	Max	65	60
Uniq Queries	Avg	3.05	2.54
	Median	3	2
	StdDev	1.41	1.3
	Max	65	60
# characters per query			
All Queries	Avg	13.73	13.6
	Median	13	13
	StdDev	7.13	6.8
	Max	263	501
Uniq Queries	Avg	18.48	17.5
	Median	17	13
	StdDev	7.92	9.13
	Max	263	501

categorization. We discuss mobile search application specific issues in section 4.3.

4.1 First-Order Analysis of Mobile Queries

We begin the mobile query analysis by considering individual queries. We first examine the quantitative statistics of unique queries. Then, we discuss the mobile query distribution patterns derived from the query repetition pattern.

4.1.1 Unique Queries

Table 1 summarizes the characteristics of the sample queries and unique queries derived from the sample data sets. For the sample queries examined in this study, there are roughly 4.49M unique queries in the US data set, and 3.7M in the international data set. On average, a query is repeated 4.46 and 6.08 times during the 2 months test period in the US and the international data set, respectively; on average, over 20% more repetition of a query in the international data set.

The average number of words per query is 2.35 (mean, 2; std. dev: 1.16; max., 65) for the US queries, and 2.1 (mean, 2; std. dev, 1.09; max 60) for international queries. The average number of characters per query is 13.73 (mean, 13; std. dev, 7.13; max, 263) and 13.6 (mean, 13; std. dev, 6.8; max 501) for the US and international queries, respectively. US users are using about 11% more number of words than the international users for almost the same length of a query. We plan to investigate if there is any underlying difference in the query pattern between the two groups that causes this difference, such as more adoption of abbreviated terms by the US users.

When only unique queries are considered (i.e., with no weight by their repetition), the average numbers increase quite substantially. The average number of words per unique query is 3.05 (mean, 3; std. dev: 1.41) and 2.54 (mean, 2; std. dev, 1.3) for the US and international samples, respectively. The average number of characters per unique query

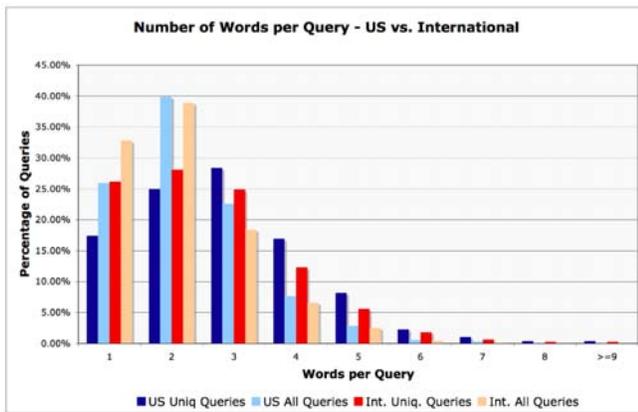


Figure 3: Distribution of word lengths per query - US vs. International for unique and all queries

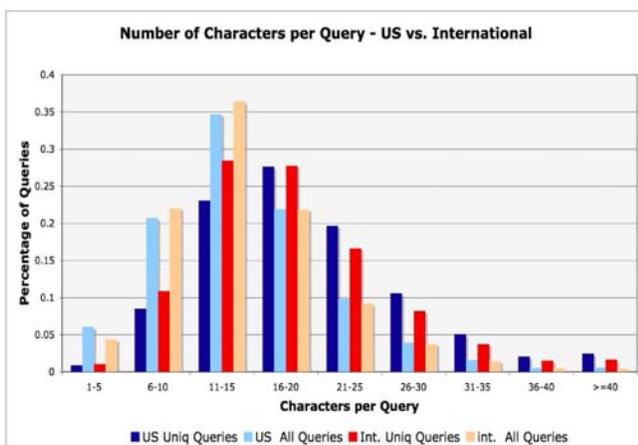


Figure 4: Distribution of character lengths per query - US vs. International for unique and all queries

is 18.48 (mean, 17; std. dev, 7.92) and 17.5 (mean, 13; std. dev, 9.13) for the US and international queries, respectively. The increased lengths on the unique queries imply that many *head queries* (queries with high frequency of repetitions) are shorter than average, and longer queries lie on *tail queries* (queries with very small number of repetitions).

