SAIL: Small Area Indoor Localization

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Abstract

An indoor localization solution is being built for a two-floor home as an integral part of its smart-home transformation. With the help of wearable devices such as an Android phone, Wi-Fi signal strength and other sensor data from the barometer and magnetometer are gathered to determine the rough location of the user – accurate to which room they are in. The results are displayed in real-time on a website. As a prototype of a cost-effective small-area localization solution, the system targets its application in elderly care, smart-home automation, and general purpose monitoring.

It leverages user interaction to improve the performance over time by keeping feeding desirable sampling data back to the training set. It also fuses "Wi-Fi signature" with barometer and magnetometer available on a typical smart phone for localization.

Introduction

Indoor localization has come a long way, but there still yet to be seen in mass commercial adoption. This is partly due to the emphasis on high accuracy, universal usage on any device, and reasonable cost. However, for early adopters, especially those who are transitioning to a quantified, connected and automated smart home, high accuracy and device universality are not the priority. As a result, SAIL is being developed as a holistic solution to meeting their indoor localization needs.

The system is streamlined to be functional through four steps.

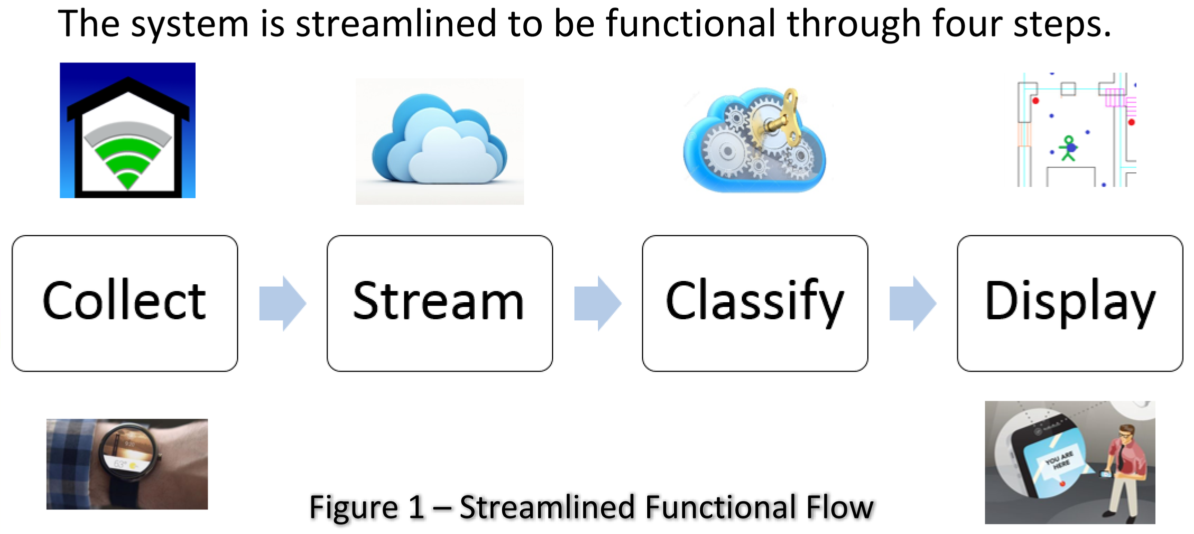

Figure 1 – Streamlined Functional Flow

SAIL aims to be cost effective, user specific, and easy to maintain. The hardware it uses should be either readily available or versatile to handle other smart-home application. For example, the Wi-Fi access point can also serve as a sensor hub that gather room temperature, humidity, CO2 level, etc. to make for a quantified home. The magnetometer on the phone, while assisting with the localization, can monitor whether major home appliances such as the TV and the electromagnetic stove are operating.

The requirement on house-specific training best utilizes the well researched "Wi-Fi Signature" technique to create a radio map of the entire house to start with. The innovation to incorporate chronicle user feedback to improve the house radio map should theoretically improve the localization.

