Advanced Science and Technology Letters
Vol.112 (Architecture and Civil Engineering 2015), pp.46-49
http://dx.doi.org/10.14257/astl.2015.112.09

A Review of Indoor Positioning Techniques

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Abstract. Location-based services (LBS) provide useful information to users based on the current user location or a given location. Therefore, one of the key techniques for LBS development is positioning, or identifying the coordinate of the spot where the user is currently located. For outdoor LBS, the GPS (Global Positioning System) provides a general solution for positioning. However, discovering a general solution for indoor positioning is still a hot research topic. This paper reviews recently published indoor positioning techniques.

Keywords: Indoor Positioning, Location based Services, Global Positioning System, Wi-Fi.

1 Introduction

Location-based services (LBS) provide useful information to users based on the current user location or a given location. LBS include services of identifying locations of persons or objects such as discovering the nearest subway station or the whereabouts of friends or valuables. Vehicle navigation systems, logistic systems, location-based target advertisement systems and coupon systems, and cabs management systems are a few examples of practical LBS [1].

LBS cannot be realized unless a general solution for positioning, or identifying the coordinate of the spot where the user is currently located, is available. For outdoor LBS, the GPS (Global Positioning System) provides a general solution for positioning. However, the indoor positioning problem is still open.

As manmade structures such as buildings and underground facilities are getting larger and larger, a demand for indoor LBS is getting stronger and stronger. Campus guides, museum guides, shopping helpers for department stores, and employee management systems are under development in the indoor LBS field [2]. Therefore, this paper reviews recently published indoor positioning techniques. In the early stage of indoor LBS, they relied upon special devices for indoor positioning. Since the time when the Internet was available everywhere, Wi-Fi based positioning methods have

[1] This work was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2011-0006942) and by the Dongguk University Research Fund of 2015.

ISSN: 2287-1233 ASTL

been hot research topics. Nowadays, many smartphone based indoor positioning techniques can be found in the current literature.

2 Related Works

Villarrubia et al. [3] summarized existing indoor location technologies as follows:

- Infrared: The characteristics of infrared include "its short range" and "requiring a line of sight." Therefore, indoor location with only infrared cannot be a general solution of indoor positioning.
- Wi-Max: Wi-Max has the range of 50 km. This is too large scope for indoor positioning.
- Bluetooth: The procedure of Bluetooth based positioning systems detects Bluetooth devices, obtains received signal strength indications (RSSI), estimates distances between the moving object and other Bluetooth devices, and estimates the location of the moving object by applying a triangulation algorithm. The disadvantages of Bluetooth based positioning include it requires many Bluetooth devices and RSSI fluctuates too much.
- Ultra Wideband: This is accurate and reliable. However, its use is not guaranteed by the law. That is, this cannot be used in some places.
- ZigBee: This is considered to be the most adequate technology for indoor positioning. However, it has a very small bandwidth and cannot offer other services such as streaming and Internet.

Villarrubia et al. [3] also summarized indoor localization algorithms.

- Direction of Arrival: With the angles of the line from at least three reference points to the moving object, this algorithm estimates the position of the moving object as deoicted in Figure 1.

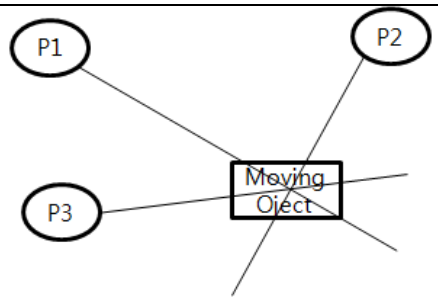

Fig. 1. A diagram to illustrate the direction of arrival method

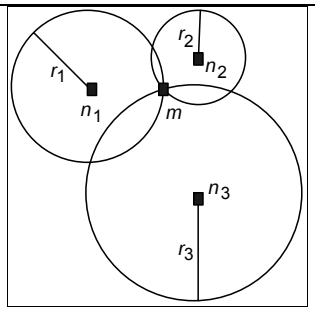

Fig. 2. A diagram to illustrate trilateration

Trilateration: If we measure N ranges, $r_1, r_2, ..., r_N$ from N base stations, to a mobile terminal as shown in Figure 2, then we can estimate the coordinates of the moving object by using trilateration. In the figure, m represents the moving object while n represents a reference node.