The distribution of the number of words per query is plotted in Figure 3. It compares US and International queries for unique queries and all queries. Figure 4 is for the distribution of the number of characters per query. We find notable differences in the distribution of the number of words (Figure 3) between our results and [9]: the most frequent query word length in [9] is 1, while ours is 2.

Figure 5 illustrates the cumulative query frequency of top 2000 unique US and International queries. The lower graph is for International queries and the upper one is for US. The top 2K most frequent queries, or less than 0.05% of the unique queries in the US, account for over 27% of the entire query volume in the US, while the same number of top queries (less than 0.06%) are responsible for 17% of the international query volume. In the cumulative graph, the lower the volume accounted for by the top-N unique

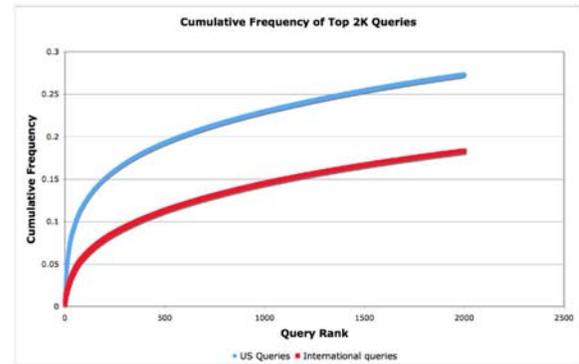


Figure 5: Cumulative Query Frequency of Top 2K Queries of US (upper curve) and International (lower) Data Sets

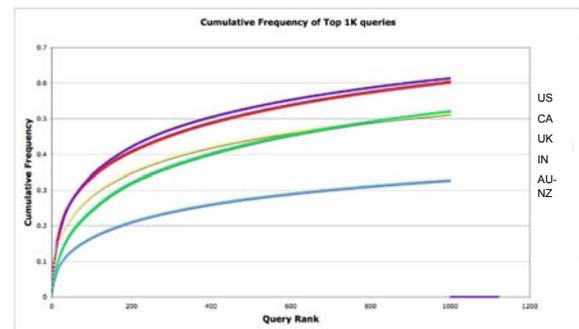


Figure 6: Cumulative Query Frequency of Top 1K Queries of US, CA, UK, IN, AU-NZ (in the order the corresponding curve appear on the graph from top to bottom)

queries, the more diverse the set of queries received. Therefore, this indicates that the US queries have less variety, even with more number of unique queries. In other words, a much smaller percentage of US head queries are much more frequently asked, thus accounting for a larger portion of the entire query volume. This is also explained by the fact that the international data set has much less number of tail queries than the US data set even with the diverse user base. (And this can be verified in the international query repetition graph, Figure 8, discussed in the next section.)

Figure 6 compares the cumulative coverage of 5 countries - US, Canada, UK, India, and AU-NZ (Australia and New Zealand combined) - for top 1000 queries from 1M randomly sampled unique queries for each country. The volume coverage of the 0.1% of unique queries varies from 32% (AU-NZ) to 61% (US). The graph indicates that AU-NZ queries are most diverse followed by India, UK, Canada, and US queries. US queries are still the least diverse, and Canada search pattern is a close mirror in terms of the frequency pattern of the head queries.

Comparison with Prior Studies.

Our query word count (avg. 2.35 words per query) stays in the range of the corresponding figures reported in [10] (avg. 2.56) and [9] (avg, 2.3). Since [9] excludes PDA queries

that are typically longer (avg. 2.7) from the calculation, their number is like a lower bound of the size of mobile queries. Our query word count (avg. 2.35) is consistent with the corresponding numbers, 2.29 on average, reported in [1], that combined PDA queries as we did, although it is not directly comparable because their study is on Japanese queries.

For the number of characters, our queries are much shorter with 13.73 characters per word on average, than [9] (15.5 in XHTML, 17.5 for PDAs) and [10] (avg 16.8).

