Indoor Localization with Wi-Fi Fingerprints Using Deep Learning and Fuzzy Sets

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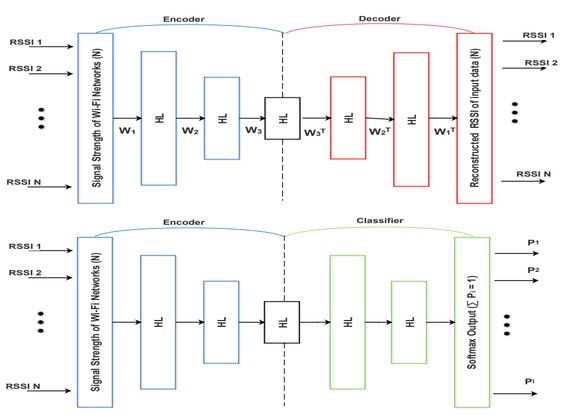
Introduction

In an indoor environment, where there is no line-of-sight signal from global positioning systems (GPSs), received signal strength (RSS) from wireless network infrastructure can be used for localisation through fingerprinting. For example, a vector of a pair of a service set identifier (SSID) and RSS for a Wi-Fi access point (AP) measured at a location becomes its location fingerprint. A position of a user/device then can be estimated by finding the closest match between its new RSS measurement and the location fingerprints in a database. A major challenge is how to deal with the random fluctuation in RSS measurements. This project investigates the use of deep learning algorithm and fuzzy sets to take into account the RSS randomness in building a location fingerprint database and finding the position.

Methodology

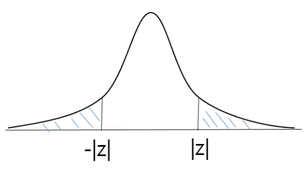
1. Deep Learning

We employed deep learning, considering about its remarkable performance in pattern recognition, to handle the fluctuation in RSS measurements instead of traditional methods like KNN which is vulnerable by noise and randomness. This method constructs an artificial neural network whose input is a vector of RSS while output provides an estimated location. Its first part is a stack autoencoder that extract the feature of input data and feed it to cascaded classifier.



2. Fuzzy Sets

Fuzzy set is a set of which all elements have membership degree. The higher membership values are, the more they meet the condition of the set. By chaning RSS measurements into membership values with respect to given condition which is a location, we conclude where we are. We use normal distribution to give membership values since sums of independent random variables have an approciamtely Gaussian distribution.

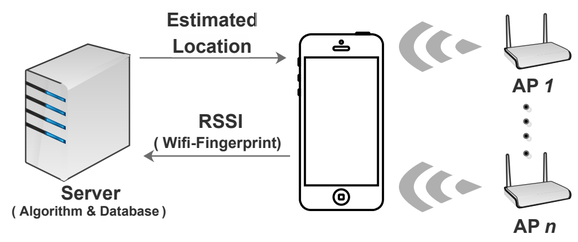


$$f(x) = P(|Z| \geqslant |z|)$$

After giving membership value, we apply similarity measure based on fuzzy integral. Fuzzy integral is to calculate an average membership value of fuzzy set. We used Fuzzy integral to calculate a distance between two fuzzy sets. The lower outcome is, the more they are similar.

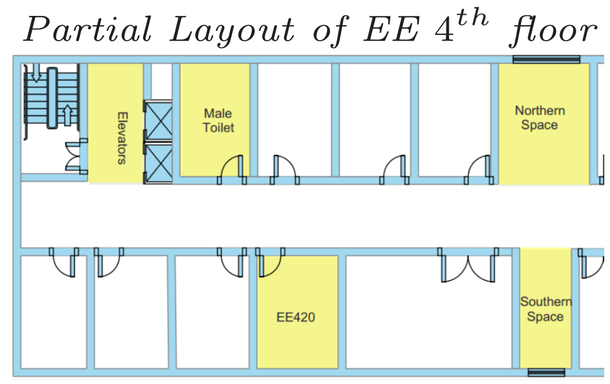
Communication between Server and Client

Using an Apache Web Server called WampServer as the initial server to detect the quantity of AP, next we constructed the back server using Flask, which is a microframework for python, then to build up the database of RSS, a database engine called SQLite3 was applied. The server holds database and implementation of localization algorithm while clients are only responsible for scanning RSS and sending it.



Data Collection

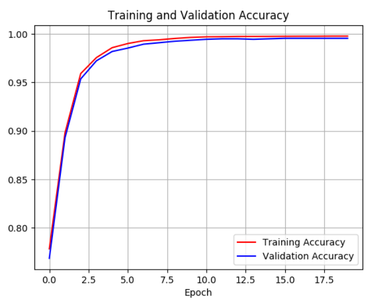
Having successfully connected server and client phones, we collected data of RSS on 4^th floor in EE. In the measurement using devices from different brands, finally, there were totally around 200 APs detected and more than 4000 sample of fingerprints were collected at different locations with labels as shown in matrix below.

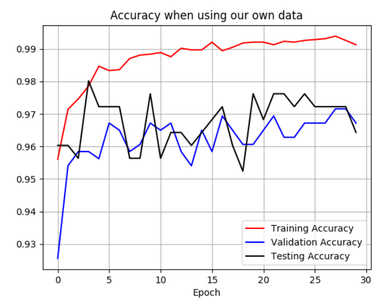


$$\begin{array}{c} \\ Spl\ 1 \\ \vdots \\ Spl\ N \end{array} \begin{array}{c} \begin{array}{cccc} AP_1 & AP_2 & \dots & AP_{200} \end{array} \\ \begin{pmatrix} -110 & -86 & \dots & -34 \\ -67 & -88 & \dots & -110 \\ -110 & -52 & \dots & -75 \\ -27 & -66 & \dots & -110 \end{pmatrix} \end{array} \begin{array}{c} Label \\ 0 \\ 1 \\ 3 \\ 5 \end{array}$$

Tinted areas are part of 7 locations selected to collect data and test the system. Both isolated rooms and public area are considered.

Results and Comparison





Fistrly, for deep leaning, we tested the performance of it in an theoretical case based on available online UJIndoorLoc dataset with less uncertainty compared with real situation. Its accuracy could reach 93%. Then, for our own case, it also has good performance as shown in the figure. Secondly, for fuzzy based one, we tested it with our own dataset. It can reach around 86% testing accuracy which is a little bit weaker than preceding deep learning method. Comparing two results, we decide to use deep learning in real time testing whose performance can be seen in our VCR.

Conclusion

In this project, we implemented a primitive indoor localization system with Wi-Fi fingerprints and compared different methods including deep learning and fuzzy sets. According to the results, it can be concluded that deep learning method has an unexpected performance and advantages:

- Immunity against fluctuation in RSS measurements
- No necessity to compare with every samples in database
- Suitable for different devices from various fabrication brands

Further research is needed for better robustness and precision of this system. Especially, a high resolution localization is desired rather than separated areas.