Abstract

Global Positioning Systems (GPS) have revolutionised technology and are used in nearly every aspect of life in today's world. However, the application of the underlying technology in GPS does not solve the problems of indoor localization. Indoor localization has recently witnessed an increase in interest, due to the potential wide range of services it can provide by leveraging Internet of Things (IoT) and ubiquitous connectivity. Many different techniques such as the use of Wi-Fi, Radio Frequency Identification Systems and others have been utilised to fix such problems. These technologies are expensive in nature due to the demands for additional infrastructure to be installed, leading to high budget and labour cost. However, with smartphones becoming more advanced and powerful, they can be utilised to solve the problems of indoor localization. In this paper, we have proposed the solution of using QR Code in conjunction with Inertial Measurement Unit (IMU), making use of in-built smartphone sensors such as accelerometer, gyroscope and magnetometer, presenting an effective way for indoor navigation with the combination of the two technologies. Usage of QR codes helps to compensate the errors from the IMU thereby providing accurate navigation. This technique involves very less cost and can be implemented in a straight forward manner. -- add result in.

Literature Review

Overview

Location-based services (LBS) have become essential services for the everyday work and life of people in recent years. The Global Navigation Satellite System (GNSS) plays an important role in LBS and the various enhancement technologies can make GNSS achieve sub meter positioning accuracy in an open area. However, the GNSS quality is significantly reduced in indoor environments as it is not possible to guarantee the availability of navigational satellite signals. Many other approaches have been utilised to help enhance such Indoor Positioning Systems such as wireless local area network (WLAN) [6], ultra-wideband (UWB) communication [7], [8], Wi-Fi-based systems [9]–[10][11], camera based systems [12], [13], ultra-sonic sensors [14], [15], laser-based systems [16], radio frequency identification (RFID) [17]–[18][19][20], inertial navigation and inertial measurement unit (IMU)-based navigation systems [21], [22], global system for mobile communications (GSM) [23]–[24][25][26], and smartphone-based position-detection systems [27]–[28][29][30]. Among these techniques, the smartphone-based position detection system is the most popular approach as there is no need for additional infrastructure installation and because it only uses a single system instead of integrating with others, it lowers the system cost and complexity. [2a] In this portion, we will be discussing about related works regarding smartphone's IMU sensors as well as Quick Response (QR) Code in indoor localization systems.

The most common implementation of such indoor navigation systems can be classified as Radio Frequency (RF) Based and Sensor Based. RF based systems are mainly consisting of Wi-Fi and Bluetooth while calculates the Angle of Arrival (AoA) and the Time of Arrival (ToA) and to improve the localization, they both also make use of fingerprints. Sensor based systems are usually implementations using Inertial Measurement Unit, where it references from a last known location, making use of data from the Accelerometers for the velocity, Gyroscope for the orientation and magnetometer for the heading.

RF Based Systems

Wi-Fi Based systems

Wi-Fi positioning systems are based on two core things: Received Signal Strength (RSSI) of the device that is being positioned and the fingerprint of the router that is sending the signal. Examples of the fingerprint can be the SSID, or the MAC address of the router.

In order to get the data of the position using a Wi-Fi based system, the indoor environment must be mapped with the fingerprint/signal strength data matching some places and interpolating the data between the locations that are measured.

A study conducted by Chouchang Yang and Huai-rong Shao investigated a Wi-Fi based indoor positioning system. They identified that in a Wi-Fi based indoor system, there are two components, firstly, the nearby anchor with the knowledge of their own location and secondly, a positioning device with the objective of identifying its location by processing wireless signal through nearby anchors. [<https://ieeexplore.ieee.org/document/7060497>].

In a Wi-Fi based system, the Wi-Fi Access points are being utilised as the anchors and a positioning device with Wi-Fi capability can be used such as a smartphone or tablets. The approach discussed in the paper by Chouchang Yang and Huai-rong Shao is to send multiple messages to improve the time of arrival measurement (ToA) and angle of arrival (AoA) estimation. [<https://ieeexplore.ieee.org/document/7060497>]

However, there are a few factors that proves to be a challenge when trying to implement a Wi-Fi Based Indoor Positioning System. Firstly, Cost is a problem as nearby anchors are required to be deployed and it is costly to develop localization devices to identify the anchors.