It is interesting that most of the top-level first order statistic quite agree each other between the other studies and ours, even with the language difference. Average number of words in a query is 2.29, 2.3, 2.35 and 2.56, for [1], [9], ours, and [10], respectively, though the number of characters per query is drastically lower in Japanese queries at 7.9 vs. 16.8 in [10] due to the language difference. Further, this is highly consistent with average number of query terms in web search reported in [7] and [14], 2.35 on average, though it is quite old data for the Web's standard, regarding the fast evolving nature of the Web.

This may indicate that mobile users repeat their search habit on a desktop search on mobile search. And this may also suggest that about less than 2.5 words are enough for users to find the information of their need, making the number of search terms indeed a "ground truth" of web search, as suggested in [9].

4.1.2 Analysis of Query Duplicates

Another interesting question about query strings is how often a query is repeated. As in desktop web search[14], our earlier observation (Figure 5) indicates that a small set of queries are repeated many times.

We have analyzed the query duplication pattern in the sample queries in terms of the number of query repetitions and the number of corresponding queries. The pattern follows the power law distribution, exhibiting a remarkably linear pattern on a log-log plot, as shown in Figure 7 and Figure 8. The x-axis of the graph represents the log of the number of query repetitions, and y-axis the log of the number of corresponding queries. The slopes of the regression line of the plots for US and international queries are -1.25 and -1.44, respectively.

The slight downward tilt on the upper left end of the international query distribution graph (See Figure 8) indicates that the international data set has much less number of tail queries (queries asked only less than a few times). In the international query data, there are 1,611,322 unique queries that were asked only once, which is about 49% of the number of entire unique queries, and about 8% of the entire sample query volume, while there are 2,669,290 unique queries in the US query data with frequency 1; which corresponds to 66% of the unique queries and about 13% of the entire sample query volume. The amount of unique queries with frequency count 1 corresponds to the y-intercept of the query distribution graph.

The most frequent query in the international data set appears over 58K times (or 0.29% of the entire sample query volume), while in the US data set, the most frequent query was appeared over 88K times (or 0.44% of the sample query volume).

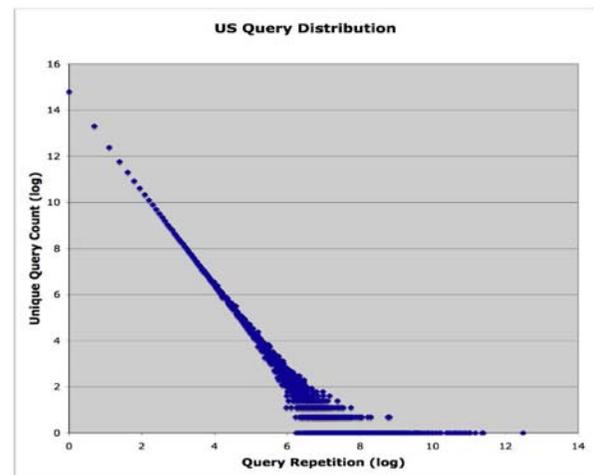


Figure 7: US Query Distribution

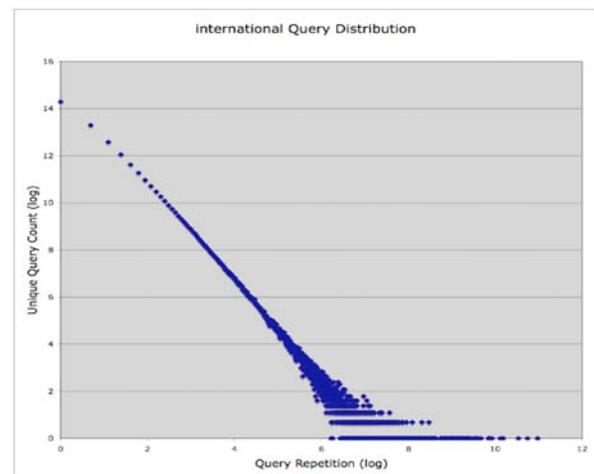


Figure 8: International Query Distribution

4.2 Mobile Query Categorization

Both US and international queries are automatically classified into the topical categories and the categorization result is summarized in Table 2 and Table 3. For the query categorization, we have used a logistic regression based classifier. Refer [12] for the detailed algorithm. For the classification taxonomy, we have used an in-house taxonomy with total 821 nodes with maximum depth 6. There are 24 top-level categories, 152 second, 281 third, 229 fourth, 94 fifth, and 41 sixth level categories. See table 2 for the list of top level categories.

