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

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Summary

Each team member studied at least two references while working on the abstract and the introduction draft and deliberated which techniques could be ut dilized in the *BEST* and which novelties might be emphasized. Due to this research necessitating machine learning knowledge, *BEST* discussed taking the Machine Learning course. The ESP32 was used as a core device and developed by the open-source Arduino IDE to build the beacon. Lastly, the Raspberry Pi and smartphone detected the beacons.

What "BEST" completed this week

- Abstract and Introduction
  - Team members had a meeting about how to write Abstract, and Introduction of paper.

- Modifications of Overview
  - In the previous overview beacon was planned to send their coordinates to the users. Due to the fundamental limit, the plan was changed to calculate the location using UUID, Major, and Minor values sent by beacons, and the beacon's coordinates have been saved in the server and retrieved directly.

- Choosing Methodology
  - Pedestrian Dead Reckoning (PDR)

    Pedestrian Dead Reckoning (PDR) is a potential autonomous localization technology that employs built-in sensors to estimate position [1]. When a person holds a smartphone horizontally, PDR assumes that walking direction and direction oriented by the smartphone are the same. However, they do not consider backward or lateral movements. PDR encounters problems with abnormal walking patterns [7]. In addition, if the smartphone pointing does not match the walking direction, localization will fail. Therefore, PDR should not be the key technology for indoor localization within fire situations.

o 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.

o 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 th\an Wi-Fi by itself.

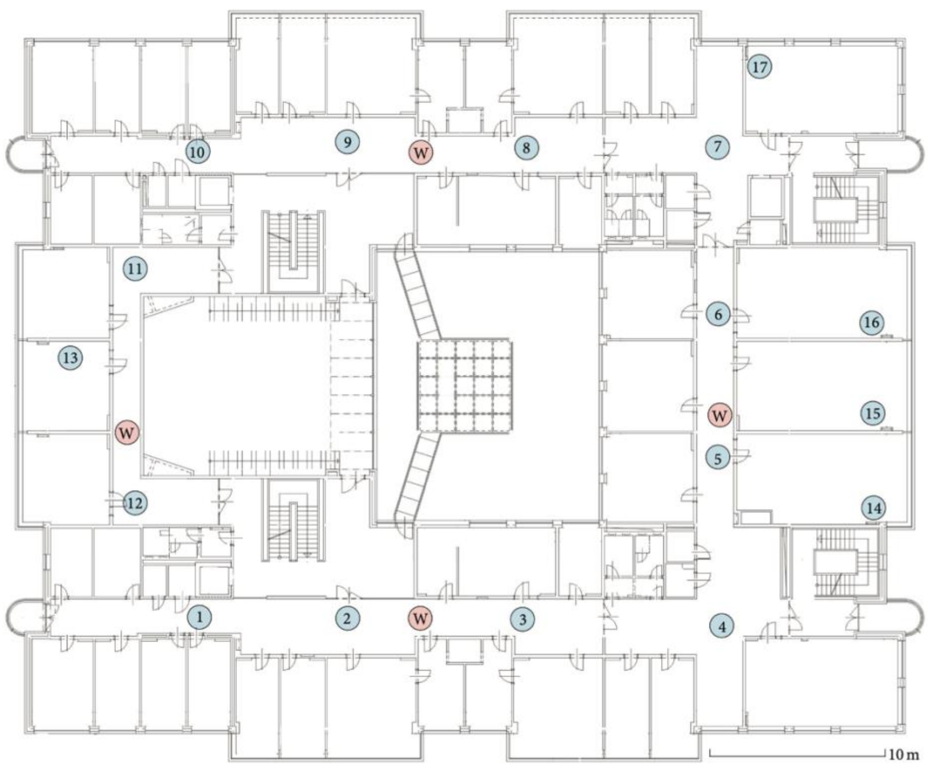

Fig. 1. Indoor Localization by Wi-Fi and Beacons [2]

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].

- ESP32s are now operated as iBeacons
  - 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. ESP32 as iBeacon

Fig. 2. shows ESP32 as iBeacon, and tested with iOS and Android Devices.

