

# Location and Orientation Based Queries on Mobile Environments

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**Abstract:** The increasing use of mobile devices and their evolution, with the appearance of integrated digital cameras and location and orientation sensors, encourage the development of new forms of interaction with the devices and can also optimize queries to the available information. In this paper, we present and evaluate an interactive point of interest query interface, which is based not only on the location of the user, but also on his orientation. Besides providing a different query interface, the interaction provided can be used as a complement to the presentation of points of interest on a map, helping identify the association between the icons drawn on a map, and the corresponding real world objects in the neighborhood of the user. This query interface is a component of an adaptive visualization framework under development.

**Keywords:** Location and Orientation Services, Mobile Devices, Information Visualization, User Study, Context Aware, Adaptive Framework.

## I. Introduction

The portability of mobile devices and the evolution of its capabilities, combined with the proliferation of wireless communication infrastructures, have contributed to the increased research effort on design and development of methods and systems for visualization of information on these devices.

The reduced display size of handheld mobile devices imposes severe usability and visualization problems. This feature is unlikely to disappear in the near future, because the device itself has the requirement of being small. Therefore, visualization on handheld devices is a challenging and important research area.

The adaptation to specific usage context is a key feature to overcome usability and display limitations. Some aspects of the evolution of mobile devices, namely the integration of digital cameras and position, orientation and tilt sensors, allows them to have a wider contextual awareness and consequently the development of new interaction techniques and information queries.

The integration of digital cameras on mobile devices enables, on one hand, the employment of vision algorithms to identify objects [1], [2] or the interaction with the device by means of the recognition of the device movements [3], [4] and, on the other hand, the use of augmented reality techniques to

display information placed over the real objects seen on the camera [5].

Usually, in these approaches, the identification of specific objects is based on the analysis of the picture or on the use of visual markers. In the former case, it is necessary to first select a set of objects that can be identified, and, on the latter, it is required that visual markers are placed on the objects that are intended to be recognized. On both cases the scope of application of these techniques is severely restricted.

The integration of location sensors in mobile devices has fostered the development of Location Based Services (LBS). Automobile navigation systems, such as TomTom Navigator [6], Navigon [7] or NDrive [8] are an example of such applications. In these applications, however, orientation can only be obtained with the analysis of the displacement made. If the user is not moving, or walking in a slow motion with non-linear displacements, the orientation will not be correctly calculated.

The appearance of new devices that already have integrated digital compasses can foster the development of Orientation Based Services. For instance, the GeoWands concept [9], that allows the identification of real world objects by pointing the device in their direction is implemented in some applications [10], [11], [12], [13], [14], [15].

On a previous work, we have developed a system which allows the visualization of points of interest over maps, on mobile devices, based on the user preferences and location. From that work we concluded that there was a necessity to enrich the visualization of points of interest on maps [16].

The purpose of the work presented in this paper is to complement the, already existent, query interface with methods that allow the association between points of interest drawn on a map, to the real world objects they represent.

The need to associate points of interest, signalled on a map, to real world objects emerges in use scenarios where, on a given location, several points of interest are shown and it is difficult to correctly identify to which physical objects they correspond to. As an example, the identification of two monuments in close proximity and with similar architectures, like churches, or the identification of plant species on a natural park.

We have, thus, designed an application to query points of interest, using not only the location of the user, but also his

orientation, taking advantage of a Global Positioning Device (GPS) and a digital compass.

Although some applications previously referred provide a way for the user to identify the landmark he is aiming at, by using the devices orientation, they do not easily convey to the user the information about what other places of interest are surrounding him, or present mechanisms to ease the identification of a certain point of interest, when in the presence of compass heading inaccuracy.

In our application, the proposed interface includes the capture of real time pictures, over which a compass rose is drawn and where surrounding points of interest are marked, giving clues to the user about other existing results, thus allowing the user to better perceive his geographic orientation and easily identify the surrounding objects.

To help the user identify and associate the existent points of interest to their physical counterparts, stored pictures of these points are used. In each instance, the pictures of the points of interest that were taken closest to the current location and orientation of the user are shown.

This work is being integrated in an adaptive visualization framework that has the goal of enabling the development of applications that use a diverse set of contexts and adaption methods.

In section 2 we present the location and orientation based interactive queries developed. In section 3 we describe the prototype architecture and in section 4 we present the user study that was performed to evaluate the proposed concepts. In section 5 we describe the integration of the location and orientation based interactive queries in the adaptive visualization framework that is being developed. Finally, in section 6 we point out some conclusions and the future work.

