User Behavior in Location Search on Mobile Devices

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Abstract. Location search engines are an important part of GPS-enabled devices such as mobile phones and tablet computers. In this paper, we study how users behave when they interact with a location search engine by analyzing logs from a popular GPS-navigation service to find out whether mobile users' location search characteristics differ from those of regular web search. In particular, we analyze query- and session-based characteristics and the temporal distribution of location searches performed on smart phones and tablet computers. Our findings may be used to improve the design of search interfaces in order to help users perform location search more effectively and improve the overall experience on GPS-enabled mobile devices.

1 Introduction

Location search engines (LSEs) are widely used to search for *points of interest* (POIs) such as restaurants, shops, filling stations, etc. and to navigate to them. Despite their importance, they have not yet been studied extensively, while most of research in the past has focused on local search and location-related queries submitted to regular web search engines. There are important differences between location search on the one hand and local search and location-related queries on the other. First, LSEs are aimed at finding POIs, rather than local information as in local search. Second, LSEs differ from location search in other systems (e.g., maps) with regard to user intents. In many cases, people use LSEs to navigate to a POI (in our logs, more than 70% of the sessions and more than 50% of the queries result in actual navigation), while in other systems users aim at locating relevant places and getting information about them.

The differences just noted make the design of an LSE a unique problem, which needs to be studied in order to improve user satisfaction. In this paper, we make the first step in this direction and study user search interaction with LSE. The main research questions that guide our work are the following: (1) Does user search interaction with LSE differ from that in web search? (2) Does user search interaction with LSE depend on the type of device?

To answer these questions, we analyze a recent log from the LSE of a popular GPS-navigation system. The studied LSE receives a keyword query and then finds relevant locations. Users can locate results on a map, check location-related information and navigate to selected results. The studied LSE is primarily focussed on car navigation and, therefore, is mostly used in the car or for pre-trip planning from home.

We analyze user search interactions with the LSE installed on *tablets* (more specifically, iPads) and *mobile phones* (more specifically, iPhones). We are interested in studying query- and session-related characteristics of user interaction as well as its temporal aspect. The results of our study can be used in search personalization, user modeling, interface design, query refinement and query suggestion.

2 Related Work

Local search and mobile search have been important research topics in recent years. In order to better understand user behavior in local search, researchers performed user studies and analyzed logs of web search engines. Berberich et al. [1] analyze logs of business web sites, customer ratings, GPS-traces, and logs with driving-direction requests. They measured the geographic distance between a user and a search result to infer relevance and to improve search. Zheng et al. [8] work with logs of GPS-enabled devices to find interesting locations and common travel sequences in a region.

Recently, several studies have focused on the device type and analyzed its effect on user behavior in desktop and mobile web search. Kamvar et al. [3] analyze mobile, tablet and desktop users and suggested that no single interface can fit all user needs and search experience should change based on the type of device. Song et al. [5] also compare the above devices and conclude that a single ranker cannot be used for all of them. They propose to use the characteristics of user behavior on tablet/mobile to improve rankers.

Researchers have also used context, such as location and temporal information, to improve local search results. Lane et al. [4] propose the Hapori framework that utilizes location, time and weather for local search. Teevan et al. [6] conduct a user study, asking participants about their location when searching, desired destination, plans about visiting a place, etc. The authors report that participants mostly search on the go and plan to visit destinations soon after querying.

Also, location related queries have been analyzed in web search engines. Gan et al. [2] study geographic searches using queries from AOL. The authors classify queries into geo and non-geo queries and report that non-geo queries are related to geo ones. In [7], the authors study web search logs to explore the relation between mobile queries and their locations. The authors propose a statistical model to predict whether a user is soon observed at the searched location.

The above studies are mostly concerned with user behavior in local search and are based on logs of a general web search engine on desktop, mobile or tablet. Our work differs as we study user interaction with a *LSE* within a GPS-navigation system. We first compare user behavior in location search to that in general web search. Then we compare user search behavior across different devices, namely tablet and mobile.

3 Dataset

For this study, we sampled the log of LSE of a popular navigation application during the period from February to June 2014. We considered search sessions from the USA and UK and filtered out non-English queries. Sessions were logged on the following

Table 1. User search behavior statistics for the LSE in a GPS-navigation system on tablet and mobile devices, compared to that in standard web search on desktop, tablet and mobile [5]. All statistics for the tablet LSE are significantly different from those for the mobile LSE ($p < 0.01$).

