An Indoor Positioning Framework for Emergency Rescue Evacuation Support System with Partial Infrastructure Support

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긴급구조를 위한 인프라 부분적 의존적 실내측위 프레임워크

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Summary

Indoor Positioning, which is a solution to locate people inside a building, has been an important component of Emergency Rescue Evacuation Support System (ERESS). Although many researches have been conducted on indoor positioning, they are either not accurate enough or not considering indoor emergency situations such as fire and earthquakes. This paper introduces an indoor positioning framework which uses partial infrastructure support to balance between the accuracy and practicality. Specifically, we propose an indoor positioning framework based on Pedestrian Dead Reckoning (PDR) and augmented with Wi-Fi Received Signal Strength Indication (RSSI), and compare the accuracy with PDR only technique. For evaluation, we modeled a building on fire using Anylogic software and compared the real time pedestrian trace with the estimated trace obtained by the techniques.

Ⅰ. Introduction

If disasters such as fire and earthquakes occur in indoor environments like libraries, shopping malls and subway stations, it can lead to the loss of lives and serious injuries. In order to prevent such tragic consequences, indoor positioning plays an important role in emergency rescue systems by locating people inside the building and guiding them to a safer place. There are two typical approaches for indoor positioning: infrastructure-based approach which uses Bluetooth or Wi-Fi beacons and infrastructure-free approach which uses smartphone inertial sensors. Normally, the infrastructure-based approach provides high accuracy than the infrastructure-free approach which relies upon highly fluctuated sensor readings and is specifically weak against cumulative errors. Unfortunately, disaster occurrence normally damages the reference infrastructure, so the use of infrastructure-based approach in disaster situations has been a challenge. To deal with the issue, we can consider adopting a hybrid approach which mainly based on infrastructure-free indoor positioning while using partial infrastructure support to improve the accuracy. In this paper, we propose a PDR-based indoor positioning framework partially dependent on WLAN infrastructure which can give a high accuracy even if some Wi-Fi APs are damaged. We show the efficiency of our framework by comparing it with the infrastructure-free PDR-only scheme using the Anylogic simulation.

Ⅱ. Background

In recent years, the significant development of wireless technology and wide availability of diverse sensors in smartphones made indoor localization techniques advance rapidly. One of the popular approaches to indoor localization is PDR which uses smartphone inertial sensor and magnetic sensor to detect movement and heading direction of the pedestrian [1]. Another widely known indoor localization technique is based on WLAN, which uses RSSI as it can be obtained with the existing WLAN infrastructure. Since the RSSI measurements are sensitive to multipath propagation in indoor environments, numerous researches have been devoted to deal with the issue. There are two typical approaches to enhance such indoor RSSI measurements: RF propagation loss model and fingerprinting. The former uses multilateration to compute the distance between user's mobile and Wi-Fi APs while the latter uses a locational fingerprint database where the RSSI data of each location measured from several APs are stored. In our framework, we used RSSI-fingerprinting as it can give a more promising result even if one or more APs break down in disaster situations [2].

Ⅲ. Implementation

We used Anylogic to model a building with walls, APs and a person moving towards an exit. At any point in the map, the RSSI signal associated with an

AP is modeled following the ITU path loss model, which calculates signal loss with respect to the distance and the number of walls between two points. Once the start and destination of the pedestrian is set, the path is determined automatically by Anylogic.

For both PDR-only and PDR+RSSI fingerprint approach, we assumed that the pedestrian provides the starting position on the map and one step takes one second. We also assumed that the pedestrian holds the smartphone pointing forward during the evacuation. Then the direction of the pedestrian can be easily obtained using the magnetic sensor. In the Anylogic simulation, we obtained the direction of the pedestrian by measuring the movement of the pedestrian for a short time and calculating the heading direction at every step. For both implementations, we applied Particle Filtering algorithm to probabilistically track the pedestrian position on the map [3].

