Context Aware Point of Interest Adaptive Recommendation

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ABSTRACT
Applications that allow the users to search for nearby points of interest have, recently, become very popular amongst mobile device users. However, the increasing amount of available information and the limitations of current mobile devices can hinder an efficient and helpful user experience. It is fundamental that what is shown to the user is relevant. We propose an adaptive recommendation function that uses location and temporal contexts combined with the historical context of the previous searches to quantify the relevance of the points of interest shown to the user.

Author Keywords
Context Aware, Mobile Devices, Degree of Interest.

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User Interfaces - *Prototyping*.

General Terms
Algorithms, Experimentation.

INTRODUCTION

Nowadays it is very common for new mobile devices to have integrated positioning devices. This has fostered the development of location based services and, for this reason, the real time information about the location of users has become widely used in an extensive range of applications.

Applications, like Google Maps [1] that allow users to search nearby points of interest (PoI) using their mobile devices have become very popular. These applications allow the user to perform numerous tasks like finding relevant locations in the vicinity, such as, a gas station or a restaurant, or to calculate the shortest route to another location. The use of maps also allows the user to compare alternative locations, helping understand where each PoI is located and their geographical relation.

However, despite the usefulness of current systems, the huge amount of information that we have to deal with, creates a limitation for the users to correctly and easily perceive what is shown to them [2]. It is thus essential that we enforce that what is shown on the screen is important information for the user [3]. Furthermore, it is fundamental to include recommendations that provide users with information to guide them in choosing amongst the available information.

Recommender systems have been a popular research topic. However, traditional recommender systems do not take into account richer contextual dimensions, such as the type of location or the time of day, which are easily obtained using current mobile devices [4]. The adaptation to these context dimensions is a key feature to mitigate the limitations in the usability of small screens. According to the definition of Reichenbacher [5], adaptive visualization concerns the adjustment of all components of the visualization process, such as the interface, the information extracted from the data and the data codification, according to a particular context. This adaptive principle is especially important to increase the usability of searching information in mobile devices and to reduce the cognitive load inherent to mobile usage contexts.

In this paper we present an adaptive degree of interest function that uses historical context information, combined with location and temporal contexts, to automatically adapt its values to the previous user choices and searches, according to when and where they were made. This function also takes into account temporal distances.

The next section describes some of the related work. Afterwards, we present our previously proposed degree of interest function and, next, how this function can be improved with the adaptation to the historical, location and temporal contexts, and the addition of temporal distances. We then describe the developed prototype and finally present the conclusions and future work.

RELATED WORK

Although not directly related to mobile devices, Furnas [6] explores the presentation of large structures in windows of reduced size and uses fisheye views to address this issue. To formalize his conception of fisheye views, he introduces the concept of a degree of interest function. This function describes the interest the user has on a certain object. This function is defined as the combination of two components: an *a priori* importance that represents the global interest on the object, and *a posteriori* importance that depends on what the user is focusing on at the moment, expressed by a distance function.

CaRR 2012, February 14, 2012, Lisbon, Portugal.

In [7] the authors created the VisDB system which considers not only the objects that match a query, but also those that only satisfy it partially. To determine the relevance of each object, distance functions are used for each attribute specified by the user. Since different attributes may have different priorities, the users are allowed to set a weight factor for each of them. The resulting distances are then combined.

Based on the previous work, Reichenbacher [8] focuses on mobile device cartography. He considers not only the object and its location but also the time of events related to the object. To calculate the relevance of each object Reichenbacher combines three distances: a topical distance, a spatial distance and a temporal distance.

In a previous work [9], we have proposed a degree of interest function that enables the user to quantify the relevance of each point of interest. This function, described in more detail in [9], is based on Furnas's degree of interest function [6] and the work of Kheim and Kriegel [7], both described earlier, and will be briefly described in the next section.

