Evaluation of Overcluttering Prevention Techniques for Mobile Devices

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Abstract

The increasing popularity of mobile devices has fostered the development of visualization applications for these devices. However, the reduced screen size and different interaction devices, which people are not familiarized, present some challenges to visualization in a mobile environment. This paper describes how, as a proof of concept, a combination of two different techniques can reduce the over cluttering of icons on a mobile device screen. An evaluation of these techniques is also presented.

1. Introduction

One of the most outstanding characteristics of our society is the growing mobility of people. This mobility is currently combined with a growing desire to use computation and communication tools in a mobile environment.

Due to the proliferation of mobile devices with integrated global positioning systems, visualization of geo-referenced data with location context have increased. For instance, commercial navigation applications, like TomTom Navigator [16], Navigon [11] and NDrive [12] are currently very popular. Google Maps Mobile [9] is another commercial application that is based on Google Maps [8] and is optimized to be used on mobile phones.

However dealing with a lot of data and producing intelligible images is still a problem. Information visualization is hindered by several technical restrictions in mobile devices, such as the screen size and its resolution, the lack of processing, storage and memory capacity, battery power, wireless network bandwidth and connectivity and inadequate input devices [1]. Of all these restrictions, the screen size is undoubtedly the most severe, not only because of the difference when compared to desktop screens, but namely due to the size of the mobile devices themselves, it is a restriction that should not disappear in the near future. Therefore there is a need for techniques to avoid over cluttered images.

In this paper we start by reviewing, in section two, techniques which aim to solve cluttering in mobile devices. In section three, we describe a combination of techniques to reduce the number of displayed icons. In section four, we describe the evaluation of the techniques proposed and present the results obtained. Finally, on section five, we present our conclusions and future work.

2. Approaches to reduce over cluttered images

The presentation of large amounts of information in small screens is, currently, an important research area.

An approach to obtain intelligible images in small screens is to reduce the amount of information shown. One way to achieve this reduction is using filtering techniques that determine the relevance of each element and use this information to exclude the less relevant ones.

Although not directly related to mobile devices, George Furnas [7] explores the presentation of potentially large structures in windows of reduced size and uses fisheye views to address this issue. To formalize his conception of fisheye views, the author introduces the concept of a degree of interest function. This function describes the interest the user has to visualize 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 an *a posteriori* importance that depends on what the user is focusing at the moment and is expressed by a distance function.

In [10] the authors also address the problem of visualizing large amounts of information. One of the problems stated is that, frequently, the result of a query to a database is composed either of too many results, overwhelming the user, or no results at all, not giving the user a clue on how to continue his search. To solve this problem, 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 of the attributes 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 [15] 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.

Another way to reduce the amount of information shown is to use generalization operators that group elements that are close to each other, replacing them with another representation. In [5] five different operators are suggested: Selection, Simplification, Aggregation, Typification and Displacement.

In [17] a similar approach is described. The visualization area is divided in a grid and the information density for each cell is determined. Then, to maintain a constant density throughout the grid, some elements can be displayed with a simpler representation, grouped with other elements or removed.

In [2] is presented additional work that has been done on the positioning of aggregation icons. In this paper the authors describe several algorithms designed to perform fast aggregations.

Using techniques like the ones described before, can help selecting the proper information and presenting it in a convenient way to the user. However, the mapping between the information and the visual elements should also be adapted to enable the user to easily apprehend its meaning.

In the next section we will describe how an adaptation of some of the techniques described before can solve the over cluttering of icons on a mobile device. Although not directly related to mobile devices, in [6], Ellis and Dix present an analysis on several clutter reduction methods and classify them according to different clutter reduction criteria. According to that taxonomy, our approach focus on techniques designated as filtering, clustering, point size and point/line displacement.

3. Visualization issues

It is very easy to over clutter the screen of a mobile device with information. Figure 1 shows the hard time a user can have while trying to understand such a confusing image.

Figure 1: Over cluttered image.

Our aim was to create an information visualization system designed for mobile devices that could present geo-referenced points of interest organized in categories (e.g. Hotel) with multiple attributes (e.g. Price, Classification). For this purpose, icons are placed over a map representing the points of interest.

