GraphTiles: A Visual Interface Supporting Browsing and Imprecise Mobile Search

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(a) (b) (c) (d)

Figure 1. Comparing *GraphTiles* with IMDb's mobile website. (a) and (b): The MPM(Movie-person-movie) *QueryType*; (c) and (d): the PMP(Person-movie-person) *QueryType*.

ABSTRACT

Although mobile devices are generating a rapidly increasing proportion of search queries, search interfaces have not changed significantly to accommodate mobile constraints. In particular, imprecise search exists in the no-man's land between specific fact-finding and general browsing, and can be especially challenging on mobile devices, when user input is difficult and environmental distractions make remembering related information difficult. We examined the prevalence of these mobile search use cases in a two-week diary study, finding that imprecise and general search accounted for the large majority of difficulty with search. Hypothesizing that the ability to view a link neighborhood around the search result could be quite helpful in these cases, we designed *GraphTiles*, a visual interface for mobile search that exploits the structured entity relationships present in a significant portion of online datasets (*e.g.* IMDb [5] and LinkedIn [6]). In an experimental evaluation, users performed imprecise searches more quickly with *GraphTiles* than with a standard mobile site.

Author Keywords

Mobile search; fact-finding; browsing; entity-relationship; imprecise search.

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION

According to recent reports, mobile search will soon surpass desktop search as measured by both queries and ad revenue [30][9]. Despite this growing importance, Cui and Roto [15] and Church and Oliver [14] find that current mobile search interfaces lead users to seek only information that is fairly specific (*e.g.* fact-finding) or quite general (*e.g.* browsing).

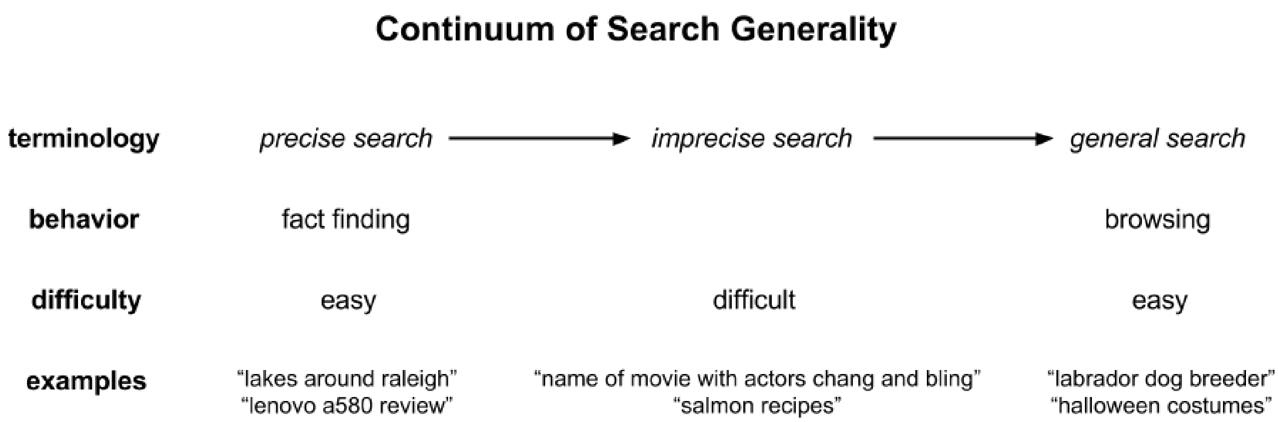

Figure 2. Our proposed continuum of search generality characterizes search according to the breadth of the information being sought. We expect that specific and broad information is generally easy for users to describe and find, but that this is not true with information in the “no-man’s land" between.

Both types of information are easy to retrieve with queries, and easy to find in search results.

However, the lack of knowledge about the information they seek and the limited query capability of the mobile interface [19] can force mobile users to repeatedly reformulate their queries, and explore results extensively. For example, a user may seek a specific actor. If she cannot remember the name of the actor (in which case she would directly search by name), she might instead search for an actor who worked with the actor they seek.

