



INDOOR POSITIONING USING INERTIAL MEASUREMENT UNITS

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ABSTRACT

With the increase in the number of smart phone users worldwide there comes a high demand for smart phone based location systems. Within the project “Indoor positioning using inertial measurement units” an android application has been developed wherein the position of the smart phone user with respect to the floor environment is determined. This has been achieved using the smart phone sensors step detector and rotation vector which act as inbuilt inertial measurement unit (IMU) in smart phones. The algorithm used is “Pedestrian Dead Reckoning (PDR).

Keywords: step detector, rotation vector, inertial measurement unit, pedestrian dead reckoning.

INTRODUCTION

Indoor location based services are becoming increasingly popular due to its social and commercial needs. There are several techniques for indoor positioning to locate objects or people inside a building using ultrasound or infrared signals, magnetic fields, radio waves and other smart phone sensory data [1].

Global Positioning System (GPS) technology are now used commonly in day to day life for tracking location. But Global Positioning Systems are incapable of effective positioning indoors as they lose significant power indoors. The building constructions floors, roofs and walls may shield the incoming signals from satellite keeping them from locating the indoor GPS receivers or multiple reflections at surfaces cause multipath propagation leading to huge errors [2]. Therefore Indoor Positioning Systems (IPS) are designed to deliver location based services that pick up where GPS is ineffective.

In radio signal based positioning systems that rely on Wireless Local Area Networks (WLANs) and Wi-Fi signals increased accuracy is achieved at the expense of wireless infrastructure equipment and installations. Also, possible signal fluctuations that may occur can increase errors and lower the overall accuracy achieved [3]. The recently popular Bluetooth based indoor positioning method using iBeacon offers a higher accuracy compared to Wi-Fi. But since Bluetooth is all about proximity, it doesn't offer a pinned location [4]. Moreover, it needs infrastructure assistance as it requires the installations of numerous Bluetooth beacons at known positions [5].

Indoor positioning and navigation using smart phones are much beneficial, the main advantage being that the system is infrastructure independent. As nowadays everyone is dependent on smart phones for their daily basic needs, this method of positioning turns out to be cost effective as the basic requirement in this system is the smart phone itself.

Effective positioning of smart phone users indoor using the basic smart phone sensors accelerometer, gyroscope and magnetometer is a great challenge to overcome. The accelerometer is impacted to any small movements of the smart phone. The compass senses where north is but is susceptible to any magnetic fields that might be around the sensors. The gyroscope can sense any

change in orientation but only for short period of time. Considering the uncontrollable errors caused by these basic smart phone sensors there was a need for smart phone composite sensors which would give significantly less number of errors.

This paper's main focus is on the use of android composite sensors which would help in achieving a more effective indoor positioning than positioning based on basic smart phone sensors. A smart phone composite sensor would generate data by processing and/or fusing data received from one or more base smart phone sensors.

The Step Detector and step counter sensor are such composite sensor which uses the underlying physical sensor accelerometer and if required other sensors as long as there is low power consumption [6]. The step counter sensor gives the number of steps taken by the smart phone user whereas the step detector sensor generates an event each time a step is taken by the user [7]. Therefore these sensors can be used to determine the distance travelled by the user in real time.

The composite sensor rotation vector uses the base sensors accelerometer, magnetometer and gyroscope (if present) and gives back the orientation of the phone in the entire three axis with the complicated math already done. This is used to determine the direction of the smart phone user provided the orientation of the phone with respect to the user is not changed.

The Rotation Vector is the result of sensor fusion of accelerometer, gyroscope and magnetometer. The following are some of the steps used in sensor fusion.

The angular speed from the Gyroscope data is converted to a quaternion representation, where $\omega(t)$ is the angular speed and $q(t)$ is the normalized quaternion.

$$dq(t)/dt = 1/2 (\omega(t) * q(t)) \quad (1)$$

Converting the Accelerometer data to world coordinates. This involves using the above quaternion. Here $A_b(t)$ is the body coordinates of the device, while $A_w(t)$ is in world-frame.

$$A_w(t) = q(t) * A_b(t) * q(t)^T \quad (2)$$



The two parameters distance travelled and direction of the user is used to locate the user's position and navigation with respect to the floor environment.