	#sessions (%)	#queries (%)	avg. queries per session	avg. session length in mins	avg. query length
Desktop [5]	N/A	13,928,038	1.89	8.61	2.73
Tablet [5]	N/A	8,423,111	1.94	9.32	2.88
Mobile [5]	N/A	9,732,938	1.48	7.62	3.05
		Tablet LSE			
All	21,936	38,129	1.74	2.69	1.93
Click	15,770 (72%)	21,208 (56%)	1.82	3.22	1.84
No click	6,166 (28%)	16,921 (44%)	1.53	1.34	2.05
Route	15,277 (70%)	19,580 (51%)	1.79	3.16	1.83
		Mobile LSE			
All	423,509	632,288	1.49	1.86	1.87
Click	305,104 (72%)	360,343 (57%)	1.49	2.22	1.78
No click	118,405 (28%)	271,945 (43%)	1.49	0.94	1.99
Route	296,568 (70%)	340,953 (54%)	1.47	2.18	1.78

devices: iPhone ("mobile") and iPad ("tablet"). Each session may consist of multiple queries. Sessions are separated by a period of inactivity of more than 30 minutes or based on closing the application. Overall, we collected 445,446 search sessions consisting of 670,417 queries: 21,936 sessions and 38,129 queries for tablet, 423,509 sessions and 632,288 queries for mobile. The uneven distribution of the number of sessions and queries between tablet and mobile is due to the difference in device usage frequency in the sampled part of our log.

In a typical scenario of user interaction, the session starts when a user opens the navigation application. After submitting a query, the user is presented with a list of location results and can click on them to see the map centered on the result, its phone number and web site address, sharing buttons and the route planning button. Then, the user can contact the chosen location, check more information about it, share the location and plan a route to it.

4 Analysis

In this section we answer our research questions by analyzing the our logs described in the previous section. First, we compare user interaction with an LSE to that with general web search. Then we compare user interaction with an LSE on tablet vs. mobile.

Table 1 shows user search statistics: the number of sessions, number of queries, average number of queries per session, average session length in minutes and average query length in words. The first block of Table 1 shows the statistics for general web search on desktop, tablet and mobile devices, as reported by Song et al. [5].

The second block reports the statistics of user search sessions in tablet and mobile LSEs. The first row for each device type shows the overall user search statistics. The

second row presents the statistics for sessions and queries in which a user clicked on one or more results. The third row shows the statistics for sessions and queries in which a user did not click on any result. Since the goal of LSEs is to help users plan a route to a desired POI, the last row shows the statistics for sessions and queries that contain the "route to" action. Absence of the route action does not mean that a user is not satisfied with the search results—in many cases users are interested in checking the results without navigating to them (e.g., pre-trip planning). The differences between the corresponding tablet and mobile LSE statistics in Table 1 are statistically significant according to the Mann-Whitney U-test at the 0.01 level.

Note that the number of sessions in the mobile LSE is much larger than the number of sessions on tablet. This is due to the fact, that LSEs are mostly used on the go and, therefore, users tend to prefer mobile to tablet. Also, the form factor of mobile phones makes them much more popular for in-car navigation, which is further stimulated by the availability of phone docking stations.

In the following, we first compare tablet/mobile LSEs with general web search, and then compare tablet LSE with mobile LSE.

Location Search in LSE vs. Web Search. According to Table 1, users submit more queries per session while performing web search on tablet compared to LSE for the same device type. The opposite is true when users interact with mobile devices but the difference is much smaller. This suggests that the way users interact with LSEs is more similar to how they interact with mobiles rather than with tablets.

Users spend less time interacting with LSEs than performing web search: three times less on tablet and four times less on mobile, even though the average number of queries per session is roughly the same. This observation can be interpreted as saying that users of an LSE are mostly on the move and have less time for searching compared to the web search scenario. Also, users can easily understand if a location is relevant or not, while in web search users spend more time on examining results.

In general, queries in location search are shorter than in web search. This can be explained by the fact that queries in location search are limited to places as opposed to web search queries, which can be about anything. This suggests that LSE would greatly benefit from custom NLP techniques different from those of general web search.