As Lee *et al.* [24] point out, this “no man’s land" of *imprecise* search (neither very general nor very specific) is more common than we might think, and some search engines have begun offering partial solutions. Search suggestions offer to complete keyword sets automatically in real time, helping users form better queries. Google’s Knowledge Graph [4] displays related facts from databases, making results easier to navigate. Yet neither solution is complete.

Inspired by this work, we propose a continuum of search generality from precise search to general search. It is based on the breadth of the information being sought, and is illustrated in Figure 2.

We believe that we can improve imprecise mobile search further by exploiting the entity-relationship structure in many online information sources to give mobile users a better overview of their results. Such sources might include movies and crew in IMDb [5], songs and artists in Pandora [7], and friends in Facebook [3]. These overviews reduce cognitive load through recognition, allow navigation of search results by attributes rather than only keyword [18], and guide users in the query reformulations that are typical of imprecise search.

In this paper, we present *GraphTiles*, a visual search interface designed to help mobile users perform imprecise searches. The interface displays an incomplete portion of the local entity-relationship neighborhood: a thumbnail of the current page alone in the left column, some pages one link away in the middle column, and other pages two links away in the right column.

CONTRIBUTIONS

The main contributions of this paper are:

- In a two-week diary study, we learned that most of the difficulty mobile search users experienced occurred during imprecise or general (browsing) searches.
- We designed the *GraphTiles* system, supporting imprecise searches on mobile devices.
- In a controlled experiment, we demonstrated that users were able to perform imprecise searches more quickly with *GraphTiles* than with a standard mobile website.

RELATED WORK

GraphTiles exploits structured data sources to facilitate information discovery, and has similarities to faceted search and various category-based interfaces. There are several systems designed to support faceted navigation, allowing users to explore a collection of information by applying multiple classification filters. FaThumb supports navigation of a hierarchical information space by incremental text entry and attribute based filtering using a numeric keypad [20]. While text entry is fastest if one knows the specific information, facet navigation is faster when one only knows the attributes of that information. The MuZeeker application supports category based filtering to refine search by category selection rather than typing additional text [23]. The system uses contextual information from the search results to relate individual search results to external resources such as YouTube videos. mSpace Mobile employs fish-eyed multi-panes, where each pane returns information for a specific facet [31].

One way of thinking about *GraphTiles* is that it exploits knowledge of information locality to improve search. Similarly, other mobile search tools often take advantage of user context such as location and time to provide a localized experience. Lymberopoulos *et al.* apply a data-driven approach where a local search model at different levels of location granularity (*e.g.* city, state, country) are combined together to improve click prediction accuracy in the search results [25]. *FindAll* is a local mobile search engine that lets users search and retrieve web pages, even in the absence of connectivity. The premise for their work is that mobile users often search for web pages that they have previously visited, known as re-finding. *FindAll* estimates the benefits of local search, by learning the re-finding behavior of users [11]. *Hapori*, a local mobile search tool, not only takes into account location in the search query but richer context such as the time, weather and the activity of the user [22]. Amini *et al.* present Trajectory-Aware Search (TAS) that predicts the user's destination based on location data from the current trip and shows search results near the predicted location [10]. *SocialSearchBrowser* incorporates social networking capabilities with key mobile contexts to improve the search and information discovery experience of mobile users [13].

GraphTiles is essentially a visualization of and search interface for the local entity-relationship graph. There has been little work specifically addressing mobile visualization [12], and to our knowledge, no work on mobile visualization for search. Karstens [21] proposes node-link diagrams of hierarchies arranged around a rectangle to make efficient use of display space. He displayed nearly 1000 nodes, each represented with a very small circle. Hao and Zhang [17] propose a space-filling sunburst display of hierarchies. Their larger nodes are easier to interact with, but their graphs are much smaller. Pattath *et al.* [26] visualize general graphs numbering just a few dozen nodes using node-link diagrams. Finally, in work most closely related to our own, Da Lozzo *et al.*[16] use node-link diagrams centered around a specific node, again with very small nodes. To recognize mobile constraints, *GraphTiles* limits visualization to a graph neighborhood as do Da Lozzo *et al.*, but like Hao and Zhang, it displays many links implicitly.