System Design

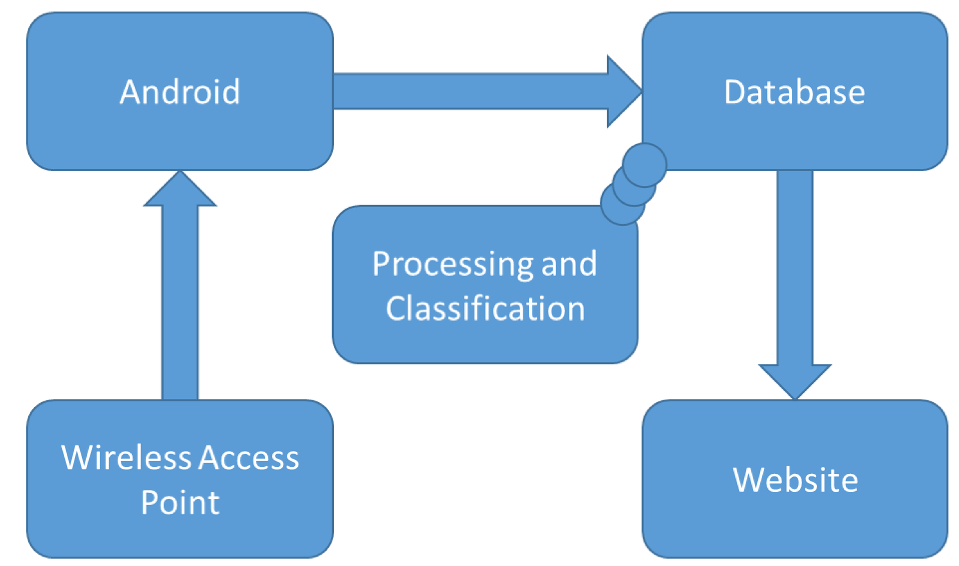

Figure 2 – System Diagram

As shown above, since this system is meant to be a holistic solution to indoor localization in a small area, i.e. a house, it consists of 5 major components, each chosen or developed from scratch.

Wireless Access Points are chosen to be Arduino Yun, due to its ease of configuration as AP and customization for other smart home applications. **Android** is prototyping-friendly and promising with the recent release of the wearable SDK. The App is developed from scratch. **Database** is chosen as MySQL. The **Processing and Classification** resides on a FreeBSD server as a mix of php and scikit-learn Python package. **Website** is built from scratch to be responsive and utilizes AJAX heavily for live info updates.