Tablet vs. Mobile LSE. The number of sessions and queries indicate that the mobile LSE is used much more often than the tablet LSE. On the other hand, the average number of queries per session, average session length and average query length for the tablet LSE are all larger than those for the mobile LSE, which means that users spend more time when using tablet devices. These observations can be explained as follows. Tablets are more often used for pre-trip planning, while mobile phones are used on the go. In trip planning, people spend more time and use more queries because they want to explore all possible results (e.g., finding appropriate hotels, restaurants, etc.). Instead, people on the move execute more targeted searches and are mainly looking for the nearest available POI that solves their direct needs (e.g., petrol station, parking, fast-food, etc.).

It is interesting to note that the above behavior is similar to that in web search (see the first block of Table 1). This means that the different form factor between tablet and mobile devices has a similar effect on how people use them for location and web search.

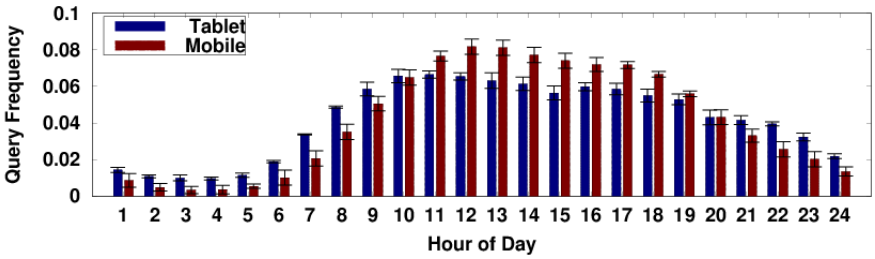

Fig. 1. Query frequency distribution in a GPS-navigation system on tablet and mobile devices.

When we consider the percentages of session that have at least one click, both LSEs are similar. In user interactions with LSEs, the routing action is a strong signal of user satisfaction. The percentage of routing in tablet and mobile LSEs reaches 70% of sessions (97% of sessions with clicks), therefore if a user clicks on a result, it is almost certain that her intent is to plan a route somewhere. In the remainder of the sessions the user was either unable to locate relevant POIs or did not want to plan a route. This can mean that a click is a reliable indicator of user intent while interacting with an LSE.

In sessions with both click and route actions (which we assume to be successful), the average number of queries per session and the average session length are usually larger than the average for all sessions. This can be explained as follows: users who do not click anywhere give up fast and submit few queries; users who are more persistent in finding relevant POIs have to click on returned results and submit more queries.

Temporal Characteristics. Here, we compare user behavior in tablet and mobile LSEs along the temporal dimension. The query frequency distribution during the day is shown in Figure 1. The graph shows that users prefer to interact with LSEs using mobile during working hours (from 11am till 7pm) and prefer to use tablet while mostly at home (from 9pm to 10am). This observation is not surprising, because users usually carry their mobiles with them, but may keep their tablets at home. Moreover, tablets are used more for pre-trip planning, usually done during non-working hours, while mobiles are used for actual navigation. We also analyzed the query frequencies for different days of the week and found that the relative number of queries in mobile LSE is lower than on tablet during weekdays, but larger during weekends. The smaller size of mobile devices may explain this difference: during weekends people are on the go and tend to use mobile devices more than tablets.

5 Conclusions and Future Work

In this paper we analyzed LSE logs of a popular GPS-navigation system and compared user interaction with an LSE to that of general web search. We also checked if user interaction with an LSE depends on the type of device, i.e., tablet and mobile.

We showed that user search interaction with an LSE and web search has certain similarities and differences. The similarities include the number of queries per session and the relative session length on tablets compared to mobile. On the other hand, due to specific usage scenarios of LSEs (e.g., on the go), sessions and queries are shorter

in location search compared to web search. Our observations on LSEs vs. web search have implications for the interaction design and underlying technology for LSEs.

Our statistical observations also showed similarities and differences between tablet and mobile LSEs. People use the mobile LSE more, especially in working hours. In addition, mobile LSE sessions and queries are shorter than on tablets. This is because tablets are more often used for pre-trip planning, while mobile phones are used on the go. These observations suggest that the interface of the mobile LSE should be adapted to be used in movement, so should be simple and provide basic functionality, while the interface of the tablet LSE can contain more details and support more complex interactions.

In future, we are interested to investigate more characteristics of user interaction with LSE to find how much users are satisfied with results and how we can improve location search. We would like to find common sequences of user activities and determine which sequences are successful and which are not. Moreover, the combined analysis of queries and destinations is a promising direction for future research.

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