Development of an optimization route guide application for indoor fire evacuation using beacons

1st Junseong Moon
Department of Software Convergence Education
Jeju National University
Jeju, Republic of Korea
jsmoon@jejunu.ac.kr

2nd Minsoo Sun
Department of Computer Engineering
Jeju National University
Jeju, Republic of Korea
tjsalstn33@gmail.com

3rd Migyeong Kim
Department of Computer Engineering
Jeju National University
Jeju, Republic of Korea
rmfosem613@gmail.com

4th Geonyeol Ryu
Department of Computer Science and Engineering
Chungnam National University
Daejeon, Republic of Korea
rjsduf0503@gmail.com

5th Namho Kim
Department of Computer Science and Engineering
Chungnam National University
Daejeon, Republic of Korea
namho.kim2@gmail.com

6th Sarah Horning
Department of Computer and Information Technology
Purdue University
West Lafayette, United States of America
shornin@purdue.edu

***Abstract*—Recently, beacon has been used to develop an evacuation system in the event of a fire accident. Beacons are characterized by Bluetooth low power energy and are used in various fields as they can measure indoor positions more accurately than other technologies. This study aims to develop an application that informs the optimal route for fire evacuation indoors using beacons. In detail, It is intended to develop an application that can be used in various buildings, not just specific buildings, and can guide the optimal route in consideration of the number of people in the building, not just the location in the building. For this paper, multiple algorithms(will modify) were developed and implemented into the application that use beacons to determine the exact location in a building, automatically analyze the design of a building, and one that calculates the weight value by grasping the density of people.(will add FUTURE PLAN)**

***Index Terms*—Bluetooth Low Energy(BLE), Beacon, Indoor positioning, Optimization Path**

I. Introduction

Still, damage due to fire accidents continues to occur. According to the U.S. Fire Administration, the average number of fire accidents from 2010 to 2019 was 1,300,000. Among these, fires in buildings have a high figure of 39.3% [1]. According to the NFPA(National Fire Protection Association) in 2021, a fire breaks out in the structure at a rate of and every 64 seconds and a house fire breaks out every 89 seconds [2].

In order to prevent accidents involving indoor fires, this study was conducted by developing an application that informs the optimal route for indoor fire evacuation by using beacons. Beacon is a short-range wireless communication technology based on the Bluetooth 4.0 protocol and features low power energy (BLE) [3] [4]. In particular, Beacon has advantages such as long transmission and reception range, low power consumption, accurate indoor location, small size, and convenience [5] [6]. Because of this, it is mainly used in university attendance systems [7] [8] or marketing strategies to inform consumers of useful information such as discount news and coupons at nearby stores [9] [10].

As the number of beacons being used is increasing, there has been an increase in studies related to them being conducted. For example, there are studies on location-based systems that help search for locations inside buildings using BLE beacon technology, and studies to improve the accuracy of smartphone user locations connected to beacons [11] [12]. In addition, there are various cases, such as research on the development of a beacon-based indoor non-approver monitoring system, mobile navigation using beacons in indoor exhibitions, and autonomous evacuation guidance systems using beacons [13] [14].

However, in existing studies, there is a limitation in that it cannot be used in other environments for specific buildings. The autonomous evacuation guidance system, one of the existing research cases, identifies the location of the beacon closest to the user, estimates the location of the user, and informs the route [13]. These studies have a problem that users do not consider how many people are gathered in the building and which route is the most optimized route.

Therefore, a generalized system that enables accurate location identification in other buildings should be designed, and it should also take into consideration the location of the user in the building.

In this paper, the goal is to develop an application to find an optimization path in a building using beacons. Unlike other cases targeting a specific building, this makes it possible to use

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it in general situations. To this end, it is significant in that it develops a user-friendly application by providing users with functions such as installing beacons directly in the building where they are located and entering designs. It is significant in that the situation is checked in real time in consideration of the density of the number of people in the building and the optimal route is found by placing a weight value thereon.