3.1 Degree of interest function

To obtain an intelligible representation, we have to control the number of results that are shown on the screen. We use a degree of interest function that enables us to quantify the relevance, for the user, of each point of interest. This function, described in more detail in [3], is based on Furnas's degree of interest function [7] and the work of Keim and Kriegel [10], both described earlier.

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.

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

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)

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

– For numerical attributes with l alternative values (e.g. number of star 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)

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

where $\max_i$ and $\min_i$ correspond, respectively, to the maximum and minimum value know 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 relevance 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 are thus able to order the various points of interest and present only the most relevant ones, reducing the amount of information presented to the user.

3.2 Generalization operators

Although the use of a filtering function allows the number of points of interest to be reduced and, consequently, minimize the probability of overlapping icons, it does not fully solve the problem. In fact, if the distribution of elements is not uniform, there is a high possibility that the points of interest, although their number was reduced, are all close together (Figure 2). Indeed, this is a quite often situation in the distribution of points of interest on a map. As a consequence, it is necessary to find some way to complement the filtering function.

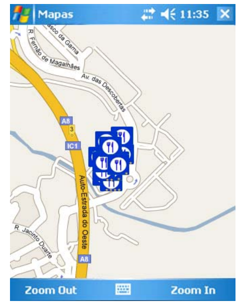


Figure 2: Local over cluttering of information.

To solve this problem we use generalization operators. To decide when to use these operators we use a grid superimposed on the visualization area. When the number of points of interest in each cell exceeds a predefined threshold, a generalization is made. The use of the grid is described in greater detail in [4].

Following the classification given in [5], we consider three different generalization operators: aggregation, typification and displacement.

If all points of interest contained in a certain cell of the grid are of the same category, an aggregation operator is used. All of the icons are then replaced by a single one that represents a group of points of interest from the same category (Figure 3).

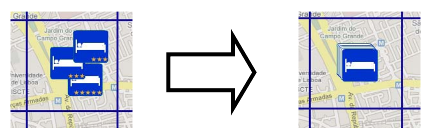


Figure 3: Aggregation Operator.

If the points of interest are from different categories, thus having no semantic connection, a typification operator is used. In this case the icons are replaced by a single one, created dynamically, that shows information about the categories of the elements grouped (Figure 4).

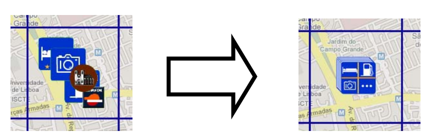


Figure 4: Typification Operator.

A third and final operator is used in situations where the previous ones can not be used (high zoom levels) or when the user explicitly requests to see individual points of interest. In these situations, overlapping of icons can occur. To minimize the overlapping a displacement operator is used. By using this operator, the overlapping icons are moved away from each others and a red line can be presented in each one to show the user the actual position of the point of interest (Figure 5).

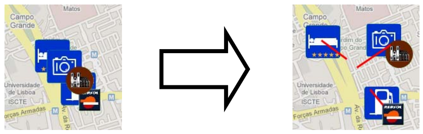


Figure 5: Displacement Operator.

4. Visualization Prototype

As a proof of concept and to enable the evaluation of the proposed techniques, we developed MoViSys, a prototype of a geo-referenced information visualization application for mobile devices [3]. The MoViSys prototype was developed for Pocket PC, with the Windows Mobile 5.0 operating system, using .Net Compact Framework 2.0. The data about the points of interest is stored in a SQL Server database and the maps are obtained through the Google Maps Web Server.

Figure 6 presents the execution flow after the query specification. This specification involves the definition of the categories, respective attributes and weights.

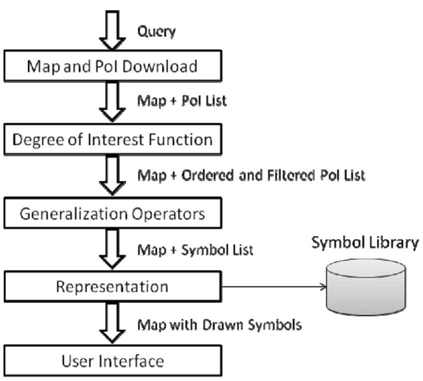


Figure 6: MoViSys execution flow.

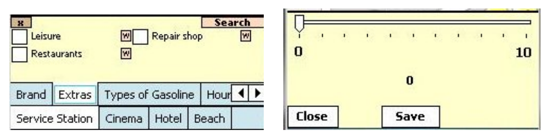
Initially, the map image and the corresponding points of interest are downloaded. Next, the degree of interest function is calculated, for each of the points of interest returned, using the values specified in the query interface.