DIARY STUDY

We wanted to understand how often people perform *imprecise* searches in regular use, and how searches influence difficulty. To capture mobile users outside of the lab, we opted for a two-week diary study, in which participants record their own behavior in their paper diaries, a technique similar to that used in [29].

Imprecise searches can be characterized by at least one of two properties [24]:

1. Users iteratively refine multiple queries to find relevant information due to difficulty formulating an exact query.
2. Users have difficulty navigating through their search results to find the answer they are looking for, leading to multiple link following.

Accordingly, we formulated the following definition of *imprecise* search, as measured by our diary study: *more than one query was required, or three or more links in the result list were followed*. However, we found one ambiguous case: one query and at least three followed links might be imprecise search, with a user arriving directly at a confusing set of search results and hunting around; or they might be general browsing search, with a user quickly finding a broad swath of interesting information, and slowly exploring it. Disambiguation might require knowing how rapidly users followed their links. Unfortunately, this sort of timing information is not reliable in diary studies. We therefore settled for grouping imprecise with general searches in our design.

We now describe the participant profile, web diary tool, and procedure of our diary study.

Participants

We recruited 32 participants (21 college students, 8 software professionals, 2 office secretaries, and 1 school teacher) through online mailing lists and flyers. Their ages ranged between 18 and 62, with 17 being male and 15 female. All had normal or corrected-normal vision. They were required to have a mobile device capable of search, and to be regular users of that functionality. 14 participants had iOS, 11 had Android, and 7 had Windows phones.

Procedure

We provided each participant with a diary booklet to keep a history of their online searches. To keep the diary study agnostic across devices and the search medium, we opted for using a paper-based diary logging method as opposed to an automatic background logger. Participants were allowed to use any app or website on their device. Further, for privacy concerns, we wanted the participants to log only those searches that they were comfortable sharing.

We asked them to record at least two searches per day in order to fill out a 25-page booklet over the two week period. We met each participant after a week in order to check their diaries and data, answer any questions, and help them improve their feedback. During the meeting, we audio-recorded the dialog to archive quotes and feedback. After the second week, we collected the booklets. Participants were either compensated $9 or earned class credit. Each participant was assigned a unique ID to maintain their anonymity. If a participant completed a booklet before two weeks were over, we gave them a new one to fill out. We informed participants that they could terminate the experiment at any time, and that they should only divulge information that they were comfortable sharing. We also mentioned that we may publish anonymized quotes from their diaries.

The booklet contained 25 pages and each page included the questions listed below. If participants were not able to find an appropriate answer, they provided an explanation. We asked the participants to write down these details as soon as possible after they performed a search.

These were the questions on each page of the diary that participants answered as soon as they performed a search.

1. Date
2. Time
3. Duration of search task
4. What app or website did you access
5. What were you searching for?

Category	Number of Searches	Percentage	Query Examples
Precise and Easy	425	49	“lakes around raleigh” “data mining companies in the US” “lenovo a580 review”
Precise and Difficult	61	7	“Where can I buy beautiful ruins at lowest price?’" “home remedy for cat diarrhea” “how to transfer when taking a grey hound”
Imprecise/General and Easy	174	20	“labrador dog breeder’" “flights to west coast” “halloween costumes "
Imprecise/General and Difficult	208	24	“salmon recipes" “name of movie with actors chang and bling” “bathroom vanity mirror, bathroom mirror"

Table 1. Four categories of mobile searches in the diary study, their frequency of occurrence and examples.

6. Did you find what you were searching for at all? YES/NO
7. If you did find your information, please continue by filling in the blanks with numbers: I performed _ searches to find my information. I followed _ links after leaving the search results page.
8. Rate the difficulty of finding your information from 1–5 with 5 being very difficult. Add text to explain if you like.

Results

During the course of the diary study, we collected 868 search entries with an average of 27 entries per person. 9% of searches (33 out of 868) failed, not providing users with the information they sought. Participants performed an average of 1.2 searches ($median = 1, min = 1, max = 5$) and followed 2.5 links ($median = 2, min = 0, max = 39$) to find their information. Participants rated search difficulty at an average of 1.9 ($median = 2, \sigma = 1$).

