ビーコンの電波強度を用いた位置分析システムと福祉施設への適用性の検討*

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Position Analysis System using Radio Intensity of a Beacon and Its Applicability for Welfare Facilities

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Abstract: A position analysis system using beacons has been proposed to support watching an elderly person. The distances between the beacon and the receiving equipment are estimated from the radio wave intensities emitted from the beacon. A position of the beacon on a two-dimensional plane in the facility is evaluated using the estimate of the distances from two receivers. The residence times of the beacon positions at any points in the facility are measured. Based on the estimated position data, the positions of an elderly person and the applicability of the proposed system as a watching support for welfare facilities are evaluated.

keywords: position measurement, beacon, radio intensity, monitoring

1. Introduction

Recently, small-sized, cheap, and long-term usable beacons have been released, and applications of these beacons have been proposed. The beacon is a device that emits radio signals periodically, and we can estimate the physical proximity of the beacon using its radio signals. Incidentally, in hospitals and nursing homes that have elderly persons with senile dementia, the position monitoring system of the persons has been required in the facility to prevent accidents caused by moving of the persons. For the care monitoring support in the facilities, the position monitoring system with image monitors has been used. However, the position monitoring system with the image monitors has the problems of the privacy violation and a large monitoring load [1-3]. In this paper, as a solution of the problems, we propose a position analysis system for the elderly person using the beacon, and discuss the applicability of the system in the facilities.

2. Measurement of radio wave intensity between beacon and receiver

The beacon is usually used to estimate the proximity position of a person from the electric field intensity of the radio signal. Since the electric field intensity between the beacon and the receiver are fluctuated due to the noises and the interferences, in most applications of the beacons, the estimated distances are treated by dividing into three regions: near range, middle range, and out-of-range [4]. However, since certain types of beacons can adjust the output power, we can obtain a continuous electric field intensity signal from the beacon based on the distance. In this paper, using the continuous electric field intensity signal obtained from the beacons, we propose the system that analyzes the moving position of the elderly person in the facility.

To estimate the continuous distance using the radio wave signal from the beacon, we first investigate a relationship between the radio wave intensity and the distance between the beacon and a receiver. Figure 1(a) shows a relation between the measured values of the radio wave intensity and the distances in one dimension. With regard to the radio wave intensity value, we used the received signal strength

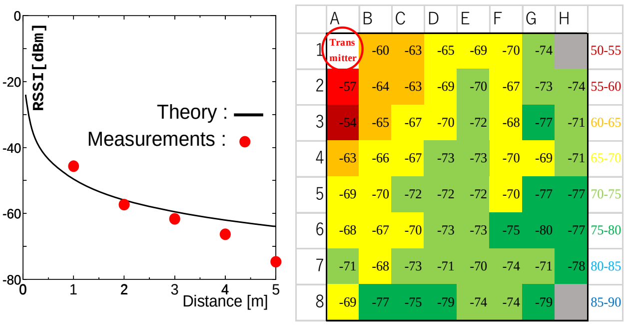

Fig. 1 Relations of the measured RSSI values to the distances ((a) one dimension (left side), (b) two dimension (right side)).

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indicator (RSSI) value. Dots in the Fig. 1(a) show measurement results of the obtained RSSI values of the received signals. In the measurement experiment, we used the beacon named MMBLEBC1, which is manufactured by Sanwa supply co. Ltd [5]. The beacon follows Bluetooth low energy specifications in 2.4 GHz band, and it can be used in the range of 100 m by adjusting the output. Also, we used a Raspberry Pi3 board as a receiver. This board has Bluetooth and LAN devices, and has the advantage of easily creating signal processing programs. The intensity values of the received signals are obtained by the program in Python language. Furthermore, since the RSSI values are varied due to the noises and reflections, we plotted the average value of three obtained RSSI values. The solid line in Fig. 1 (a) shows the theoretical relationship between the RSSI values and the distances, which is obtained by the Friis transmission equation [6]. In the comparison of the theoretical RSSI value and the measurement, we observed that although the measured values are slightly different from the theoretical values at a long distance, the both of the RSSI values similarly decrease as the distance increases.

In addition, we investigated the relationship between RSSI values and distances on a two-dimensional plane in the facility. We set the Raspberry Pi boards at an edge on the wall, divided the two-dimensional plane into an area of 1 m × 1 m, moved the beacon to each of the areas, and measured the RSSI value of the beacon. Figure 1 (b) shows the measurement result. We display the average values of the obtained RSSI values by color coding. In the figure, although there are some fluctuations in the values, the obtained RSSI values are also decreased almost in proportion to the distance of the beacon on the two-dimensional plane. Thus, we can estimate the distance between the receiver and the beacon using the RSSI value of the receiver on a two-dimensional plane.

3. Position analysis system

In this section, we measured the electric field intensity signals from different positions using two Raspberry Pi boards, and estimated the person's position using the distances which are estimated from the RSSI values. Figure 2 shows the setting of an image in the position analysis system and Fig. 3 shows an actual measure environment. For the measuring experiment, we placed two receivers at both ends of the wall as shown in Fig. 2 and moved the beacon to each area of 1 m × 1 m on the two-dimensional plane, and measured the RSSI values for each receiver. Figure 4 shows the measurements of the obtained RSSI values by the receivers.

