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Comparison of Indoor Localization Scheme for Multistory Environment

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Abstract: Outdoor localization nowadays is a part of our daily life. However, such useful localization method as the Global Positioning System (GPS) fails inside buildings. Popular alternative is to utilize the Indoor Positioning System (IPS) technologies that are accessible indoors. There is a wide range of IPS technologies that can be used within an indoor environment. Moreover, more attention has been given to IPS for multistory buildings recently. In indoor localization, different techniques and methods are used for distance and position estimation. This paper will focus on indoor localization technologies and the comparison of indoor localization methods focusing on multistory environment which will improve the localization accuracy through various models and techniques.

Keywords: *indoor localization; Indoor Positioning System (IPS); multistory environment; 3D localization; localization method*

1. Introduction

The Global Positioning System (GPS) is a popular technology that was created specifically for a purpose of localization. It works very well for outdoor environment. However, GPS navigation fails to work in indoor environment as it does not receive the satellite signals (Turgut, Aydin, & Sertbas, 2016). Thus, it cannot be used for indoor localization. In order to overcome this problem, a lot of researches on IPS has been conducted. IPS is a similar technology as GPS which provides indoor localization to track object or people inside a building. It uses technologies such as distance measurement to nearby anchor nodes to determine the location. IPS is mainly used for indoor localization, location-based advertising, and also emergency response. There are a lot of indoor localization technologies such as Wi-Fi, Radio-Frequency Identification (RFID), iBeacon which is based on Bluetooth low energy, ZigBee, Ultra-Wideband (UWB), and many more (T. Kim & Kim, 2014).

Indoor localization is generally based on Real Time Location System (RTLS) and it leverages existing telecommunication infrastructures in buildings. Thus, it is easy to adopt Wi-Fi Positioning System (WPS) as many Wi-Fi Access Point (AP) already installed in many buildings (Zhuang, Syed, Georgy, & El-Sheimy, 2015). In WPS, sensors will collect signal strength from the surrounding Wi-Fi AP and send it to location server. Location server can do the distance estimation by using Received Signal Strength Indicator (RSSI), fingerprinting, trilateration, and many more methods. Techniques based on the measurement of the signal propagation such as Time of Arrival (ToA), Time of Flight (ToF), Time Difference of Arrival (TDoA), and RSSI are defined as lateration techniques (Zhang, Xia, Yang, Yao, & Zhao, 2010). Localization is the estimated unknown node position through communication between localized nodes and unlocalized nodes. There are a few localization techniques including known location, proximity-based, angle-based, and also range-based.

Communication protocol between the tracking devices and location server follows Machine-to-Machine (M2M) communication model. M2M communication is the latest trend in industrial evolution that combines the information technology with machine data communication between

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devices or machines. There are two ways of using Wi-Fi technologies. The first approach is basically to leverage the existing location services. There are quite many Wi-Fi databases that already exists. Some of them are Google Location Service and Mozilla Location Service (MLS) which has millions of access point databases in the network. The other approach is custom tagging which provides accurate personalized indoor positioning. There are two types of map which are Google Maps and customize floor plan. We can leverage to Google Maps, but in some cases we do need to customize floor plan. There are a lot of areas especially private areas that are not covered with Google Maps such as office buildings. Some people or organization just do not want to send their location to Google because it is public services and they have their own privacy policy but they need to access their tracking information internally.

2. Problem Statement

There are a lot of Wireless Sensor Network (WSN) applications such as temperature measurement, humidity level, lighting condition, air pressure, noise level and many more. The emergence of WSN in IPS in several application scenarios such as healthcare, life safety monitoring, agriculture, and environment monitoring utilized a wide range of new and existing technologies. The evolution of WSN technology especially in life safety monitoring results in indoor localization that can be performed without requiring manual or human-centric operations. According to (Li, Becerik-Gerber, Krishnamachari, & Soibelman, 2014), accurate localization in buildings during fire emergency response operations is very crucial as it helps to reduce various building fire-caused casualties and injuries. Moreover, estimating an accurate location in multistory buildings is important for the building admin personnel to correctly spot and track any object or people in the shortest possible amount of time. A multistory building is a building that has several floors at different levels above the ground. Thus, location tracking systems for indoor environment in multistory buildings is very important and need to be installed in every existing building in order to aid rescuers during emergencies.

