

# Indoor Disaster Detection and Real-Time Escape Guidance System

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## Abstract

**Background/Objectives:** When disasters occur in crowded indoor spaces, many property and human lives are lost. Simulate an indoor disaster escape system to minimize damage.

**Methods/Statistical analysis:** Data measured by sensors or disaster robots are sent to middleware responsible for the area. Each middleware uses data to determine whether a disaster has occurred indoors. If a disaster occurs, locate victims of disaster and provide safe escape routes through pre-built maps. Through these methods, we simulate whether a disaster occurred and how well we can identify the escape route.

**Findings:** BLE BEACON was used to locate victims of disaster. Later, he informed the victim of the shortest route to escape through middleware and servers. As a result, they were able to create indoor navigation with errors of about 3 meters. Using this system, it was confirmed that it could escape indoors.

**Improvements/Applications:** The indoor disaster detection and escape route guidance system provides information on the existence of an indoor disaster. And the victim can identify safe escape routes.

**Keywords:** Disaster, Indoor, Escape, Simulation, Detection.

## 1. Introduction

Advances in building technology are creating many large and complex buildings. These buildings have a large floating population. People also work indoors most of the day. The disasters that occur indoors can be attributed to these characteristics, causing a lot of damage to people and property.

In order to prepare for disasters, most countries have been operating national disaster networks [1]. However, since the national disaster network system operates nationwide, it takes a lot of time and money to set up the network. Therefore, national disaster networks are not suitable to identify and prepare for disasters in certain areas, such as hospitals and department stores, and a space-specific evacuation system is needed. The purpose of this paper is to come up with the idea of calculating escape routes in real time from data collected in case of an indoor disaster and simulating the most suitable route among escape routes. In this paper, data collected by the sensor network or the disaster robot is sent to middleware responsible for each region in the event of an indoor disaster. Each middleware determines whether it is a disaster. If a disaster occurs, send a disaster warning message to the server. The server identifies safe locations and applies them to pre-built maps to identify escape routes from current disaster victims.

## 2. Materials and Methods

In this paper, disaster detection and real-time escape calculation systems are conducted through middleware[Figure 1]. The system

to guide disaster victims to evacuation consists of the sender, receiver and map data[Figure 2].

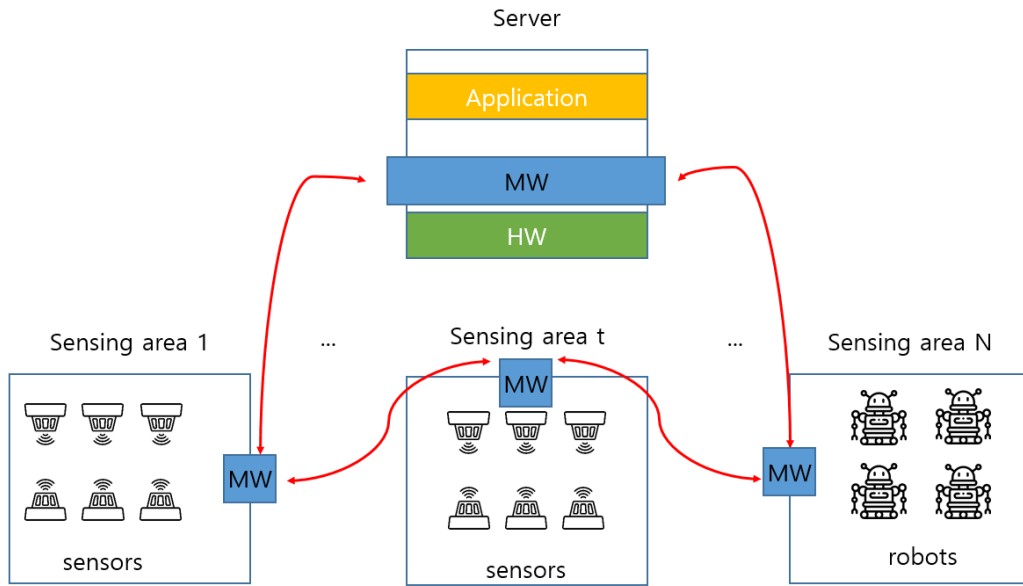


Figure 1: Disaster Detection and Real-Time Escape Calculation System with Middleware