Secondly, the number of nearby anchors proves to be another problem as unlike in the outdoor environment, the indoor environment and space limits the number of anchors that can be properly deployed, hence affect the accuracy of such systems.

Lastly, a complicated indoor environment plays a part in the system. In a Wi-Fi based indoor positioning system, the signals coming from the wireless routers are used to measure distance and angle and often suffers significantly from obstacles such as walls, objects and/or human beings, leading to multi-path effects. [<https://ieeexplore.ieee.org/document/7060497>]

<http://doi.org/10.1111/j.1467-9671.2009.01152.x>

<https://ieeexplore.ieee.org/document/7060497>

Bluetooth Based systems

Bluetooth based systems makes use of Bluetooth Low Energy (BLE) beacons that are placed throughout the building or infrastructure. The concept of Triangulation helps to estimate the position within the building using the received signal strength and the fingerprints of the installed Bluetooth beacon.

By measuring signal strength of the Bluetooth technology to locate, is a low power short range wireless transmission technology. Install the appropriate indoor Bluetooth LAN access points, configure the network based on multi-user network connection mode, and to ensure that the Bluetooth LAN access point is always the master of this piconet, the user can always get location information, to achieve the use of Bluetooth positioning purposes.

A study done by Adam Satan on a Bluetooth based indoor navigation mobile system explored the usage of Bluetooth beacons together with an Android smartphone. Bluetooth beacons emits radio frequency signals which can be used to calculate the distance. With the distance, user’s location can be estimated based on how far the user is from the beacon. Dijkstra’s shortest path algorithm was used to handle the route planning. [<https://ieeexplore.ieee.org/document/8399651>]

The author tested the study in an indoor building with multiple stories. Each story is covered with 7 Bluetooth beacons while the ground floor was covered with 9 Bluetooth beacons. [<https://ieeexplore.ieee.org/document/8399651>].

[R. Faragher and R. Harle, Location Fingerprinting With Bluetooth Low Energy Beacons. IEEE Journal on

484 Selected Areas in Communications, vol. 33, no. 11, pp. 2418-–2428, Nov. 2015.] proposed an indoor positioning method by using the fingerprints in conjunction with BLE beacons, making use of 19 beacons to construct a fingerprint map for positioning the user. Through this study, it has showed that the beacons can be used more effectively than Wi-Fi devices in terms of positioning, however there are factors such as multipath fading attenuation and interference that can cause the RSSIs to fluctuate in indoor environment. This will lead to inaccurate positioning results.

There are also multiple restrictions with a Bluetooth based system, firstly is that it would require additional installations of the BLE beacons in the building to help facilitate the estimation of the position using such system. This results in an increase in the system cost. The environment also affects the stability of the signals by noise signal interference if the indoor environment is complex. From the experiment conducted, the application suffered from errors such as position misplacement to nearby positions and position losses where the application couldn’t determine the position as a result of lack of signal coverage. [<https://ieeexplore.ieee.org/document/8399651>]

<http://cui.unige.ch/~deriazm/masters/bekkelien/Bekkelien_Master_Thesis.pdf>

Sensor Based

Geomagnetic field

In recent years, geomagnetic field has been another technology that is utilised for IPS. By using geomagnetic field, there is no need for additional infrastructure installations. Gozick et al. [B. Gozick, K. P. Subbu, R. Dantu, and T. Maeshiro, Magnetic maps for indoor navigation. IEEE Transactions

486 on Instrumentation and Measurement, vol. 60, no. 12, pp. 3883-–3891, 2011.] has shown in his study that magnetic signatures from a building is stable over time and is suitable to be used in an IPS. Haverinen et al. [J. Haverinen and A. Kemppainen, Global indoor self-localization based on the ambient magnetic field.

488 Robotics and Autonomous Systems, vol. 57, no. 10, pp. 1028-–1035, 2009.] proposed in the study a localization method using geomagnetic field. In the study, the used a particle filter to determine the position of a robot and a person from any given initial point. The problem with this approach is that the positioning results from geomagnetic positioning systems are limited due to the magnetic field not discernible from inside the building

IMU Based navigation system – write more about IMU.

Indoor positioning systems plays a crucial role in everyday life as most people spend their days indoors. Global positioning system has been a very efficient positioning technology for outdoors navigation but is susceptible to indoor situations due to signal interference or weak signals. In order to achieve decent position estimations indoor, the idea of using Inertial Measurement unit sensor data to estimate indoor position has been widely proposed.

