Wi-Fi RSSI Heat Maps Based Indoor Localization System Using Deep Convolutional Neural Networks

Alwin Poulose and Dong Seog Han*

School of Electronics Engineering
Kyungpook National University

Daegu, Republic of Korea

alwinpoulosepalatty@knu.ac.kr, dshan@knu.ac.kr*

Abstract

An indoor localization system that uses Wi-Fi RSSI signals for localization gives accurate user position results. The conventional Wi-Fi RSSI signal based localization system uses raw RSSI signals from access points (APs) to estimate the user position. However, the RSSI values of a particular location are usually not stable due to the signal propagation in the indoor environments. To reduce the RSSI signal fluctuations, shadow fading, multipath effects and the blockage of Wi-Fi RSSI signals, we propose a Wi-Fi localization system that utilizes the advantages of Wi-Fi RSSI heat maps. The proposed localization system uses a regression model with deep convolutional neural networks (DCNNs) and gives accurate user position results for indoor localization. The experiment results demonstrate the superior performance of the proposed localization system for indoor localization.

1. Introduction

Indoor localization systems use IMU sensors [1], Wi-Fi access points (APs) [2], ultra wideband (UWB) signals [3] and camera sensors [4] to estimate the accurate user positions. Among these indoor localization systems, the Wi-Fi RSSI based localization approach is the most common and easy to implement. As compared to other indoor localization system, the Wi-Fi APs are common in indoor environments and the strength of the RSSI signals gives accurate user distance information. The conventional Wi-Fi localization approaches are Wi-Fi fingerprinting algorithm [5], trilateration algorithm [6][7] and weighted path loss algorithm [8]. These conventional approaches use raw RSSI values for identifying the user distance from Wi-Fi APs. The main challenges that affect the localization accuracy of conventional systems are RSSI signal fluctuations, multipath effects, shadow fading and blockage of the RSSI signals. To overcome the localization challenges of conventional approaches, we proposed a Wi-Fi localization system, which uses the RSSI heat maps instead of raw RSSI signals and estimate the user positions. The RSSI heat maps are free from the signal fluctuation and the deep convolutional neural networks (DCNNs) [9] in the proposed system use the advantage of heat maps for user position prediction. The proposed localization system reduces the localization errors as compared to conventional approaches and give accurate user position results for indoor localization.

The main contributions of this paper are summarized as follows.

- We formulated a Wi-Fi localization system using four APs and collected the RSSI values using a smartphone. The smartphone uses an Android application and gives the current RSSI values of a particular location in the experiment area.
- We generated Wi-Fi RSSI heat maps and it shows the RSSI signal strength of four access points for a particular location in the

experiment area. We used the generated heat maps for locating the current user position.

- We implemented DCNNs for localization using Wi-Fi RSSI heat maps and the experiment results indicate that the proposed localization system achieves the best localization accuracy as compared with the conventional localization approach.

The rest of the paper is organized as follows. Section 2 presents the proposed Wi-Fi RSSI heat maps based localization system using DCNNs. In Section 3, we illustrate the experiment and result analysis of the proposed system and Section 4 concludes this paper and shows some future works.

2. Proposed Wi-Fi RSSI Heat Map based localization System using DCNNs

The proposed localization approach uses RSSI heat maps and DCNNs for identifying the current user position. The RSSI heat maps are used for the model training and estimated the user position with test heat maps. In conventional localization approaches, the neural network model uses raw RSSI signals for training [10]. However, the raw RSSI values for a given location in the experiment area are usually not stable due to the complex propagation of indoor environment. To make a stable localization system, we generated heat maps for each location that provides accurate user positions. Fig.1 shows the proposed Wi-Fi RSSI heat maps based localization system using DCNNs.

From Fig. 1, it can be seen that the proposed system consists of an RSSI data collection, RSSI heat map generation, training and testing the DCNNs model with heat maps and estimate the user positions. The RSSI data collection is held by a smartphone with android application. We divide the experiment area into different locations for training and test data collection. After the RSSI raw data collection, we convert the RSSI values into RSSI heat maps. The RSSI heat maps are used as the input of DCNNs. After training the DCNNs model, we generated test heat maps for estimating the user position. Using the test heat maps, the model predicts the user position of each location with a minimum localization error.

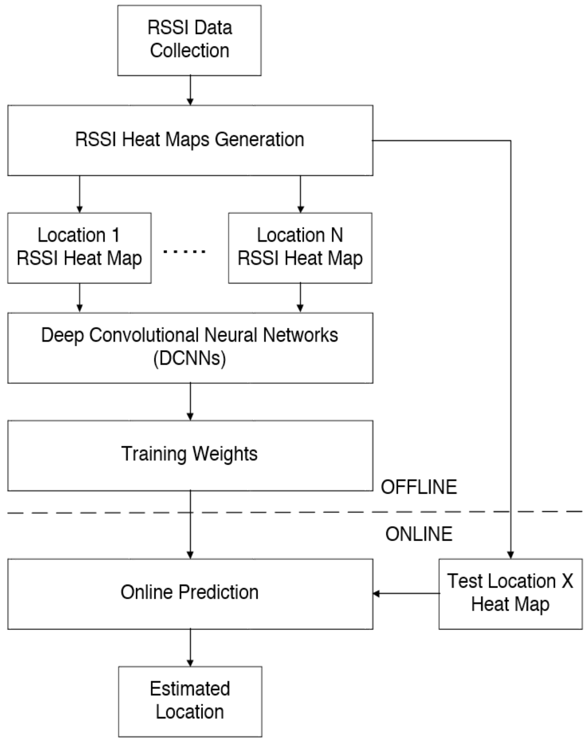

Fig. 1 Proposed Wi-Fi RSSI Heat Maps Based Localization System Using DCNNs.