## II. Interactive Point of Interest Queries

The MoViSys system [16] was proposed for the visualization, on mobile devices, of geo-referenced data (organized in categories and with multiple attributes), that correspond to points of interest. In that system, the query and filtering interface is dynamically built as a function of the meta-information about the data structure, and its result visualized as icons drawn over a map. The query is made using information on the location of the user and the visible area of the map.

Using a digital compass, we have developed another interface for querying points of interest, inside a limited area, centred on the location of the observer and orientation dependent. Next, we will present the underlying aspects of the query algorithm and the prototype interface.

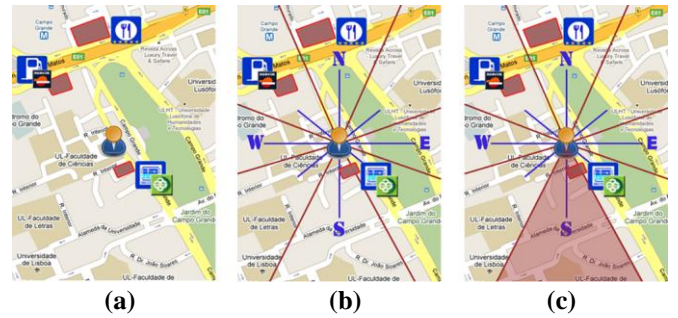
### A. Search Algorithm

We intend to identify the points of interest that are located in the direction the mobile device is aiming. However, we have chosen to make an initial query that identifies all the existent points of interest in a quadrangular area, aligned with the primary axis and centred in the location of the user. As a result of this query, the obtained list of points of interest is then organized taking into account the location of the points in relation to the user. Figure 1 shows a simple example of how

the algorithm works: on the left picture (a), the search area is defined and the location of the point of interest bounding boxes are taking into account; on the middle picture (b) the area is divided (in this case into eight areas) and the points of interest are associated with each one; finally, on the right picture (c), the direction being aimed at by the user is selected. For a better understanding of the pictures, the icons representing the points of interest have been slightly moved to allow the corresponding bounding boxes to be visible.

The reason we do this initial query, is because of efficiency and flexibility of the system, having the following in mind:

- the user can do several queries in the same location, using different directions;
- the query on a certain direction should correspond to the intersection with a vision cone, even if limited.



**Figure 1.** Point of interest bounding box placement and association to different regions

If we use a quadrangular search area, aligned with the axis, the calculations required to determine the inclusion of the points of interest in that area are far simpler, when compared to intersections with other kinds of regions. This can substantially reduce the computational load when querying a database with many elements. We should stress that this option is transparent to the user, who only needs to specify what kind of points of interest he is interested in and the radius of the search, and who does not need to be aware of the previous calculations.

Thus, we have chosen to define quadrangular search area, centred on the location of the user, and afterwards organizing the known points of interest in that area, according to the regions that divide the search space.

### 1) Search Area Definition

The first step we need to do is to obtain the coordinates from the GPS device, to understand where the user is geographically located. Our location on the Earth is referenced in relation to the equator and the Greenwich Meridian, and is translated in three numbers: latitude, longitude and altitude. On our system, we will only consider latitude and longitude [17].

It is still necessary for the user to specify the distance, in meters, between his geographic location and the edges of the search area. To optimize the query and the exploration of the neighbouring space, and without hindering the final result, we have considered a quadrangular frontier, aligned with the main axis that correspond to the W-E and S-N directions, centred on the user location.

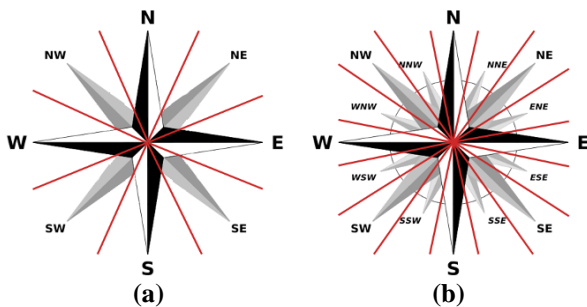
Since the coordinates of the points of interest are geographic coordinates, we also need to determine the latitude

and longitude variation intervals for the points that are inside the search area.

