Mixed Environment Adaptive System for Point of Interest Awareness

Paulo Pombinho, Ana Paula Afonso, Maria Beatriz Carmo
Faculdade de Ciências da Universidade de Lisboa
Campo Grande, Lisboa, Portugal
ppombinho@lasige.di.fc.ul.pt, {apa, bc}@di.fc.ul.pt

ABSTRACT

Location based services (LBS) are now very common, but are mainly developed for outdoor areas. Despite the existence of some indoor LBS, they either require physical building infrastructures or employ a complex and expensive conjunction of positioning systems to achieve good accuracy. Furthermore, they are not commonly used for both indoor and outdoor environments. In this paper we propose a point of interest LBS for both indoor and outdoor environments that automatically adapts the interface according to the type of environment. We use an affordable and low-cost smartphone equipped with GPS, compass and accelerometer to provide these functionalities. The positioning algorithm proposed uses information obtained when the user is outdoors to improve the positioning accuracy while indoors.

Author Keywords

Indoor Location, Mixed Environments, Context Aware, Mobile Devices

ACM Classification Keywords

H5.2 Information interfaces and presentation: User Interfaces - *Prototyping*.

General Terms

Algorithms, Experimentation.

INTRODUCTION

Location based services are becoming very common in new mobile devices and, for this reason, the real time information about the location of users has become widely used in an extensive range of location based applications.

When used inside a building, location based applications can be used to show relevant information concerning the location of the user and aid the navigation in an unknown building, for example a museum or a university campus. Indoor location has also been suggested to allow emergency services to explore unknown areas in an easier and more efficient way [1, 2].

Despite being reliable and sufficiently precise when in an open field, GPS devices need to “see” a large portion on the sky to be able to correctly calculate the position of the user. Thus, when indoors, GPS devices become useless and the requirements of measurement error change. Alternative positioning systems, like GSM based algorithms, do not have sufficient precision or need an expensive physical framework. This limitation hinders the development of indoor location based applications [3].

An alternative positioning method is to use new mobile devices that have integrated accelerometer and digital compass to detect when the user is moving and the direction of the movement, and use this information to calculate the user location. However, the results obtained when using this type of approach are very dependent on the way each particular person moves, causing a potentially large error when used for long periods of time or distances [4].

Our goal is to develop an affordable system that does not need a physical infrastructure, and uses only the sensors that are commonly integrated in the new mobile devices. In this paper we present our work in progress on a system that aims to allow mixed (indoor and outdoor) positioning, automatically adapting the interface based on the user’s location and how the user holds the mobile device. Additionally, this system collects, automatically and transparently, information when the user is outdoors, and uses it to improve the indoor positioning by adjusting the algorithm parameters for the type of movement being done by a particular user.

In the next section we will describe the most relevant related work. Afterwards we will explain the indoor positioning algorithm used and, in the next section, how this positioning can be improved using data gathered when the user is outdoors. We then describe the user interface of the developed mobile point of interest application to assist users both in outdoor and indoor environments and finally we present conclusions and future work.

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RELATED WORK

There are some works that explore indoor positioning mechanisms. There are several diverse approaches that use transmitters of some kind, installed on the buildings, and corresponding receivers, carried by the user. Some systems use infrared transmitters [5], RFID tags [6], VHF radio [7], or Bluetooth beacons [8].

Several systems have explored the use of Wi-Fi network access points, and operate by identifying and processing the signal strength information of multiple base stations to triangulate the position of the user (see for instance [9]).

Regarding infrastructure free positioning, Kourogi et al. [10] use sensors placed on the waist of the user, to detect walking stance and velocity. Some approaches use shoe mounted sensors to detect the displacement made by the foot in each footstep and consequently the displacement made by the user [11]. Finally, Glanzer et al. [12] present a pedestrian navigation system that uses a set of diverse sensors to estimate changes in position and attitude, and obtain the final position of the user.

Although they focus mainly on how to obtain the indoor position, there are also some works that research different types of indoor location based services. As an example, in Jensen et al. [2] a review of several indoor location based services and systems is done.

Despite providing solutions for the problem, the works presented are either based on the existence of an infrastructure in each building, or the need of external sensors placed, for example, on the user's shoes or waist. These sensors are a potential limitation to the natural movement of the user or the practicability of the system. Furthermore, some of the systems require expensive equipments and others, although using cheap beacons, need to install a large number of these to obtain good accuracy.