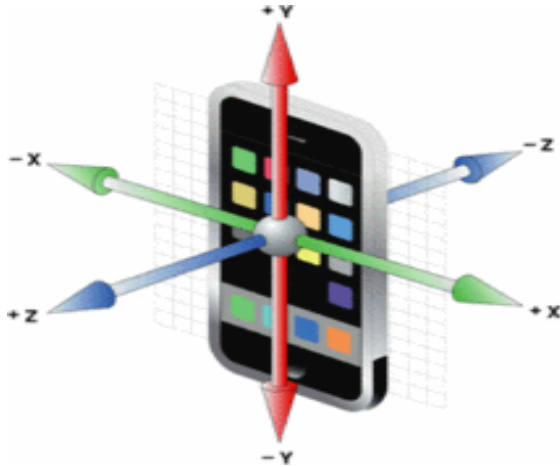


Figure-1. Smart phone reference frame.

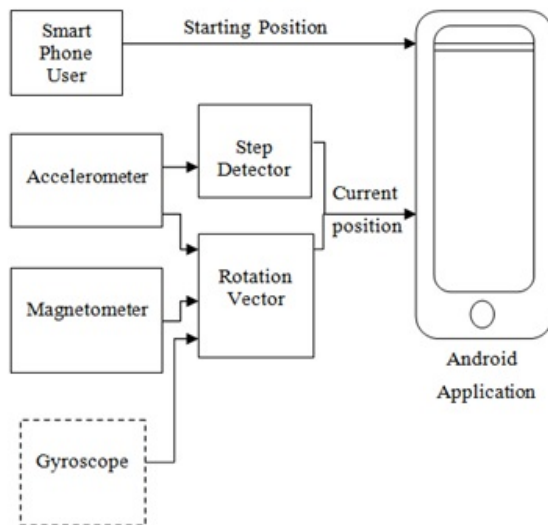


Figure-2. System architecture.

METHODOLOGY

The users location is displayed on the floor map using the step detection event and the direction faced by the user in real time. The positioning is implemented with the development of an android application which is to be installed on the user's smart phone.

Data collection

Since indoor positioning is all about locating the user or object with respect to the indoor environment, collection of floor data is an essential information required in positioning. Hence, the basic floor details that is the dimensions of the floor (width and height) along with the floor maps are the initial data collected. Instead of the user starting from a certain reference point, the starting position of the user is taken as input for the users convenience. There is no requirement of the initial direction faced by

the user to be taken as input as the rotation vector sensor gives the orientation of the phone with respect to the magnetic north.

Positioning technique

The entire floor is divided into square grids of side 1 meter. The floor map is also divided in the similar way into equal number of square grids to equal number of square grids. The starting position of the user taken as input is represented on the floor map on the corresponding grid. With the assumption that two steps taken by the user is approximately equal to 1 meter, on every two steps taken the user moves to one of the adjacent grid. Movement of user from one grid to adjacent grid depends on the direction the user is facing. The user's direction with respect to the magnetic north is easily determined from the rotation angle of the smart phone detected by the rotation vector sensor. The angle of rotation of the smart phone in z-axis is only considered for this purpose since the orientation of the phone in the other two axes are unwanted.

The step detector sensor has lower accuracy compare to step counter sensor producing more false positives but the step detector sensor has a very low latency in reporting the steps, which is generally wit in 1-2 seconds. Hence, the step detector sensor is used as it is recommended for the application that want to track the steps in real time and want to maintain their own history of each and every step.

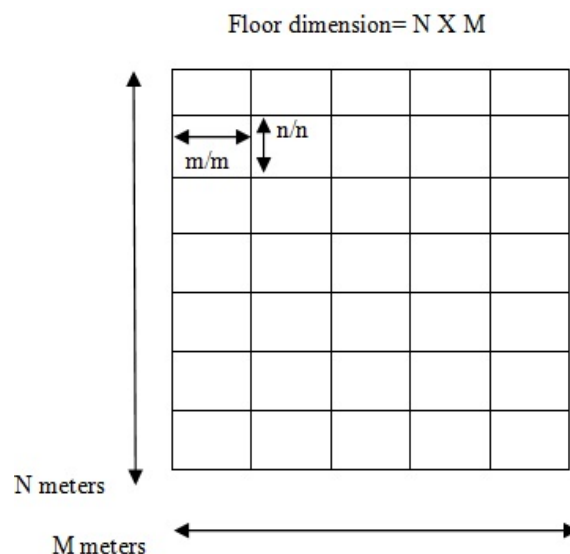


Figure-3. Division of floor into square grid.