The most popular category for both data sets was the adult category that is predominantly for pornographic queries. This result is consistent with previous mobile search studies [9, 10]. However, the relative volume of adult queries in our sample is far greater than what have been previously reported. Not only it is more than 3 times higher than the number of pornographic queries on conventional Web searches that accounted for less than 10 percent of all queries in 2001[15], it is considerably higher than even a comparable study on recent mobile queries[10]. Kamvar and Baluja [10]

Table 2: US Mobile Query Categorization

Categories	Unique Queries			All Queries		
	% of queries	Avg. words per query	Avg. chars per query	% of queries	Avg. words per query	Avg. chars per query
Adult	33%	3.20	18.58	40%	2.54	14.42
Arts & Humanities	<1%	3.14	19.32	<1%	2.39	13.73
Automotive	2%	3.29	18.89	1%	2.60	14.48
Consumer Goods	2%	3.07	18.5	2%	2.28	13.70
Entertainment	11%	3.42	19.39	11%	2.57	14.64
Finance	1%	3.36	21.24	1%	2.18	12.39
Government & Politics	1%	3.05	20.99	<1%	2.87	17.52
Health & Pharma	2%	3.27	20.85	1%	2.57	16.36
Hobbies	<1%	3.06	19.04	<1%	2.49	15.67
International Interest	<1%	3.33	19.90	<1%	2.56	14.98
Life Stages	2%	3.33	21.15	1%	2.71	16.66
Miscellaneous	2%	3.17	18.71	2%	2.49	14.38
News	2%	3.21	19.35	2%	2.50	14.61
People	3%	2.73	17.18	5%	2.24	13.96
Reference	1%	3.64	21.89	<1%	2.75	16.91
Religion	1%	3.05	19.40	1%	2.17	14.33
Retail	5%	3.36	20.08	4%	2.35	14.21
Science	1%	3.13	19.70	1%	1.83	10.66
Small Business	2%	3.25	20.83	1%	2.57	16.22
Sports	3%	3.29	20.46	3%	2.40	14.23
Technology	6%	3.36	20.54	7%	2.19	12.74
Telecommunications	2%	3.49	21.05	2%	2.75	16.56
Travel	7%	3.34	20.03	7%	2.30	12.30
Uncategorized	12%	1.45	11.59	9%	1.26	8.98

Table 3: International Mobile Query Categorization

Categories	Unique Queries			All Queries		
	% of queries	Avg. words per query	Avg. chars per query	% of queries	Avg. words per query	Avg. chars per query
Adult	34%	2.82	18.23	40%	2.82	14.68
Arts & Humanities	<1%	2.94	18.26	<1%	2.94	14.66
Automotive	1%	3.01	17.49	1%	2.50	14.15
Consumer Goods	1%	2.81	17.13	1%	2.33	14.72
Entertainment	8%	3.11	18.60	7%	2.47	14.90
Finance	1%	2.95	18.51	1%	2.38	15.90
Government & Politics	<1%	2.55	18.86	<1%	2.55	15.77
Health & Pharma	1%	3.02	19.48	1%	2.48	13.62
Hobbies	<1%	2.80	18.21	<1%	2.80	15.56
International Interest	<1%	2.63	17.00	<1%	2.27	14.82
Life Stages	2%	2.80	18.81	1%	2.29	14.68
Miscellaneous	<1%	2.94	18.82	1%	2.93	15.36
News	1%	2.87	18.52	1%	2.87	14.81
People	3%	2.85	18.23	4%	2.85	14.24
Reference	<1%	3.48	21.78	<1%	3.48	17.53
Religion	<1%	2.43	17.97	<1%	2.43	15.04
Retail	3%	3.02	18.39	3%	2.21	15.93
Science	<1%	3.02	19.75	<1%	3.02	16.31
Small Business	1%	2.82	19.35	1%	2.40	14.53
Sports	2%	3.05	18.85	1%	2.35	14.99
Technology	5%	3.01	20.46	5%	2.11	15.97
Telecommunications	2%	3.13	21.48	2%	2.26	14.57
Travel	3%	2.30	17.75	2%	2.02	10.86
Uncategorized	28%	1.70	14.81	28%	1.45	13.63