Very recently, some preliminary works have started to appear that focus only on the use of sensors integrated in the mobile devices, like [13, 14]. However, both these systems and those referred above are designed to be used only indoors, do not take into account the movement made while the user is outdoors. There are also no works focused on the dynamic adaptation to these environment changes. Since we aim to develop a mixed environment (indoor and outdoor) application, our goal is to develop an approach that will use information obtained while outdoors to improve the users indoors positioning.

INDOOR POSITIONING ALGORITHM

To obtain the position of the user inside a building we have previously proposed an approach based on a step detection algorithm [4] that allows the detection of the user's motion and its direction. In the next section we will, briefly, describe this approach.

Step Detection Algorithm

The algorithm uses an accelerometer integrated in the mobile device to capture, in real time, the accelerations it is being subjected to. When the user is walking he will apply, not only, a forward acceleration, but also, with a greater magnitude, a vertical upward acceleration followed by a vertical downward one, in a consecutive way. Figure 1 shows an example of the shifts in acceleration during a three step movement.

There are four step detection parameters used to detect each step (Figure 1): A peak amplitude λ_p that represents the minimum positive shift in acceleration, caused by a step; a negative amplitude λ_t, that represents the minimum negative shift in acceleration; a Δt_{min} minimum time interval, that needs to pass for step to be detected, and a Δt_{max} maximum time that cannot be exceeded.

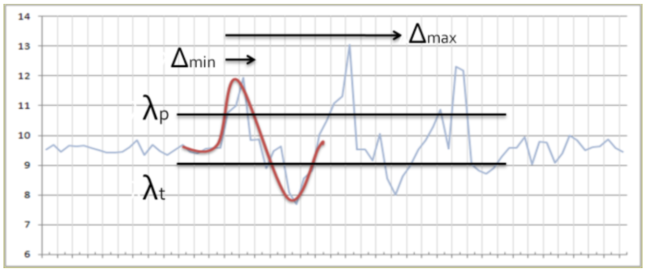

Figure 1. Shifts in the acceleration vector while the user is walking and step detection parameters. The thick red line shows the pattern for a single step.

To be able to identify the location of the user inside a building, the last known position is used, obtained with the GPS while still outside, as the initial position of the user. Next, as each step is detected, the orientation, obtained from the digital compass, and the medium step size is used to calculate de movement done by the user. By adding all these displacements it is possible to infer the trajectory of the user inside the building and calculate his current position.

Algorithm Accuracy Errors

Although the described algorithm gives an accurate positioning when used for short periods of time, it can, on the long run, accumulate a large accuracy error.

There are four types of errors present on this type of algorithm. Steps not being detected (false negatives); steps being incorrectly detected (false positives); errors in the size of the step used; and compass orientation errors.

For all of these types of errors, only the compass orientation errors are user independent, being caused either by poor compass accuracy or by disturbances in the magnetic field caused by metal in the vicinity or other devices interference. The remaining three types of errors are mainly due to the use of parameters that are not suited for the way a particular user moves or even the type of movement the user is doing at a specific time.

Due to this, if these parameters can automatically adapt themselves to each user and their type of movement, the errors can be minimized giving the algorithm a much better accuracy.

OUTDOOR ASSISTED INDOOR POSITIONING

To be able to improve the positioning of the user while inside a building, we use information obtained when the user is outdoors, where we can use the GPS to verify the accuracy of the step detection parameters. However, the type of movement done when a person is outdoors is different from the type of movement when he/she enters a building [4].

Indoor / Outdoor Comparison

In [4] we have performed a user study that identified the correlation between the movements performed in outdoor areas and those done in indoor areas. In these experiments seven users (with heights and weights ranging from 160 cm to 180 cm and 65 kg to 81 kg, respectively) walked at different paces, both outdoors and indoors. The data collected during the experiments allowed the analysis of the walking pattern of each user and determine, for each step, the optimal detection patterns.

By comparing the optimal detection patterns for each user, in each environment, and for different speeds, we were able to calculate the ratio, for each user, between the indoor and outdoor experiments at the same speed. The average ratios obtained were 0.96 for the λ_p, 1.05 for λ_t, and 1.1 for the Δt.