We categorized searches by type and difficulty. Searches were imprecise or general (browsing) when they employed more than one query or three or more links clicked in the result list. Otherwise, the searches were precise (fact finding). Searches were too hard when they failed, users rated them difficult (4 or 5 on the scale), or they required more than 2 minutes of searching. Otherwise, searches were easy.

Using these two categories, we were able to bin the searches into four combined groups. 49% of the searches were precise and easy, 7% were precise and difficult, 20% were imprecise or general and easy, and 24% were imprecise or general and difficult.

Although search was usually successful, it was difficult about a third of the time (31%), especially when search was more imprecise or general. In fact these searches formed the large majority of the difficulties users were having. Further, roughly one third of imprecise and general searches sought information from datasets structured by entity relationships, such as movies and crews (`http://www.imdb.com`) or recipe ingredients and dishes (`http://www.allrecipes.com`). (This number may be significantly larger, because many participants only recorded their search tool, not the information they sought).

Some of the comments by the study participants on why they found imprecise or general searches to be difficult, include: *“could not come with the right descriptors for the mirror to find the one I had seen in the store"*, *“had to navigate lots of links to find something useful"* , *“had a hard time finding the right video of the musician as I didn’t remember his name"*, *“could not come up with the right search terms to find a book by a particular author and did not remember the author"*. Table 1 shows various corresponding examples.

On reflection, it is not surprising that search difficulty was focused in imprecise or general task types: they are simply more complex. We believe the large majority of problem searches could have benefited from a tool that helped users navigate through the complex information neighborhoods typical of imprecise and general search, and that a good starting point for such a tool would be exploiting the structure available in many datasets.

THE GRAPHTILES INTERFACE

The diary study shows that there is a spectrum of mobile search, ranging from general search to more specific precise search, and imprecise search falling somewhere between. Imprecise search is characterized by user difficulty describing the information being sought. This results in users reformulating queries, and spending extended time navigating through results from poorly described searches. While several apps and mobile websites exist to address the first two classes of mobile search [15, 14], we designed *GraphTiles* to help mobile search users handle the most challenging use case identified by our diary study, *i.e.* imprecise search.

We sought to address these problems by:

- presenting a succinct overview of the results, given mobile constraints. This helps users find their information more quickly, and may help them recall more detail about the information they seek.
- enabling rapid navigation through the results with simple gestures, including scrolling and faceted search with the results themselves as parameters. Not only is this necessary given mobile constraints, it again helps users find information more quickly, and also helps avoid the necessity of new queries by drilling down in the results themselves.

Our interaction design was influenced by Schneiderman's information seeking mantra of detail-on-demand using overview with zoom and filter [28].

As shown in Figures 1(a) and 1(c), the *GraphTiles* interface assumes that users will employ search to find a locality of concern around a central node (*e.g.* for IMDb, "near John Wayne"), represented by a thumbnail alone in the left column. Distance in the *GraphTiles* layout from this central node reflects relational distance from the center (*e.g.* for IMDb, degrees of working separation from John Wayne), with the middle column one link away, and the right column two links away. To see the complete two link neighborhood, users can scroll the central and right columns vertically. We display links largely implicitly: every node in the middle column has an implied link to the central node, and every node in the right column is reachable from the middle column. To represent links between the middle and right columns we support both explicit link display, and interactive reordering. Explicit links appear only when both linked nodes are currently displayed. With reordering, when users select a thumbnail from these columns, *GraphTiles* highlights thumbnails linked to the selection and reorders to place them onscreen or nearly so. Users can restore the previous order by deselecting the thumbnail. When necessary, users can drag a non-central node to the left to change the central node.

We considered a circular (or rectangular) layout to make better use of the blank space in the left column, with a scroll around the central node rather than along it, but discarded it so that we could provide a glimpse of a larger two-link neighborhood. A circular layout with a two-link neighborhood would require much smaller nodes (difficult to touch with a finger tip), and would fit poorly in rectangular mobile displays. Representing within column links explicitly can be confusing, so for such cases we rely on interactive reordering alone (see (c) in Figure 3, depicting data from the Seattle Band Map [8]).