PREVIOUS DEGREE OF INTEREST FUNCTION

The degree of interest function (DoI) quantifies the interest the user has on certain point of interest, p_j, as the average of the user interest (UI) on the k different attributes a_i, $i=1,2,\ldots,k$, multiplied by a weight w_{cat} for the category of p_j. Both a_i and w_{cat} are specified by the user.

$$DoI(p_j) = \frac{\sum_{i=1}^{k} UI(a_i, p_{ji})}{k} \times w_{cat} \in [0,1]$$

The User Interest function $UI(a_i,p_{ji})$ depends on the distance between the value selected by the user for the attribute a_i and the value p_{ji} of the point of interest p_j in the same attribute. The following distance functions were defined:

- For nominal attributes with l alternative values (e.g. types of restaurant)

$$Dist\left(a_i, p_{ji}\right) = \begin{cases} 0, if\ a_{i1} = p_{ji} \vee a_{i2} = p_{ji} \vee \ldots \vee a_{il} = p_{ji} \\ 1, if\ a_{i1} \neq p_{ji} \wedge a_{i2} \neq p_{ji} \wedge \ldots \wedge a_{il} \neq p_{ji} \end{cases}$$

- For numerical attributes with l alternative values (e.g. number of stars of a hotel)

$$Dist(a_i, p_{ji}) = min\left\{\left|\frac{a_{i1} - p_{ji}}{max_i - min_i}\right|, \left|\frac{a_{i2} - p_{ji}}{max_i - min_i}\right|, \ldots, \left|\frac{a_{il} - p_{ji}}{max_i - min_i}\right|\right\}$$

- For numerical attributes with a range of values (e.g. price)

$$Dist(a_i, p_{ji}) = \begin{cases} 0, if\ a_{i1} \leq p_{ji} \leq a_{i2} \\ \left|\frac{a_{i1} - p_{ji}}{max_i - min_i}\right|, if\ p_{ji} < a_{i1} \\ \left|\frac{a_{i2} - p_{ji}}{max_i - min_i}\right|, if p_{ji} > a_{i2} \end{cases}$$

where max_i and min_i correspond, respectively, to the maximum and minimum values known for that attribute.

- For the geographical distance, we use a normalized Euclidean distance

$$Dist(a_i, p_{ji}) = \sqrt{\left(\frac{x_a - x_{p_i}}{max_x - min_x}\right)^2 + \left(\frac{y_a - y_{p_i}}{max_y - min_y}\right)^2}$$

where (x_a, y_a) and (x_{pi}, y_{pi}), correspond, respectively, to the position of interest defined by the user, and the location of the point of interest.

After having calculated the distances, it is possible to determine the value of the UI function:

$$UI(a_i, p_{ji}) = 1 - Dist(a_i, p_{ji}) \times w_i,\ w_i \in [0,1]$$

where w_i is the weight for the attribute a_i, which can be defined by the user to specify the importance he gives to that attribute in the query being made.

Since all the distance functions, as well as the UI function, can only have values between 0 and 1, the result of the DoI function is also between 0 and 1, reflecting the degree of interest the user has on a certain point of interest.

By using the degree of interest function, we were thus able to order the various points of interest and present only the most relevant ones, while providing a numerical recommendation for those displayed.

ADAPTIVE DEGREE OF INTEREST FUNCTION

After evaluating the previously described degree of interest function [10] it was concluded that although considered useful, the use of this type of function can be confusing. One of the reasons for this is the need to specify a large set of attributes for each query made and simultaneously understand and specify the weights for each of them.

To overcome these limitations we propose some enhancements to the previous DoI function. These improvements are detailed in the following sub-sections.

Historical Context

To allow the reduction of the cognitive load when the user is specifying a query, we have added an option to use the historical context to automatically enhance the queries.

For each pair (attribute type, attribute value) we store an internal count of how many times it was queried. Whenever the user specifies a query, the attributes specified and their value are updated in the internal database. This historical log allows a summary of the interest of the user to be assembled over time. For instance, if the user almost always goes to Italian restaurants, it is possible to use this information to automatically specify the "type of restaurant" attribute without further action from the user. The weight used in the automatically defined attributes is calculated as a function of how many times it was chosen versus other queries.