### 2) Determination of the Location of the Points of Interest in Relation to the User

At a first stage, we need to determine which points of interest are inside the user defined search area. Next, the location of these points in relation to user is identified. Since the user can be near a certain point of interest and if it corresponds to a building with a large volume, it can be visible in a wide array of orientations. To make the placement of the points of interest in each location closer to the actual surroundings, we have chosen to create a bounding box for each of them that try to replicate the actual gross building area they occupy. For each of these bounding boxes, we calculate the location and relative orientation to the user, allowing us, afterwards, to quickly calculate which of these are inside the area the user is currently facing.

By default the surrounding area is divided in eight regions that correspond, respectively, to the areas associated with the cardinal and intermediate directions (Figure 2, a). A further division of the compass rose could be used (Figure 2, b).



**Figure 2.** Division of the search area considering eight and sixteen regions

For each point of interest, we determine to which regions of the search area it is associated to, by calculating which regions are traversed by its bounding box.

The point of interest bounding box can correspond to the actual limits of its gross building area, when this area is known, or to a square area, whose side size has a default value that is dependent on the point of interest category.

### 3) Point of Interest Distance to the User

After all the points of interest are associated to each orientation, since each of these can have more than one point of interest, all of them are then ordered by increasing distance to the user.

## B. Interface

The developed interface was designed to allow the search of points of interest in the vicinity of the current location of the user, helping him in the visual identification of the real objects that correspond to the displayed results. For this reason we have combined, in the interface, stored pictures of the points of interest, with pictures captured in real time by the device's camera. The latter support the perception of the devices aiming orientation, which is used to perform the search. If a certain point of interest corresponds to the object that is

currently being aimed at, its picture should correspond to the real time picture captured by the device's camera. To allow this to happen, several stored pictures should exist, for each point of interest, corresponding to several observation orientations and distances. Additionally, the shown stored picture should be the one that was captured with the closest orientation and location to the one where the user is currently standing, relative to the location of the point of interest.

Although the presence of several pictures for each point of interest can improve the comparison between the stored picture and the real time image, and consequently the identification of a certain point of interest by the user, it is important to note that, to prevent an hinder to the feasibility of the system, these pictures are not mandatory and that some points of interest might not have an associated stored picture available. In these cases, an icon associated with the point of interest category is shown instead.

The interface is made up of a configuration interface and a search interface that uses location and orientation information.

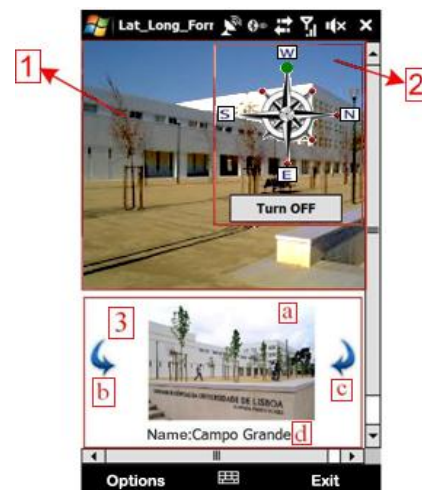
### 1) Configuration Interface

The configuration interface allows the user to personalize the search area that he intends to analyse, and also activate the GPS device and the digital compass. The search area is specified in meters. The device can then obtain the geographic location of the user, that is, his latitude and longitude, and also calibrate the compass. If the activation is done successfully, a positive feedback message is sent to the user, who starts the search interface through the selection of a "Start" button.

In a mobile environment it is crucial to have an efficient use of the wireless communication resources available. For this reason, and also to avoid the overloading of the application, new locations are only captured at the request of the user. We leave to the user criteria to evaluate if there has been a significant change in the location that would justify the search to be updated, and the redistribution of the points of interest in the compass rose directions.

### 2) Search Interface

In the search interface, the points of interest that are a result of the database query are shown, and it is possible to obtain more detailed information about the results found (Figure 3).



**Figure 3.** Interface areas

This interface is split into three main areas: Real Time Picture Area, Digital Compass Area, and Point of Interest Area.

In the Real Time Picture Area (Figure 3-1), the pictures that are captured in real time, by the device's integrated camera, are shown, allowing the user to verify the orientation in which he is aiming the device. This area has an overlapped compass representation that notifies the user on the geographical orientation of the device. This interface area helps the user to compare the pictures shown on the point of interest review area, with the real world objects he is watching.