3. Indoor Localization

The localization principle developed 20 years back with the development of GPS for military application is hugely commercialized nowadays. Location-tracking systems based on radio frequency, ultrasound, or another technology could aid rescuers in determining their own location as well as that of others in emergency situations. Currently, many applications that are connected to the Internet uses location information such as Google Map, Uber, Grab, Waze, Foursquare etc. There are a huge number of scenarios like indoor environment, underwater environment, and unfavorable weather condition where GPS does not work. Hence, alternative techniques is required. Most indoor or outdoor localization methods and navigation systems nowadays are designed for two dimensional (2D) conditions and are not suitable for navigation services which need altitude information, such as for navigation in multistory buildings or around mountains (He et al., 2012). Table 1 below shows the comparison of two dimensional (2D) and three dimensional (3D) localization.

Table 1. COMPARISON OF 2D LOCALIZATION AND 3D LOCALIZATION

2D Localization	3D Localization
No altitude information.	Provides accurate altitude information that use atmospheric pressure.
Less accuracy.	Better accuracy.
Not possible for localization and navigation in multistory environment and around mountains.	Provides seamless localization across indoor and outdoor environment.
	Possible with smartphone that use an application software for downloading the maps.

There are several parameters that have been used to compare an IPS with other technologies such as accuracy, localization type, method, algorithm, signal measure, coverage, and cost (Liu, Darabi, Banerjee, & Liu, 2007). Accuracy roughly refers to the difference between the estimated position and the actual one; as this difference could change depending on the condition. Each localization system consists of distance or angle estimation, position estimation, and localization algorithm. Several people like firefighters and police officers lose their life each day while performing their jobs in dangerous situation especially in indoor environment (Milano, 2012). These circumstances can be overcome by equipping them with several WSN devices.

According to (Sotenga, Djouani, Kurien, & Mwila, 2017), information pertaining to the location of sensor nodes is very crucial especially in indoor environment where GPS cannot operate as it does not receive the satellite signals. The interactions between user and devices will locate the estimated location (Shan et al., 2015). An IPS estimate the target object location from the observation data collected by a set of sensing devices or sensors. Positions could be given in a number of different coordinate systems, depending on the purpose of the application. For example, in outdoor navigation systems, the latitude and longitude are associated with a spherical coordinate system, meanwhile for indoor localization, generally a flat Cartesian coordinate system is better suited. In any case, a coordinate system transformation is always possible, so this is not one of the most crucial issues.

RSSI estimates the distance between two nodes based on the signal strength received. According to (T. Kim & Kim, 2014), RSSI is an indication of signal received by the receiver. The RSSI is measured in dBm and is a negative value which means the closer the value to 0, the better the signal is (Rosli et al., 2015). This value can be used as a measurement of how well a receiver can receive a signal from a sender. RSSI measurement is usually operated by Wi-Fi-based technique or radio map fingerprint to locate position. RSSI distance estimation is one of the easiest method to implement, has the simplest requirements, has low complexity, no time synchronization, and low power usage. However, it has low accuracy problem because it tends to fluctuate according to multipath fading in indoor environment (Xiong, Sottile, Spirito, & Garello, 2011). Multipath fading occurs when one transmission find multiple paths to the receiver. This will cause phase shifting and attenuation or amplification of the signal.

There are a wide range of techniques to be used for indoor and outdoor localization. Table 2 below shows the comparison of existing localization techniques for indoor and outdoor environment. Most technologies nowadays are focusing on accurate real time object tracking and localization within buildings (Farid, Nordin, & Ismail, 2013). Thus, the rapid growth of indoor localization technologies has become an important demand for some markets. Researches on IPS are still widely conducted in order to improve the performance of localization technologies.

Table 2. COMPARISON OF EXISTING LOCALIZATION TECHNOLOGIES

Localization Technology	**Localization Environment**	**Localization Range**	**Localization Measurement**	**Description**
GPS	Outdoor environment	6m-10m	Known location, ToA	Satellite-based.
Infrared Radiation (IR)	Indoor environment	1m-2m	Proximity-based, ToA	Short range communication.
Wi-Fi	Outdoor and indoor environment	1m-5m	Proximity-based, ToA, TDoA, RSSI fingerprinting	Can leverage existing Wi-Fi infrastructures, but the initial deployment is expensive.
Bluetooth	Indoor environment	2m-5m	RSSI fingerprinting	Short range communication.
RFID	Indoor environment	3m-4m	Proximity-based, ToA, RSSI	High response time rate. Real time location system.
ZigBee	Indoor environment	3m-5m	RSSI fingerprinting	Low data transmission rate.