Using the resulting relevance, the points are ordered and the less relevant are discarded. After the ordering phase, every cell of the grid is checked and, if necessary, the generalization operators are used. The icons for each point of interest (or group of points of interest) are created using a symbol library. Finally, the icons are drawn over the map and this is passed to the user interface.

Figure 7 (a) shows the organization of our query specification interface in two main areas: map area and the query specification area. In the map area the user performs pan and zoom operations. On the upper right corner of the screen there is a button to increase or decrease the size of the icons according to the user state (in motion or stopped). In the query specification area, the user selects the categories he intends to visualize. These selected categories are shown using a double tabbed interface: a bottom tab line with the categories, another tab line with the attributes of the selected category and an area with query devices (Figure 8) for the values of the selected attribute.

(a) (b)

Figure 7: MoViSys query specification interface (a) and context menu (b).



(a) (b)

Figure 8: Boolean (a) and weight (b) query devices.

For example, suppose a user that needs to find a service station that sells GPL fuel and, if possible, with a restaurant. He could select the “Service Station” category, and then select the attribute “Type of Gasoline” (Figure 8 – a) with weight 10 and as an extra the attribute “Restaurant” with weight 5, reflecting the relative importance he gives to each restriction.

Figure 7 (b) shows the context menu that allows the user to use different options, like zooming in or out, centring the map, obtaining detailed information about a point of interest, amongst others, depending on what he selects.

5. User study

Using the developed system we conducted a user study to find if the proposed techniques were useful to the users and to find the main usability difficulties.

In the next sections, we will describe the user study and the results obtained. The graphs shown in the following subsections consist of information about the average and respective standard deviation.

5.1 Participants

To allow a correct evaluation of these concepts, we based ourselves on the work done by Nielsen [13, 14]. These studies indicate that with the evaluation of only five users it is possible to discover about 85% of the existing problems. When evaluating groups of people with distinct profiles, this number should be slightly increased so as to capture different group behaviours.

In our study 15 users were tested, six male and nine female and their ages ranging between 18 and 58. Their background was quite diverse: four were from Computer Science; another four were from Natural Sciences; three from Administration; two from Literature and another two from Arts. Their experience in using visualization applications in mobile devices was also diversified: five were more experienced users; six had no experience whatsoever; two were experts on the subject and two were young students with plenty of experience in the use of mobile devices but not in visualization applications.

5.2 Tasks

To evaluate all the aspects of the techniques proposed and the developed prototype, users where requested to execute a set of five tasks:

First Task - The initial task consisted of a free interaction with the map where the users were asked to test the different panning and zooming interaction alternatives, namely the keys, pointer or fingers.

Second Task - In the second task users where asked to choose a random category and evaluate different icon sizes, freely chosen by the users, with the purpose of identifying an ideal icon size. An icon size increase button (shown in the top right corner of Figure 7), to aid icon selection when walking, was also tested.

Third Task - In this task, users were asked to evaluate the context menu and its options, as well as the detailed information displayed for each point of interest.

Fourth Task - The fourth task evaluated the use and the effectiveness of the generalization operators. To achieve this purpose users where asked to test situations where several operators were used.

Fifth Task - In the final task, real life scenarios were simulated that allowed us to test how users reacted to different situations, and if they comprehended and made effective use of the degree of interest function. There were three different scenarios created. In the first, users were asked to search for an Italian restaurant in an area where no such restaurant existed. The second scenario simulated a situation where the user wants to find a restaurant with several specified attributes, but also needs a gas station in the vicinity. Finally, the third scenario involved searching for tourist attractions in an area were many results existed.

5.3 Setup

The test was conducted using a 200Mhz Pocket Pc with 128 MB of ROM and 64 MB of RAM. The screen had a size of 2, 8’’ with a resolution of 320x240 and 65000 colours. The device was equipped with the Windows Mobile 5.0 operating system.

To obtain the most realistic scenarios, real points of interest were loaded, with data obtained from collaborative internet sites, aimed at navigation applications. This approach allowed us to obtain over 8000 points of interest, divided by eight categories, and with an accurate geographic distribution.

