Infrastructure-free Indoor Positioning System using Smart Phone Sensors

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Abstract— **In this paper, we propose a method for predicting the user location in complex indoor environment, by using a variety of sensors. Our scheme has a salient feature of detecting a user's step pattern and exploiting the information to estimate the user location. We mainly depend on the Pedestrian Deal Reckoning (PDR) and geomagnetic signal, and optionally consider Wi-Fi radio signal to improve the accuracy. Geomagnetic signal varies on each position and can be measured by a device without built-in infrastructures. On the other hand, Wi-Fi signal can be obtained with the infrastructure established in advance, but it can improve the estimation accuracy significantly. We merge the PDR and geomagnetic signal by the Kalman filter. Experimental results show that we can estimate the user location in a substantial accuracy even in indoor environments.**

Keywords-PDR, Geomagnetic, Wi-Fi

I. INTRODUCTION

To provide precise indoor location information of a mobile target without any special infrastructure requirement is one of the most addressed problems in the field of geo-location technologies after the success of Global Navigation Satellite Systems (GNSSs) such as GPS in recent years. Several techniques have been proposed to solve this issue of the complex indoor canyon where RF signals go under high attenuation due to multipath, absorption and fading effects. Indoor positioning systems (IPS) are mostly categorized into two types solutions commonly known as Infrastructure-based and Infrastructure-free solutions. In the case of infrastructure-based solutions, a specialized hardware (sensors, tags, smart lights) are required to be installed prior in the environment to run the position estimation system. These solutions provide a certain level of accuracy at the cost of expensive installations in the environment. In contrast, infrastructure-free solutions are more adaptable in nature as they utilize the existing resources available in the environment (Wi-Fi, Geomagnetic).

II. APPROACH AND IMPLEMENTATION

We propose a system which incorporates multiple resources available in the environment for IPS. Our system is based on three kinds of commonly available resources: Wi-Fi infrastructure, Motion sensors and Geomagnetic. Fingerprinting technique is used for Wi-Fi bases positioning which provides the initial location information for Pedestrian Dead Reckoning (PDR) approach of motion tracking using inertial sensors commonly available in handheld devices. To compensate the non-ideal situations, we also employed Geomagnetic field positioning in case of inappropriate or no Wi-Fi facility. Proposed IPS is a smart mobile-based system to estimate position locally, whereas for the Geomagnetic and fingerprinted Wi-Fi are performed prior using a desktop system and mobile phone as a scanning device.

A. Wi-Fi Fingerprinting

Wi-Fi network is a commonly available resource in these days, therefore, we selected Wi-Fi fingerprinting as our primary technique for position estimation. Wi-Fi fingerprinting normally have two stages: offline fingerprint database generation survey of the environment and online fingerprint matching to estimate the location of the target node. In offline DB generation, a list of Wi-Fi RSSI values of access points (APs) at each reference point in the information is stored in the DB as raw Wi-Fi scans with location tags, which is a further process to generate fingerprinting database. Whereas in online location estimation stage the target nodes send the real-time list of mac addresses of visible APs at the particular position with RSSI level to position estimation procedure, which finds a matching fingerprint in the DB generated in offline phase. Fingerprint matching algorithm uses KNN, SVM etc. technique

