RETHINKING MOBILE SEARCH QUERIES USING CONTEXT

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Abstract: In some search domains, user context is often related to user search intent or preference. Such context however is rudimentarily used in search queries. Mobile devices, through their sensors and data content however have an abundance of information that can indicate the user context. Such context information can be used to influence, filter or re-rank search results to better match user needs. In this, paper we present some of the previous work where user context was used to improve the mobile search experience, as well as work that attempted to understand how user context is related to search intent. Our findings show that previous work primarily focused user location, with great neglect to other types of context that may be of great significance to search results. The work we present in this paper attempts to understand how a wide range of types of context influence a particular search domain. The types of context we study include location, time, day, weather and movement. We analyze how such context information can influence search needs when searching for restaurants and movies. Our analysis is based on a survey that was taken by 179 respondents. We describe the survey, how it was authored and reviewed, and then analyze the results and findings as deals with the most important contextual pieces of information that could be used to enhance the mobile search experience.

1 INTRODUCTION

Search engines are expected to respond to query requests with results that are characterized with high precision and recall. However, many users continue to be challenged with formulating proper search query terms that match their true intent, often impairing the ability of search engines to properly return and rank appropriate results in harmony with user intent. Furthermore, the large number of results makes them practically impossible to be fully browsed by any user.

The use of search engines however is no longer limited to personal computers. Ubiquitous devices, such as smart phones, are becoming more common as a new channel for search. As presented in (Church et al., 2009), 67% of people's information needs are delivered while they are mobile. Studies in (Kamvar et al., 2009) showed that search patterns initiated on phones vary significantly in query length and topic diversity. Mobile phone searches tend to have shorter queries that encompass a narrower range of topics compared to other resourceful devices. Moreover, limited screen space and mobility makes it more difficult to browse through a large number of results.

Location information has long been mistakenly perceived as being the most important piece of contextual information relevant to search queries, as evident by most commercial search engines. However, we hypothesize that further contextual information obtained from the ambience of mobile devices can be used to enhance search queries issues from such devices, yet little is known in literature about the type and usefulness of such information for performing web searching under such conditions.

In this paper, we have a clear objective, which is to understand the type of contextual pieces of information that are most relevant in enhancing search queries initiated from mobile devices. For this purpose, we start off by presenting related work that helps in understanding the relationship between user context and mobile search intent. We then describe a study that we conducted to identify and weight the types of contextual information that would be relevant in performing mobile entertainment-related search queries, in which we limit the entertainment domain to searching for restaurants and movies.

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2 RELATED WORK

In this section, we present two types of related work. The first type is work which focuses on understanding the relationship between user context and search intent, especially in mobile environments. The second type of work is that which attempts to improve the mobile search experience by using information about user context.

Many attempts have been made to define and classify contextual information. More notably, Ranganathan in (Ranaganathan et al., 2003) tried to summarize and categorize the types of context to include: Physical, environmental, informational, personal, social, application, and system. Even though categorization attempts are many, but to mention a few examples in Ranaganathan's categories, physical context includes location and time. Environmental context includes weather, light and sound levels. Informational context includes stock quotes, and sports scores. Personal context includes health, mood, schedule, and activity. Social context includes group activity, social relationships, and collocation. Application context includes email received, and websites visited. Finally, system context includes network traffic, and the status of printers.

2.1 Understanding Search Behavior and Intent

To improve the mobile search experience, it is important to understand mobile search patterns and how they are different or similar to desktop search. According to (Church et al., 2009), to understand search behavior, the main two approaches have been to understand what people search for, and why they search for it. Analyzing search behavior and what people search for involves the study of things like the length of queries and their topics. Analyzing search intent (why people are searching) can be categorized to the following classifications (Church et al., 2009): navigational (reach a site), informational (learn about a topic or answer a question), geographical (search for a location), transactional (web-mediated activity e.g. games, downloads), and personal information management (find personal information).