- Fingerprinting: This method records fingerprints of every interested points in the domain. Given a fingerprint, it identifies the interested point that matches the fingerprint. We use a set of sensor values collected at an interested point as the fingerprint of the point.
- Multilateration: This method estimates distances between the moving object and at least three reference points whose coordinates are known. With the distances and the coordinates of the reference points, it determines the location of the moving object.

The purpose of [3] is developing a museum guide app. This app recognizes the monumental work that the user is watching and plays a video content that is closely related to it on the user's smartphone. The process of recognizing the monumental work is follows: 1) It identifies the room where the user is located with Wi-Fi technology. 2) The user takes a picture of the monumental work. 3) It performs the image process to recognize the monumental work.

Poosamani and Rhee [4] pointed out the disadvantages of existing methods as follows:

Most practical indoor location-based services use specialized devices and RF signals or beacons.

Wi-Fi signal fingerprinting methods requires extensive calibration and deployment overhead.

Indoor positioning using smartphone sensors consume too much battery energy of the smartphones.

Indoor positioning using averaged received signal strength (RSS) of 2G cellular signals is too rough because RSS is determined by too many factors.

Developing practical indoor positioning methods with already existing available resources such as Wi-Fi and smartphone sensors is the main concern in the field of indoor positioning. Poosamani and Rhee [4] proposed an indoor positioning system that logically estimates user location referring to signal received quality (RSRQ) and reference signal received power (RSRP) and other physical (PHY) layer information from 4G cellular network signals. Their method is a kind of fingerprinting method. However, their method does not require deployment overhead because they build fingerprints in near real-time.

Rida et al. [5] designed and implemented a trilateration algorithm based on RSSI of the Bluetooth low energy 4.0 (BLE) to determine user indoor location. Chen and Lin [6] proposed a neural network for indoor positioning. They trained the neural network with ZigBee link quality indicator.

Li et al. [7] reviewed techniques for RFID (radio frequency identification) based indoor positioning. Near field communication (NFC) tag is Android version of RFID. Android app developers can read NDEF (NFC data exchange format) data from NFC tag using the tag dispatch system.

Lee and Yim [8] described a few Wi-Fi based indoor positioning systems. Two of them built by the fingerprinting method: one used the K-nearest neighbor method and the other used the decision tree method. They also described a Wi-Fi based indoor positioning system built by the trilateration method. Then, they described the extended Kalman filter process for Wi-Fi based indoor positioning.

Yim [9] introduced indoor positioning method that determines the user's current position with the smart phone's sensor values. Referring to the accelerometer values, this method counts steps. An example collection of Z axis accelerometer is shown in

Figure 3. With the orientation values, this method estimates the direction. With the step count and the direction, this method determines the current location of the user.

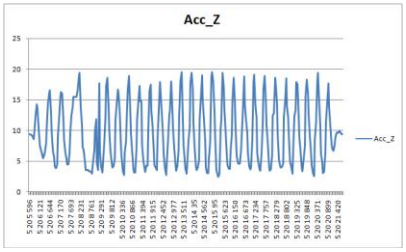

Fig. 3. An example collection of Z axis accelerometer [9]

3 Conclusion

As the demand for indoor LBS is increasing, indoor positioning, one of the key techniques for indoor LBS development has been hot research topic. However, a general solution for indoor positioning has not been discovered, yet. This paper reviewed recently published indoor positioning techniques. Discussed techniques will helpful to indoor LBS developers.

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