to find the best match among

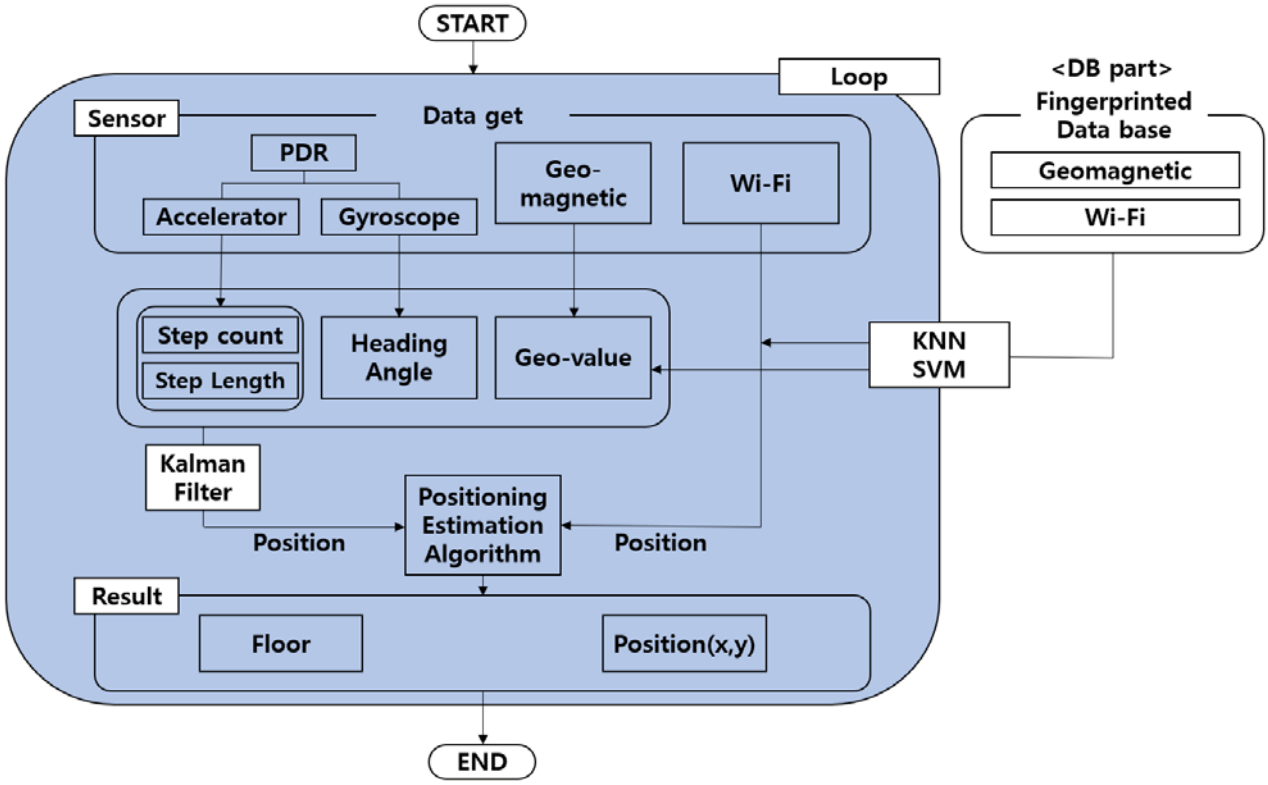

Figure 1. System diagram of proposed approach

candidate location fingerprints with minimum error distance.

B. Pedestrian Dead Reckoning

Pedestrian Dead Reckoning (PDR) is a technique to estimate the distance traveled and heading angle of a user carrying a smart device bearing motion sensors or Inertial Measurement Unit (IMU) also known as Inertial Navigation System using Step and Heading System (INS-SHS). By applying the threshold on the measurement of the accelerometer and incorporating some correction using gyroscope values we estimate the step length and step count of a person carrying a smartphone with IMU sensor. Where are by fusing the Compass (Magnetometer) reading and angular velocity from gyroscope the heading angle estimation is performed. The System uses PDR information between successive location estimation from Wi-Fi fingerprinting technique to limit the estimation in a particular region.

C. Geomagnetic

Geomagnetic is another potential resource for indoor position estimation which available naturally. Positioning based on the magnetic field is also a two-stage process similar to Wi-Fi fingerprinting: model training stage and fingerprint localization stage. In the first stage, a localization model is built by fingerprints of magnetic field collected spatially with location tagging information of environment. In localization stage, the location of the target node is estimated by comparing the real-time magnetic signals collected at target node position with the localization model build in training stage. A Sliding window technique is used to estimate to avoid the similarity between magnetic field at target location and fields of multiple candidate locations.

