# Indoor Positioning Using a Mobile Phone with an Integrated Accelerometer and Digital Compass

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**Abstract.** Although location based applications have been gaining popularity, most positioning devices do not work when in an indoor environment, hindering the development of indoor location based applications. In this paper we propose a technique, based on the detection of footsteps, and the direction in which they were taken by the user, to be able to calculate the position of the user inside a building. We use information about the buildings floor plan to create a graph that can be used to improve the accuracy of the system.

**Keywords:** Mobile Devices; Indoor Positioning; Step Detection Algorithm.

## 1 Introduction

Global positioning devices (GPS) are becoming progressively more 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. Despite being reliable and precise while in the open, GPS devices need to be able to view a large portion of the sky to correctly calculate the device's position. This renders the GPS useless while indoors. Furthermore, alternative positioning systems like the ones that use GSM or mobile phone tracking do not have enough accuracy to be able to correctly identify a position inside a building.

There are some works that explore indoor positioning mechanisms. Most of these can be divided in three types: the use of infrastructures installed on the buildings, explicitly for indoor positioning; the use of existing Wi-Fi networks; and the use of sensors installed in the mobile device or the user himself.

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 [1], RFID tags [2], VHF radio [3], or Bluetooth beacons[4].

Several systems have explored the use of Wi-Fi wireless 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 [5]).

Regarding infrastructure free positioning, Kourogi et al. [6] 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

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consequently the displacement made by the user [7]. Finally, Glanzer et al. [8] 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.

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.

Since we aim to develop mixed environment (indoor and outdoor) adaptive visualization applications, our goal is to develop an approach that does not need external sensors, beyond those integrated in the mobile device, and that can be used in buildings with no infrastructure installed. Furthermore, since the user is holding the mobile device in his hand, we want an approach that does not hinder the users hand movements, allowing him to retain the freedom of movement they usually have.

In this paper, we present an algorithm that allows the position of users inside a building to be inferred from the movement done by the user. To achieve this goal we use a mobile device with an integrated accelerometer to detect when the users takes a footstep, and a digital compass to determine the direction of the footstep. From this information and the knowledge of the buildings floor plan we can calculate with an acceptable accuracy the indoor location of the user. In the next section we will describe the algorithms and techniques used.

## 2 Indoor Positioning

We use a 3-axis accelerometer integrated in the mobile phone to capture, in real time, the accelerations that the device is being subjected to.

When in a standing / resting stance, the only acceleration that is present in the mobile device is gravity. If we consider the mobile device to be perpendicular to the floor plane, the X and Z axis would be measuring no acceleration, and the vertical Y-axis would be measuring the gravity, with a value of approximately -9.8 $m.s^{-2}$. Since the users can freely use and move the mobile device, we have no prior knowledge of which accelerometer axis is, at a given point, measuring the vertical acceleration. For this reason, despite potentially adding some noise, we have chosen to analyze the resulting acceleration vector norm, instead of analyzing each axis separately.

When walking, the user will, not only, apply a forward acceleration but also, with a greater magnitude, alternatively apply a vertical upward acceleration followed by a vertical downward one. We have defined four parameters that are used to detect a footstep: a peak amplitude $\lambda_p$ that represents the minimum positive shift in acceleration caused by a footstep, a trough amplitude $\lambda_t$ that represents the minimum negative shift in acceleration, a minimum time interval $\Delta t_{min}$ that needs to go by before completing the footstep pattern and a maximum time interval $\Delta t_{max}$ that cannot be exceeded for the footstep pattern to be detected. All of these parameters can be changed inside the application in real time.

The step detection algorithm works by constantly checking if the current acceleration is greater than $\lambda_p$. When that happens, the application starts to check if the footstep pattern is happening. If a sudden shift in acceleration occurs in less that $\Delta t_{min}$, we assume that it was caused by another movement and the step is discarded. If the pattern occurs in more time than $\Delta t_{min}$ but less than $\Delta t_{max}$, and it reaches $\lambda_t$ creating a pattern similar to the one shown previously, a step is recorded along with the current orientation, which is obtained from the digital compass. If after $\Delta t_{max}$ we still have not detected the footstep pattern, the step is discarded.

To correctly identify the location of the user inside a building, we use the last known position given by the GPS as the initial position, the information about the steps recorded, the information about the orientation in which they were taken, and the average step length. With this information we can calculate the trajectory of the user and his position. However, to minimize errors caused by steps that are not detected (false negatives), or steps incorrectly detected (false positives), we make corrections to the position of the user through the use of the building floor plan.

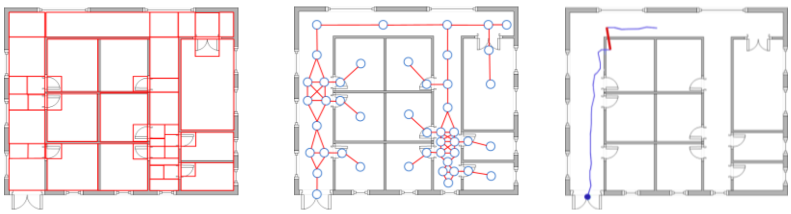

**Fig. 1.** Definition of the floor plan graph.

We have opted to divide the floor plan in rectangular areas of different sizes, where transition areas (for example, doors) have the smallest size, and areas with no transitions (for example, corridors with no doors) have the bigger areas. Each of these areas corresponds to a node in the graph. Figure 1 shows, on the left, the floor plan with the considered areas in red. In the center figure the graph that was defined is shown, with a node for each area. Finally, in the right figure an example of the path detection and correction is shown. The path the user has taken is drawn in blue over the floor plan and the corrections displayed in a red thick line.

The use of graphs allows us to calculate with each step, the position of the user inside a certain node area. If at any time, the calculated position is outside the current node area, the system will verify if there is a valid transition to another node in the specified direction. If there is, the system calculates the location in the new node area. If there is no valid transition, the system searches for the nearest position where the detected movement would be valid and corrects the user position.

## 3 Conclusions and Future Work

In this paper, we propose an indoor positioning method that does not need previously installed infrastructures in a building. Furthermore, this approach does not need external sensors, avoiding the restriction of the user's natural movements when using a mobile device and walking indoors.

In the near future, we need to perform extensive user experiments. These experiments will, not only, allow us to precisely assess how accurate the obtained position of the users is, but also, most importantly, obtain valuable data about the differences in the step patterns originated from a diverse set of users. This knowledge can give us the insight on what the best default step detection parameter values are, and also help us in implementing an automatic calibration of these values. A particularly important parameter, which can cause a high accumulated error, and should thus be automatically adjusted, is the step size, since it varies not only between different users, but also depends on the speed and way the user is moving. Since our aim is to use this algorithm in mixed environment visualization applications, one solution is to use information from the GPS when the user is outdoors.

We also intend to test more complex buildings plans, and the detection of footsteps when going up and down a set of stairs, and the use of escalators and elevators.

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