- Mobile Application

  Mobile Devices can detect the Universally Unique Identifier (UUID), Major, Minor, RSSI and Proximity from iBeacons. The applications have been programmed to detect the 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 Pixel3. Each ESP32 has different signal power.

Strength of iBeacon Signal	Percentage of detected iBeacon	
	iPhone12	Pixel3
-127	77%	81%
0	23%	11%
128	0% (Detected but RSSI cannot be measured)	8%

TABLE I. Relationship between Strength of iBeacons and RSSI of mobile devices

TABLE I. shows that when the signal of ESP32 is weak, the percentage of detected iBeacons by smartphones is decreased. The percentage are rounded to

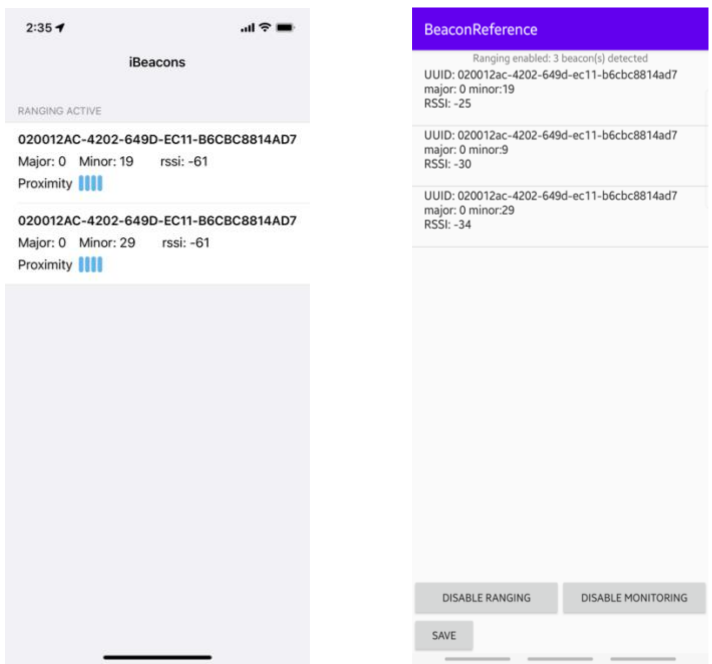

Fig. 3. iOS and Android Application

Fig. 3. 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 among the papers presented by team members. Among those papers, “Optimization of BLE Beacon Density for RSSI-Based Indoor Localization”[15] is one of the articles we used as a reference for our future studies.

The ideal number of BLE beacons for indoor localization has been investigated to achieve optimal indoor localization accuracy[15]. To improve the indoor localization accuracy, two algorithms, trilateration, nonlinear least squares, and two types of filtering, moving average and Kalman, are used. 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 will be started [15].
  - Seminars for Support Vector Regression (SVR) model and Kalman Filter-Support Vector Regression (KF-SVR) will be started [16].

- Methodology for evacuation Algorithms
  - Seminars for A* Algorithms and Dijkstra Algorithms.

- Additional Seminars for Machine Learning
  - As team members are not familiar with Machine Learning, have to start studying Machine Learning.
  - 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 articles such as "Distance Estimation on Moving Object using BLE Beacon" to detect the moving objects

Problems or challenges:

- Beacon Detection problem
  - Developed an application which detects iBeacon devices. However, problem occurs when getting a RSSI value.

- Absence of data about relationship between RSSI value and real range
  - Solved the problem by developing BLE detector via Raspberry Pi, which collects UUID, major, minor, RSSI for the data. We will collect data and apply it to Machine Learning.

- Raspberry Pi costs too high
  - Professor Smith advised using ESP32 rather than Raspberry Pi.
  - Start developing building ESP32 as Beacons.

- Novelty of paper have not set yet
  - Discussion about future objective: Child vs Accuracy.
  - We decided to focus on every people, not only child.
  - Have to work on the articles based on fire victims, and smoke.

- The references analyzed by our team will be employed in future research.

Reference

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