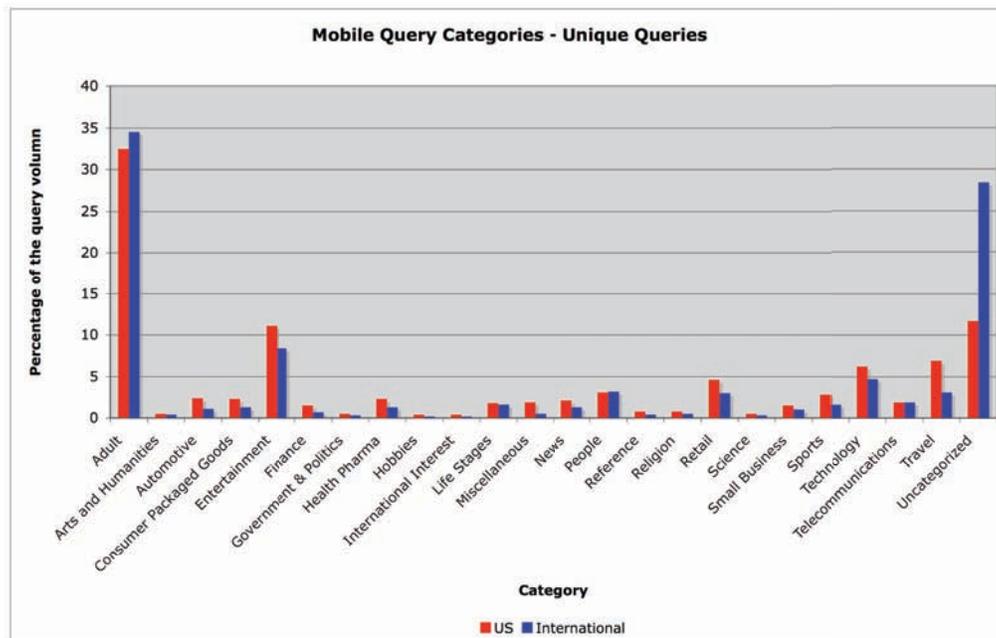


Figure 9: Mobile Query Categorization (Unique Queries): US vs. International

reports about 25% of all their sample queries Google has received belongs to the adult categories, an increase from about 20% in [9] published in the previous year.

As pointed out by [10], two conjecture may potentially explain why mobile search has higher volume of adult queries than the web search in general. First, wireless search is still in the very earlier stage than desktop search, and it may follow the pattern of the Web search in the early days where a considerably higher proportion of adult queries was asked. [15] reported that the pornographic queries in the Excite queries were decreased to half (from 16.8% to 8.5%) during the period from 1997 to 2001. If mobile search is following the path web search has taken, the amount of porn queries on mobile is expected to drop, too, over time. Second, since the cell phones are much more personal device and most cell phones do not cache due to the limited storage space capacity, people feel more comfortable querying adult queries on them, than on desktop computers where their search footprints stay much longer.

In addition, we have an additional conjecture why Yahoo! mobile query data has more adult queries than Google's. We assume most porn queries are for searching images. This assumption is indirectly validated by the fact that Yahoo! SMS queries get very little porn queries, only slightly over 1%, because the text based interface can not render any image at all. The federated nature of Yahoo! oneSearch that provides better image search results might have contributed to attract more adult queries. In addition, Yahoo!'s web search results pages tend to retain all the images, while Google's XHTML transcoder used to eliminate most images on the search results pages. Further, Kamvar and Baluja also has acknowledged that their volume of adult queries

Table 4: Entertainment Subcategories

Sub-categories	US queries	Int. queries
Music	47.70%	41.13%
Movies	15.86%	21.27%
Games	14.72%	17.24%
TV	11.48%	11.47%
Radio	2.14%	1.34%
Amusement	1.94%	1.29%
Performing	1.38%	0.95%
No sub-category	4.64%	5.19%

has been increased from 20% to 25% after launching a new transcoder that retains more images than the earlier version of transcoder [10].