System Snapshot

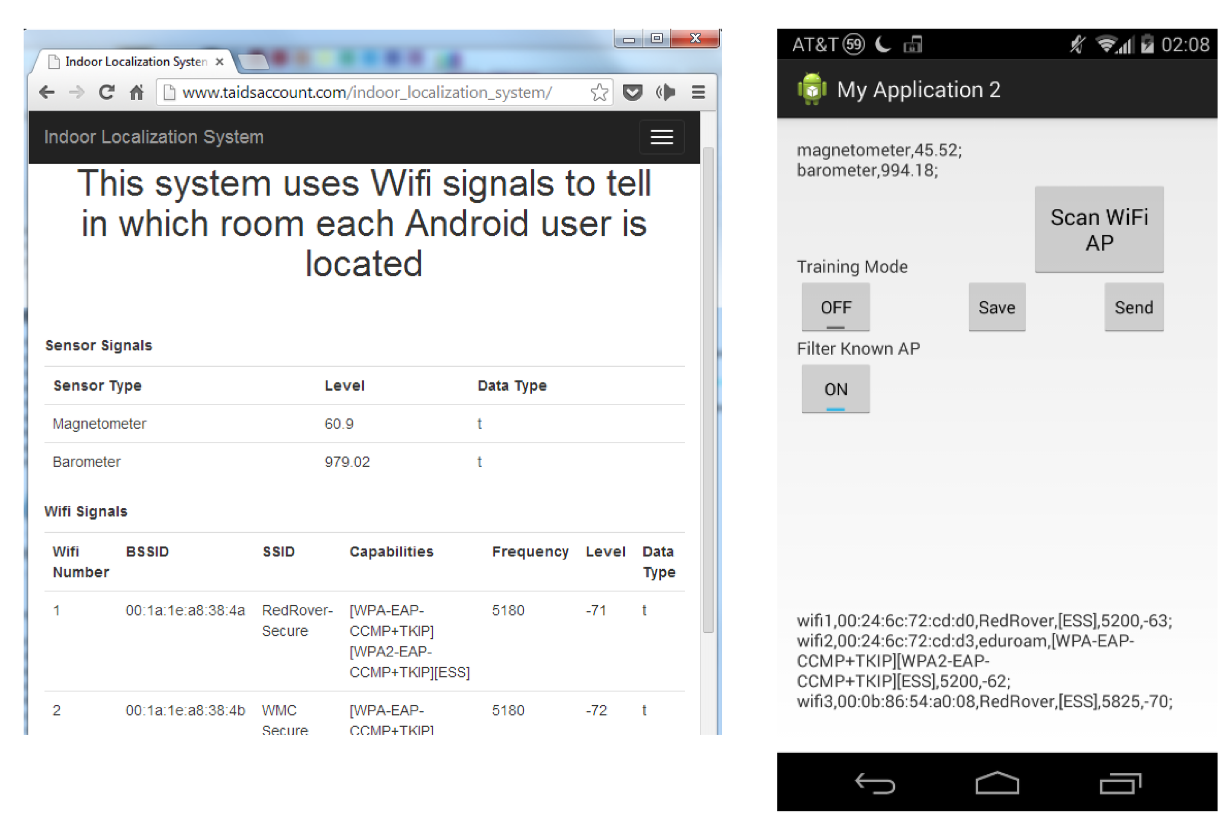

Figure 3 – Snapshot of Preliminary Website (top left), the Android App for data acquisition (top right), and the Arduino Yun module (bottom left)

Implementation

Before the real world implementation, testing is done inside the Carpenter lab upstairs. The system is able to differentiate the three rooms after being trained to use specific Wi-Fi Access Points for reference. Barometer readings are also consistent to be used to localize which floor the device is at. Magnetometer, on the other hand, tends to fluctuate too much to establish a reliable reference level. This could also be due to the fact that given the relative spacious room size, and the magnetic interferences from many computer stations, a lot of noise is captured.

The real world implementation is to be done at a home setting. Figure 4 illustrates the process of the indoor localization process. For simplicity, only the floor plan on the second floor is shown.