Location and Temporal Aware Historical Context

The type of searches made by the users is, however, not always the same according to the location and temporal contexts. As an example, a user might have a different interest whether he is searching for a restaurant at noon near his work or looking for one at dinner time near his home.

For this reason, we allow the users to define geographical areas that are relevant for them (for example, a work area, or a home area), by selecting, on the map, two of the area's corners. When the user performs a query, the logs are recorded / updated in the appropriate geographical area / time of day section. Whenever a new query is made, the attributes are automatically adapted according to the user's current location and temporal contexts.

Similarly, we also added the option of automatically storing the number of visits to specific points of interest, so that the application could identify which ones might be more important to the user and those that have never been visited.

Finally, it is important to stress out the need for the user to always have the option of over imposing the options automatically chosen by the application with the ones explicitly chosen by him/her.

Temporal Distances

As important as understanding what points of interest exist in the vicinity of the user is to identify which of these are open by the time the user gets there. As an example, if the user is searching for a service station to fuel his car, it is not useful to display results for stations that might not be open when the user finally arrives there.

For this reason, we have added a new temporal distance function and time attribute to the degree of interest function. This distance can be subdivided into three different distance calculations, depending on the category of the PoI being searched. On these calculations h_{op} and h_{cl} are, respectively, the point of interest opening and closing hours, h_{ar} is the users expected arrival time (either specified by the user or automatically calculated according to the users current location), Δt_{st} is the minimum staying time interval and Δt_{tol} is a tolerance time interval (both can be specified by the user, but have default values predetermined according to the point of interest category).

- The user intends to arrive only during opening hours, never before or after

$$Dist_{temp} = \begin{cases} 0, if\ h_{op} \leq h_{ar} < (h_{cl} - \Delta\ t_{st}) \\ 1, if\ h_{ar} \geq (h_{cl} - \Delta\ t_{st}) \vee h_{ar} < h_{op} \end{cases}$$

- The user intends to arrive before (using a tolerance time interval) or during opening hours, never after

$$Dist_{temp} = \begin{cases} 0, if\ h_{op} \leq h_{ar} < (h_{cl} - \Delta\ t_{st}) \\ \dfrac{h_{op} - h_{ar}}{\Delta\ t_{tol}}, if\ h_{ar} < h_{op} \wedge h_{ar} \geq \left(h_{op} - \Delta\ t_{tol}\right) \\ 1, if\ h_{ar} \geq (h_{cl} - \Delta\ t_{st}) \vee h_{ar} < \left(h_{op} - \Delta\ t_{tol}\right) \end{cases}$$

- The user intends to arrive before opening hours (using a tolerance time interval), never during or after

$$Dist_{temp} = \begin{cases} \dfrac{h_{op} - h_{ar}}{\Delta\ t_{tol}}, if\ h_{ar} \geq \left(h_{op} - \Delta\ t_{tol}\right) \wedge h_{ar} < h_{op} \\ 1, if\ h_{ar} > h_{op} \vee h_{ar} < \left(h_{op} - \Delta\ t_{tol}\right) \end{cases}$$

PROTOTYPE

To be able to evaluate the proposed changes to the degree of interest function, we have developed a prototype, for a Samsung Galaxy S mobile device with the Android 2.2 operating system.

The prototype was developed using the Chameleon Adaptive Visualization Framework for mobile devices previously developed [11].

We use a PoI database with data obtained from several collaborative internet sites, aimed at navigation applications, which allowed us to obtain over 8000 PoI, divided in eight categories, with an accurate geographic distribution.

Figure 1 (a) shows an example of the query specification interface. The user is able to select which attributes are explicitly specified and also change the default weight for each of them. As an example, in the figure, the user has selected price and distance with a low weight and the temporal distance with a higher weight.