The second most popular was the entertainment category as expected. Since it is expected to be one of the most popular query categories, it is worthwhile to explore users' interests within this category. Table 4 lists popular sub-categories of entertainment queries.

In addition to the topical categorization, there are a few notable query types or intent. First, there are queries with *local intent* that intend to search for local information. This is not necessarily a topical category, but rather a meta category that can be combined potentially with any topical search. The local search intention might not be always explicit with the location information given with the query, such as a zip code or a city name. We estimate about 9-10% of our queries has local intention. We have found about 5% of our queries being URL (or navigational) queries which is much lower than the result reported by [9] at 17%. There,

Table 5: Mobile Query Categorization - by Search Applications (The columns might not sum to 1 due to rounding error.)

Categories	Browser (US_WAP)	Y! Go (US_YGO)	Y! SMS (US_SMS)
Adult	46%	23%	1%
Arts & Humanities	<1%	1%	<1%
Automotive	1%	2%	2%
Consumer Goods	1%	2%	2%
Entertainment	9%	11%	13%
Finance	1%	1%	2%
Government & Politics	<1%	<1%	1%
Health Pharma	1%	1%	2%
Hobbies	<1%	<1%	<1%
International Interest	<1%	<1%	<1%
Life Stages	1%	1%	2%
Miscellaneous	1%	1%	6%
News	1%	2%	2%
People	5%	5%	1%
Reference	<1%	<1%	2%
Religion & Spirituality	<1%	1%	2%
Retail	3%	4%	8%
Science	<1%	<1%	<1%
Small Business	1%	1%	1%
Sports	2%	8%	13%
Technology	4%	4%	7%
Telecommunications	1%	1%	1%
Travel	6%	18%	17%
Uncategorized	13%	11%	12%

also, are queries searching for mobile specific products and services, such as mobile games, ringtones, wallpapers, email services, etc.

Figure 9 illustrates query categorization pattern of unique queries between the US and international queries. The graph shows there is no major difference in terms of the topical interest of queries of the users of the two groups, except the 'travel' and 'uncategorized' class. In fact, the same kind of graph for all queries shows very similar pattern between the two data sets, and thus is omitted from the paper for brevity. Please note that this does not mean that the actual queries are quite identical. Rather it means that the types of queries are quite similar. For example, individual queries asked by the US users that belong to sports may quite different from sports queries asked by the international users. Therefore, there could be subcategories that show meaningful differences between the two groups. We avoid the detailed discussion due to the lack of space.

4.3 Application-Specific Query Patterns

In this section, we examine distinct search behaviors of users using various types of search application interfaces. As discussed earlier, Yahoo! mobile search offers three distinctive mobile search application interfaces: a widget-based Go application, a browser based oneSearch interface, and an SMS text message interface. Since each application requires different level of device sophistication and the communication medium, we initially hypothesized each user group may possess different demographic variations as well as device capability, and therefore different search interests.

Table 6: Sports Subcategories

Sub-categories	Yahoo! GO	Yahoo! SMS
Auto Racing	3%	<1%
Baseball	33%	58%
Basketball	7%	2%
Fantasy Leagues	2%	<1%
Football	37%	22%
Golf	3%	2%
Hockey	4%	<1%
Snow	<1%	<1%
Soccer	3%	<1%
Tennis	2%	<1%
Wrestling	3%	1%
etc.	2%	10%

Table 7: Travel Subcategories

Sub-categories	Yahoo! Go	Yahoo! SMS
Air & charter	5%	59%
Car Rental	<1%	14%
Destinations	71%	<1%
Hotels & Lodging	3%	3%
Maps	1%	1%
non-US	3%	6%
etc.	17%	14%

We separated the US query sample data set into three, each containing queries only from the corresponding search application: US_SMS for Mobile SMS, US_YGO for Yahoo! Go, an US_WAP for the browser based oneSearch queries. The classification result is listed on table 5 and plotted on Figure 10.