In the Digital Compass Area (Figure 3-2), the digital compass representation is composed by the cardinal and intermediate directions. The orientation of the device is shown as the upper vertical direction, as indicated by the compass. Beneath the compass there is a "Turn ON/Turn OFF" button that, respectively, activates and deactivates the dynamic update of the compass orientation, allowing two alternative interaction modes described in next section.

When there are results for a particular orientation, small coloured circles are placed over the edges of the different compass bearings. These circles can have a red or green colour. The circle will be green if this is the direction of the currently selected point of interest. The other circles that may, eventually, exist, will have a red colour because the points of interest they represent are not currently being visualized. To aid in its identification, the green circle has a wider radius, since the application is intended to be used on the exterior, where light conditions are very variable. On the other hand, the distinction between the circles, by using different sizes, also helps their identification by users with colour impairment.

Finally, in the Selected Point Of Interest Area (Figure 3-3), there exist four subareas that show:

- a stored picture of the currently selected point of interest (Figure 3-3(a));
- an arrow to successively select the different points of interest, in a counter clockwise sequence (Figure 3-3(b));
- an arrow to successively select the different points of interest, in a clockwise sequence (Figure 3-3(c));
- the identifier of the currently selected point of interest (Figure 3-3(d)).

By selecting the stored picture, details-on-demand about the currently selected point of interest are shown in a new window. If there is no active point of interest, this area remains empty. By default, the selected point of interest corresponds to the closest one, in the direction the device is aiming.

To see pictures and information about the other existent points of interest in the same direction, we can use one of the two arrows. To be able to see points of interest located in other directions we have two alternatives: aim the device in the desired direction, or pressing the coloured circle placed on the desired direction in the compass.

Next, we will describe the two alternative modes of interaction in this interface.

### 3) Dynamic Mode and Static Mode

To allow the access of information, about the different points of interest that exist in the search area, in a flexible way, there

are two interaction modes: dynamic and static.

In the dynamic mode, the digital compass rotates according to movement and rotation of the device, and the closest, if available, point of interest in the current direction is shown in the selected point of interest area (Figure 3-3(a)). Over the compass, the green circle will be placed on top, showing the current direction. By using the available arrows (Figure 3-3(b) and 3(c)) we can sequentially select the points of interest that exist in that direction only. The dynamic mode of interaction is selected by default.

In the static mode, the movement of the compass is deactivated (Figure 4). To select this mode we can select the "Turn OFF" button, in the digital compass area, or, in alternative, select one of the red (smaller) circles in the desired orientation.

In this mode we can obtain information about all the points of interest that exist in the surrounding search area. When we select a different orientation, the circle will turn green and increase its size. The point of interest that is shown, by default, is always the closest to the user in the selected orientation. To select the following ones, we can use one of the two arrows (Figure 4-3(b) or 3(c)). After having gone through all of the points of interest in the current direction, the ones in the next direction are shown.

As an example, in Figure 4, the active point of interest is located to the North of the user, since this is the orientation with the green circle. In this example, when the compass was deactivated, the device was aiming West. In the static mode, the capture of real time pictures by the device's camera is turned off.

The decision was made, on one hand, due to efficiency options and, on the other hand, because in this mode, since the compass is not being updated, the picture could produce incoherent states, where the picture captured does not correspond to the currently selected point of interest (Figure 4).

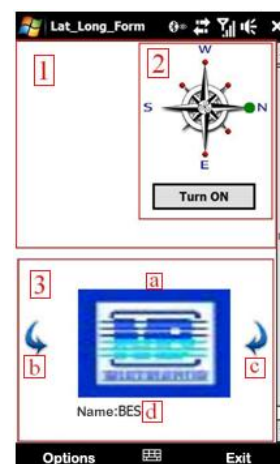


Figure 4. Static mode interface

To return to the dynamic mode of interaction, we can press the "Turn On" button.

## III. Prototype

This prototype was developed for a Pocket PC, with the Windows Mobile 6.1 operating system, using the .Net

Compact Framework 3.5, DirectShow for the image capture and the C# programming language.

When we began developing this prototype there were very few available mobile devices that incorporated a digital compass. Additionally, these integrated digital compasses sometimes have a significant inaccuracy, mainly due to tilt errors and magnetic field fluctuations that are caused by proximity of the mobile device itself. For this reason, to determine the device's orientation, we used a LEGO compass that is used in robotics applications, which could be placed just far enough from the device to minimize interferences, and tilted to a correct angle. This compass was connected to the mobile device through a NXT device, also from LEGO that transmits the orientation from the compass to the PDA through Bluetooth.

