

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! *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, oneSearch

General Terms

Measurement

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.

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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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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. There is tremendous market opportunity on wireless services, especially for advertising businesses, 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 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 Yahoo! mobile search query log data. Yahoo! oneSearch⁴ is a 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:

- comparison of underlying query distribution and characteristics to find new trends

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>



Figure 1: Sample Search Results of Yahoo! oneSearch

- 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 through Yahoo! mobile search 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 categorization and the results, and section 4.3 for mobile search application specific issues. We provide an overview of

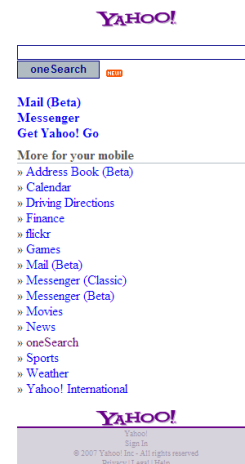


Figure 2: Yahoo! oneSearch Front Page Interface

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 INTERFACES

Yahoo! 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 Yahoo! 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.

Yahoo! oneSearch servers process all mobile search queries coming from 3 different Yahoo! search 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 Yahoo! 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 Yahoo! 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

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 Yahoo! 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, Yahoo! 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 (ex. short code: 92466 for the US), 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 platform 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 5.41 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

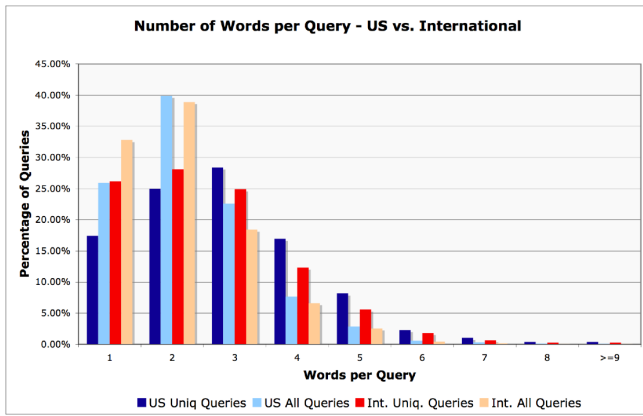


Figure 3: Distribution of word lengths per query - US vs. International for unique and all queries

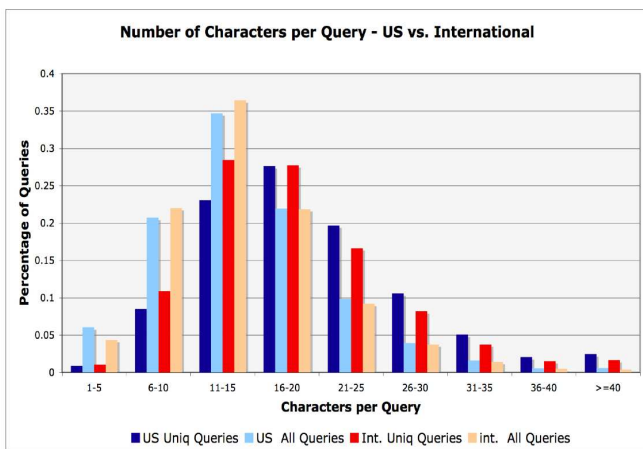


Figure 4: Distribution of character lengths per query - US vs. International for unique and all queries

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

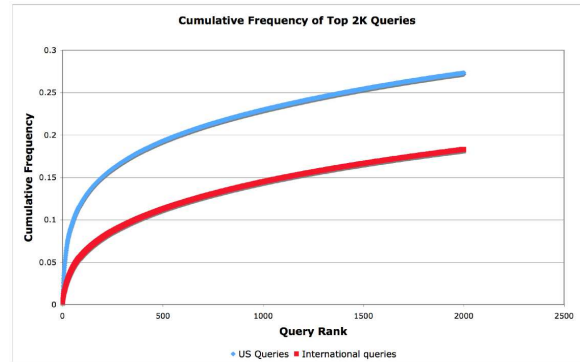


Figure 5: Cumulative Query Frequency of Top 2K Queries of US (upper curve) and International (lower) Data Sets

