Acquisition of indoor area information for evacuation support in ERESS

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Abstract— In recent years, many people have died by sudden serious disasters such as fire, terrorism, and earthquake around the world. It is necessary to guide quick evacuation by offering disaster information and evacuation support information to evacuators for the reduction of victims. Therefore we develop Emergency Rescue Evacuation Support System (ERESS) as a system providing evacuation support in real time. This system automatically detects a disaster by collecting the action state information of the neighboring terminals. In this paper, we focus on guidance of the evacuation course and propose an acquisition method of the indoor area information for evacuation support by using iBeacon. We perform the performance evaluation by the disaster simulated experiments to show the effectiveness of this proposed method. We show that the proposed method in ERESS is able to guide evacuation to evacuators effectively.

Keywords— disaster, MANET, evacuation support system, indoor area information, iBeacon, ERESS

I. INTRODUCTION

In recent years many people have died by sudden disasters such as fire, terrorism and the earthquake around the world. One of the main reasons is that evacuators far from the disaster outbreak place have difficulty in acquisition of the information about the disaster. Therefore offering the quick disaster information to evacuators is very important immediately after the disaster outbreak.

The representative systems which support evacuation are sensor network systems [1]. When the system detects disaster outbreak by various sensors of heat, gas and smoke installed beforehand in a building, it triggers an alarm. However, it is unsuitable for the evacuation support at the time of the sudden disaster with emergency because cannot provide a disaster outbreak place and the evacuation route to evacuators. Authors have developed the Emergency Rescue Evacuation Support System (ERESS) for the purpose of urgent evacuation support of evacuators to solve the problems mentioned above [2], [3]. ERESS is a system using handheld units such as smartphones. This system configures MANET among neighboring terminals which exchange the information of position and action state each other. We detect disaster outbreak based on the information and support evacuation. This system is composed of five phase i.e. (1) Exchanging and sharing information by MANET, (2) Behavior analysis of terminal holders, (3) Disaster detection, (4) Evacuation route search, and (5) Evacuation route display and guidance.

In this paper, we focus on evacuation route display and guidance that is not studied in ERESS. Because the current ERESS system does not have function of the evacuation guide, we study the position estimation of mobile terminal by using indoor area information. We acquire the current area by using iBeacon in conventional ERESS, but there are two problems as follows.

1. There is no way how to set some iBeacons.
2. Area estimate accuracy is low under large rooms.

We propose an indoor area information acquisition method for evacuation support in ERESS to solve the problems mentioned above. The purpose is to improve area estimate accuracy under some moving situations. We use iBeacon for the acquisition of the indoor area information, and estimate moving direction and state from several sensors on mobile terminals.

We describe ERESS in section 2 and a proposed method in section 3. We show experimental results in section 4 and conclude in section 5.

II. RELATED WORK

In this chapter, we describe sensor network system, navigation system in disaster and ERESS.

A. Sensor network system

The sensor network builds an autonomous network using a large number of small sensors and servers with a wireless communication function. These sensors acquire the environmental information such as the vibration by the disaster, the rise in temperature and transmit the information by using ad-hoc network. Because a server collects and analyzes the information, we can detect disaster outbreak. However, this system has the following serious problems.
1) High cost
It is necessary to introduce various sensors and servers into the whole building, so we need high cost.

2) No function under the damage of sensors
By the damage of sensors and the server, the system cannot notify the outbreak of the disaster to evacuators.

3) Not real time
Because we cannot grasp the congestion situation of the passage to change every hour in real time in the sensor network, it is difficult to support emergency evacuation in real time.

B. Navigation system in disaster
An evacuation support system with the cell-phones includes navigation system at a disaster [4], [5]. Because this system registers evacuation maps of the all over Japan beforehand, we can notify to the cell-phone holder the information such as the direction and distance from the present location to the nearest place of evacuation or home. However, the communication state becomes unstable due to traffic congestion by increasing traffic explosively in short time just after the disaster outbreak. So the evacuators cannot acquire disaster situation information quickly.

C. ERESS
ERESS is an evacuation support system having high real time processing composed of only mobile terminals which build MANET. This system is able to reduce the victim by detecting the disaster and starting to guide quickly. In addition, the quick evacuation is enabled by identifying a disaster outbreak place and a disaster kind. We describe characteristics of ERESS.

(1) Working under only handheld units
ERESS does not depend on the existing communications infrastructure to use MANET and is available only with a handheld unit under various environment.

(2) Suitable for local disaster
ERESS provides appropriate evacuation support information to each terminal holder in local disasters.

(3) Evacuation guidance
Since ERESS is to search for the evacuation route with safe, it can guide evacuation route appropriately.

We pay attention to Evacuation route display and guidance that is phase (5) in ERESS. However, the current system does not have the function of the indoor area information that is an essential element to realize an evacuation support. We acquired the current area by using iBeacon in conventional ERESS, but this method includes the following problems.

1) There is no way how to set some iBeacons.
Conventionally, we cannot acquire the area information that considered an evacuation instruction because I install a beacon in various places and experimented on a wall or a ceiling to grasp a disaster outbreak area.

2) Area estimate accuracy is low under large rooms.
In the large room where multiple beacons are installed, recognition of area might be missing by the decreasing of received signals from iBeacon. Therefore it is important to improve area estimation accuracy in a large room.

III. PROPOSED METHOD
We propose an acquisition method of the indoor area information for evacuation support by using iBeacon. By using moving action and direction, we can improve estimation accuracy of available indoor area information. We carry out experiments to investigate the effectiveness of the proposed method.