(a) **(b)**

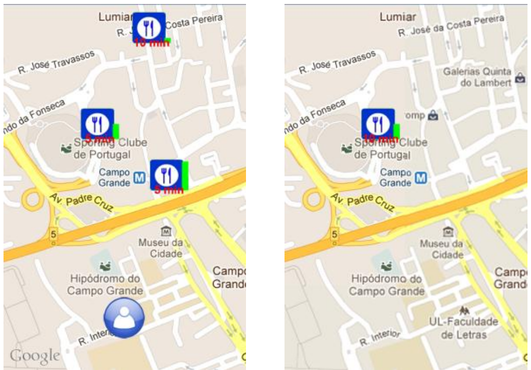
Figure 1. (a) Query specification interface (b) Point of interest icon.

The results interface displays a map with icons representing each point of interest. These icons are composed of three different areas (Figure 1 (b)): the main area indicates the category of the displayed points of interest; in the right, using the approach proposed in [12], a green bar indicates the relevance value calculated using the DoI function (the higher the bar the more relevant the result); in the lower part of the icon, a number indicates how much time the user would need to get there.

The DoI function can be used in three different recommendation modes: a Standard mode that uses the DoI function without the historical context to recommend the PoI, the Exploratory mode that removes previously visited PoI from the recommendations, and the Adaptive mode that uses the historical context, adapted to the users current location and time, to determine the PoI recommendations.

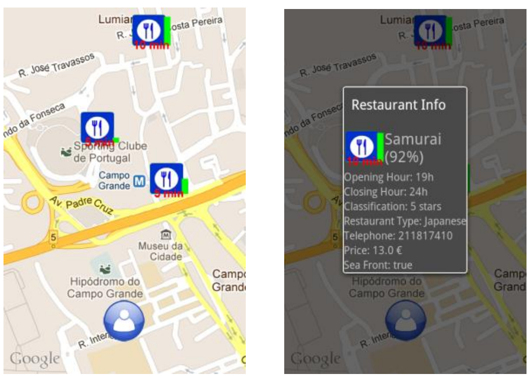
The Standard mode uses the previous DoI function (enhanced with the temporal distance) without the historical context. In Figure 2 (a) an example is given. In this case the user is searching for a restaurant but has only specified the geographical distance attribute to be used. For this reason, the relevance of each PoI decreases as the geographical distance to the user increases.

The Exploratory mode is intended to be used when the users want to “try something new”. It uses the information about previously visited PoI to remove the ones already known to the user. In the example, in Figure 2 (b), two of the restaurant had already been visited previously by the user and were filtered out.



(a) **(b)**

Figure 2. (a) Standard DoI results (b) Exploration results



(a) **(b)**

Figure 3. (a) Adaptive DoI results (b) Information about the selected PoI

Finally, the Adaptive mode uses the adaptive historical log to adapt unspecified attributes to the previous queries done by the user, depending on the current temporal and location contexts. In the example, in Figure 3 (a), the user had a previous experience of going mostly to Japanese restaurants for lunch while in his work area. For this reason, the restaurant at the top of the screen (which is Japanese) has a higher relevance. Figure 3 (b) shows contextual on-demand information about the selected restaurant.

CONCLUSIONS AND FUTURE WORK

In this paper we have proposed an adaptive degree of interest function that improves a previously proposed relevance function. This function uses information about historical logged previous queries to be able to adapt new point of interest searches to the user interests.

The next step in our work is to perform an extensive user evaluation of the proposed DoI function and the developed prototype. We also intend to explore the use of additional context dimensions, such as weather conditions or the type of user movement, to further adapt the DoI function. We also intend to explore the use of different adaptive icons that change dynamically according to the contexts and explore the automatic detection and definition of the user’s relevant geographical areas.

ACKNOWLEDGMENTS

The work presented here is based on research funded by the FCT - Fundação para a Ciência e Tecnologia (Portuguese Science and Technology Foundation) through the SFRH/BD/46546/2008 scholarship.

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