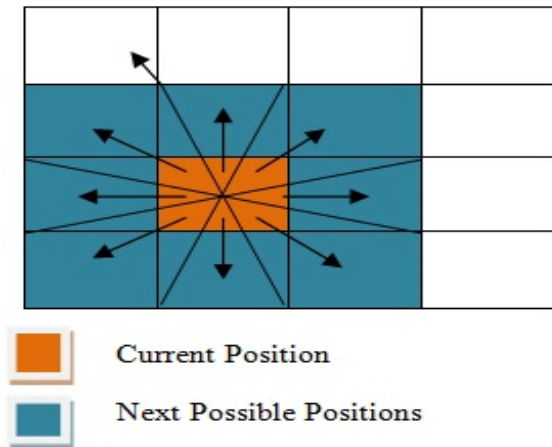


Figure-4. Movement to adjacent grid based on Smart phone orientation.

Android application

The indoor positioning methodology described above is implemented in an android application. The user's starting position is taken as touch input on the floor map displayed on the android application. The user's position is located using a marker on the floor map. The marker occupies a square grid representing the user's current position. The marker's position on the floor map dynamically changes corresponding to the grid representing users current position.

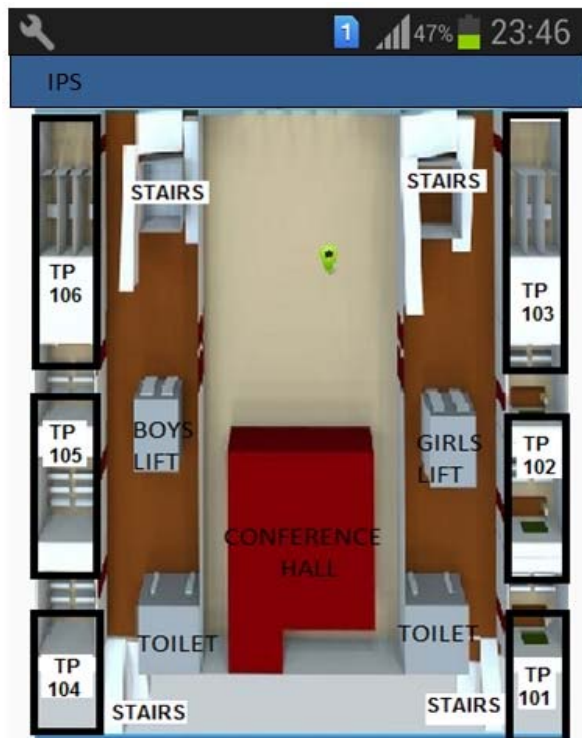


Figure-5. Android application.

ALGORITHM

Dead Reckoning is the process where a person's or objects current position is calculated with the help of a previously determined position and estimated distance or speed over elapsed time [6].

Pedestrian Dead Reckoning is a popular smart phone sensor based indoor positioning algorithm. The accuracy achieved sensor precision, step length of the smart phone user, various magnetic disturbances in indoors cause limitations in the accuracy achieved.

Most PDR systems find the distance travelled by the user from the number of steps taken using pedometers and accelerometers and the heading direction from the inbuilt gyroscope sensor with no help from external references. Here, in the implementation of the algorithm every two steps taken causes the position to move from the current grid to an adjacent grid in the direction determined from the rotation vector sensor readings.

EXPERIMENTAL RESULTS

To evaluate the system's reliability walking test was done with the smart phone held in hand. The phone was held in such a manner that the phones orientation with respect to the user was hardly changed.

Smart phone users of different heights were used in the experiment to detect the error caused by the step length variations.

The testing was done in the first floor of the Technology Park, SRM University, Chennai, India. The smart phone used for this experiment is "coolpad note 5" with android marshmallow operating system.

The error percentage in positioning with travelled distance is shown in the Figure 6. In the experiment, the error percentage in step detection for 10, 20 and 30 metres were noted. It can be inferred from the figure that longer the travelled distance lesser the error percentage.

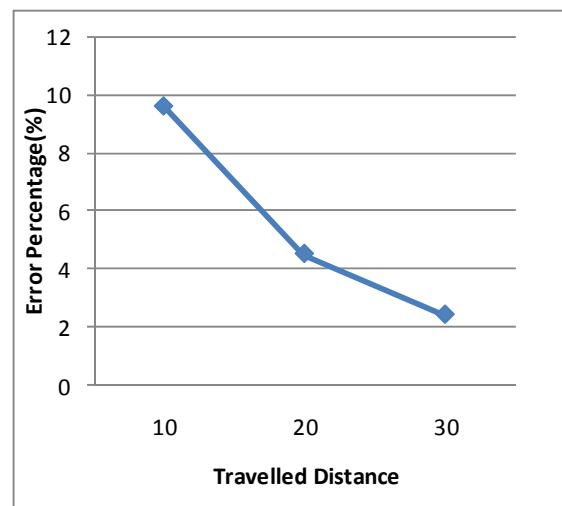


Figure-6. Error percentage of step detection.