Collecting data about mobile usage is a challenge due to the difficulty of discreetly collecting data. There have been several methods for collecting such data such as interviews (Arter et al., 2007), log data analysis, observation, diary study, or a combination of two or more methods. Log data has the benefit of providing realistic and large-scale data of usage. However, in (Amin et al., 2009), it is argued that log analysis is not sufficient as location-based needs are not always explicitly expressed in the queries.

In (Church et al., 2009), results revealed that 67% of people's information needs are while they are mobile (i.e. away from home or work computer). 58% of these needs are informational, 31% geographical and 11% is personal information management. Another observation is that 75% of geographical entries were generated while the user is mobile. Most of the geographical information needs were temporally dependent (i.e. only relevant at a particular point in time), even though most queries did not include explicit temporal cues. It was noted that the user's current activity has an important factor that triggers the user to perform a search. Regarding the topics searched, the most dominating topics were 20% travel and commuting searches, 16% general information searches, 13% local services searches, and another 13% were entertainment searches.

In (Amin et al., 2009), a hybrid approach is used to collect information on users' search activities. They data they collected included the search event log (queries, clicks, etc.), location at the time of search, a diary where participants logged more details about their context at time of search such as who they were with, their current activity, the importance of this task, and the success of their task. A post-study interview was conducted with the participants where they clarified any unclear or missing entries. The results showed that the main domains of interest were stores (27%), foods and drinks (24.5%), entertainment (14%), news (12%), and transport (10%). Over 86% of tasks are goal-oriented whether the goal is finding a specific piece of information or to make a higher level decision.

Queries were analyzed with respect to the spatial, temporal and social context. Regarding spatial context, results indicated that most searches are performed either at home, work, while commuting in between, or at regularly visited places. With the exception of weekends, participants followed regular routes and visited regular places. Another discovery was that the target places are more often related to their regularly visited places rather than their current location. The common places were: at family/friends' home (6.5%), public places (8.5%), at work (12%), on the move (20%), and at home (53%). Temporally, the results showed that 66.1% of searches were related to a spontaneous need (e.g. need a number to make a call). 21.5% were less urgent and related to something planned that day

(e.g. book a table in a restaurant). The remaining 12.4% were exploratory tasks and not urgent at all. Socially, 76.1% percent of searches were performed with the company of others. Tasks performed alone were driven by necessity (e.g. weather inquiry, directions), while tasks performed with people around were mostly driven by conversations with people. The reasons participants chose a place for their desired local service were the availability of a particular product or service (24%), recommendation by others (16%), a decision made with others, e.g. friends, family (13%), closeness to current location (8%), whether it's a favorite place to them (8%).

2.2 Context-enhanced Mobile Search

In this section, we list related work that helps enhance queries issued from mobile devices. Once the relationship between context and a search query is understood, the search experience can be improved by concatenating context words to a query. This disambiguates the query, refines the search and thus returns fewer, more specific results. Alternatively, context words can be used to filter results and return the results most relevant to this context. (Kraft et al., 2006) present 3 algorithms to implement contextual search:

i. Query Rewriting: In this approach, context words are simply appended to the original query. This makes the search more specific and therefore returns a smaller response set. This poses the danger of low recall because if the search becomes too specific, the engine may return too few results or none at all.

ii. Rank Biasing: This approach also appends context words to the original query but only as optional ranking terms. Optional ranking terms may also be given weights to capture the importance of each. The advantage of this approach is that it guarantees the same level of recall as the original query. However, this requires a modified engine that can accept such a complex weighted query.

iii. Iterative Filtering Meta-search: In this approach, candidate context words are generated. Query templates are also selected which are templates that define the query and context combinations that will be used. The template generates multiple queries, each submitted to the search engine. The results from the multiple queries are aggregated and re-ranked.

There have been several attempts to use context in desktop search to improve the user's search experience by trying to resolve any ambiguities via analyzing the user's context. The types of context used in such applications include the previous queries submitted by the user (Cao, 2009), the URLs recently clicked by the user, the recently browsed documents (Cao and Shen, 2009) (Rahurkar and Cucerzan, 2008) and, the contents of the documents on the desktop (Chirita et al., 2006), and the activities the user is engaged in standard applications (Leake and Scherle, 2001).