EXPERIMENT: COMPARISON TO IMDB'S MOBILE SITE

To confirm that *GraphTiles* supported imprecise search well, we performed an experiment comparing it to a standard mobile information interface. We expected that the specialized *GraphTiles* interface would allow users to perform imprecise search more quickly than an interface supporting the full continuum of information-seeking.

As a typical mobile information interface, we chose the IMDb mobile web app. An imprecise search making use of IMDb is often similar to this: a user wants to recommend a movie to a friend, but cannot remember the name of that movie, nor the name of any actors in that movie. This makes using standard search interfaces somewhat difficult. They do however know that one of the actors in the movie they want to recommend was also in a different movie they can name. They navigate from movie to actor to movie. We focused on answering imprecise queries of that nature.

Figure 1 shows a comparison of the visuals used in *GraphTiles* and IMDb's mobile website (`http://m.imdb.com`) to answer movie-person-movie(MPM) queries of this type, as well as person-movie-person(PMP) *QueryTypes*.

Method

Our experiment had 20 participants, all of them employees at a large corporate research center. We obtained informed consent from the participants, and asked them to read the instructions for the experiment. We then familiarized them with the task using 8 training datasets, two for each combination of link *interface* and *QueryType*. Participants were free to ask verbal questions during training. Each participant performed 120 information seeking tasks, each using a different graph neighborhood in the IMDb database, with median size of 115 nodes. On average, they completed all their tasks in one hour.

We used a fully crossed within subjects 2×2 design. As participants performed the tasks, we systematically altered two variables. *Interface*, or the tool used to access the IMDb information, had two levels: *GraphTiles* and the IMDb web app. *QueryType* had two levels: a movie-person-movie (MPM) query or a person-movie-person (PMP) query. If *QueryType* was MPM, we asked participants to find the person who worked in two given movies. In this case, the central node at the left of the visualization was always a movie. If *QueryType* was PMP, we asked participants to find the movie on which two given people collaborated. In this case, the central node at the left of the visualization was always a person.

To answer a question, participants typically scrolled in the right column to find the second given person or movie. This reordered the middle column, making it easier to scroll in the middle column to find and select the connecting movie or person. Alternatively, participants could first scroll in the middle column, then select each movie or person there and scroll the reordered right column to find the second given person or movie. However, participants quickly learned that the right-first approach was more efficient: it took advantage of faceted search to require only one switch between the right and middle columns, while the middle-first approach ignored the provided faceted search parameter and required several switches.

GraphTiles displayed link lines and used interactive reordering. Every participant performed 30 trials with each of the $2 \times 2 = 4$ experimental treatments. We grouped trials by *Interface* into two blocks of 60 trials each. Thus participants performed all trials with the current Interface before moving on to the next. To combat the effects of fatigue and learning, we used complete counterbalancing across participants: half of them performed the *GraphTiles* block first, the other half the web app block first. Within each of these blocks, we randomly ordered the levels of *QueryType*. We randomized the order of graph neighborhoods without replacement, so that each participant saw each neighborhood exactly once.

Apparatus

We implemented *GraphTiles* on three Samsung SGH-i917 phones running Windows Phone 7.5, with an AMOLED display and a full capacitive touch screen. The monitor used to display questions was a 1920×1200 pixel Dell 24". Participants interacted with the visualization on a phone by scrolling with a swipe gesture or selecting nodes with a long tap.

(a) Band and artist relationship

(b) Band relationship

(c) Interactive reordering with dimmed image when not related.

Figure 3. Applying *GraphTiles* to Seattle's music band data.

We obtained our IMDb graph neighborhoods using the official IMDb API (`http://www.imdb.com/interfaces`), obtaining a large cross section of its database (approximately 3GB in size). We then randomly selected 60 nodes within the IMDb graph describing well known actors (supporting PMP queries), and 60 nodes describing well known movies (supporting MPM queries). We then sampled the two-link neighborhood around each actor (PMP) node by adding the top movies linked to it as indicated by IMDb's own API call; and then for each of those top movies, adding its top actors, again as indicated by IMDb's API call. We created two-link neighborhoods around movie (MPM) nodes similarly. The number of top movies returned by IMDb's API was generally much lower than the number of top actors.