For this purpose, the detailed goals of this study are as follows:

- Use beacons to determine the exact location of the user in the building.
- Develop user-friendly applications such as informing users of the beacon installation location by providing users with the ability to enter and modify building designs.
- Identify the density of people in the building and calculate the weight value to inform the optimal path.

II. Literature Review

Beacons are small, inexpensive devices which periodically transmit packets of information to all nearby BLE enabled devices [15]. It is a small signal transmitter and has applications in areas such as indoor navigation, mobile payment, store browsing, indoor positioning and item tracking. Beacons have been created as the latest solution to solve the disadvantages of being vulnerable to obstacles and structures when used indoors.

Based on the characteristics of these beacons, there are research cases on how to apply the indoor positioning system to the mobile navigation application and how visitors use the navigation system. Liu, Hsieh said that due to accuracy problems, indoor positioning is not as widely used in everyday applications as outdoor positioning systems, and there are few types of services to be provided. In this study, if the accuracy of indoor positioning can be improved, the service model of the outdoor positioning system can be expanded to indoor use. [16].

Another study was conducted on the accuracy of indoor location using beacons by Phutcharoen *et al*. In this study, in order to increase the accuracy of the indoor location, the accuracy was improved by measuring several times. The case of one measurement is studied and compared with the case of an average of five measurements. From the results, it can be seen that the average and median values of distance errors could be reduced by 0.86 m and 0.90 m, respectively, compared to a single measurement. They showed that the average multi-measurement can increase the accuracy of indoor positioning because it reduces the effect of multi-path fading that occurs densely in an indoor environment [11].

Another study was conducted on the escape guidance system using beacon information and Dijkstra's Algorithm by Shmizu and Kushida. This study improved the existing system [17] in which users select emergency exits to implement the automatic evacuation exit and route determination function in mobile devices and demonstrated the efficiency of the integrated system through evacuation induction experiments [13].

However, existing studies only take into account location data, so it is not possible to consider how many others are gathered, and studies on accuracy improvement have a limitation that it is difficult to use in other buildings because it was measured only in specific buildings. In this study, in order to improve these limitations, an application that can be used in any building was developed by considering the location of all users.

III. Methodology

A. Application structure

In order to achieve the purpose of this study, the flow of application structure were designed as shown in Fig. 1.

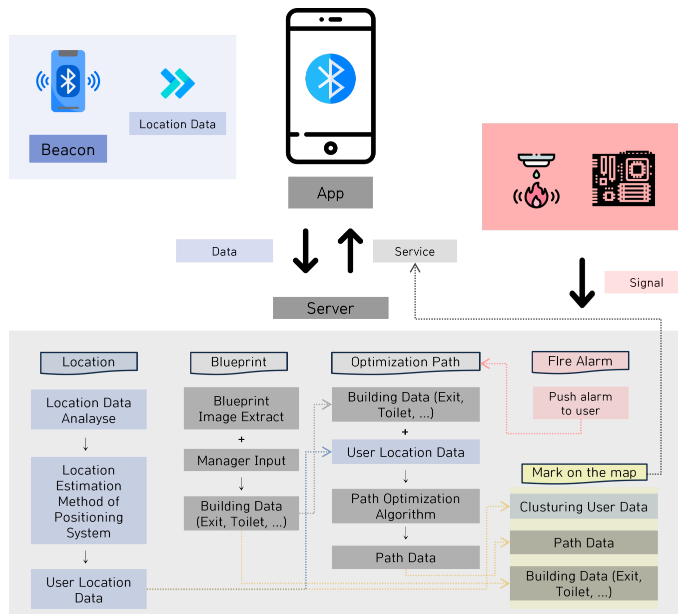

Fig. 1. Flow of application structure

When the manager uploads a blueprint for each floor, the application converts it to a map, and the administrator enters the name of each room Using Bluetooth beacon, the user's location data is obtained. In peacetime, the application shows an optimized route to the destination that the user wants. In the event of a fire, a fire alarm that is linked to the server notifies the server of the occurrence of the fire, and the server notifies the user of the fire through the application. The application displays the current population cluster and the fastest escape route from the current user location on the map.