3 METHODOLOGY

After surveying many related work dealing with contextual searching, and after making two major conclusions: (1) That location is still perceived to be the most important contextual information used in searching and (2) That there is little understanding about other types of context that may help mobile contextual searching, we decided to conduct a study that better understands the relevance of other types of contextual information that may enhance the results of mobile search queries.

In our methodology, we hypothesize that context, beyond location,should be a reflection of user search intent. We eventually designed and conducted a survey on 179 respondents to understand mobile search usage patterns and how the aforementioned context influences their preferred search results. Table 1 shows the type of context information we are interested in and the sources that they can be extracted from.

Our main hypothesis is that user context especially physical, environmental and personal context such as time of day, day of week, weather, location, calendar events, and whether or not the user is on-the-go does influence the user's preferences. We test this hypothesis with special focus on the entertainment search domain. This main hypothesis breaks down to the following specific hypotheses:

- Time-of-day influences user preferences.
- Current location influences user preferences.
- Mobility influences user preferences.
- Weather influences user preferences.
- Day-of-week influences user preferences.The type of event users are going out for influences their preferences.

We built a survey with questions that aim to validate these hypotheses. We concentrated on restaurant/food search as the domain that the questions tackle. In this section, we discuss the main

and minor goals of the survey and its structures. Then we discuss how the survey was authored, then reviewed by a focus group, and shared with the respondents.

Table 1: Contextual information and sources of extraction.

Context Information	How to extract?
Time of day	Phone time settings
Day of week	Date and time
Location	GPS
Weather	Weather web service and GPS
Movement	Accelerometer
Type of events, Meetings/deadlines	Calendar entries

3.1 Survey Goals

To figure out which types of context affect what types of preferences when picking a restaurant to eat at, we authored a survey to find out to what extent respondents agree with our hypotheses. The main goal of the survey is to find out how people's preferences regarding the restaurant/type of food they want change as their context changes. A secondary goal of the survey is to understand how people use internet services from mobile phones.

The questions are tailored such that the answers allow us to compare the importance of each type of context and in what way it affects respondents' choice of restaurant. Some questions were intended to understand the respondent's profile (e.g. age, gender, profession). Another set of questions were posed to understand how fluent the respondents are with technology and how reliant they are on it. The main bulk of the survey was meant to understand how the user preferences are influenced by contextual situations.

3.2 Survey Structure

The survey is composed of the following sections:

- *Demographic and General Information:* (e.g. country, age, gender, profession).
- *Technology Use:* Question technology fluency.
- *Search Use:* Question whether and how search engines are used to find information about entertainment.
- *Time:* Question how the preferences are influenced by the time of day.
- *Location and Movement:* Question how preferences regarding location of restaurants changes with mobility.
- *Weather:* Question how weather conditions imply the attributes of the place they would like to go to (e.g. outdoor vs. indoor seating)
- *Calendar:* Question how the type of gathering/meeting influences the attributes of place they would like to go to.

3.3 Survey Reviewing

The survey went through two cycles of review before being published. In these review cycles, the survey was shared with a focus group, a group of people who were asked to both fill the survey and provide comments and feedback about how they found the questions. They were asked to identify any flaws in the survey. We provided them with some hints and guidelines while asking them not to limit themselves to these guidelines. They were impelled to point out ambiguous questions, redundant questions, words that are hard to understand, questions that seem to direct the user to give a certain answer, or questions that seem invasive or offensive. They were also encouraged to look at the multiple choice answers for any missing possible answers or overlapping answers. We also asked them to point out if they found the survey to be too long. The size of the focus group was five people in each round.

The survey evolved as we made changes in response to the focus group's comments. Such comments included pointing out difficult terms, missing options in multiple-choice answers, ambiguous words, and how they felt at certain points (e.g. annoyed after a series of similar questions). Some questions which were related and had the same set of multiple choice answers were aggregated in one tabular question. In some cases, answers with numerical ranges, such as commute time that a respondent finds reasonable, needed to be aggregated into fewer bigger ranges to become more meaningful.

