Beacon and Wifi based Indoor Fire Evacuation System using Augmented Reality

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***Abstract*—The inefficiency of evacuation has been the issue since the present evacuation method is unsuitable for complex buildings in mass society. In large and complex buildings, estimating the evacuee's present location is challenging, especially when there are fire threats such as high temperatures and explosive objects. Furthermore, due to the smoke and collapse, no safe and quick evacuation path can be founded. Victims may be perplexed by the navigation, which is not intuitive for this situation. BEST (Beacon-Wifi-based Evacuation System) aims at three main components needed to make efficient: high accuracy of indoor localization, real-time optimized route algorithm, and user-friendly augmented reality (AR) navigation. First of all, the Extended Kalman Filter (EKF) and machine learning-based triangulation were utilized to estimate the user's location accurately. Second, for dynamic individual fire evacuation path decisions, an optimized route recommendation based on the A* algorithm was designed, which considered the components of buildings and disaster information. Lastly, coming up with a more simplified way to utilize Augmented Reality(AR) to help guide the shortest path without any confusion is one of the main goals.**

***Index Terms*—Bluetooth Low Energy, Augmented Reality, iBeacon, Indoor Localization, Real-time communication**

I. Introduction

From 2017 to 2019, 106,700 multifamily residential building fires were reported in the United States, resulting in 400 deaths, and 3,875 injuries [1]. When a fire occurs in a large and complex building, people who do not know the building's structure would be exposed to a danger. It will be difficult for them to be aware of their current location, as well as the exit route and the location of fire hazards in a panic situation. The inefficiency of the current evacuation method could be fatal when evacuating fire victims safely from the fire [2]. Therefore, safe, and efficient evacuation systems that can estimate the evacuees' current position has been studied to handle such problem. Three components of these studies have been categorized into indoor localization, optimized route algorithm and navigation.

The most common indoor localization method is using wireless electronic devices that utilize the WIFI localization method. The WIFI localization approach indicates Access Points (AP) [3], although it does not show the user's exact location. Some studies used the Pedestrian Dead-Reckoning (PDR) [4] method; however, since the situations during emergencies are different, the result of notifying the location by footstep was inaccurate. Optimized route algorithms are conducted with Dijkstra's algorithm and A* algorithm [5] [6] improved for the fire evacuation situation. These approaches place emphasis on calculating the shortest distance or time to find optimized route, and they are prior factors for selecting path. However, the error of these algorithms is lack of consideration that can influence safe and quick evacuation. Temperature, congestion, location of explosive objects, and evacuation components have not take into account, and these factors are not updated in real-time. These systems cause evacuee not to notice various hazard, eventually put them in danger. Studies of navigation system have been conducted two-dimensional (2D) based navigation and vision based navigation [5]. In case of fire evacuation, 2D-based navigation has its limit on being dependent on angle and detecting the actual escaping route in complex building. Smoke and collapse from fire give rise to malfunction of recognizing the exact location.

In this paper, we would like to propose BEST (Beacon-Wi-Fi based evacuation system). The BEST method utilizes smartphones that catches the beacon signal calculating the Received Signal Strength Indicator (RSSI) [7]. It filters the fluctuation of the RSSI with EKF (Extended Kalman Filter)

[8]. Support Vector Regression (SVR) and triangulation [9] can be used to estimate the current position and the indoor decision-making scenarios. Raspberry Pi detect fire and check the beacons for maintenance. Temperature sensor and humidity sensors were used to detect fire, and the status of the Beacon will be used to check malfunctions of the beacon. During an actual situation of fire, it will be used to monitor hazards. The server calculates optimized escaping routes with estimations of the victims' current location in real time. Sensor-based disaster context information and the components of buildings such as the location of flammable objects and evacuate components were designed using the A* algorithm [6]. It stores map data and user's current location. When storing data, server provides user's ID and matches the user ID to specify individual's information and location. Utilizing AR implementation developed to work for both iOS and Android platforms will help the fire victims to implement the optimized route allowing them to evacuate safely [10].