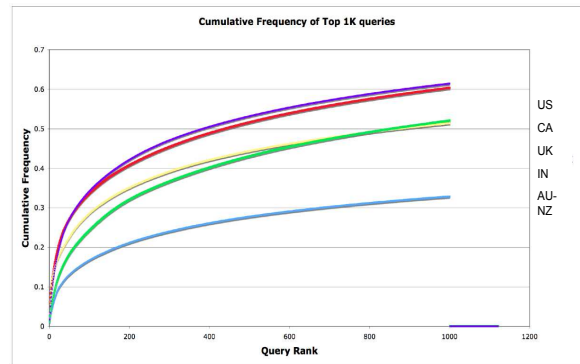


Figure 6: Cumulative Query Frequency of Top 1K Queries of US, CA, UK, IN, AU-NZ (in the order the corresponding curve appear on the graph from top to bottom)

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 some of their search habits from 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).

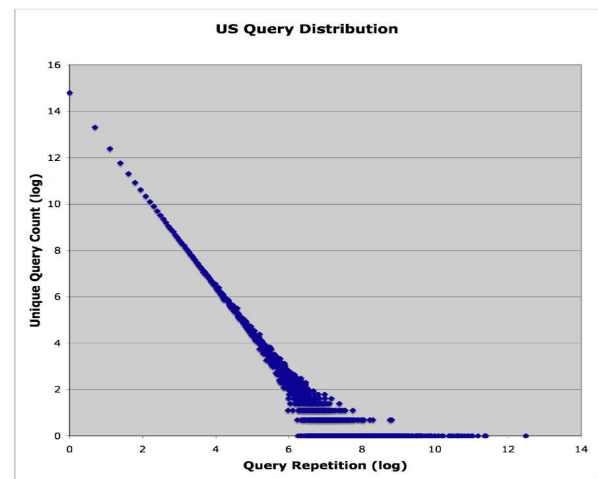


Figure 7: US Query Distribution

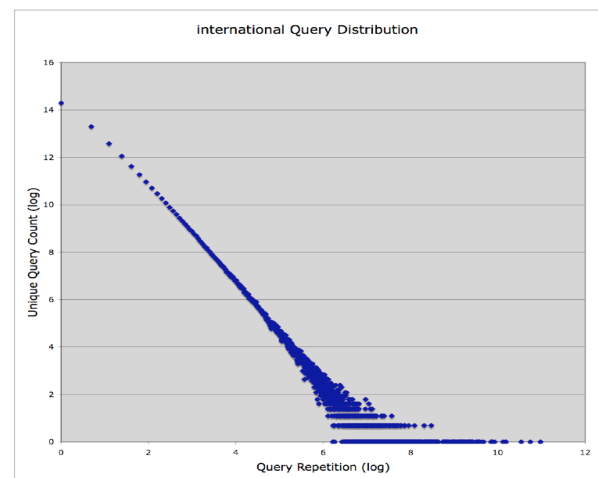


Figure 8: International Query Distribution

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 3. For the query categorization for this study, we have used an open source logistic regression based classifier⁵. Refer [12] for the detailed algorithm. We have used US English Web search queries for the training of the classifier. For the classification taxonomy, we have used an in-house taxonomy with total 821 nodes with maximum depth 6. There are 23 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.

To our knowledge, automatic query categorization by a machine learning algorithm is in its infancy and it is a highly difficult problem. Not only are the search queries typically short and ambiguous, but they also lack context. This makes query categorization a much more difficult problem than page content classification. In addition, due to the difficulties of mobile device input user interface, the mobile queries

⁵The library is available at <http://www.csie.ntu.edu.tw/~cjlin/liblinear/>.

