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From: BEST (Beacon-based Evacuation System and Technology)
Bacon Beacon

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Summary

Two teams were formed, one for surveys and the other for experiments. For experiments, collected the data between Received Signal Strength Indicator (RSSI) and the Range of relationship to make the training data. This data will be processed using Machine Learning (ML). During the experiments, issues such as fluctuating signals and ESP32 performance occurred, but they were resolved. The issues will be resolved later with the newly provided beacon.

What "BEST" completed this week

- Abstract and Introduction
  - Finished with the Introduction and Abstract, and team members had a deliberated about Introduction, and tried to make the Introduction easily readable. Based on Introduction, we started writing Abstract.

- Modifications of Overview
  - Our team started discussing about which kind of packets to use.
    - For the Raspberry Pi which detects fire and sent to server, we use HTTP request instead of TCP or UDP packet, because Raspberry Pi sends HTTP packet only if they detect fire. The reason why TCP and UDP is not suitable is maintaining the connection every moment is unnecessary. For UDP, we cannot know whether the packet has been sent successfully or not.

    - For the smartphone and server, if server notices fire from Raspberry Pi, it sends notification to the Google and Apple cloud server to make notification to the iOS and Android device.

    - If the iOS and Android device starts to run the BEST application, socket communication will start to begin. Discussion which type of communication is most suitable, considered which to choose TCP and UDP packets, but it was not suitable for a Real-time communication. Therefore, conclusion was using socket programming to keep Real-time communication.

- Choosing Methodology
  - Filtering Algorithm
    - RSSI is very much sensitive data. It easily fluctuates by varying factors (e.g., obstacle, multipath propagation). That is why it needs to be filtered before used.

- AR Navigation with computer vision

  AR Navigation that uses computer vision and location markers has been widely used in indoor localization. AR navigation system captures 3D maps with advanced computer vision. It fuses 2D markers that already located specific positions and 3D features. The system tracks users with visual simultaneous localization and mapping (SLAM) algorithms to achieve continuous tracking [5]. However, computer vision and detecting location markers in a fire situation can be incredibly challenging. The BEST will use AR to show the correct path using beacons and Wi-Fi, rather than a navigation system using computer vision and SLAM.

- Indoor Localization with Wi-Fi and Beacon

  Wi-Fi was once the most reliable way to track the location of devices. Although, because the cost of an Access Point is too high, Beacon was chosen. RSSI, which stands for signal strength, is used by beacons to track the exact location of devices. According to this lecture, the accuracy of combining Wi-Fi and Beacon is 20% higher than the Wi-Fi by itself.