The main contributions of this article are summarized as follows:

- In this article, BEST propose high accuracy indoor localization system using Beacons and Wi-Fi. For precise estimation, triangulation combined with EKF data and SVR were used. Filtered RSSI with EKF and SVR model can estimate the distance the receiver and transmitters. The accurate estimation of user's current location will be derived.
- For dynamic individual fire evacuation path decision, optimized route A* Algorithm with consideration of hazards and components of buildings were designed. This route will be sent to each user in real-time.
- To prevent the accident from sight-blocking situation, user-friendly AR technology was adopted. Evacuee will be provided both two-dimensional (2D) map and three-dimensional (3D) AR navigation to notify the whole map with current location and direction.

The remainder of this paper is organized as follows. In Section 2, related work is presented. In Section 3, we will discuss about how we build our project. Section 4, we will explain about experiments settings. On Section 5, the result of experiments are evaluated. Section 6 then concludes this paper.

II. Related Work

To improve the accuracy of localization with BLE beacons, trilateration and Kalman Filter are utilized [11]. BLE beacons periodically broadcast bluetooth signals representing it's identity. The packet of the BLE beacon contains identifying information such as UUID, major value and minor value. A mobile device estimates the self-position by receiving beacon signals. The distance between the BLE beacons and the mobile device is calculated by measuring the strength of the received signals [12]. The closest beacons to the receiver have the strongest received signal strength indicator (RSSI) values. However, the propagating signals are commonly susceptible to noise and it can cause significant errors in RSSI values.

Filtering algorithms can be use to reduce the error that can occur with fluctuating RSSI values. There are several filter algorithms such as Moving average, Moving Median [13]. One of the most common filters used to smooth RSSI is Kalman Filter [14]. Kalman Filter is optimized estimation filtering algorithms for linear system. It recursively predict the filtered RSSI based on the previous estimation and update the predicted value with the measurement [9]. Feasibility of Indoor localization with Kalman filter will be fulfilled when the receiver gets the signal in same distance or in constant velocity. The arguments in process phase should be selected appropriately to reflect tracking victims for optimal estimation. However, in fire evacuation case, the assumption that evacuees move constantly cannot be satisfied. In the limited situation which acceleration has not been modeled, the filter would uncertainty [8]. Therefore, BEST selected the Extended Kalman Filter(EKF) that provide optimized recursive estimation based on Bayes' theorem for nonlinear system that added Gaussian noise.

By using filtered RSSI, User's location can be found by Trilateration is used as the way in [12]. When receiving the beacon signals at a mobile device, the device calculates RSSI values with the signals. 3 beacons which transmit the signals generating strongest RSSI values are used for calculation. RSSI value is strong when it is close to the user. For triangulation, each beacon is set on a coordinate system. The distances between the receiver and the beacons are calculated by a machine learning model. With the coordinates and the distances, the target location can be estimated.

After figuring out the target location, an optimal evacuation route has to be configured based on the estimated location. In previous study [15], Dijkstra algorithm can be utilized for generating the optimal evacuation route. Deployed beacons are defied as nodes of Dijkstra algorithm. The estimated location is a start node, and emergency exits are goal nodes. If fire occurs in the middle of the graph, the graph is re-generated in real time.

Although there is already lots of study about using the Dijkstra algorithm for evacuation system because the size of the weights directly reflects the road's evacuation status [16]. Although, Dijkstra's critical flaw is that it explores all possible routes, wasting a lot of time and resources [17]. The A* algorithm is a graph search algorithm that uses a heuristic estimate function to find the best path from a given initial node to a goal node. Heuristics can help reduce the number of options from an exponential to a polynomial [17]. To compare the running times of A* and Dijkstra's distributed systems while keeping the constraints as similar as possible. The goal of our reasearch is to provide an evacuation system that can be used in large-scale buildings and multi-user situations. This would necessitate computing the shortest path in the shortest amount of time, which could be computationally intensive [18]. To reduce the server's load and evacuate fast as possible a* algorithm is selected for the path finding algorithm.

Our research proposes an optimal evacuation route using A* algorithm, since it has a lower time complexity than Dijkstra.

Especially in a fire situation, the design and update of the evacuation routes should be performed quickly. Therefore, A* algorithm which guarantees a lower time cost is selected for creating the optimal routes.

The evacuation routes were traditionally presented in static 2D methods [10]. In an emergency, such as when it is hard to secure sight of the building, the static 2D methods have visual limitations. Users have to use their spatial ability to interpret 2D maps to locate their position in the 3D building. This situation is overcome in our article by supplementing the visualization using AR.

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