3.4 Survey Sharing

To ease the distribution of the survey and the consolidation of results, it was created as an online survey. The tool used for this purpose was Survey Gizmo. The snowballing approach was used to share the survey. The survey was sent in mailing lists and shared via Facebook. Friends with large networks were messaged directly and asked to share the survey with their friends.

4 FINDINGS

The survey was taken by 179 respondents. The survey results and analysis is discussed in this section. We discuss several aspects of the results; the respondents' demographics, their comfort with technology and search, and how the context influences their preferences about the type restaurant or place that they would like to go to. The types of context discussed are time of day, day of week, weather, location and type of event.

It was also deemed important to be able to give a value for the strength of the relationship between a certain context and a user preference pair. This allows us to filter out pairs with weak relationships and rank them by significance. For this purpose we calculate the confidence of the relationship between each pair. The confidence of each relationship is a value between 0 and 1 that is basically the percentage of agreement. There are two question types used in this case; 5-likert scale and checkbox-based. How the confidence is calculated in each type is explained below:

i. **Five poInt Likert Scale Questions:** Answer options are: strongly agree (SA), agree(A), neutral (N), disagree (D), strongly disagree(SD). The confidence of the relationship presented in such questions is calculated as:

$$(\#SA + \#A) / (\#\text{ respondents}) \quad (1)$$

ii. **Checkbox-based Questions:** In these questions, respondents check a checkbox if they agree that the two items in question are correlated. The confidence calculated as:

$$(\#\text{ checks}) / (\#\text{ of respondents}) \quad (2)$$

4.1 Demographics

Around two-thirds of respondents are female. Almost 90% of respondents are in the 18-35 age group. There are no respondents in the 55 and above age group and only couple in the under-18 age group. Since the survey was spawned in Egypt, it is not surprising that 82% of responses came from Egypt. 11% of responses came from the United States. Due to the nature of the network of survey authors of there is a considerable percentage, 29%, of respondents are from the technology/programming domain. Other respondents are students (13%) or came from research (11%), construction (8%), education (12%), and other domains.

In correlation with the respondents' age groups, 99% of respondents have at least a bachelor's degree, with more than half of those with a post-graduate degree too. Putting that in mind, we can conclude that respondents whose profession is student, are in fact mostly Master's or PhD students.

4.2 Technology and Search Use

The vast majority of respondents have mobile phones, are comfortable using the computer, and use the internet on a daily basis. Regarding mobile usage, we notice some important trends:

- 73% of respondents use the internet from their mobile phone at least a few times per month for one purpose or another (figure 1a).
- 23% use internet from the mobile phone all the time, regardless of whether they have access to a PC (Figure 1b). This confirms that internet usage from mobile phones is becoming more common and more of a main internet channel rather than just a backup channel.

The top eight purposes mobile internet is used for are: Email (88%), social networking (67%), instant messaging and chatting (48%), maps (42%), checking weather conditions (41%), seeking information such as word definition, movie reviews (37%), news and sport scores (36%), and searching for local entertainment such as movie theatres and restaurants (27%). 18% of respondents use mobile internet to search for local services (e.g. pharmacy, bookstore), 18% watch or download music and/or videos, 10% download wallpapers and ringtones, 7% play online games, and 5% shop online.

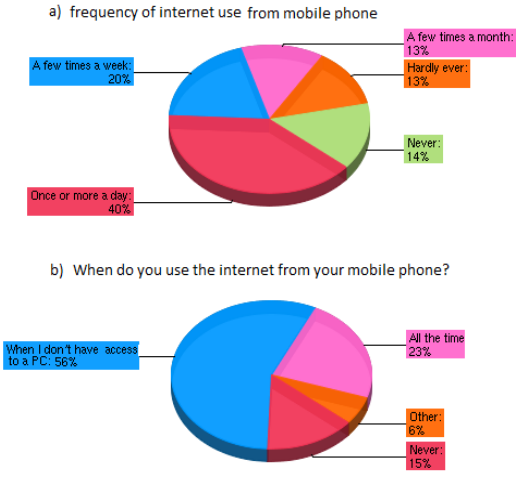

Figure 1: Mobile internet usage. a) Frequency of usage. b) When do people mobile internet.