It is also essential to choose the right step size since, in the long run, it can originate a high amount of error. The average step size obtained in [4] is 65 cm. However, this study also shows significant variations depending on the speed of the users and also if the movement is indoors or outdoors. Despite capturing very diverse step lengths, the ratio obtained between each pair of indoor / outdoor experiments is fairly constant (0.9).

Indoor Step Detection Parameter Adjustment

To be able to adapt the indoor positioning parameters we first need to find the optimal parameters for the user while outdoors. To achieve this we capture the positioning information, obtained from the GPS, and calculate at certain intervals the displacement and speed of the user, and also create a log of the values returned by the device's accelerometer.

Using this information, we can automatically adjust the step detection parameters in order to be coherent with the user's movement. Furthermore, using the distance traveled and the number of steps, we are able to calculate the average step size of the user, while outdoors.

Having obtained the optimal step detection parameters for the outdoor environment, we adapt these values for the indoor environment by applying the indoor / outdoor ratios described in the previous section. Thus, it is possible, to improve automatically, and in a transparent way to the user, the accuracy of the system.

USER INTERFACE

The developed mobile application assists the user in searching nearby points of interest in mixed environments and consists of three main interfaces, two for outdoor use and another for indoor use. The application was developed using the RUBI open source augmented reality platform [15].

Outdoor Interface

By using the device's accelerometer, we are able to detect the device's pitch, yaw, and roll angles, and consequently how the user is holding the mobile device. When the user is outdoors, there are two types of interface that can be changed automatically.

Figure 2. Outdoor augmented reality view.

If the user is holding the mobile device in front of him, perpendicular to the ground, we use an augmented reality view that depicts nearby points of interest as circles drawn over a real time video feed from the device's camera (Figure 2). On the lower left part of the screen, a compass radar is shown to enable the user to become aware of other points of interest that exist in the surrounding area.

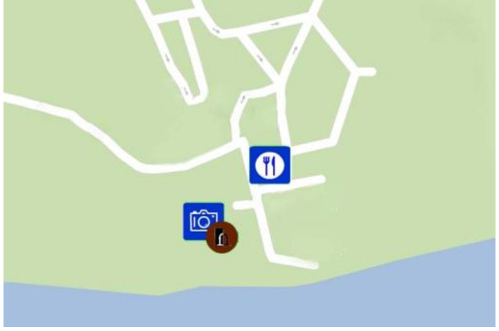

Figure 3. Outdoor map view.

When the user lowers the mobile device, parallel to the ground, we switch to a map view, where the nearby points of interest are depicted as icons drawn over the map (Figure 3).

Indoor Interface

When the user enters an indoor area, the application automatically changes the view to a 2D floor plan of the building, showing the points of interest that exist inside the building, depicted as icons drawn over the floor plan (Figure 4). The trajectory walked by the user is, optionally, drawn over the map as a green dotted line.

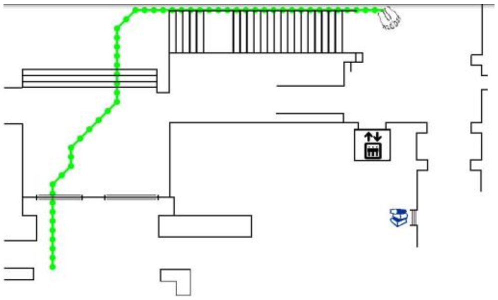

Figure 4. Indoor floor plan view.

CONCLUSIONS AND FUTURE WORK

In this paper we have proposed an affordable and low-cost location based system that works simultaneously in indoor and outdoor environments. The proposed system adapts automatically the interface depending on the user environment, and also depending on how the mobile device is being held.

To be able to obtain an accurate positioning while indoors, the proposed application uses information obtained while the user is outdoors, to adapt the positioning parameters specific to that user and also the type of movement the user is currently doing. These parameters are also adjusted when the user enters an indoor area, to compensate differences between indoor and outdoor movement.

Regarding future work, we intend to integrate a filtering and searching module, which would allow the user to search for a specific point of interest, and also to develop a mobile navigation assistant that directs the user to the requested point of interest.

Finally, we intend to perform an extensive user experiment, to be able to understand how much more accurate the system is while using the proposed automatic adaptation, when compared to the use of fixed positioning parameters. We also want to evaluate the proposed interface and use the NASA TLX [16] to understand the workload of the proposed approach on the users.

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