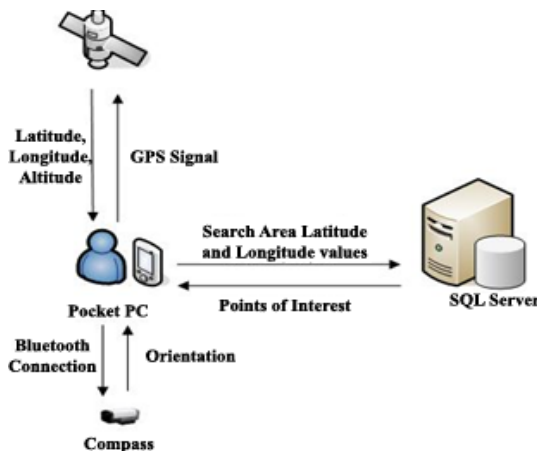


Figure 5. Flow of information

We have used the database that was created for the MoViSys system [16], using SQL Server. We had, however, to add additional information for each point of interest, namely the information about the bounding boxes and also the stored pictures, relative to at least one orientation. The orientation in which the picture was captured is stored, allowing the application to choose the most adequate in each situation. For points of interest that have no available image, we use the icons that were used in the MoViSys system [18] in the representation with maps (Figure 4).

The flow of information between the different components is shown in Figure 5.

## IV. User Study

Using the developed system we conducted a small user study to find if the proposed point of interest query interface is useful to the users and also to try and 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 the respective standard deviation.

### A. Procedure

Users were initially asked to answer some questions to establish their profile and also their experience in the use of mobile devices, touch screens, and compass enabled mobile

devices.

Each user was initially briefed about what the purpose of the application was, and how some of the proposed concepts worked. Then, they were given some time to experience with the application until they felt comfortable to proceed to the tasks.

While the users were carrying out the tasks, observations were made and user feedback was taken note of.

After performing all the tasks the users were asked to classify some of the features tested, using a six level Lickert scale (where 1 represented the worst classification and 6 the best). Finally, comments and suggestions were also asked for.

### B. Participants

In our study 10 users tested the application, six of them male and four female. Their ages ranged between 18 and 60. Their background was also diverse: four were from Administration areas, three from Natural Sciences, two from Arts and one Computer Scientist.

All of the users frequently used mobile devices (four several times a week, and the remaining six daily), but only six had previously used a touch screen device, and merely two had used a digital compass equipped mobile device.

### C. Tasks

To simulate several real life scenarios, users were asked to execute a set of four tasks.

**First task** – In the initial task, users were asked to use the application to search and identify, in the real world, a hotel that was visible, but had no easily identifying feature. This hotel, although being surrounded by other buildings, had no other point of interest in the vicinity.

**Second task** – In the next task, the reverse was asked. Users were shown two real life churches that have similar architectures and are located right in front of each other, and were asked to use the application to identify their name and some details about them.

**Third task** – In the third task, users were placed in the middle of a large square, and were asked to explore their vicinity and identify what points of interest surrounded them.

**Fourth task** – Finally, the last task was similar to the first, but had the users placed in a moderately sized square with several restaurants, and with the purpose of finding a specific one with the help of the application.

### D. Results

Regarding the first two scenarios, we wanted to understand if the users had any problems when performing two relatively simple tasks: identifying where, in the real world, an isolated point of interest is, and identifying what point of interest a certain real world building is.

Regarding the first task, all the users correctly identified the hotel without having much trouble, and only one of them chose to select the circle representing the hotel in the compass, to be able to see its stored image and then find the hotel visually. All the other chose to rotate in the direction the compass showed the hotel, and only then compare the real time captured picture

with the stored one.

Similarly, the second task was also done without difficulty. All the users pointed the device in the direction of each church and correctly identified both of them.

In the third task, we wanted to understand how capable the interface was in enabling the users to correctly identify all the surrounding points of interest. We wanted to know, from the set of 10 points of interest that existed in the square the users were located at, how many they would identify, and how they chose to interact with the application to perform the task. Six of the users chose to rotate around themselves to visualize the whole square through the device. The remaining four used the sequential arrows to go through all the points of interest.