B. Image scanning

In order to implement an application that can be used in any building, a program for image scanning was created. After graying was performed using OpenCV, a threshold was arbitrarily set using the Oats algorithm, divided into two categories, and the operation of calculating the contrast distribution of the two categories was repeated. Among the numbers of all cases, the threshold value, when the distribution of the two classes was the most uniform, was selected. After that, the elements inside were erased and the remaining noise was removed using a denoising function. The results related to this are presented in Fig. 2.

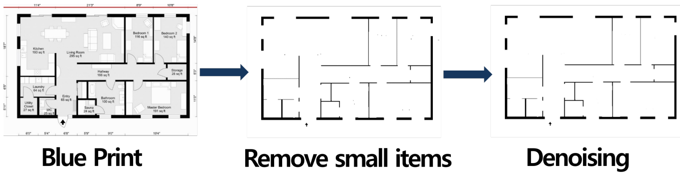

Fig. 2. Result of image scanning

C. Location measurement

In order to measure the position, the trilateration method was performed using the signal value sent from iBeacon.The iBeacon has Tx Power(transmission strength) and RSSI (reception strength). Through this, it is possible to obtain a straight line distance between iBeacon and a smart device [18] [19]. At this time, if at least three distances can be obtained, the trilateration method can be used to find the indoor location.

The trilateration method is a popular method for positioning [20]. Trilateration is the process of determining the relative position of a node (Observer) by distance measurements from other anchored nodes (Broadcasters) [21].

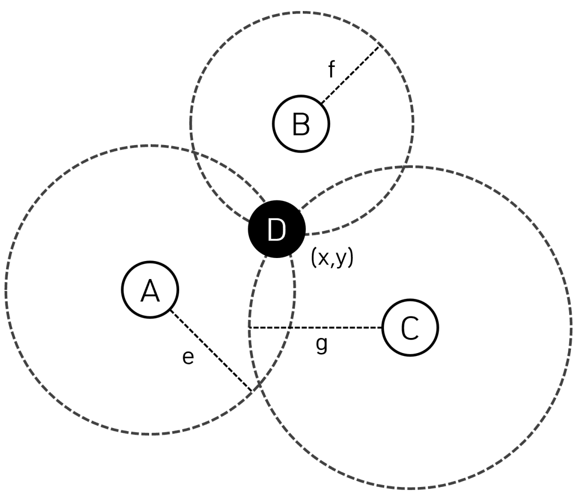

Fig. 3. Setup for trilateration

$$RSSI = -10n \log_{10} d + C(Txpower) \tag{1}$$

$$d = 10^{(C-RSSI)/(10*n)} \tag{2}$$

In order to determine the user's location, trilateration was used as shown in the Fig.3. Nodes A, B, and C are the locations where the beacon is installed, and D is the location (x,y) of the smart device. The calculated distances from nodes A, B, and C to the smart devices are e, f, and g d, respectively, which is determined using the path loss model (1). The RSSI of Equation (1) is expressed as a dbm value. By applying the dbm value to Equation (2), it can be expressed as a distance(m) [15].

However, location measurement is not accurate due to noise generation and signal density(due to obstacles). In particular, signal density has a greater influence on positioning than noise [22]. To solve this problem, when installing a iBeacon, the installation location can be recommended by the application. In order to implement the beacon installation site recommendation, this study conducted data collection on accuracy for specific buildings. The iBeacon installation site with the highest accuracy was identified and tested in other buildings. The location measurement error range in the two buildings was confirmed to be about **(n.m)Meter(정확한 연구 결과 작성 필요).** Based on this, indoor location measurement was performed by recommending an installation site.