4. Multistory environment

There are various methods, techniques, algorithms, and models used for distance and position estimation in localization scheme in order to reduce localization errors in multistory environment. (Gansemer, Hakobyan, Püschel, & Großmann, 2009) proposed an indoor localization in multistory buildings by utilizing Wireless Local Area Network (WLAN). This research proposed an expansion of the 2D localization into the 3D localization based on the RSSI values and explained that we can rely on WLAN localization algorithm to estimate the discrete vertical position. Similar approach was followed by (Alsehly, Arslan, & Sevak, 2011) in their research to propose an indoor localization with floor determination by using RSSI signals from the available Wi-Fi. This research came out with two different models to determine the floor number in multistory buildings. The two models are “The Nearest Floor Algorithm” and “The Group Variance Algorithm”. The first model is used in fingerprinting method meanwhile the second model classified the RSSI values from Wi-Fi based on the floor number and compare their variance to find the best match floor number. (Maneerat, Prommak, & Kaemarungsi, 2014) used the same approach to accurately determine the mobile target's floor number. The proposed algorithm is based on the use of RSSI values obtained from wireless interface of sensor nodes to determine the floor number where the target node is located.

(He et al., 2012) proposed a seamless 3D localization and navigation for smartphone based on atmospheric pressure. The devices will be attached with atmospheric pressure sensors to calculate the user's altitude on a map of the user's device. The calculated distance will be extended into the user's floor on the map for a better improvement of location accuracy. This seamless 3D localization system will combine the outdoor GPS and indoor Wi-Fi APs technologies to measure the user's altitude. (Manzoor & Menzel, 2011) proposed an indoor localization by using passive RFID technologies to reduce the overall implementation cost while improving the localization accuracy. Low cost passive RFID tags get together to locate and track the unknown tags' locations. The simulation results showed an average linear error in positioning of 1.32m from reader 1 and 3.14m from reader 2. The advantages of this proposed algorithm can be demonstrated in a practical deployment in multistory environment.

(I. Kim, Choi, & Oh, 2012) proposed an observation and motion models to track pedestrian in indoor environment through their Wi-Fi-equipped smartphone. The outcome of this observation is that three component motion models provides better proposal distribution of a pedestrian's motion. However, this localization system has its own limitation which is it needs a pre-built Wi-Fi fingerprint map of the environment. Similar approach was used by (Farshad, Li, Marina, & Garcia, 2013) in their research to study the impact of various aspects in Wi-Fi fingerprinting system. They found that the combination of fingerprinting method and location estimation algorithm provides an accurate localization. However, it is also depending on the environment itself such as a specific floor within the given environment. This research also demonstrated that the choice of frequency band (2.4GHz or 5GHz) and addition of virtual AP has a significant impact to improve the location estimation accuracy. In this research, it is concluded that 5GHz signals are less prone to variation and this will lead to a better location estimation accuracy.

(Jaworski et al., 2017) proposed a real-time 3D indoor localization in multistory environment by utilizing 3D particle filter that is used in transition between floors. The filtration with particle filter can be used in both 2D and 3D environment. This method works based on the information gathered from inertial sensors, Wi-Fi signal strength, barometric, and building data. (Riota, Kristanda, & Prasetiyowati, 2017) proposed an indoor localization by using Earth's magnetic field through mobile application. This system used the combination of fingerprinting method and k-nearest neighbors (KNN) algorithm to compare magnetic values between database and sensor readings. A positioning filter based on previous location, direction, and magnetic values is used to filter data before applying the algorithm. (Wang & Luo, 2017) proposed an indoor localization based on RSSI ranging from Wi-Fi. The RSSI signals are collected and processed by Gaussian fitting and Kalman filter. The distance between the device and AP is obtained based on indoor signal propagation model. Then the vertical distance is eliminated by geometric method, and the plane distance between the AP and the device is obtained. Finally, the position coordinate is calculated by the weighted centroid algorithm of no height influence. A floor number recognition method is combined with the 2D planar positioning to form a near three dimensional (N-3D) indoor location algorithm for multistory buildings.

5. Conclusion

This paper surveys the current indoor localization technologies and the comparison of indoor localization methods focusing on multistory environment which will improve the localization accuracy through various models and techniques. IPS use sensors and communication technologies to locate objects in indoor environments. IPS are attracting scientific and enterprise interest because there is a big market opportunity for applying these technologies. There are many previous surveys on indoor positioning systems. However, most of them lack a solid classification scheme that would structurally map a wide field such as IPS, or omit several key technologies or have a limited perspective. Current surveillance systems for multistory building lack in supporting real-time monitoring of every point of a level in multistory buildings at all times. Solutions using wireless sensor networks, on the other hand, can gather sensory data values from all points of a building continuously, day and night to provide fresh and accurate data.

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