5.4 Procedure

Users were initially asked to answer some questions to establish their profile and also their experience in the use of geo-referenced visualization applications, both on desktop and on mobile devices.

Before each task the users were briefed about what the task consisted of. Then, while the users were carrying out the tasks, observations were made and user feedback was taken note of. When something was asked to be classified, a six level Lickert scale was used where 1 represented the worst classification and 6 the best. Finally, to complement to the use of the Lickert, the observations were taken into account and, in the end of each task, an interview was made about what had been done, where several comments were asked for.

To allow a statistical analysis of the proposed techniques, a log was also made. It recorded, for each visualized screen, data about the functioning of the filtering mechanism and generalization operators. Data recorded included: how many points of interest were returned, how many were filtered, the number of overlapping icons after the filtering phase, the number of icons drawn after the generalization phase, how many of these were aggregations and typifications, and finally the average degree of interest value for the given points of interest.

5.5 Results

5.5.1 First task

Although all interaction options (pointer, fingers, keys) were considered easy to use (Figure 9), it was noted that users with less experience in the use of mobile devices took a little longer to get used to the pointer. However, after an experimentation period, the majority of users preferred to use this interaction device. The use of the fingers to interact with the system was almost always the worst classified, with the exception of the younger users who were the only ones who would actually prefer this interaction type.

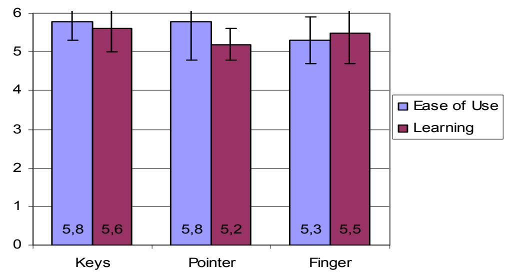


Figure 9: Interaction mechanisms evaluation.

5.5.2 Second task

When the users were asked to choose the size of the icons, the best size could not be obtained. Although the average size is around 40 pixels, the standard deviation is quite high (over 10 pixels), with size values ranging from around 20 to 60 pixels. These results give a clear sign that the best size used to depict information on a mobile device differs considerably between users, and as a consequence an option that allows the personalization of this parameter should always be present.

Although the option to increase icon size when walking was considered useful (average 5.0, standard deviation = 0.8), some users took advantage of this shortcut to increase icon size and reduced even more the default icon size, using this option as a “quick zoom” function sporadically to enhance visualization. This result suggests that the use of a “magnifying glass” button that temporarily magnifies information could be useful.

5.5.3 Third task

The context menu was considered to have the right options. The detailed information about the points of interest was considered adequate and presented in a clear way (Figure 10).

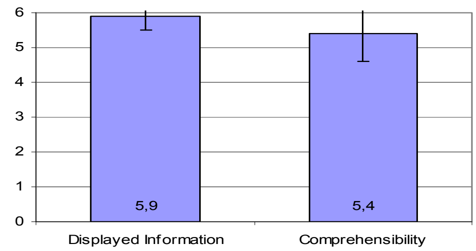


Figure 10: Context menu and point of interest information evaluation.

5.5.4 Fourth task

Regarding the generalization operators, users found both aggregation and typification operators very helpful in creating a less confusing visualization (Figure 11 in the left).

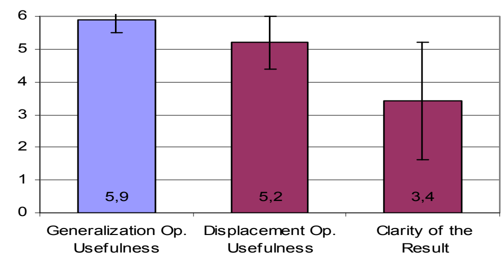


Figure 11: Generalization operators’ evaluation.

The use of the displacement operator had opposite feelings according to the condition in which it was used. When used with higher zoom levels and fewer elements it was highly classified. However, when used in lower zoom levels which have lots of elements, the resulting image was sometimes very confusing and was consequently poorly classified. This fact resulted in the operator being evaluated as useful (Figure 11 in the centre) but not very understandable (Figure 11 in the right). This signifies that the choice of using a generalization operator should not be dependent only on spatial constraints but also related to the zoom level being used.