D. Route recommendation

The algorithm was designed to show the optimized evacuation route considering the position of the entire user. The equation presented in the existing study does not take into account the number of people [13], so we used a new algorithm.

The time using the A* algorithm was 5ms and Dijkstra algorithm took 18.9ms. However, when searching for an emergency exit, there are many exits, and the weight is calculated as 1, so there may be some time deviation. We chose the Manhattan equation with a heuristic algorithm, the equation is below (3).

$$f(n) = g(n) + h(n) + w \tag{3}$$

g(n) is the cost from the start node to the current node, and h (n) is the expected cost from the current node to the target node. The equation for f(n) is below (4).

$$h(n) = d(A, B) = \sum_{i=1}^{n} |a_i - b_i| \tag{4}$$

When there are a start node A and a target node B, the ↖-direction node having the smallest f(n) among the eight nodes is selected as the next search node, and the direction peripheral node f(n) is obtained again. By searching for the node having the minimum f(n) in this way, calculating f(n) of the peripheral nodes again, searching, and repeating the calculation process, the target node B can be reached.

IV. Implementation

A. Develop Process

The development process of this study is as follows. First, iBeacon was set up to use beacons and a User Interface for application was implemented. In addition, the database and the server were connected so that they could operate in the application. Thereafter, it was implemented to be able to detect a straight distance using iBeacon in the application. Based on the straight distance, trilateration was used to confirm the user's

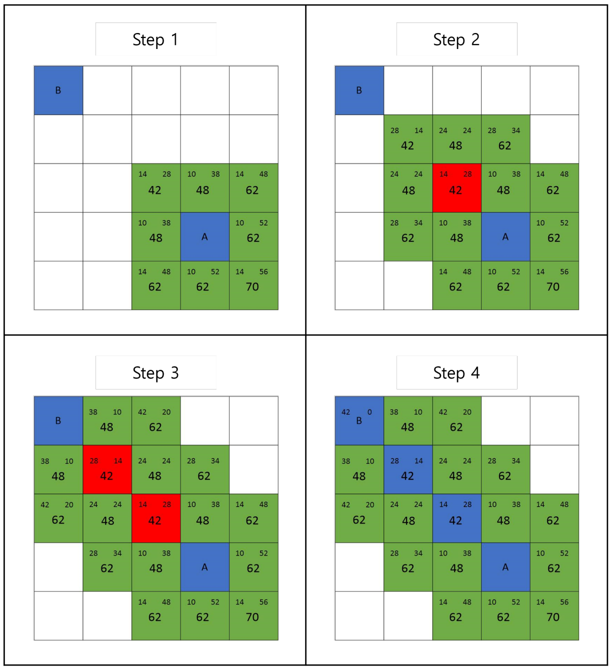

Fig. 4. Path detection method of the A* algorithm

location on the server. In addition, algorithms such as building design image recognition and optimized path recommendation were developed and applied to enable location measurement in multiple buildings. Based on this, tests were conducted to accurately measure location, and beacon installation location recommendation was implemented in the application. The process of this are shown in the following Fig.5

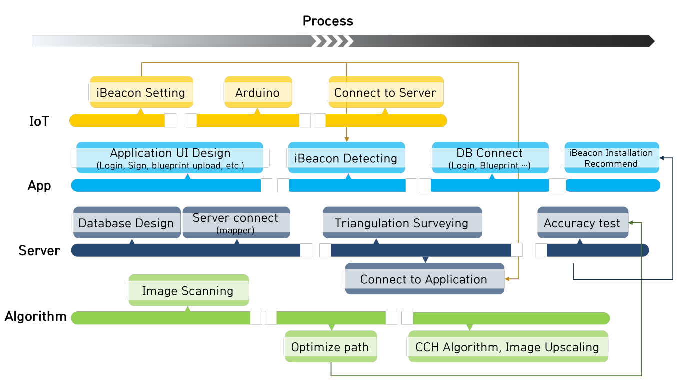

Fig. 5. Application development process

B. Prototype

실험으로 측정한 건물 설계도와 비콘 설치 장소, 아두이노(화재감지 센서,wifi)를 그림으로 보여줌. H/W, S/W 구분하여 보여주고, 맵을 보여주면서 구현한 것이 이런것이다를 뚜렷하게 보이게끔 함(앱을 보여준다는 것이 아니라, 설계도(맵)을 기준으로 이렇게 세팅할 수 있다를 보여주는 것이 좋을 듯)