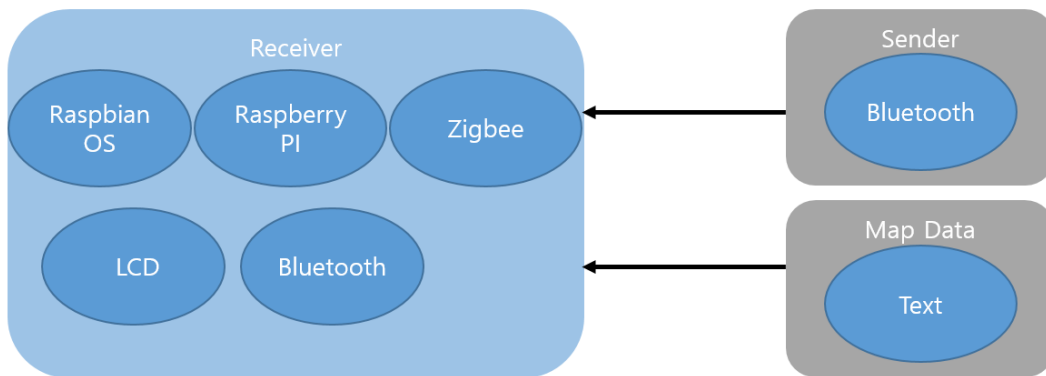


Figure 2: Structure of Disaster Evacuation System

2.1. Disaster Evacuation

Disaster evacuation is divided into the system structure part and the core algorithm part. The system structure of disaster escape consists of three parts. Map data, sender and receiver. Key algorithms of disaster evacuation are the current user's coordinate output using the strain algorithm of the trilateration measurement method, the shortest-path algorithm to escape, and the directional algorithm.

2.1.1. System Structure

Map data consists of MAP node, EXIT node, and BEACON node. MAP node is a node that was created to draw a map. EXIT node is the node that represents the location of the escape route. BEACON node is a node for determining the location of BEACON. Map data have x, y, node status, x-calibration value, and y-calibration value. The x, y, x, and y-calibration values are used to represent the exact coordinates of the map. The status of the node indicates what type of node is. You can create a virtual map with this map data[Figure 3].

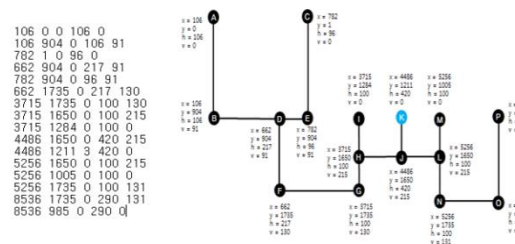


Figure 3: Map Data Sample and Create a Virtual Map

The receiver is a device for victims of a disaster to escape from inside in case of a disaster. The receiver can locate the victims of the disaster through communication with the sender and receive escape routes from their current location through communication with the server or middleware. The escape route is provided by an LCD mounted on the receiver. In this paper, the receiver was composed of Raspberry Pi 3, Raspbian OS and LCD 1602 I2C modules.

The sender consists of an Arduino R3 compliant board and HM-10, a Bluetooth BLE 4.0 module. The sender functions as BLE BEACON and sends the node ID, RSSI, and Tx information to the receiver. Node ID is subdivided into Major ID and Minor ID and fixed by predetermined rules. The Node ID therefore identifies which BEACON is located near the disaster victim. The RSSI and Tx values are used to measure the distance between disaster victims and BEACON.

### 2.1.2. Key Algorithms

The transformation algorithm of the trilateration can find coordinates of disaster victims with a receiver. Existing trilateration algorithm is made by obtaining three sides using RSSI values, obtaining two points of A and B, and removing one of the points from the intersection point using C[2-3]. However, it is rare for the three circles to meet at one point of intersection because the RSSI value is measured far beyond the actual distance due to obstacles etc. This can be solved using triangulation and the intersection of three circles [4]. Based on this, we implemented a transformative algorithm of the trilateration[Figure 4].

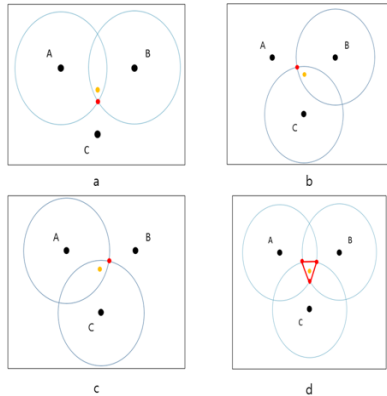


Figure 4:Transformation Algorithm of Trilateration

The transformative algorithm of the Trilateration goes through four stages: 1) Using the three BLE BEACON's RSSI values, obtain the distance to the receiver and make a circle with the radius of the circle. 2) Select two of three circles and obtain two points of intersection of the selected circles. 3) Choose one of the two points that is close to the center of the unselected circle. 4) Repeat steps 1 through 3 in all cases.

