# Worker's location prediction system for providing location-based service inside poultry houses

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**ABSTRACT**

The objective of this study was to determine the precise location of workers in poultry houses using BLE beacons methods. Data was collected from two poultry houses using smart device systems during the experimental period. A score map was developed using a fingerprint algorithm based on the obtained data. Moreover, the fingerprint algorithm with a score map was used to identify the position of the worker in real-time in the poultry houses. With and without data filtration techniques have been applied during the data processing period. The developed algorithm showed a low accuracy in predicting the position of the worker by using the unfiltered data. However, it was also found a better accuracy by applying the filtered data in the same algorithm. Therefore, the study recommended using BLE beacon methods in a score map-based location prediction system for identifying the optimal position of workers in poultry houses. The current study also suggested that filtered data provided better accuracy in predicting the position of workers compared to unfiltered data using the same algorithm. This study shows to have benefits in location prediction using BLE beacons in poultry houses.

*Keywords: BLE beacon, Beacon filtering, Fingerprint, Scoremap*

## 1. INTRODUCTION

The Fourth Industrial Revolution is an intelligent revolution with digital technology infrastructures such as artificial intelligence, big data, and the Internet of Things. Currently, the domestic livestock industry is further developing due to the application of state-of-the-art technology, which plays an alternative role in the use of human resources [1]. The collected data can provide high-dimensional information to workers through processing and analysing.

Recently, the concentration of manure's odour and harmful gas generated by large-scale livestock environments may exceed the permissible exposure standard. The main components of harmful gas are ammonia (NH3) and hydrogen sulfide (H2S). Ammonia can be sensed through the worker's nose, even at low levels, and irritates the worker's eyes and lungs. Hydrogen sulfide is heavier than air and produces a foul odour even at low concentrations, causing headaches, dizziness and nausea. Hazardous gases can act toxic if workers are exposed to long-term or at high concentrations; similarly, 15 ppm of ammonia gas can cause respiratory illness in humans [2]. The working environment needs a system that can track the real-time position of the worker and avoid the dangerous area in order to avoid the worker's exposure to dangerous gas.

The introduction of Internet of Things technology in the livestock environment will enable workers to provide real-time, location-based services tailored to their situation. Location-based services currently in use are GPS (Global Positioning System), RFID (Radio-Frequency Identification) [3], Bluetooth [4], and Wi-Fi [5]. GPS is used to provide typical location-based


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services, but it cannot receive GPS signals in indoor environments. Therefore, network-based technologies such as RFID, Bluetooth, and Wi-Fi are used for indoor location-based services. Since RFID uses the signal response reception of the tag and the reader, the accuracy of user position prediction is high. However, RFID is difficult to apply in special industrial environments and environments with many signal interference factors [6]. Wi-Fi is difficult to install in a festive environment because wireless routers consume relatively high power. In addition, Wi-Fi has a problem that the error increases when there are many obstacles or when the transmission/reception effective range is exceeded [7,8]. BLE (Bluetooth Low Energy) consumes up to 90% less power than traditional Bluetooth. Currently, the maximum transmission range of BLE is about 243m, which is wider than the maximum transmission distance of 150m for long-distance communication based on Wi-Fi. In addition, BLE 5.0 provides a direction-finding (Bluetooth 5.1 Direction Finding) function, which enables more accurate position prediction than the position prediction of the existing simple signal board. Therefore, BLE can be applied more flexibly to the livestock environment than RFID and Wi-Fi, so it was used as the core technology of this paper.

Bluetooth technology currently in use includes BLE (Bluetooth Low Energy) based beacons [4]. A beacon is a wireless communication device that can recognize a smart device at a short distance and transmit data. Currently, BLE beacons can operate for 2 to 3 years on a single battery and have a wide transmission range. Beacons can be serviced in environments where power supply is limited, such as axes, making it difficult to install wired devices. However, beacons contain a lot of errors and it is difficult to provide services using a single or a small number of beas[9]. Therefore, in this study, a fingerprint algorithm is used to improve the low accuracy problem of the beacon.

The fingerprint algorithm is a technique for selecting an arbitrary position in a service environment and predicting the position using the received signal strength collected at each position. Any position is defined as a reference position, and the accuracy of the fingerprint algorithm increases as the reference position becomes denser and larger. However, because the process of generating reference positions is passive, many reference positions produce a large workforce [5, 10]. The score map is a map generated by dividing the received signal strength collected at the reference position into arbitrary grids, and after finding the error between the grid strength and the collected received signal strength through similarity comparison, the grid with the lowest error is considered as the predicted position of the worker.