C. Server Working Flow

서버에서 동작하는 흐름을 그림으로 보여줌(서버 동작 과정만 보여줌. 어떻게 이리저리 돌아다니고 동작하는지 설명 추가)

D. Application

구현 화면 변경이 되면 그 부분 추가하면서 변경해야함 In order to implement the application developed in this study, it was implemented as shown in Fig. 6. A screen was configured to register a manager so that the manager of the building could enter the floor plan of the building. If you do not log in as an administrator, the rest of the functions except for the administrator page function that may input and modify the inside of the building may be used in the same manner. Sidebar Navigation was implemented to make it easier to check the guidance function. In order to guide the optimal route escape, the general situation and the fire situation were divided and configured. In general situations, the population density is shown in a circle, and in the event of a fire situation, the optimal route can be seen.

V. Conclusion

We are going to ....

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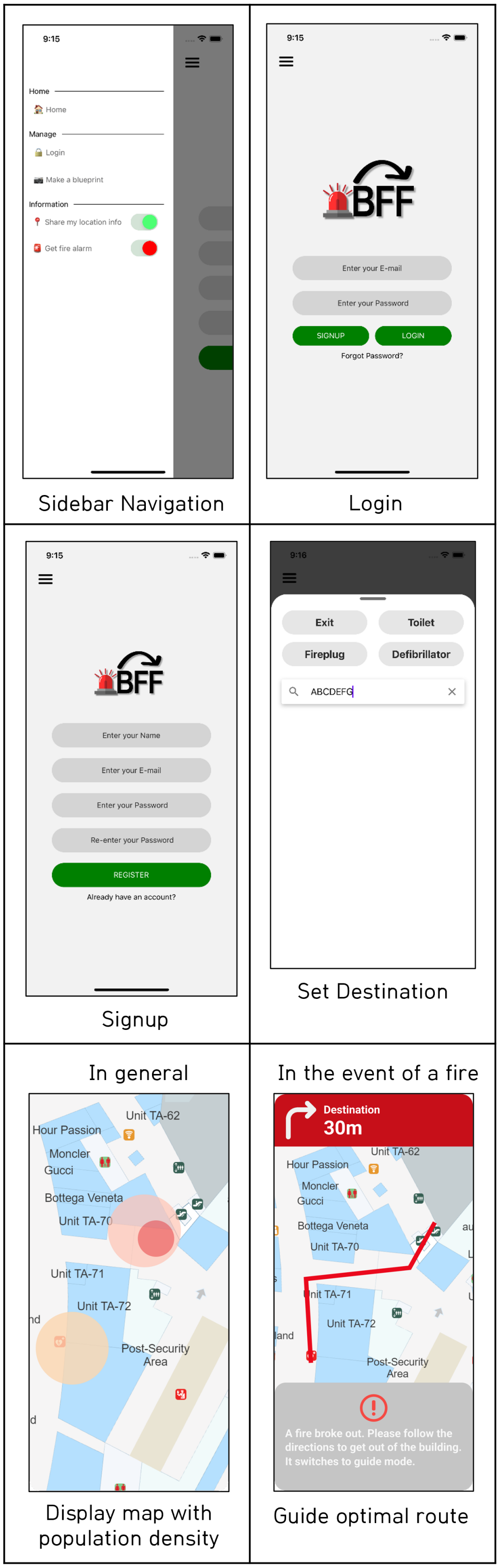

Fig. 6. The screenshot of application

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