As shown on the graph, each user group exhibits highly distinctive adult query search behavior. US_SMS queries have only a little pornographic queries (about 1%), while US_YGO queries have noticeable amount of decrease (by 10%). As briefly discussed in Section 4.2, we believe the extremely low volume of adult queries in the SMS sample query data set is primarily due to the users' inability to browse images as the search results through the text only interface. We conjecture the decrease of the adult queries on Yahoo! GO interface is perhaps due to the potentially different demographic of the users that steer their search interest more towards leisure oriented queries. The increase of adult queries on WAP data set in comparison to the entire sample queries is a simple consequence of the decreased adult query volume in the rest of the samples.

Other potentially interesting pattern shown on the table 5 is the increase of leisure oriented searches, such as *sports* and *travel*, for both US_YGO and US_SMS. Table 6 and 7 list the subcategories of *sports* and *travel* and the US_YGO and US_SMS query distribution on them.

5. RELATED WORK

Search engine query log data is an invaluable source of information for understanding user intention and the characteristics of user queries, as well as for measuring search results relevance. Accordingly query logs have been widely explored for various purposes, including profiling of search query characteristics ([14, 7, 15] for the desktop web search,

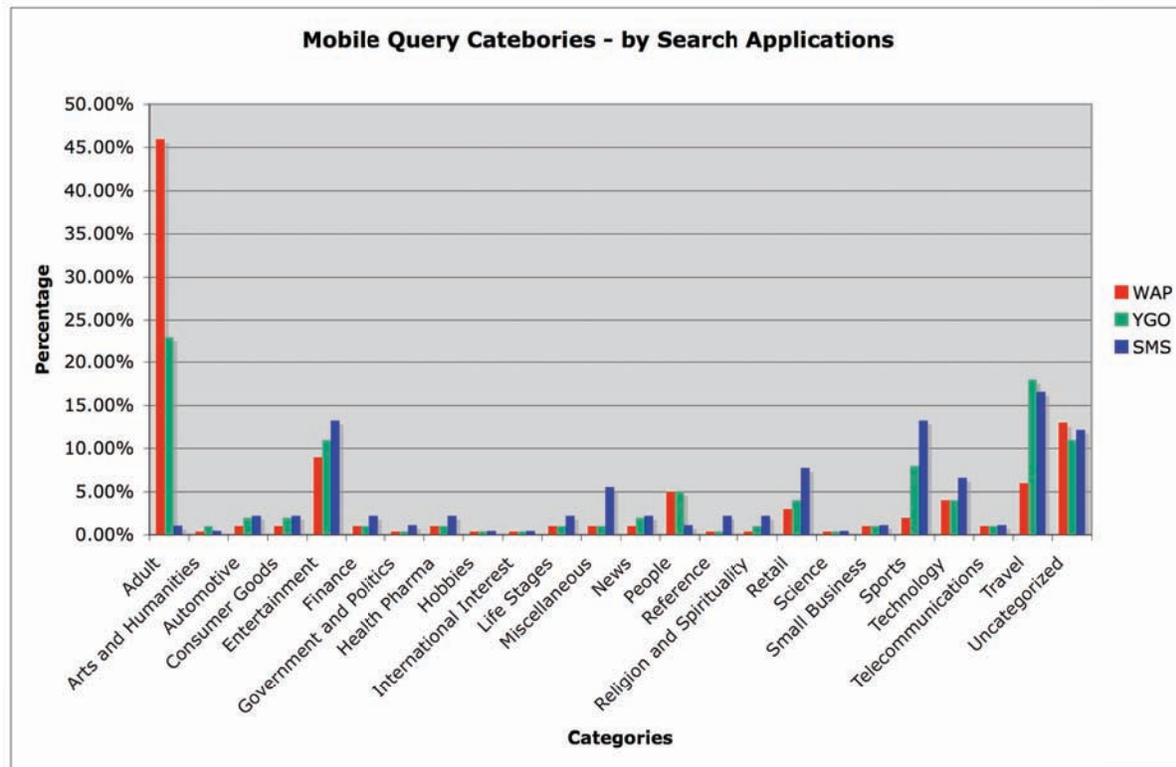


Figure 10: Mobile Query Categorization - by Search Application

and [1, 9, 10, 4] for mobile search). Another related and interesting problem of identifying user goals and intent of a query using query log data is discussed in [13, 11, 6]. [2, 13] have manually classified query log data to capture user needs behind the search. In addition, [16] and [5] have used query logs for topic identification and result clustering, and for better snippet generation, respectively.