In this system, since the RSSI values are measured using two independent receivers, we have to gather the RSSI values of the receivers into one receiver to estimate the position of the beacon. Since we used the Raspberry Pi boards with LAN ports as the receivers, we can use the LAN connection to gather the RSSI values. As a protocol in the LAN connection, we adopted the user datagram protocol, which can transmit the text information easily in real-time and make the transmit protocol program by Python language. Using the obtained two RSSI values, we estimated the corresponding distances for these RSSI values, and we drew the circles with the radii of the distances. Then, we calculated the intersection position of these circles on the two-dimensional coordinate as the estimated point of the beacon. ordinate as the estimated point of the beacon.

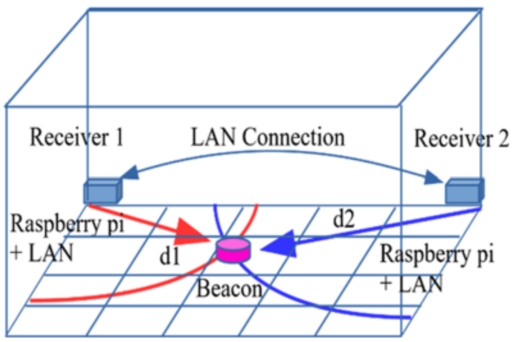

Fig. 2 Setting image of the position analysis system.

Fig. 3 Measurement environment.

-34	-65	-67	-68	-72	-73	00-50
-58	-63	-61	-68	-73	-70	50-60
-63	-67	-70	-73	-70	-71	60-70
-67	-68	-71	-70	-71	-72	70-80
-73	-72	-71	-72	-74	-73	80-90

-71	-69	-70	-67	-58	-29
-70	-71	-63	-60	-59	-61
-72	-69	-65	-64	-62	-65
-72	-71	-70	-67	-64	-66
-75	-72	-71	-69	-69	-71

Fig. 4 Measurements of the obtained RSSI values for two receivers.

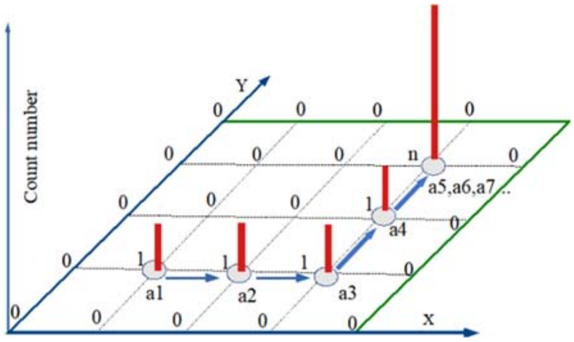

Fig. 5 Experiment path for measur-ing (from the position a1 to a7).

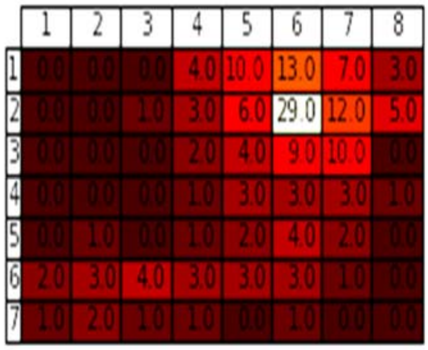

Fig. 6 Heatmap of the counts in each area.

3. Estimation experiment of moving and staying position of a beacon

Using the proposed position analysis system, we performed an experiment for searching the route of a person and measured the staying time of the person. Figure 5 shows an experiment path (from position a1 to a7) for measuring the moving position in the two-dimensional coordinate. In the experiment, we held the beacon and moved along to the path, as shown in Fig. 5. Moreover, we estimated the moving positions every second using the received RSSI values, and counted the numbers that the estimated moving positions enter into each of the one-meter area. Then, we estimated the movement of the watching target from the change of the count number at each area. Moreover, if the count number at an arbitrary moving area exceeds a certain threshold, we assumed that an unexpected accident has occurred for the target person and send a notification call to the observer. To visualize the information of the movement and stay time of the person obtained from the beacon, we made the heatmap of the counts for each area using the seaborn which is one of the Python visualization libraries. The heatmap of the counts is shown in Fig. 6. Using the figure, we can watch the condition of the person's movement visually.

4. Conclusion

This paper proposed a position analysis system using a beacon to monitor an elderly person. In the proposed system, we obtained a continuously received electric field intensity from the beacon with two Raspberry Pi boards as the receivers, shared the received electric field intensity values via the LAN connection. Using the received electric field intensity values, we approximated the distances of the person which has the beacon, and estimated the position of the person. To confirm the position of the person visually, we drew a heat map of the moving position of the person at any location. From the transition of the count number in the heatmap, we could confirm the movement of the person and the staying time. Since the measurement time of the system is set as one second and the movement of the elderly person in the facility is slower than the measurement time, we can watch over the elderly person using the proposed system.

As a future study, we will search for the suitable emitting power of the beacon and the correction method of the distances due to the signal variation.

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