Only 28% of respondents have searched for

entertainment from their mobile phones, however, 83% have searched for entertainment from a computer. With the growing prevalence of mobile internet usage, we can forecast that searching for entertainment from mobile phones will become more common with time. Another interesting trend is that 68% of outings are planned on the same day. This supports the assumption that the timely context is in fact relevant to the user's searches when it comes to searching for something like entertainment. See Figure 2 to see how much time in advance respondents have planned for outings before.

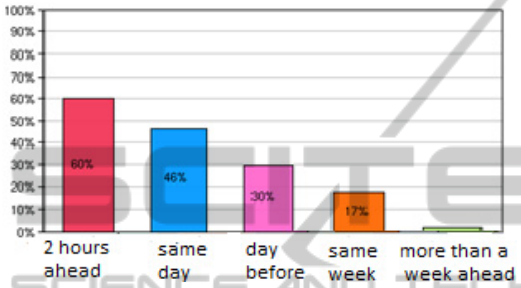

Figure 2: How much time in advance outings are planned.

4.3 Context Influence on Preferences

Focusing on restaurants, we posed questions that aim to validate some hypotheses regarding how we suspect that people's choice of restaurants would differ as their context changes. Such attributes include the restaurant location, working hours, menu, presence of shaded parking, view, WiFi availability, ambience, indoor/outdoor seating, etc. In this section, we discuss the context and restaurant attribute pairs that gained more than 50% of respondents' agreement.

4.3.1 Time of Day

Table 2 shows the relationship between time-of-day context and the restaurant attributes and the confidence of each relationship.

Table 2: Time-of-day context, related restaurant attributes, and the confidence of the relationship.

Context	Restaurant attribute	Confidence
Any time	Open at current time	0.85
Time is before noon	Breakfast menu	0.60

4.3.2 Day and Time of Week

75% of respondents agreed that their restaurant choices differ between weekends and weekdays. When it comes to restaurant location, on weekdays, around 80% of respondents are willing to spend up to 30 minutes maximum on the road to get to the restaurant. On weekends, respondents are willing to spend more time on the road, with around 80% willing to spend up to one hour.

Table 3 shows the relationship between the restaurant attribute and the day of week (weekend vs. weekday) with distinction between mornings and evenings, along with the confidence. It was also concluded that:

- The majority of respondents want coffee and light sandwiches on weekday mornings while wanting a more sophisticated breakfast menu on weekend mornings with a nice view to enjoy.
- On weekend evenings, respondents also want to enjoy a nice view, have a decent meal, discover a new place or cuisine, and have fun at a place that offers fun activities such as pottery or karaoke.
- On weekday evenings, some people also want a decent meal but would probably opt for fast food or take-away food. This makes sense since people tend to have less time for leisure on weekdays and opt for the faster option.

Table 3: Day-and-time-of-week context, related restaurant attributes, and the confidence of the relationship.

Day/time	Restaurant Attribute	Confidence
Weekday evening	Take-away	0.65
	Fast food	0.61
	Dining (i.e. main meal)	0.57
Weekday morning	Coffee	0.63
	Light sandwiches e.g. cold cuts	0.54
Weekend evening	A new cuisine/place to discover	0.81
	Dining (i.e. main meal)	0.8
	Nice view	0.66
	Special activities e.g. pottery/karaoke	0.59
Weekend morning	Breakfast menu	0.7
	Nice view	0.66

4.3.3 Weather

The attributes that respondents preferred in a restaurant at changed depending on the weather conditions (pleasant, cold, hot, raining, windy and humid). If the weather is pleasant, 92% would rather enjoy it and therefore prefer a place with an outdoor seating area. In unpleasant weather conditions, the preference is more towards indoor seating areas: cold (66%), raining (64%), hot (56%), windy (55%) and humid (51%). If the weather is hot, 53% want to keep their cars cool in a shaded parking lot. If it's raining, 60% would want a nearby location. That's probably because people prefer to drive less in the rain.