The use of the arrows to explore the surrounding had better results, since the users who used this technique were able to sequentially go through all the points of interest, while the ones that rotated missed some of them (Figure 6).

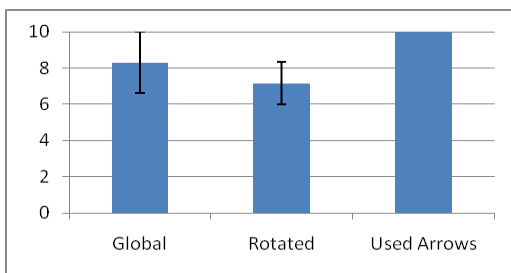


Figure 6. Average of number of points of interest found

This happens for two reasons: Firstly, the speed at which the device is able to update the compass direction is sometimes slower than the speed users turn around, creating gaps of information. Secondly, when users are rotating (in the dynamic mode) the application selects what points of interest to show by calculating the nearest one in the current region. This option was chosen to minimize the load on the application, however it is in fact limiting the number of points of interest that are able to be shown in this mode to the number of regions available.

The rotation problem that we were made aware of in the third task was also evident in the final task when trying to identify a specific restaurant in the middle of a square with several ones. From the six users that tried to find the restaurant by rotating, only three immediately identified it, the remaining had to eventually use the sequential arrow. When using the arrows all the users identified the restaurant easily, with the exception of one that had some trouble to visually identify it (Figure 7).

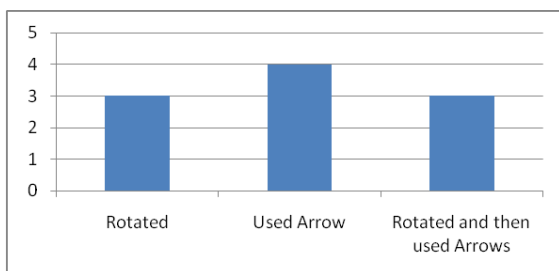


Figure 7. Number of users that employed the different methods to identify the restaurant

Finally, users were asked to classify the usefulness of some

features of the application (Figure 8). The compass was evaluated as being useful (average 4.9, standard deviation 1.0). However, most of the users classified the presentation of the points of interest inside the compass as confusing (average 2.7, standard deviation 0.9).

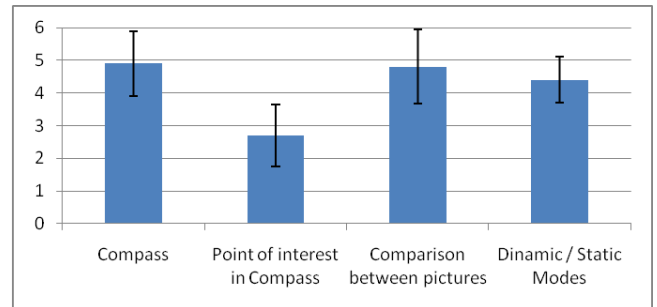


Figure 8. Application features classification (0 = not useful at all / 6 = very useful)

The main reason for this bad result was due to the limitations detected in the third and fourth task, where points of interest exist all around the user and, in this case, the coloured circles used in the interface are not useful to identify a specific point of interest. A suggestion given by one of the users, which could help in this type of scenarios, was to present a textual list of all the surrounding points of interest that would allow the users to filter the results to show only specific ones.

The comparison between the stored pictures and the real time capture was also considered useful (average 4.8, standard deviation 1.1).

When asked about the availability to choose between the dynamic and static modes, users found it useful (average 4.4, standard deviation 0.7) and six of them do not have a preference between them, while three prefer the dynamic mode, and only one the static mode.

When in the static mode, the majority of the users agree that the capture of the real time picture should be turned off, only one user disagrees. Regarding the compass, we had an opposite response only two users agree that it should be turned off, while eight think it is still useful and should be left on. The general justification for this result was that even when in the static mode, the compass can still help the users to understand where they are looking and, consequently, aid in the visual identification of the points of interest.

## V. Adaptive Visualization Framework Integration

The demand for the adaptive visualization to a specific mobile user context will probably be strong in the near future, with the growing amount of geo-referenced information available. The adaptivity principle is especially important to increase the usability of visualization on mobile devices and to reduce the cognitive load inherent in mobile usage contexts. Besides location and orientation, we are exploring other types of context and the correspondent adaptations to the components of the visualization process in response to changes in the user's context.