After all the steps, you can obtain three intersection points as [Figure 4]. Think of the intersection points from a, b, and c as the apex of the triangle, and find the incenter, and you will find the user's position as shown in d.

The shortest-path identification algorithm to the exit is based on the user's initial location and identifies the nodes that must pass through the shortest path to EXIT node [Figure 5].

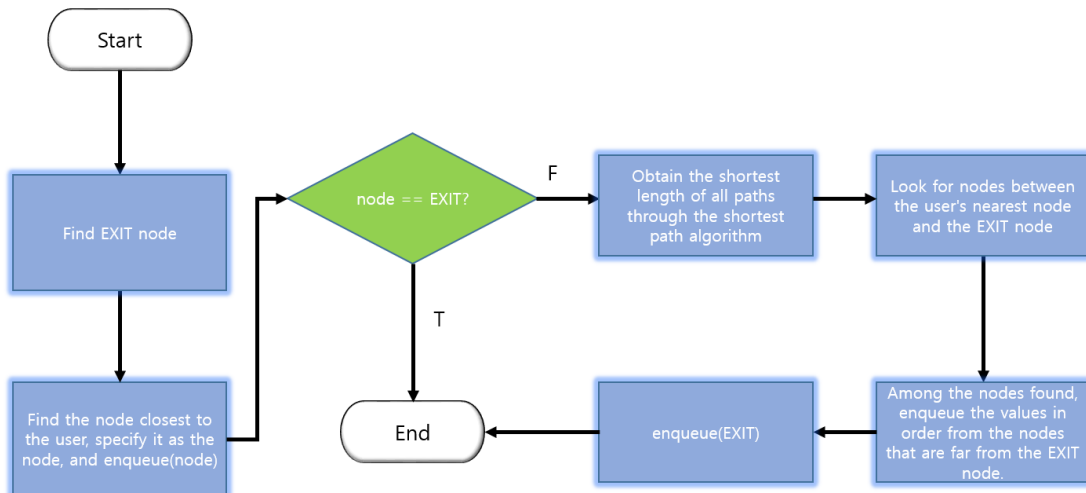


Figure 5: Algorithm flow chart of shortest path to exit

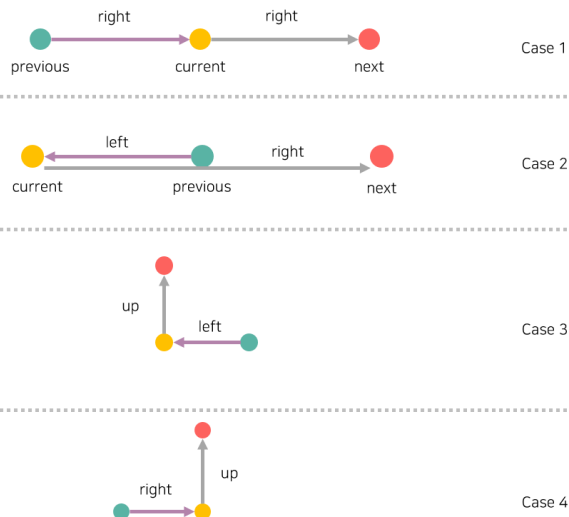


Figure 6: Direction Identification Algorithm

The direction identification algorithm compares the previous and current locations of victims of a disaster and looks for directions that victims should go. It determines which direction the victim will move in. This algorithm requires the assumption that the victim moves in only four directions, up, down, left, and right [Figure 6].

In Case 1, comparing the position of the past victim with the current victim position, it is shown that the user has moved in the right direction on the map. To go with the current position of the victim point, on the map to compare the position of the victims must be transferred to the right to know. When both directions are in the same direction as Case 1, the victim should go straight. Case 2 is also compared with Case 1, where the two directions compared are in the opposite direction, the victim should reverse. Case 3 and Case 4 are the cases in which movement is required to the right or left relative to the current victim's position. In this case, rotating clockwise or counterclockwise can reveal four different cases. Therefore, exceptions should be made for right and left movement as in case of Case 3, Case 4.