III. PROPOSED SYSTEM

The system of the proposed in shown in Figure 1. We utilize several smartphone sensors to use the proposed system. First, It needs two things, fingerprinted Wi-Fi data and continuous Geomagnetic value, to build a database in advance for the indoor environment. Then, these data are used for on-line testing via KNN and SVM.

PDR detects user's step through acceleration sensor, then derives user's step count and step length. However, PDR has a cumulative error for the step continuously, so it must be corrected through other sources. The gyro sensor sets user's direction of walking. This is a very important task. In fact, even if the gyro sensor is going straight forward, there is a slight error from side to side. Therefore, it has to modify this with Geomagnetic. It constantly compares with values taken from the database and produces the most appropriate result. Through this, PDR and Geomagnetic are hybridized to detect multiple candidates, and the most probable vector is determined as the user's location.

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Wi-Fi also does something similar to Geomagnetic and derives user's current position. Finally, if each other's position does not exceed the threshold, the average of the two points is determined as the final user's position. Otherwise the Wi-Fi data

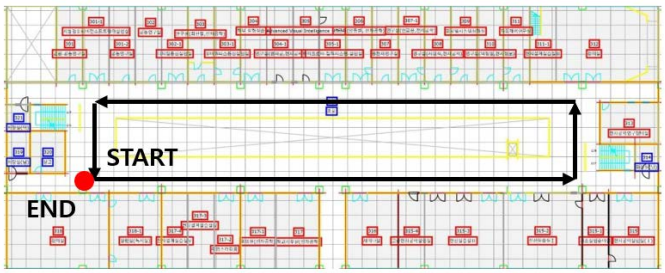

Figure 2. The path used for experiments.

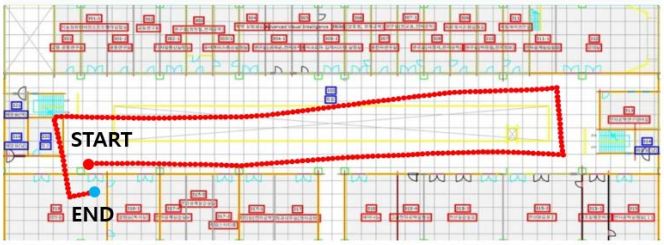

Figure 3. Result of using PDR only.

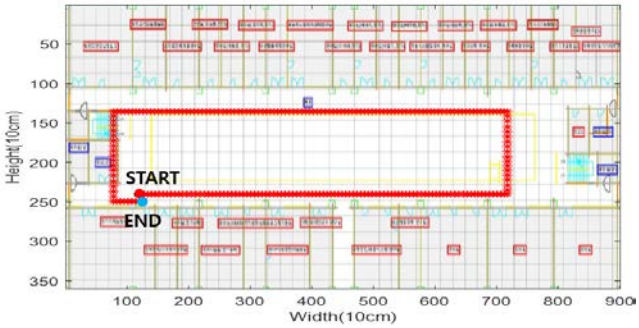

Figure 4. Result of Proposed System.

is ignored. This is because Wi-Fi is heavily influenced by the indoor environment and the number of un-reliable Wi-Fi is high.

IV. EXPERIMENT AND RESULT

The experiments are conducted on the 3rd floor of the Yeungnam University Electronic Engineering building using Samsung Galaxy S9+ (SM-G965N) device. The path used for the experiments is shown in Figure 2. In Figure 3, the average error is 7.05m and maximum error is 13.5m when using only PDR. On the other hand, in Figure 4, the average error is 3.76m and the maximum error is 6.49m when using proposed system.

V. CONCLUSIONS

We can estimate the user location in indoor environments by utilizing a single technique only. However, the estimation accuracy improves significantly when we combine information from multiple sources, because each technique can compensate the limit of another efficiently. Our proposed scheme is a hybrid IPS that utilizes Wi-Fi fingerprinting, IMU based PDR and Geomagnetic at the same time. With a realistic experiment, we can observe that the proposed scheme achieves high-level of estimation accuracy in indoor environments.

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