Pedestrian Dead Reckoning is an algorithm that is commonly used in indoor positioning with IMU sensor data.

Pedestrian Dead Reckoning

Pedestrian Dead Reckoning (PDR) is an algorithm that make use of multiple sensors. Current day PDR systems detects number of step events using pedometer or accelerometer and then determine the location by moving forward in the direction determined by the magnetometer or gyroscope. As everyone’s step length is different, the step length is adjusted to cater to the walking speed and then used to estimate the user’s current location.

[<https://ieeexplore.ieee.org/document/6987239>]

An experiment was conducted using IMU’s sensor data to estimate the position indoor. The team designed a Kalman Filter algorithm for two different sensor fusion algorithms, first one for pitch and roll estimation, using the accelerometer and gyroscope data and the second algorithm for heading estimation, using the magnetometer and gyroscope data. The team also proposed the pitch-based step detection algorithm to detect steps. [<https://ieeexplore.ieee.org/document/8606925>]

A paper by Wonho Kang and Youngnam Han explored the applicability of a Smartphone-Based Pedestrian Dead Reckoning for Indoor Localization. This approach was undertaken by them as the accuracy of GPS indoors is greatly affected due to the signal interferences and usage of smartphone in individual’s everyday life is increasing and such smartphones are embedded with sensors that are increasingly advanced. Many other techniques that were utilised such as Ultra-wideband (UWB), Wi-Fi signal strength, RFID, inertial measurement unit, vision etc are very complex, if not impossible due to these techniques having to be based on the infrastructure. Hence, this paper proposes the use of smartphone embedded sensors such as Accelerometer, Gyroscope and Magnetometer to observe the pedestrian movement. [<https://ieeexplore.ieee.org/document/6987239>]

One of the major drawbacks of using PDR alone for navigation purposes is the accumulation of errors over a period as the PDR’s algorithm estimates the current location based on the prior estimate of the last step. The errors comes from stride length and orientation, factors that are unavoidable with present commercial grade sensors. This makes the PDR unreliable if used for a long period of time or distance. This error was also mentioned in the paper where the localization error generally increases as distance walked increases due to cumulative error on step event detection and heading direction estimation. [<https://ieeexplore.ieee.org/document/6987239>]

In order to increase accuracy, the technique of PDR is used in conjunction with other techniques for better positioning.

Quick Response Code as Landmark.

Quick Response Code

In response to the cumulative error brought about by the smartphone's IMU sensor data, the idea of introducing QR Code to tackle that problem has been proposed. Below are studies regarding QR Code and why it is a feasible approach in conjunction with smartphone IMU sensor to provide a robust indoor navigation application. QR codes are placed at intersections and along the path that is being measured.

A study on QR code as landmarks for indoor localization was conducted.

In a paper written by Zheqi Li and Jidong Huang, they did a study on the usage of QR codes as landmarks for indoor positioning systems. Making use of the high definition RGB camera and depth sensor of the Kinect, they aimed to apply it on a robot and aid it in doing indoor navigation. Each QR Code was encoded with its own unique identifier and the indoor reference location. The conclusion derived from the study of QR code with Kinect has led to very promising results that could be applied to similar fields of studies such as robots or unmanned vehicles working indoors. [Study on the use of Q-R codes as landmarks for indoor positioning: Preliminary results] This could also be applied in a similar approach for smartphone devices. This will be discussed in detail in the next paragraph.

To reduce the accumulative error brought about by the Inertial Measurement Unit, QR codes can be introduced as landmarks to counter the error. A study conducted on the usage of QR codes as landmark brought about very positive and promising results. This approach would be greatly beneficial in terms of counteracting the accumulative errors that the smartphone's IMU sensor would bring about. It will act as a reset where in a situation which the IMU sensor data deviates from the path, using the smartphone camera to capture the QR Code and fed with the geo-location of that particular QR Code, the position of the user in the application will then be reset and appears at the co-ordinates that the QR Code was encoded with.

//insert images or formula.

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A paper written by C. P Rahul Raj, SeshuBabu Tolety, Catheine Immaculate is the application of a QR code-based navigation system for closed building using smartphones. QR codes are being used to provide information to the users in an optical manner. The smartphone will then decode the QR code to provide accurate indoor navigation for end users.