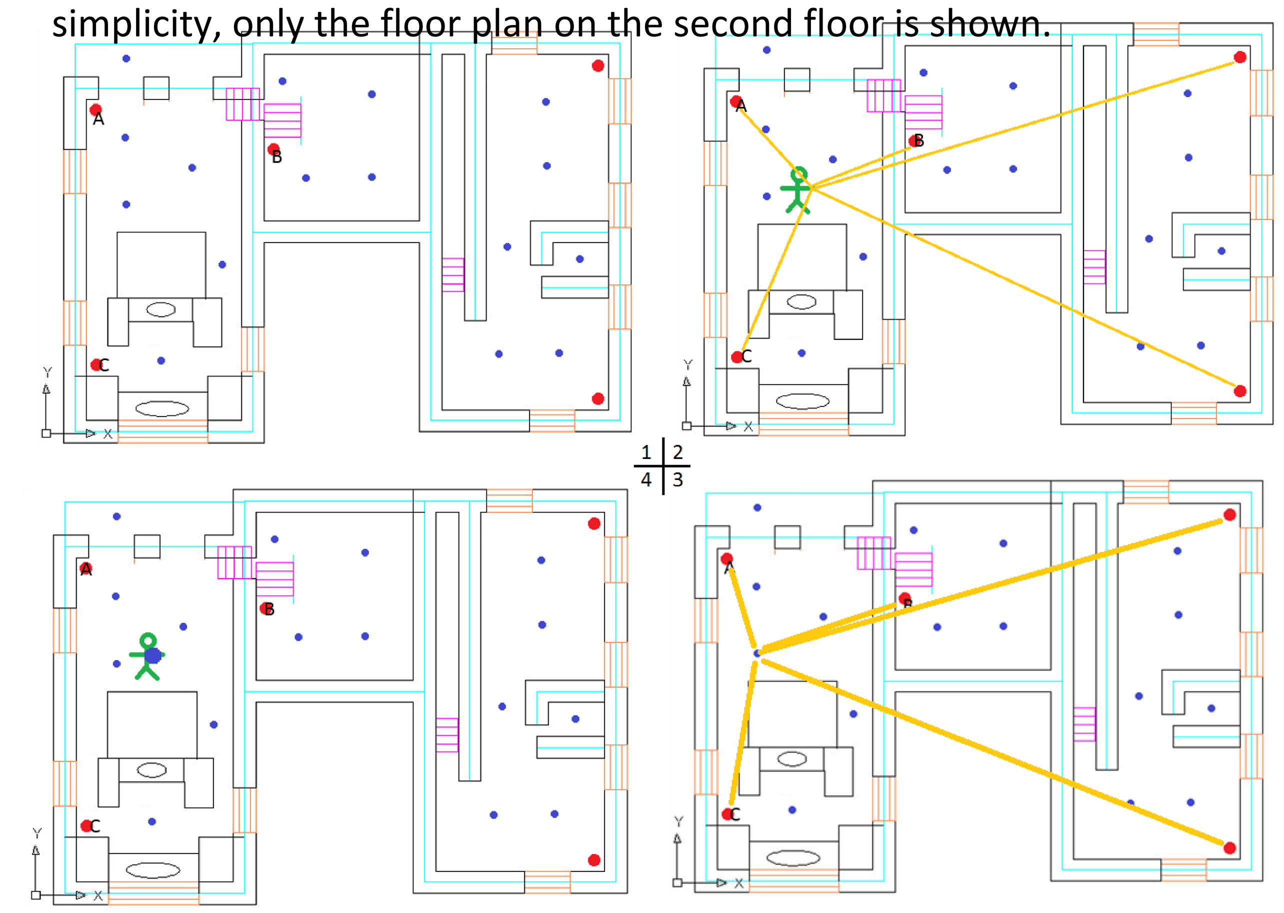

Figure 4 – System Implementation Workflow. Red dot represents known Wi-Fi Access Points. Blue dot represents the training location to gather Wi-Fi signal strengths as the signatures. Yellow line represents the Wi-Fi signal.

As shown, with the Wi-Fi Access Points strategically placed, a number of locations are chosen to measure the time-averaged Wi-Fi signal strength. These training locations will act as the "signatures." When the user is inside the room, the Android phone captures the real-time signal strength from all known Access Points to generate a sample dataset, which is compared with what was stored for the "signatures" to infer their most likely location. Finally, it is up to the user's discretion whether to recommend this instance of sample measurement to be stored as one of the "signatures" in the training dataset. However, the system has the final authority on whether to store it, depending on its similarity to existing training data and other factors.

Considerations

The SAIL focuses on real-time localization, which requires varying skillsets from in-class assignments done in Matlab. The implementation is unpolished, but sufficient for the purpose of a prototype. As discussed, the system aims at a narrower band of users who are likely early adopters of a smart home. Therefore, it has the advantage of being built on existing infrastructures economically, and engaging the user to actively improve the system overtime. Longer testing is needed to evaluate the performance and the user behavior should also be taken into account for system improvement.

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