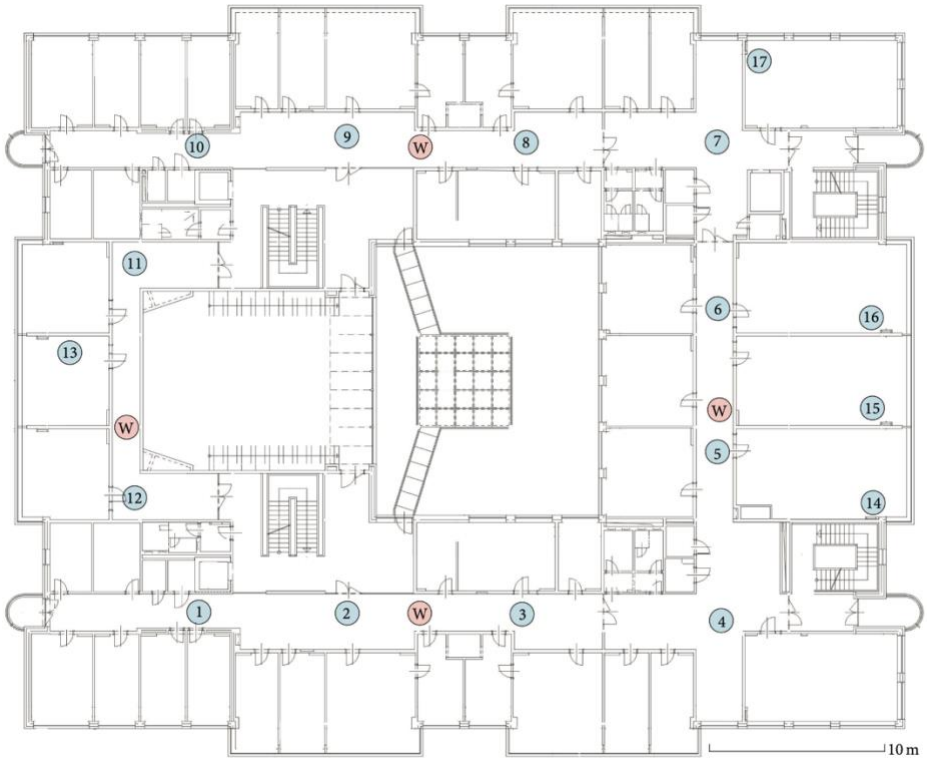

Fig. 1. Indoor Localization by Wi-Fi and Beacons [2]

Fig. 1. describes how to locate Access Points and Beacons to improve indoor localization.

- Trilateration

  One of the most commonly used techniques for indoor localization is trilateration. If there are more than three reference nodes, the calculation will be based on the three with the highest RSSI values. Once the three closest reference points are determined, the coordinate system is then adjusted to the center of the closest reference. Localization techniques could use trilateration as a methodology. When beacons are arranged in a straight line, trilateration operations are inaccurate [15].

- Experiments
  - In terms of cost, the ESP32 beacon was chosen over the Raspberry Pi.
  - Enhanced signal strength makes mobile devices (iOS, Android) detect iBeacon smoothly.
  - ESP32s have been developed by Arduino IDE, and they work as iBeacon [3].

Fig. 2. Experiment of Relation between RSSI and range

Tested by marking on every 0.5m, and placed the iOS and Android device on every title mark.

- Mobile Application

Mobile Devices can detect the Universally Unique Identifier (UUID), Major, Minor, RSSI and Proximity from the iBeacons. The applications have been programmed to detect information from iBeacons, and save it as CSV files. IOS application has been developed with Core Location Framework from Apple [8], and Android application has been developed with Altbeacon Framework [13]. Signals from three ESP32s have been tested by iPhone12 and Galaxy A30.

Now, our team made an experiment about correlation between RSSI and range. As the distance gets farther, strength of RSSI gets weak.

Generally, it shows that RSSI reduced exponentially. Some exceptions were shown the outliers values of the RSSI.

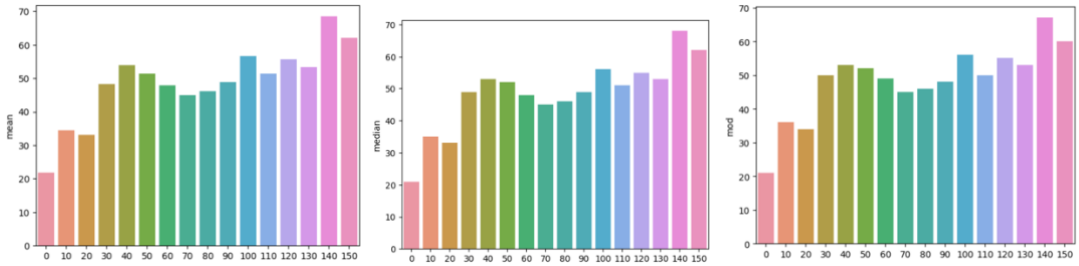

Fig.3. Mean, Median, Mod of RSSI received by iOS

iPhone12 was used as iOS device. The modulus of RSSI value is illustrated at the graph.

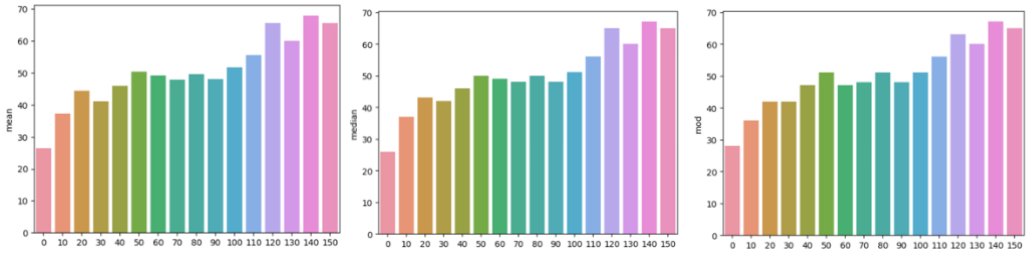

Fig.4. Mean, Median, Mod of RSSI received by Android

Galaxy A30 was used as Android device. The modulus of RSSI value is illustrated at the graph.