QR Code is used to contain the information regarding the floor plan's link as well as the latitude, longitude and altitude of the physical location of the QR Code. The codes are then placed along the pathway as well as important locations in the subject area.

A smartphone application is then developed, making use of the smartphone's camera to read frames continuously. The frames are checked for QR Code's presence and obtaining of the floor plan's URL and geo-location details.

Using a QR detector, it processes each frame and checks for the presence of the code. If a QR Code is detected, the detector forwards it to the decoder. Decoder will decode it and obtains the contents. The content is then taken by the content parser module and parsed to find out the URL of the floor plan as well as the geo-location details. A floor plan handler will download the map using the URL and overlays the floor plan on the geographical map. Lastly, the geo-location decoded from the QR Code will provide the user's current location.

With this approach, the main advantage is that it is cost effective as there is no need for the users to make any additional investment for this system. The complexity and time for implementation is also reduced and there are no additional configuration required by users to maintain this system.

This is similar in the approach chosen as it uses QR Code to provide an accurate estimation of the user's location indoors. This approach would be greatly beneficial in terms of counteracting the accumulative errors that the smartphone's IMU sensor would bring about. It will act as a reset where in a situation which the IMU sensor data deviates from the path, using the smartphone camera to capture the QR Code and fed with the geo-location of that particular QR Code, the position of the user in the application will then be reset and appears at the co-ordinates that the QR Code was encoded with.

Finally, hybrid positioning approaches try to overcome the limitations of individual technologies. For example, in [O. Woodman and R. Harle, Pedestrian localisation for indoor environments. Proceedings of the 10th

495 international conference on Ubiquitous computing - UbiComp ’08, p. 114, 2008.][ L. Klingbeil and T. Wark, A Wireless Sensor Network for Real-Time Indoor Localisation and Motion

497 Monitoring. International Conference on Information Processing in Sensor Networks (IPSN 2008), pp.

498 39-–50, 2008.], they developed a system that utilizes IMU-based PDR positioning in conjunction with Wi-Fi positioning systems. As Wi-Fi Systems uses RSS fingerprints and provides better accuracy, it can act as a counter to handle the heading drift error that the IMU brings about.

* Add more in this section.

From <[*https://www.researchgate.net/publication/283039766\_Exploring\_Smartphone-Based\_Indoor\_Navigation\_A\_QR\_Code\_Assistance-Based\_Approach*](https://www.researchgate.net/publication/283039766_Exploring_Smartphone-Based_Indoor_Navigation_A_QR_Code_Assistance-Based_Approach)>

Introduction

In current day, location-based services (LBS) have become an important part of people’s daily lives. Demands for LBS in indoor environments have also increased for purposes like indoor path finding and navigation, marketing, entertainment and location-based information retrieval. Many technologies have been utilised for LBS in indoor however many are inaccurate.

Smartphones in the current generation has become increasingly powerful and advanced, especially its built-in sensors, wireless technologies and processor computing power. Hence, many users are making use of such advanced and power technologies embedded on their smartphone to perform many different functionalities.

One main application that users are using on their smartphone is the LBS for outdoor navigation. Such applications have been developed using the global positioning system (GPS) which provides the users with geographical information, street view and different kinds of maps. Such services have been asked to be replicated for an indoor environment. However, such approaches used in outdoor based location services cannot be applied to indoor based as the signal reception indoor is limited in indoor environment such as in buildings, tunnels etc. This often leads to poor or inaccurate position within the building being reflected to the users.

In order to address such challenges posed from the GPS in indoor environment, many different technologies have been studied and utilised to be applicable for indoor based location services. Instead of using GPS, some technologies studied for indoor based location services are the use of Wi-Fi, Bluetooth Low Energy (BLE) Beacon, Ultra-Wide Band (UWB), Ultrasonic wave, Radio Frequency Identification (RFID), Geomagnetic field and Inertial Measurement Unit (IMU). [R. Harle, A survey of indoor inertial positioning systems for pedestrians. IEEE Communications Surveys &

447 Tutorials, vol. 15, no. 3, pp. 1281-–1293, 2013.][ W. Sakpere, M. Adeyeye Oshin, and N. B. Mlitwa, A State-of-the-Art Survey of Indoor Positioning and

449 Navigation Systems and Technologies. South African Computer Journal, vol. 29, no. 3, pp. 145-–197, 2017.

450 3. G. Deak, K. Curran, and J. Condell, A survey of active and passive indoor localisation systems. Computer

451 Communications, vol. 35, no. 16, pp. 1939—1954, 2012.] These listed technologies can perform personal indoor navigation, marketing, location-based entertainment, indoor emergency localization and many others. With such technologies being actively utilised in several aspects for the individual users, the technologies must be able to provide reasonably accurate positioning data for the different type of indoor positioning application.