To accomplish an efficient management of the diverse usage contexts, adaptation objects and adaptation methods, we are developing an adaptive visualization framework.

The work presented in this paper is being integrated in the adaptive framework Figure 9 presents an overview of the complete framework, with the modules that are used in the current work in a darker colour.

The user interacts with the “Augmented Reality Interface” which is composed of adaptation objects that are managed by the “Information Presentation” module. These objects are then adapted by the “Visualization Adaptation” and “Information Adaptation” modules. The contexts used to perform this adaptation are obtained through the use of user personalization context and contexts obtained with hardware sensors (namely the GPS, digital compass and camera).

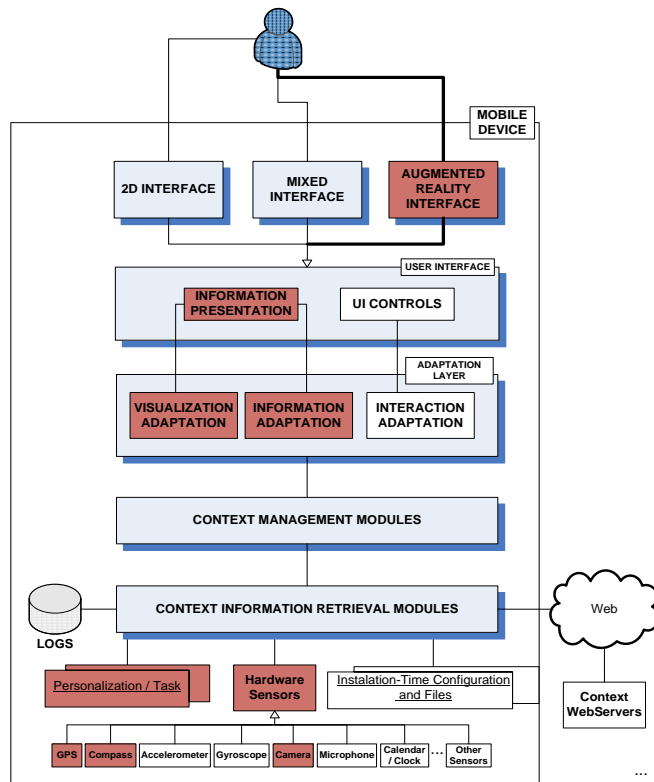


Figure 9. Framework integration

## VI. Conclusions and Future Work

This paper presents a location and orientation aware application for the search of points of interest in mobile devices that uses, not only the location of the user, but also his orientation. These values are obtained through the use of position and orientation sensors. The developed interface includes a dynamic indication of the device’s orientation, complemented with the capture of real time pictures, using the device’s integrated camera. The addition of these pictures helps the user to compare the stored pictures with what he is currently seeing in the real world, and correctly identifying the shown point of interest. By default, the selected point of interest is the one closer to the user, in the same direction the device is aiming at. However, it is possible to see information about all the points of interest that exist in the surrounding search area. By placing graphical marks on the compass drawn on the screen, the location of the existing points of interest is shown to the user.

The user study that was carried out allows us to understand

the main problem that existed in our approach. Regarding the presentation of the surrounding points of interest in the compass, the discussion with the users concerning the difficulties they encountered, made us aware of possible solutions to this limitation. A possible workaround to this problem is to use the suggestion given by one of the users, to use a textual list of all the points of interest. However, the algorithm itself could be changed to allow better results. Ideally, if we can reduce the load on the application, and make it faster, we could further reduce the size of each region or use only the information about the angles at which each point of interest is visible to determine which result should be shown at each instance.

Despite the limitation identified, the general feeling about the application was that it was very useful to explore the surrounding environment, and particularly useful in the kind of scenarios presented in the second task, that allow the users to very easily identify a certain point of interest, and easily obtain information about it.

We want to improve the identification of the points of interest that are in the field of view of the device’s camera. Besides considering the organization of the points of interest according to their location in relation to the user, and the sorting in function of the distance to him, we intend to use the real time picture capabilities, to be able to automatically compare the point of interest stored pictures, to the ones captured on real time.

Both the visualization of points the interest on a 2D map and the location and orientation based query interface described in this paper are been integrated in an adaptive visualization framework.

## Acknowledgment

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 PTDC/ EIA/ 69765/ 2006 project and the SFRH/ BD/ 46546/ 2008 scholarship.

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