Fig.3. and Fig.4. shows when the distances between beacons and smartphones get farther, strength of RSSI becomes weaker. The distance was increased by 10cm.

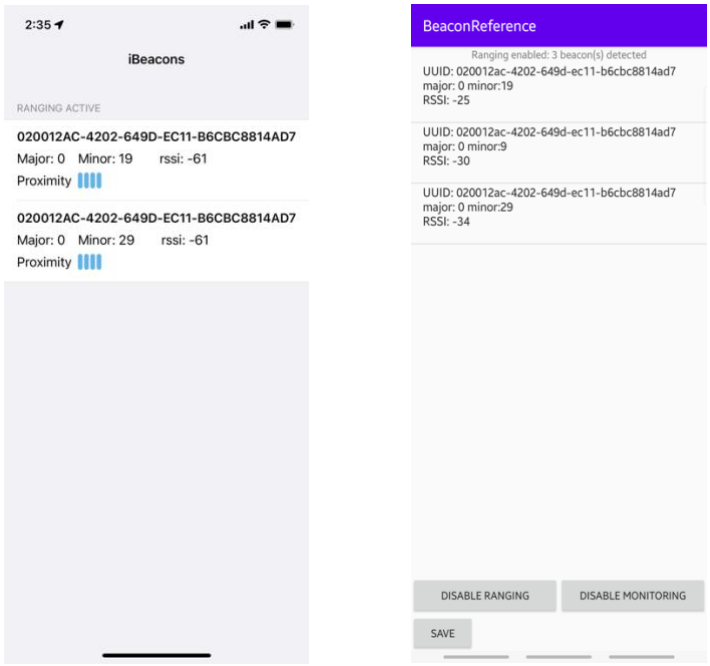

Fig. 5. iOS and Android Application

Fig. 5. shows the list of UUID, Major, Minor, RSSI value of detected iBeacons.

- Paper Review

  Indoor localization [1], [2], [4], [7], AR Navigation [5], Beacon [14], [15] were the main topic of papers presented by team members. Among those papers, "Optimization of BLE Beacon Density for RSSI-Based Indoor Localization" [15] is the article we used as a reference for our future studies.

  The ideal number of BLE beacons for indoor localization has been investigated to achieve optimal accuracy [15]. To achieve this, as a result of comparing some algorithms, trilateration, nonlinear least squares, and two types of filtering, moving average and Kalman, was concluded to use.

  Consequently, the best result was been achieved using a nonlinear least-squares algorithm with the three closest references and a moving average filter, with the lowest error of 1.149 meters and a standard deviation of 0.698 meters.

Things to do by next week

- Methodology for indoor localization
  - The experiment will be conducted with Trilateration and Nonlinear Least Squares by using smartphones and ESP32.
  - The experiment should be tested several times to get accurate indoor localization.
  - Data from mobile devices that include information from iBeacons will be collected, and used to make a path-loss model.

- Methodology for filtering Algorithms
  - Seminars for Moving Average and Kalman Filter are planned to be start[15].
  - Support Vector Regression (SVR) model and Kalman Filter-Support Vector Regression (KF-SVR) are planned to have seminars [16].

- Methodology for evacuation Algorithms
  - Seminars for A* Algorithms.
- Additional Seminars for Machine Learning
  - As team members are not familiar with ML, have to start studying.
  - Previous research predicted the location of stable objects [15], but our goal is to pinpoint the exact coordinates of the moving objects.
  - The experiments will refer to supplementary article such as "Distance Estimation on Moving Object using BLE Beacon" [16] to detect the moving objects.

- Beacon detection experiment with new equipment
  - Conduct experiment that smartphones detect RSSI from beacons using brand new beacons that we ordered.
  - Compared the detection data between RSSI and the previous result using ESP32.

Problems or challenges:

- Beacon Detection problem
  - Developed an application which detects iBeacon devices. However, problem occurs when getting a RSSI value.
  - Relationship between RSSI and distance is not as good as our team expected. For example, the signal of 20cm is weaker than signal of 50cm. We will solve this problem by conducting more strict experimental environments and using different beacons.
- Paper work
  - The paragraph in the introduction was too wordy and complicated, so we decided to take baby steps and solve the problem.
- The references analyzed by our team will be employed in future research.

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