The most commonly studied technologies for the indoor positioning systems (IPS) are Wi-Fi and Bluetooth beacons as these two technologies are much more readily available than other technologies – with wireless access points being installed in many common areas and Bluetooth access in the common areas as well. The Wi-Fi and Bluetooth positioning method mainly focus on time of Arrival (ToA), angle of arrival (AoA) and Received Signal Strength Indicator (RSSI), with RSSI based positioning system the most widely implemented due to its reasonably acceptable indoor positioning accuracy. However, this method heavily depends on the stability of the RSSI as well as the line of sight between the transmitter and receiver devices.

Another popular implementation is the IMU sensor, consisting of accelerometer, gyroscope and magnetometers. The implementation of such IMU sensors are relatively low cost and the pedestrian dead reckoning positioning algorithm does not require any additional installation of infrastructure. However, the use of this method only allows for a reasonable accuracy for a short distance as it suffers from a cumulative error, leading to a drift in heading estimation over time. This drift error will also accumulate over time while utilising low cost IMU sensors embedded in the smartphone but can be handled with heading drift reduction techniques. Integration of other technologies in conjunction with IMU sensors can help to mitigate the drift error brought about by the IMU sensors from the smartphone.

In this paper, an application using the smartphone’s embedded IMU sensors together with Quick Response (QR) Code is developed for indoor positioning. The QR code will contain the coordinates that helps to reset the indoor position of the user holding on the smartphone in order to counter the heading drift. It will also effectively tell how far the user is away from the QR code.

Background

Many different approaches has been applied in the aspect of Indoor navigation. With the increased amount of WiFi access points and Bluetooth low energy beacons emerging in buildings such as shopping malls etc, many applications are making use of that infrastructure to construct a reliable indoor navigation system. However, such systems are susceptible to error due to multi path effect faced, as well as stability of the signals coming from the devices can be affected by the indoor structures. Also, in order to use this approach in new buildings, each building must be equipped with additional infrastructure in order to support this implementation, which leads to additional costs.

Smartphones are also growing at an incredible rate, where each smartphone can perform advanced tasks due to the fast advancing rate of smartphone technology. Sensors embedded within the smartphone can be utilised to capture various data and be applied in many fields, indoor positioning being one of it. As this approach does not require any additional installation of infrastructures such as Access Points or beacons, it is a relatively popular approach. However, this approach often leads to inaccuracy because the sensors in the smartphone suffers from drift error.

In order to improve on the existing smartphone sensor-based approach, Quick response code can be introduced into a sensor-based system, creating a hybrid approach. The QR Code can help to realign the smartphone’s position that is being calculated from the sensors after the drift error accumulates. This ensures that even if the position is incorrect due to the drift error, the QR Code can help calibrate and reset the position of the smartphone.

This hybrid method is proposed as opposed to using WiFI AP or BLE is because of cost. Cost plays an important factor in determining the approach selected. The cost of a single wireless access point can range from \_\_\_\_\_\_ to \_\_\_\_\_ (check) while a BLE can cost from \_\_\_ to \_\_\_\_. Comparing these prices to a smartphone which is a necessity in most of the people’s lives today, it is relatively more expensive to install AP or BLE. In an indoor environment, the whole building would also require more than a single AP or BLE. Quick Response code can also be generated online without a cost and the information encoded in the QR code is flexible, which can be determined by the developer themselves, hence the hybrid approach of smartphone embedded sensor and QR code is chosen.

Background

<https://ieeexplore.ieee.org/document/6884282>

Background

What did other people do, and how is it relevant to what you want to do?

3.1 Guidance

•

Don’t give a laundry list of references.

•

Tie everything you say to your problem.

•

Present an argument.

•

Think critically; weigh up the contribution of the background and put it in

context.

•

Don’t write a tutorial

; provide background and cite references for further

information.