In this paper, we propose a worker position prediction system using a beacon. Filtering on the collected data was performed to improve the low error of the beacon and use the fingerprint algorithm to improve the low position prediction accuracy. The position prediction algorithm predicts the position of the worker by performing the similarity comparison with the score map on the received signal strength collected in real-time from the smart device.

## 2. MATERIALS AND METHODS

### *2.1. Measurement of received signal strength and selection of poultry houses*

Two poultry houses were selected for this test. The first poultry, with the dimension of 40 m × 10 m was termed Env1 hereafter. The interior of Env1 consists of a steel structure and a sandwich panel. The second poultry was Env2, and the dimension was 56m × 10m. The interior of Env2 was made of steel structure and concrete (Fig. 1).

The signal received from a similar beacon from both poultry houses (Env1 and Env2) was measured in terms of distance. The signal measurement period was set to 0.1 seconds, and 100 received signal strengths per unit distance were collected and averaged. The experimental results are shown in Fig. 2. The received signal strength gradually decreased at a distance of 5 m. Therefore, the effective distance of the beacon was determined to be within 5 m, and the installation interval of the beacon was set to 5 m.

The installation location of the beacon is shown in Figure 3. The number of installed beacons was 10, and the installation interval of beacons was set to 5M. Each zone had a square structure of 5 m along with the beacon installation interval and is defined as A1, A2, A3, and A4 respectively.


**Figure 1** Inside the poultry houses (A)Env1; (B)Env2

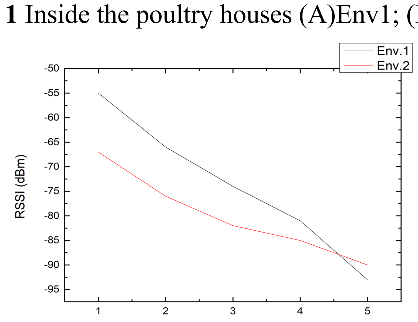


**Figure 2** Received signal strength Indicator value by distance

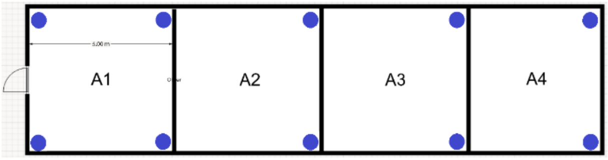


**Figure 3** Beacon installation location

## *2.2. Position prediction system model design*

For the model design, the specification of the system was Windows 10 ver. 1909, the CPU Intel(R) Core(TM) i5-9600K CPU @ 4.8GHz, and the operating system of the user device was Android ver. 8.0. For the beacon model, the BuildIt BuildThing beacon model supporting BLE was used, and the signal strength of the beacon was set to 4dbm with a signal transmission distance of 70m in the range of –23dbm to 4dbm [9]. Figure 4 shows the indoor location prediction system model using beacons. The worker received the data from the beacon, and the data were processed according to the type selected by the client, and then transmitted to the worker's smart device in real-time using the TCP communication protocol. The workers can check the predicted location using a smart device and can monitor the location in real-time from other systems connected to the server.

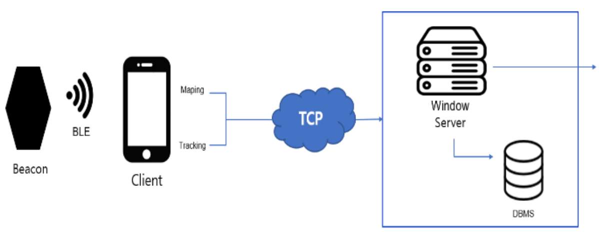


**Figure 4** Location detection system structure diagram

## *2.3. Communication format design*

The communication format has three types: a new connection, a request from a client, and a response from the server (Figure 5). In a new connection, the server was connected through the address of the smart device, and the server's task was executed based on the type of the client's request. The types include location measurement and score map generation, and the server processes the tasks requested by the client for each type and returns it as a server response. The server received the beacon information and received signal strength through the name and value of the data requested by the client, and received the coordinates of the score map through the message. In the server response, the predicted coordinates were returned based on the operation type of the data requested by the client.