In PDR-only approach, we estimated the next position of the pedestrian by using the heading direction and assuming that the pedestrian moves in a certain speed. To get a more accurate result, we scattered 'n' particles around the estimated position, and got rid of the particles if there is a wall between their positions and the previous estimated position. As shown in Eq. (1), the estimated position is then updated by averaging the positions of the particles 'p' after the filtering.

$$(x_{estimated}, y_{estimated}) = \left(\frac{\sum_{i=0}^{n}(x_{p_i})}{n}, \frac{\sum_{i=0}^{n}(y_{p_i})}{n}\right) \quad \text{Eq. (1)}$$

In PDR+RSSI fingerprint approach, we first divided the map into 10x10cm rectangular grids. We calculated the RSSI fingerprint—the vector of the RSSI for each AP—for each grid and stored them in a fingerprint database. When the simulation starts, 'n' particles are scattered around the pedestrian's position. At every second, the particles are moved a certain distance toward the walking direction of the pedestrian, and are assigned certain weights based on the RSSI fingerprint for resampling. The RSSI fingerprint of a particle is that of the grid to which the particle belongs. A particle gets more weight if its RSSI fingerprint in the database is more close to the RSSI measured by the pedestrian's smartphone. Resampling reselects the group of 'n' particles, and those with more weights have higher chance of getting picked, so we can implicitly get rid of the particles which are far from pedestrian as shown in Figure 1.

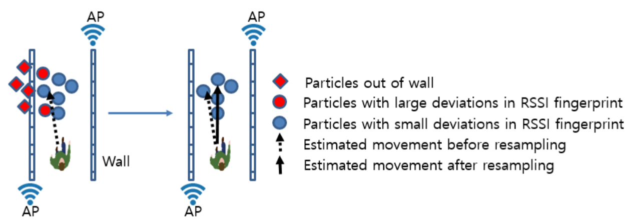

Figure 1 Resampling of the particles

For the estimated position of the pedestrian, we choose the position of the particle 'p' with the highest weight as shown in Eq. (2):

$$(x_{estimated}, y_{estimated}) = \underset{(x,y)}{\operatorname{argmax}}\left(W(x_{p_1}, y_{p_1}), \dots, W(x_{p_n}, y_{p_n})\right) \quad \text{Eq. (2)}$$

IV. Results

Figure 2 shows the visual display of the running simulation. The black dots represent particles, and the person in the middle is the actual location of the pedestrian whereas the red-shaped small person is the estimated location of the pedestrian.

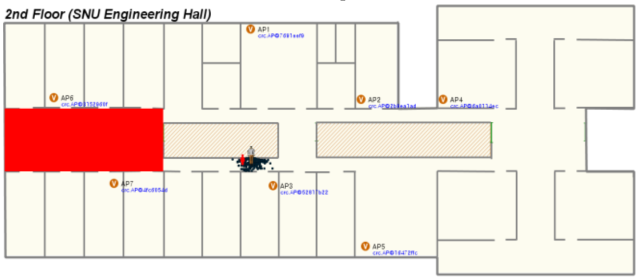

Figure 2 Visual display of the simulation

Figure 3 shows the simulation results. PDR-only approach did not give a promising result because the speed of the pedestrian is fixed and there is no way of figuring out the exact distance the pedestrian has moved. In PDR+RSSI approach, we measured the distance error for different numbers of APs since APs may break down in disaster situations. The result gets better as more APs are used.

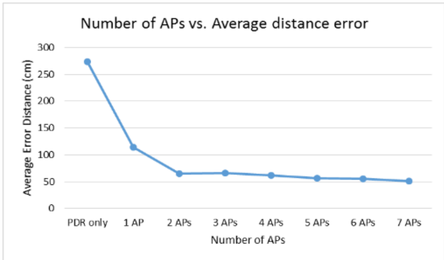

Figure 3 Simulation Results

V. Conclusion

In this paper, we proposed and simulated an efficient PDR+RSSI fingerprint framework for indoor positioning in fire situation. The proposed framework shows better accuracy than the PDR-only approach so it can be used as a reference for ERESS evaluations. In the future, we will get the wall temperature data from real fire situation, and apply it in our simulation by adding the breakdown of APs upon specific wall temperature to get more practical evaluations.

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