5.5.5 Fifth task

The use of the degree of interest function revealed some problems which were not initially expected. When testing the first scenario, the users had to search for an Italian Restaurant in an area where no such restaurant existed. Since we use the filtering function to quantify the relevance of each object, we allow not only exact matches but also the partial ones to be selected. This meant that, although its relevance was quite low, the only restaurant that existed in the area was shown. Since most of the users are accustomed to exclusive searches, all of them immediately assumed that the restaurant shown was in fact Italian.

In the second scenario, all the users searched for the restaurant / gas station pair in a similar way, and only three of them did not use the degree if interest function to choose the best pair.

In the third scenario, which involved large quantities of results, users chose the museums in two different ways: seven of the users made their pick only by the use of the degree of interest function, while the other eight made a combination of zooming in and the use of the displacement operator.

As can be seen in Figure 12, due to the differences between this type of filtering mechanism and the ones most users are currently used to, the degree of interest function was considered to be a little confusing. However, it was still globally well classified, being considered useful and with all users saying they would prefer to use the function.

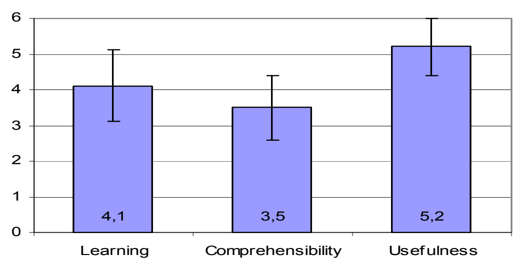


Figure 12: Degree of interest function evaluation.

5.5.6 Logged data

Finally, the analysis of the log created during the test showed that before filtering, there is an average of 17.9 points of interest (standard deviation = 43.7; max = 650; min = 1) and after filtering there are on average 8.7 (standard deviation = 8.0; max = 53; min = 1). Although having a very high variation, the reduction of both the average and standard deviation confirmed that the filtering function does indeed reduce the probability of occurrence of overlapping icons. However, there is still an average of five overlapping icons per screen. The use of generalization operators eliminated all of these conflicts and produced on average 4.6 icons. Of these 1.3 corresponds to aggregations and 0.5 are typifications.

The average degree of interest of the displayed points of interest was 0.65 with a standard deviation of 0.19. This result suggests that, in general, queries return relevant results to the users.

6. Conclusion

Research on mobile device information visualization is still a recent subject and there are many issues to solve. The limitations imposed by the device characteristics, namely the screen size, severely hinder the applications.

In the present work, some techniques were presented that can minimize some of the problems caused by the small size of the screens. A degree of interest function was proposed, that can quantify the relevance of a given point of interest. The use of this function allows us to filter the results, showing only the most relevant ones. Since this function only reduces the probability of overlapping icons, generalization operators, which group elements that are close together, were used. The combination of these two techniques solved the overlapping of icons.

To evaluate the proposed concepts, a prototype was developed, and a user study was done. This evaluation allowed us to conclude that the referred mechanism, not only solved the cluttering problem, but also had a positive global assessment. A correlation between the results obtained and the user profiles was also made. However, despite differences in background and user experience, the results were globally very similar.

There are, however, some open problems. These derive, mainly, from the fact that these techniques are different from what the users are accustomed to. It is therefore essential to transmit to the user that results do not necessarily satisfy all specified criteria. To solve this problem, we could include an option which allowed the user to directly switch to an exclusive query. Another approach would be the use of different icon colours according to the relevance, or adding an indicator that clearly expressed the degree of interest value as was used in [1].

The users found the filtering function difficult to learn. This problem can, possibly, be solved through the use of a better query specification interface. Despite the initial difficulty, users expressed their preference for the filtering function, after learning how to use it.

Although the global evaluation was positive, some other areas should also be targeted for future work. Regarding the displacement operator, it is important to research more complex algorithms, which could give better results in the positioning of the icons.

The exploration and adaptation of the techniques proposed, based on the location of the user and his preferences, should be broadened to other contexts. Some examples of these are: spatial context (e.g. orientation and speed); temporal context (e.g. accessing information based on the current time); surrounding environment (e.g. light conditions); personal context (e.g. emotional state and behaviour patterns); social context and other more enriched contexts.

7. Acknowledgements

This work was supported by FCT, through project PTDC/EIA/69765/2006 and through the Multiannual Funding Programme.

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