4.3.4 Location and Movement

Figure 3 demonstrates the percentage of respondents who have indicated certain preferences regarding restaurant location. Please note that respondents were allowed to make more than one selection and that is why the percentages do not add up to one hundred in the indicated graph. Most notably, whether stationary or on the move, and 41% would rather have that location close to their homes.

4.3.5 Type of Event

The restaurant attributes that respondents need/prefer are also related to the type of gathering/event they are going out for. For example, after work or school, most respondents want take-away food. This is similar to weekday evenings. If the meeting is for studying or working, respondents need a quiet place that serves coffee and has WiFi. If the event is a casual meeting or a special event e.g. birthday, respondents are interested in dining, a nice view to enjoy, and are willing to discover a new place/cuisine. If it's a special event, respondents would like a place that has special activities such as pottery or karaoke. See table 5 for details.

Table 4: Type of gathering/event, related restaurant attributes and the confidence of the relationship.

Type of Event	Restaurant Attribute	Confidence
After school/work	Take-away (not necessarily fast food)	0.59
Casual meeting w/friends	A new cuisine/place to discover	0.62
	Coffee	0.59
	Dining (i.e. main meal)	0.54
	Nice view	0.53
	Breakfast menu	0.51
Special event e.g. birthday	Nice view	0.62
	Dining (i.e. main meal)	0.62
	Special activities e.g. pottery/karaoke	0.56
	A new cuisine/place to discover	0.54
Studying/ working	Coffee	0.64
	WIFI	0.64
	Quiet environment	0.61

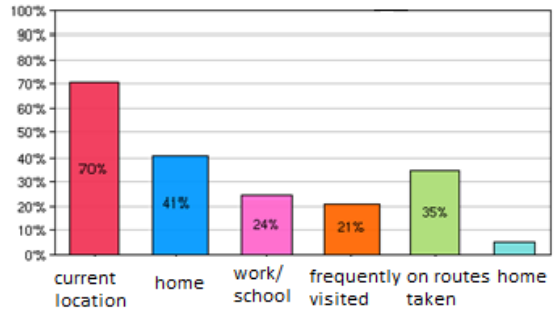

Figure 3: Preferred restaurant location.

5 CONTEXT-SENSITIVE SEARCH SYSTEM

We envision the use of our results in a context-sensitive system. The system would be triggered if a certain context situation is satisfied when the user issues a query in a particular topic. A mapping of a context situation to context-words would have to be created as shown in Table 6 with confidence values based on our results. The corresponding context-words would be looked up and used to refine the search and/or filter/re-rank the results. The context-word weights can be further fine-tuned based on the user profile (e.g. age, gender, profession). Ultimately, the confidence should evolve based on the user's previous searches and clicks and therefore making the weights more personalized.

6 CONCLUSIONS

In this paper, we presented previous work in understanding the relationship between context and search needs/intents. We then presented our work in developing and reviewing a survey intended to understand how a wide range of context situations influence user preferences in restaurant search. Our results lay a foundation of understanding for subsequently building a system of mobile search queries that is sensitive to user context, and in line with user intent. Future work includes developing a system that builds on the conclusions of this analysis to produce a context-sensitive mobile search system. Further work would involve generalizing these conclusions by analyzing how context influences search in other domains.

Table 5: Sample context to context-word mappings.

Context situation	Context words (may be expanded)	Confidence
Morning	"Breakfast [menu]"	0.76
Pleasant weather	"outdoor seating [area]", "open-air"	0.92
Hot weather	"shaded parking", "underground parking"	0.53
Weekday evening	"Take-away", "to go"	0.65
	"Fast food"	0.61
Weekday morning	"Coffee"	0.63
Weekend evening	"Dining", "main platters"	0.8
Studying/working	"WIFI", "internet"	0.64

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