## 2.2. Disaster Detection and Real-Time Escape

The middleware is divided into three parts: the WSN communication, the DB, and the other middleware communication [Figure 7]. Middleware receives periodic sensor data using Zigbee in the area where it communicates with WSN [5-6]. At this point, the Sensor Identifier determines the identity of the sensor receiving the data and recognizes which sensor it is related to. The DB has the id, the sensing data value, the different middleware id, the different middleware information, the position (x, y) value, and the layer information of the sensors in its sensor area. This information is used to inform other middleware or servers of their status. The parts that communicate with other middleware or sensors periodically exchange measured sensor values in their sensor area. If a server loses communication with a particular middleware or if a sensor value is exceeded, a disaster has occurred and the room, hallway, and stairs that middleware belongs to are excluded from the escape route. The server finds the shortest way out of the safe routes, not the dangerous routes excluded from the escape route, and notifies the receiver.

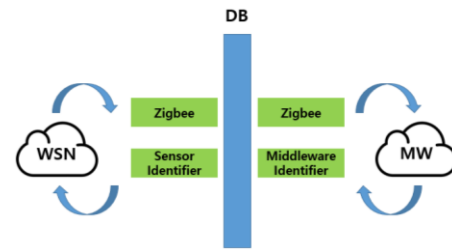


Figure 7: Middleware Architecture

## 3. Results and Discussion

Through its components and algorithms, the Indoor Disaster Detection and Real-Time Escape Guidance System were developed. It implemented a system environment based on the corridor of the SunMoon University. Based on the actual measurement of the RSSI values indoors, the RSSI values were measured, which differed significantly from the theoretical values in 4m and 6m [Figure 8]. This appears to be an error caused by interference, reflection, absorption of signals due to obstacles. Therefore, BLE BEACON was installed at intervals within 4m, which is measured at a relatively normal value.

The RSSI values are collected 200 times from the surrounding BLE BEACON and the average values are adopted. As a result of the experiment, the victims managed to escape. In order to check the system functioning properly, the victim moved in a different direction than the system guided him. However, in real time, the direction of the system was corrected. Finally, the EXIT node was guided and the system was shut down. Therefore, it is possible to present escape routes with minimal route from the current location of disaster victims to EXIT nodes.

Two problems arose during the experiment. Even if the average value of the RSSI was calculated, there was a margin of error of up to 3 meters from the location of the victim. Also, it took about 10 seconds to calculate after receiving about 200 RSSI values and BEACON information. Therefore, complete real-time guidance was impossible.

There is a lot of research done using BEACON's RSSI [7-11]. It is also possible to upgrade the study by referring to the values measured and calibrated in these studies.

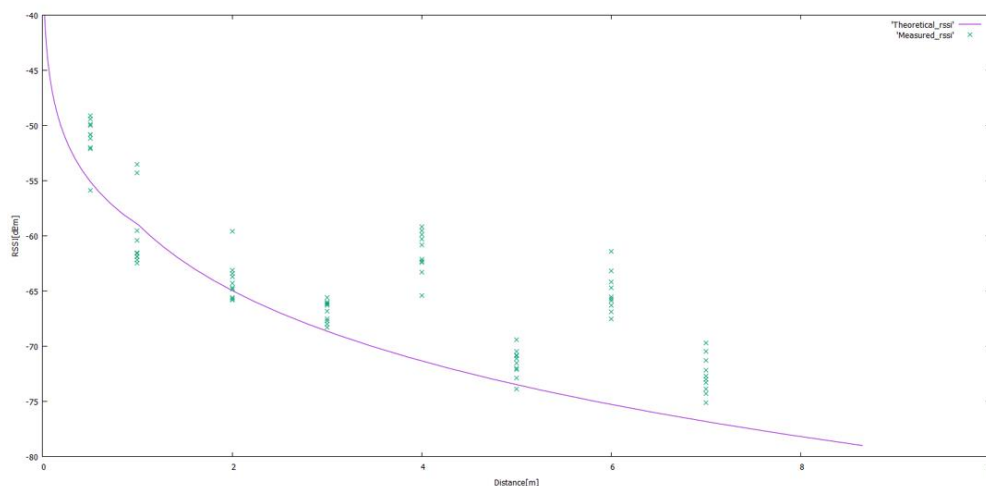


Figure 8: RSSI Value Measurement Result

## 4. Conclusion

In this paper, we conducted a study on a system that determines whether an indoor disaster occurs and identifies the route of evacuation in the event of an indoor disaster. The study found that

the location of the victim was within 3m of error, and based on the location, the escape route was changed in real time to show the victim. But the error will be a big deal in an urgent real disaster. The RSSI calculation process also takes about 10 seconds, which is a very large time in an emergency situation. It will be necessary

to study the accuracy of future positioning and follow-up to make quick calculations.

## Acknowledgment

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