Results

All participants performed all trials correctly, so we report only completion times here. We tested significance using a two-factor repeated measures ANOVA. Only the two single variable effects were significant; they did not interact.

When using *GraphTiles*, participants were significantly ($F(1, 19) = 2291.833$, $p < 0.001$) faster than when using the IMDb web app. Average completion time with *GraphTiles* was 18.2s ($\sigma = 5.27$), while with IMDb web app, it was 31.5s (SD 5.26).

Although its effect was significant ($F(1, 19) = 11.27$, $p < 0.005$), *QueryType*'s effect was not meaningful. The difference in completion times when participants looked for movies rather than persons was 0.6s: (25.0s for movies, 24.4s for persons). The likely explanation for this effect was the consistent differences in MPM vs. PMP neighborhoods.

Discussion

Results in fact exceeded our expectations, with *GraphTiles* users were almost twice as fast as when using the IMDb web app. There are two explanations for *GraphTiles*'s superior performance. First and most important, the faceted search implemented in *GraphTiles* reduced the number of actions users had to take. By first selecting both given people or movies, users could display only the movies or people connecting them. In contrast, IMDb did not implemented faceted search, and required users to examine a much larger set of possibly connecting movies or people. Second, *GraphTiles* had several visual advantages. It was a more effective overview: rather than requiring interaction to reveal information two links away (*i.e.* other people in the first person's movies, or other movies in which the cast of the first movie acted), it displayed at least some of them immediately. *GraphTiles* was also less cluttered, without the ads and tertiary information IMDb contains. Finally, *GraphTiles* was less textual than IMDb, and perceptual research consistently shows that visual information is more rapidly understood than text.

Although the degree of *GraphTiles*'s superiority was surprising, that superiority itself was not. *GraphTiles* was designed specifically for imprecise search; IMDb is a more general tool. What remains to be seen is whether or not a single interface can support the full continuum of search generality well. Future work might also attempt to extend our results with other and more types of imprecise search, and by examining the performance of *GraphTiles* with general and indeed precise search.

CONCLUSION AND FUTURE WORK

As mobile devices become the dominant form of computing, mobile search will become increasingly important. In this paper we described *GraphTiles*, a new search interface specifically designed for imprecise search. In a diary study, general and imprecise search proved to be the focus of most user difficulty. In an experimental evaluation, accessing the IMDb graph for imprecise search with *GraphTiles* was nearly twice as fast as with the existing IMDb mobile web app.

A number of possible design improvements to *GraphTiles* could be studied in future work. The current design is optimized for smartphones; on devices such as tablets *GraphTiles* might display larger neighborhoods. *GraphTiles* could also use improvements to maintain visual continuity when users change the central node: currently users can quickly become disoriented.

Several limitations of and questions raised by our work also deserve followup. Most importantly, how easily could *GraphTiles* be generalized? There are two primary data constraints that we exploited in *GraphTiles*. First, the presence of visual thumbnails, which are an effective way of improving experience and summarizing available information [27]. Second, the existence of a structuring graph of entities and their relationships, which enable users to navigate through information in an intuitive manner. In our experience, there are many sites that match these constraints, including IMDb [5], AllMusic [1] and Allrecipes [2].

When sites do not contain thumbnails, one might substitute text. For example, the *GraphTiles* interface could initially display abridged ingredients of salmon dishes with additional interaction for showing longer descriptions. Another option might show summarizing thumbnails built on the fly, containing both text and imagery [27]. For sites without an entity-relationship graph, a navigable structure is still a necessity. It may be possible to use the links in a webpage or search engine results to provide this structure.

Will or should *GraphTiles* always be a special case, or can it be part of a unified solution for specific as well as imprecise and general search? Researchers might examine this question by folding *GraphTiles* into a more general information interface. Finally, it could be profitable to learn about the various contributions to mobile search difficulty of general vs. imprecise search. We were not able to disentangle the two in the diary study we used here, but future work might employ a different measurement method.

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