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
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	44%	3.26	18.78	51%	2.55	14.68
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
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	42%	2.88	18.30	47%	2.77	14.71
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

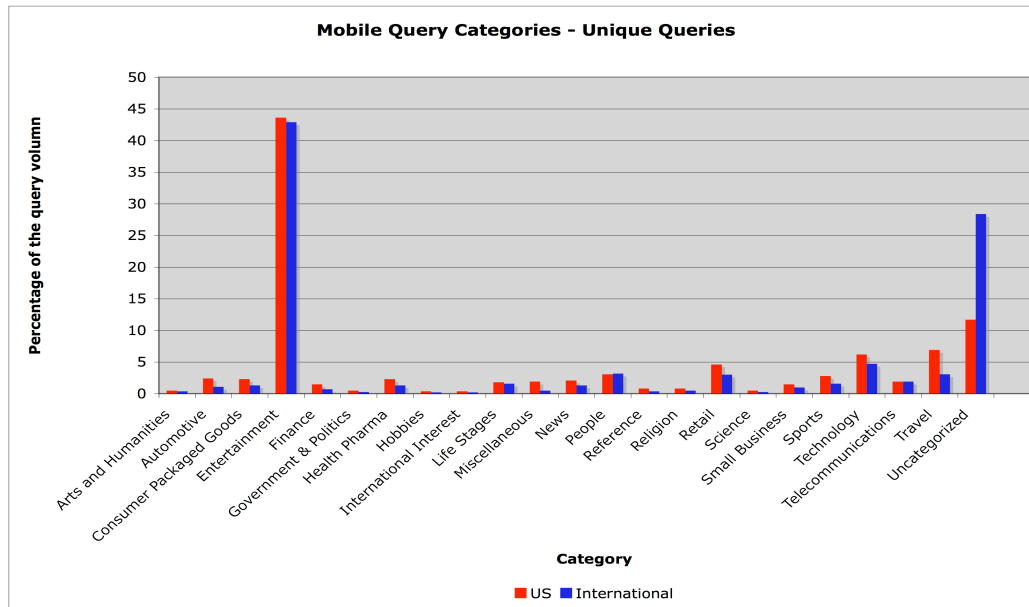


Figure 9: Mobile Query Categorization (Unique Queries): US vs. International

Table 4: Entertainment Subcategories

Sub-categories	US Queries	Int. Queries
General Entertainment	76%	82%
Music	12%	8%
Movies	4%	4%
Games	4%	3%
TV	3%	2%
Radio	1%	<1%
Amusement	<1%	<1%
Performing	<1%	<1%

suffer from a higher rate of spelling error. One notable point in the overall categorization results is that the percentages of uncategorized queries are high. This might be due to the fact that many uncategorized queries are too short. Notice that the average number of words and characters per query for uncategorized queries are only 47% (US unique queries) and 67% (international unique queries) of that of the entire query sample. With much less information from the query and lack of context, the classifier might have not been able to perform as well on those queries. Another notable difference in the query classification results is much higher percentage of the uncategorized queries in the international samples: 9 (for unique queries) and 12% (for all queries) for US sample data vs. 28% for the international sample data. The fact that we have used US Web search queries to train the classifier may explain the underperformance of the classifier on the international queries.

Table 2 and 3 list the top-level categories and the percentage of the queries, the average number of words per query, and average characters per query for the US query samples and international query samples, respectively. Other than uncategorized queries, there is no statistically significant variations between the categories in terms of average words and characters per query.

The most popular category was the entertainment category. Table 4 lists popular sub-categories of entertainment queries. The entertainment category itself is a broad category with multiple sub-types of queries, such as queries related to music, movies, games, TV, amusement, adult and romance, radio, performance, etc. We anticipate that the entertainment category is substantially more sizable as a percentage of overall queries relative to the findings in [10]. This is in part due to the fact that in this analysis adult-related queries, which in previous studies have represented a fairly sizable percentage of overall queries, were evaluated in the entertainment category. In addition to the two conjectures given in [10], the reason why adult-related queries are so high on mobile search may be because image-related search queries are included in the overall analysis due to the nature of Yahoo! oneSearch's federated search model. Kamvar and Baluja has observed that their volume of adult queries has been increased from over 20% to over 25% after launching a new transcoder that retains more images than the earlier version of transcoder that eliminated most images on the search results pages [10].