There have been several large scale studies in the near past on mobile query log analysis for deciphering mobile search query patterns, including [1], [9], and [10]. Kamvar and Baluja reports the study conducted using 1 million randomly sampled Google mobile query log data for a month period of 2005 [9]. It is the first large scale mobile query log analysis we are aware of, that provides a large number of quantitative statistics on wireless search performed on cell phones and PDAs. They report a large amount of first-order statistics on search terms and the topics of the search queries that provide insight on how and what the mobile users are searching for. In their follow-up study [10] using 1 million page-view randomly sampled from Google's logs in early 2007 confirms some of the findings in their previous study, and finds some differences and changes during the period that provides a very useful insight about how mobile search is evolving. Some of their findings include the search terms in 2007 study are more diverse (i.e. less homogeneous queries), more high-end device, and more adult queries.

Another large-scale mobile query log analysis was by Baeza-

Yates, Dupret and Velasco on Yahoo! Japan's search logs. Their findings include results consistent with US mobile search results, such as average number of terms per query, even with the drastic differences in language, with some results that are drastically different. For example, average number of characters per query is only half as much as other US queries.

Silverstein et al. conducted a very large scale query log analysis and reported many interesting aspects of web search [14]. Though we can not draw any conclusion for mobile search directly from the web log analysis results, they will continue being an invaluable reference information for comparison and giving us insight on how the mobile web search might evolve in the near future. It will be interesting to find out if the mobile web and the search would follow the footprint and growth of the web, or it'll branch out towards a totally different path.

Some other work on mobile query log analysis includes [3, 8] that address better information display mechanism for mobile devices.

6. DISCUSSION AND FUTURE WORK

The goal of this mobile query analysis study is to provide quantitative statistics on various aspects of mobile search that can help us to gain better insight on the mobile users' information needs, and to better understand how they are

fulfilling their needs by mobile search. Although some of the previous studies have already provided with very insightful data on some of the mobile search characteristics, albeit with restrictions and limitations, we find there are many more aspects and issues the previous studies have not addressed upon.

We have conducted a large-scale study on English mobile queries from the US, Europe, and Asia. We have analyzed various top-level statistics on individual queries, and their repetition patterns to identify query distribution and quantitative patterns. We have automatically classified the sample queries into a topical categories in order to capture the areas of user interest. We have compared the results with the previous studies, between inter-regional and inter-national groups, and between the user groups of various search applications. The following is a few interesting points and trends from the results:

- The most popular queries are for adult content: Most queries in this category is for adult image content.
- Personal entertainment is a popular interest of the users: As expected, users are searching for personal entertainment, including music, movies, games, and TV.
- Mobile query pattern is still dynamic: Based on the differences observed among various studies, in terms of query distribution, we believe mobile users are still figuring out ways they can utilize the new device and services, and their usage pattern is still evolving.
- Regional patterns: There exist meaningful variations in the regional query pattern in terms of the quantitative statistics. US users use longer and more word queries than international users. There are more tail queries in the US data set. And queries from the US users are still the most homogeneous among the countries studied, followed by Canada, UK, India, Australiz-New Zealand. However, they show very similar topical interests, at least at the top level.
- Application-depedent patterns: We have found interesting differences among users of various search applications in terms of their topical interests of their queries. We conjecture some variations are due to the different capacity of their mobile devices, while some originate from the demographic differences from the groups of users. In this study, we have not attempted to perform any analysis on the demographic variations, however, and further discussion is beyond the scope of this study.

In the future, we plan to study click-through data to better understand the impact of search results grouping and to come up with better results blending algorithm. We also like to improve query concept identification and to conduct research on user query intent analysis.

7. ACKNOWLEDGMENTS

The author would like to thank the entire Mobile one-Search team at Yahoo! – Amod Panshikar, Cecil Baalzen, Shiv Ramamurthi, Pinghua Young, Yarram Sunil Kumar, Arya Goudarzi, Qinwei Gong, Tao Feng, and Sudhir Rao – for creating the product and laying the foundation that enabled this study.

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