The initial error in the first 10 meters travelled is due to the time taken by the step detector sensor to detect the initial steps based on the walking pattern of the user. The experimentation resulted in an average accuracy of 5.5% in positioning provided the orientation of the phone with respect to the user is least changed.

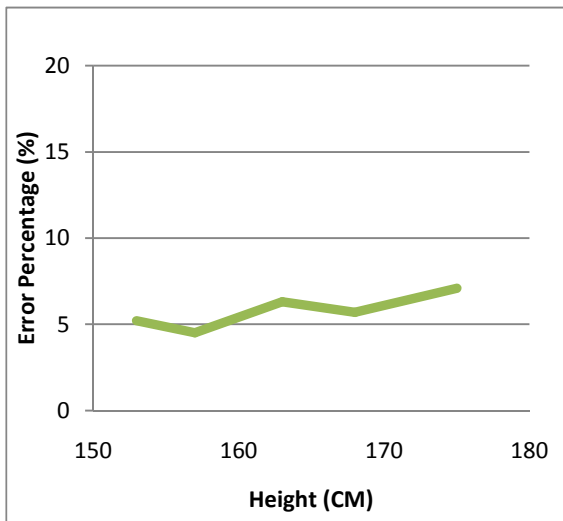


Figure-7. Error percentage in step detection (20 meters distance).

Figure-7 shows the error percentage of 5 test subjects of varied height for 20 meters travelled distance. Since, the step length varies with height, the number of steps taken for a certain distance also varies with the height of an individual. Also, it can be inferred from the graph that walking patterns of individuals have significant impact on step detection. The average error percentage with height for 20 meters travelled distance is 5.76 %.

CONCLUSION AND FUTURE WORK

Indoor location based systems have gained huge popularity in the recent years for their increasing demand in the commercial market.

Smartphone sensors based indoor positioning systems are popular area of research as the system is inexpensive and infrastructure independent.

Composite smart phone sensors like step detector and rotation vector have proved to have achieved greater accuracy in terms of positioning than base sensors like accelerometer, magnetometer and gyroscope.

The system has the advantage of being cost effective, infrastructure independent, user friendly, low power consumption of smart phones.

The system can be improved by using strong sensors having lower latency, determining the starting position of the user from other methods like Wi-Fi based positioning and detecting the orientation of the user with respect to the smart phone dynamically for user's convenience.

REFERENCES

- [1] Vrajesh Akabari, Divyesh Dhedi, Vishal Rabadiya, Siddhesh Doiphode " A Survey on Android based Indoor Wi-Fi Positioning System using Tri-Lateration". International Journal of Computer Applications (0975 – 8887) The National Conference on Role of Engineers in National Building.
- [2] Myung Chul Park, Vinjohn V Chirakkal and Dong Seog Han, Senior Member, IEEE "Robust Pedestrian Dead Reckoning for Indoor Positioning Using Smartphone". In IEEE International Conference on Consumer Electronics (ICCE), pp on 2015.
- [3] Md.Sabbir Rahman Sakib, + Md Abdul Quayum, + Karl Andersson, + Kåre Synnes, * Ulf Körner. "Improving Wi-Fi based Indoor Positioning using Particle Filter based on Signal Strength ". 2014 IEEE Ninth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP) Symposium on Computational Intelligence Singapore, pp on 21–24 April 2014.
- [4] Laura Filardo; Federica Inderst ; Federica Pascucci. "C-IPS: a Smartphone based Indoor Positioning System". 2016 International Conference on Indoor Positioning and Indoor Navigation (IPIN), pp on 4–7 October 2016.
- [5] Jiuchao Qian, Jiabin Ma, Rendong Ying, Peilin Liu, Ling Pei. "An Improved Indoor Localization Method Using Smartphone Inertial Sensors". 2013 International Conference on Indoor Positioning and Indoor Navigation, pp on 28-31st October 2013.
- [6] Azkario Rizky Pratama¹, Widyawan², Risanuri Hidayat³. "Smartphone-based Pedestrian Dead Reckoning as an Indoor Positioning System". 2012 International Conference on System Engineering and Technology, pp on September 11-12, 2012.
- [7] Petra Hafner, Thomas Moder, Manfred Wieser, Thomas Bernoulli. "Evaluation of Smartphone-based Indoor Positioning Using Different Bayes Filters". 2013 International Conference on Indoor Positioning and Indoor Navigation, pp on 28th-31st October 2013.