We also notice that most of the top level categories other than entertainment, people, retail, sports, technology, and travel categories, represent only a small percentage ($\leq 2\%$) of the US query volume. A similar pattern holds true for the international queries. This skewness in the topical interest may change over time as the mobile search usage grows. Wireless search is still in a very early stage relative to desktop search. It may follow the pattern of Web search in the early days where *head* queries represented a relatively high proportion of overall queries. If mobile search is following the path Web search has taken, we would expect that that the *tail* of search queries would lengthen over time, and we would anticipate the category percentages including entertainment queries, would change. Spink *et. al.* reported that there had been substantial changes in the Web search query

distribution between 1997 and 2001 [15]. *Entertainment* queries decreased from 19.9% to 6.6%, and *adult* queries from 16.8% to 8.5%, while *commerce*, *travel*, *employment* or *economy* queries combined increased from 12.5% to 24.7%, and *people*, *place*, and *things* combined from 6.7% to 19.7%.

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.

Another notable type is navigational queries. 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, 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 differ 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 platforms: a widget-based **Yahoo! Go**, a browser based **Yahoo! oneSearch** interface, and an SMS text message interface. Since each platform 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.

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

As shown on the graph, each user interface exhibits quite distinctive patterns in the entertainment category. For example, **US_SMS** queries has only 14% entertainment queries, while **US_WAP** has 55%. One possible explanation for the variance is that it may be due to the user interface, since SMS search results cannot include images. As a result, other categories for which SMS may be well suited, such as Sports, occupy a much higher percentage of queries.

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)
Arts & Humanities	<1%	1%	<1%
Automotive	1%	2%	2%
Consumer Goods	1%	2%	2%
Entertainment	55%	34%	14%
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%

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%
Socket	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%

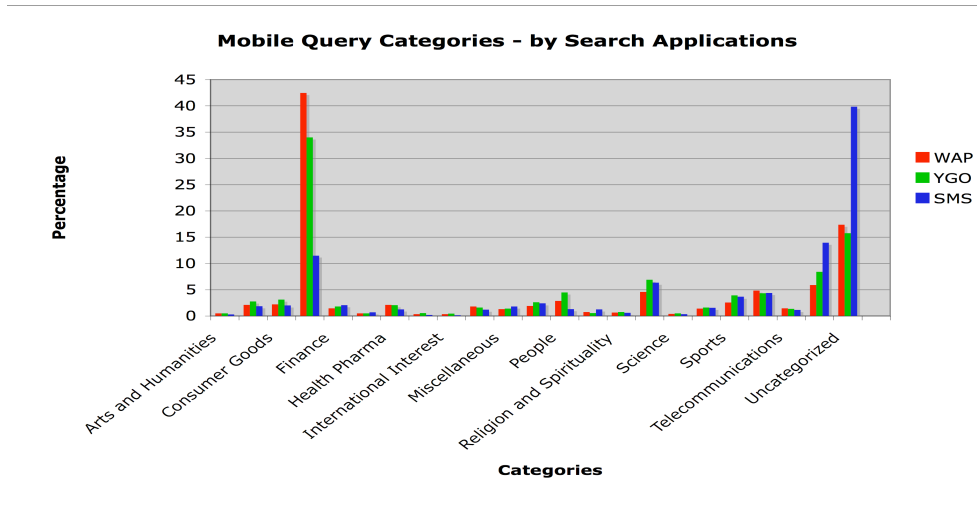


Figure 10: Mobile Query Categorization - by Search Application

Another potentially interesting pattern shown on Table 5 is the increase of Sports and Travel categories in US_YGO. One possible explanation of this may be due to the availability of services in the Yahoo! Go product such as Sports and Maps, which may encourage users to search for those related topics more frequently. Table 6 and 7 list the sub-categories of sports and travel and the US_YGO and US_SMS query distribution.

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, 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:

- Personal entertainment is the most popular queries: As expected, users are searching for personal entertainment. The entertainment category is a broad category with multiple sub-types of queries, such as music, movies, games, TV, amusement, adult and romance, radio, performance, etc.
- 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.

Finally, with the recent launch of unstructured voice input in Yahoo! oneSearch, we plan to study how spoken queries may differ from typed queries.

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