3. Experiment and Result Analysis

To evaluate the performance and accuracy of the proposed Wi-Fi RSSI heat maps based localization system, we considered an experiment area with four access points. The Wi-Fi RSSI data are collected at the fifth floor of IT building 1, Kyungpook National University, South Korea. During data collection the user (Age 28, Height 175 cm) held the smartphone in his hand and walked in the predefined path. The experiment area is divided into 30 training and test locations and collected 3000 RSSI data samples for training and 1500 RSSI data samples for testing. The experiment is carried out in an Android 4.4.2 (KitKat) platform on a LG G3 smartphone with Snapdragon 801 processor and 3 GB RAM. The collected RSSI values are used for generating heat maps and Fig. 2 shows the generated heat map of a particular location in the experiment area.

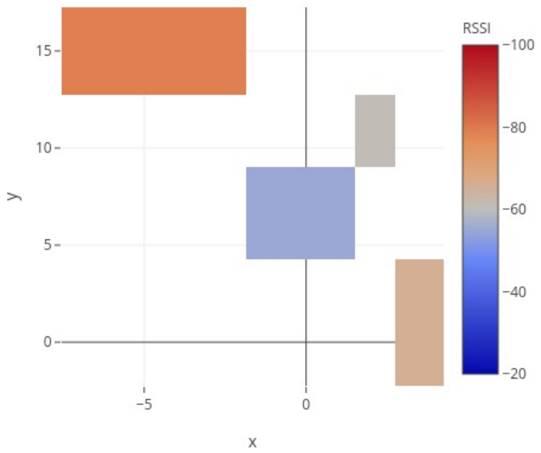

Fig. 2 Wi-Fi RSSI heat map.

In Fig. 2, the x and y-axis are the APs locations and the RSSI signal strength from four APs are indicated as different colour patterns. From Fig. 2, it can be seen that the RSSI pattern of a particular location in the experiment area is unique and the heat map pattern varies with RSSI signal strengths.

The accuracy of the proposed localization system is assessed and evaluated by mean localization error. Fig. 3 shows the mean localization error results from the proposed localization system and conventional localization approach. In the conventional approach, we used the raw RSSI values instead of heat maps and feed into the DCNNs.

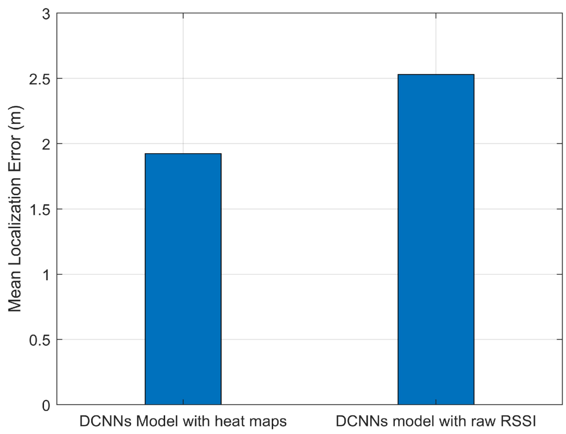

Fig. 3 Mean localization error.

From Fig. 3, the proposed localization system outperforms than conventional localization approach. The proposed method is free from RSSI signal fluctuations, shadow fading and multipath effects. The proposed approach gives accurate user position results for indoor localization. Table 1 shows the performance of the proposed and conventional localization approaches.

Table 1 Performance of the localization approaches.

Localization Approach	Mean Localization Error	Standard Deviation of Localization Error	Training Time (sec)
Proposed Localization Approach	1.92	1.01	25.3
Conventional Approach	2.52	1.10	165.7

From Table 1, the proposed localization approach has lower mean localization error than conventional localization approach. The proposed approach reduces the localization error by utilizing the advantage of heat maps. The DCNNs shows better performance for RSSI heat maps as inputs than raw RSSI signals. Through extensive experiment results and analysis, the proposed approach demonstrates the superior performance than conventional localization approach.

4. Conclusion

In this paper, we proposed a Wi-Fi localization system using RSSI heat maps. The proposed system uses the advantages of DCNNs and solve the RSSI signal fluctuations and multipath effects for indoor localization. The proposed system gives accurate user position results in indoor areas with minimum localization error. The experiment results show that the proposed system gives a better localization performance than conventional approaches. In the future works, we intend to add hybrid neural network model to the system for better performance.

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