3.1 Purpose and summary
The purpose of this proposed method is to improve area estimation accuracy under various situations. We express its characteristics as follows.

(1) Acquisition of indoor area information

The iBeacon can offer the indoor area information that is transmitting area of each iBeacon.

(2) Use of moving action and direction

We can adapt to the panic situations by using moving action and direction in real time.

(3) Use of various sensors with a terminal

It is available to acquire the moving actions of people by using acceleration and geomagnetism sensors with ERESS terminal.

3.2 Proposed algorithm
It is necessary to set movement probability to estimate an area exactly, but it is difficult to estimate the moving in real time. Therefore, we propose an indoor area information acquisition method using moving direction. This method uses the identification of the stopping and the moving states, and current moving direction each person. The procedure is composed of the following four steps.

Step 1: Acquisition of iBeacon information and various sensor data
We acquire data from acceleration and geomagnetism sensors with ERESS terminals for the action analysis of people. In addition, we acquire neighboring iBeacon information to perform area estimation. Received signal power is obtained by RSSI from each iBeacon as follows.

\[ P_{[\text{dBm}]} = 10 \times \log_{10} \left( \frac{P_{[\text{dBm}]} - P_{0}}{10} \right) \]

Here, \( P_{[\text{dBm}]} \) expresses RSSI [dBm] of area j beacon.

Step 2: Action identification from the acceleration sensor
We perform three kinds of action identification such as stopping, walking and running by using SVM.
Step 3: The direction acquisition from the geomagnetism sensor

We acquire the moving direction from the geomagnetism sensor. We estimate the area by using RSSI and the moving direction.

Step 4: Correction of area information by weight

We show angle difference theta which is defined the difference between two lines of neighboring iBeacons and moving direction in Fig. 1. Based on the moving direction in Step 3, we have weight on each area in Fig. 2. We set weight according to θ in Table 1. We calculate $R_j'$ by multiplying weight by RSSI ($R_j$) of each area, and then we estimate an area that has the largest $R_j'$.

We may have an error about up to 20 degrees for the direction acquisition with about up to 20 degrees for the direction acquisition with the geomagnetism sensor because of the degree of the environmental factor and calibration. So we assumes the threshold is 72 degrees (+36 degrees) more than 3 times of 20 degrees not to affected by the error of the geomagnetism sensor in Table 1. The setting of the weight is large value as a beacon located near moving direction and the weight is low value as the beacon far. Since the RSSI has a variation of about 3 dBm, an error may occur twice in maximum in some cases. For this reason, the weight is set to a value larger than 0.5 so that an area with lower RSSI is not affected.

The acquisition of indoor area information is possible by this method.

IV. PERFORMANCE EVALUATION

We carry out evaluation experiments to show the effectiveness of the proposed method.

4.1 Experiment summary

(1) Evaluation of the proposed method

The purpose of this experiment is to show the improvement of area estimation in the proposed method. We compare the proposed method with the conventional method using only RSSI. We have iPhone6s in hand in a lecture room and acquire the iBeacon while moving some courses decided beforehand. The room contains no obstacle and iBeacon devices are set 7 m away on ceiling at nine places in total in Fig. 3. We test 4 patterns to move in two courses at two states of walking and running. The acquisition interval of the area information is 1 second. We show two course patterns of the experiment in Fig. 3.

(2) Evaluation of the evacuation support

The purpose of this experiment is to evaluate the effectiveness of the evacuation support in ERESS. In this experiment, we assume the situation that fire breaks out in a building. We compare the evacuation completion time in whether obtaining the information from the ERESS terminal or not. We change the place of safety zone to change the disaster situation. The experiment examinees are 83 students in total. We show experiment field and display example Fig. 4 and 5, respectively. The safety zone is selected from A to C. Examinees start to evacuate at the experiment place. We change the place of the safety zone at every experiment and investigate the evacuation completion time of all examinees. Table 2 shows three patterns of safety zone.
Table 2 Experiment pattern

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<td>(b)</td>
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<td>(c)</td>
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Fig. 6 Walking in course 1 [1-4-7-8-5-3-6-9]

Fig. 7 Running in course 2 [1-2-3-5-7-8-9-5-1]

Table 3 Evacuation time with and without ERESS

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4.2 Experimental results

(1) Evaluation of the proposed method

We show area numbers at walking in course 1 and at running in course 2. The conventional method has wrong area number around 12 second but the proposed method can acquire the right area number in Fig. 6. The conventional method acquires wrong area number 18 and 30 seconds, but the proposed method can acquire right area number in Fig. 7. From these results we find that the proposed method can reduce the number of false area estimation in comparison with the conventional method.

(2) Evaluation of the evacuation support

We show the evacuation time with and without ERESS in Table 3. In the pattern (a), the mean evacuation completion time with and without ERESS is the same. We find the improvement of ERESS is about 13 seconds in pattern (b) and (c). We are able to confirm that the propose method can shorten the evacuation time.

V. CONCLUSIONS

We have developed Emergency Rescue Evacuation Support System (ERESS) for the quick evacuation in sudden disasters. We focused on Evacuation route display and guidance that is one of the functions of ERESS. However, the conventional system did not have the function. In addition, we can acquire the area information by using iBeacon, but there are some errors. So we have proposed an acquisition method of the indoor area information for evacuation support. By the evaluation experiments, we are able to show the proposed method improves the indoor area estimation accuracy. In addition, the proposed method is able to shorten the evacuation time by display guidance. Therefore, the effective evacuation support in ERESS was enabled by the proposed method.

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