Transfer Data:

New Connection

| Data1 | Data2 | Data3 | Data4 |
|---|---|---|---|
| Start | Address | Type | End |

Request

| Data1 | Data2 | Data3 | Data4 | Data5 | Data6 |
|---|---|---|---|---|---|
| Start | Type | Name | Value | Massage | End |

Response

| Data1 | Data2 | Data3 | Data4 |
|---|---|---|---|
| Start | Type | Location | End |

Details:

Start: start signal

| Address | Type | Name | Value | Massage | Location |
|---|---|---|---|---|---|
| IP & Mac Address | Processing Type | Beacon's ID | RSSI | Client Label | Client's Cordinate |

End: end signal

**Figure 5** Server communication data protocol

## *2.4. Fingerprint Algorithm Design*

The fingerprint algorithm goes through a two-step execution process. The score map generation step was a step of creating a score map based on the received signal strength measured in each zone by dividing the environment to be predicted in advance into a grid. The prediction step predicted a location by comparing the previously generated score map with the currently received signal strength. If there is a previously measured score map, it was calculated by comparing the received signal strength of the worker's current location and the score map similarity. At this time, the coordinate with the lowest error becomes the predicted worker's current position.

The format of the score map generation is shown in Figure 6. The score map requires items from Data1 to Data4, which correspond to each location, message, name, and value. The location had the location information of the corresponding area, and the message had the identification information of the area. The name had the identification value of the beacon, and the value was the received signal strength of the beacon measured in each zone, and it becomes a similarity comparison standard in the process of estimating the location of the system.

Map Data:

Map Creation

| Data1 | Data2 | Data3 | Data4 |
|---|---|---|---|
| Location | Massage | Name | Value |

Details:

| Location | Massage | Name | Value |
|---|---|---|---|
| Map's Location | Map's Label | Beacon's ID | RSSI |

**Figure 6** Map data protocal

## *2.5. Design of similarity comparison algorithm including filtering in beacon environment*

As the filter of the similarity comparison algorithm, an interquartile range (IQR) filter was used. A quartile indicates a value that quartiles the whole when the entire set of observation data is arranged in small order. Since the total quartiles are 25%, 50%, and 75%, respectively, they are expressed as Q1, Q2, and Q3, respectively, and the spread of the distance from Q3 to Q1 can be used as a measure. This number is called IQR. IQR can be implemented and operated quickly and easily in a simple way, and has the advantage of being robust against outliers. The similarity comparison algorithm used RMSE (Root Mean Square Error). The RMSE error function is a function that calculates the standard error of two sets and expresses the difference between the values.

## 3. RESULTS AND DISCUSSIONS

### *3.1 Simple measurement location prediction data analysis*

The location determination criterion was conducted based on whether the smart device existed in the corresponding area. The accuracy value was calculated with 10 predictions in each area, and the result of location prediction is shown in Figure 7. Since the average position prediction accuracy was 0.57 and 0.6, for Env1 and Env2 respectively, these values were not much different from the minimum accuracy, which is 0.5. So, it showed that the position prediction accuracy of the system was low. From this result, a lot of error was found in the received signal strength measured by the system using the beacon at the poultry house. Therefore, in order for the system to have high accuracy, it is necessary to remove errors in the data.

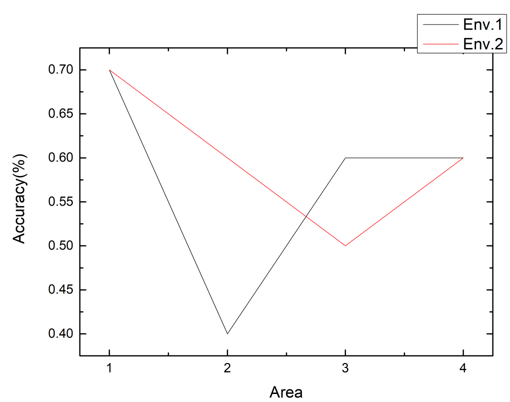


**Figure 7** Position prediction accuracy by area

### *3.2 IQR filter applied location prediction data analysis*

Figure 8 and Figure 9 show the accuracy of predicting the worker's location, with and without using filters, in Env1 and Env2 respectively. The result of Env 1 showed that, the average accuracy of 0.85 was obtained when applying IQR filter, which is higher than that of taine without using filter. Similarly, in Env2, the accuracy of 0.75 was found when applying the IQR filter which is also greater than the accuracy obtained without using the filters i.e. 0.6.

Overall, we found that the position prediction accuracy was improved when a filter such as the IQR filter is applied rather than the structure in which the operator position prediction system applies only the fingerprinting algorithm. However, the reason that the filter-applied location prediction accuracy does not reach the target accuracy of 0.9 was that the filter cannot completely remove outliers. Therefore, in further study, it can be expected that the location prediction accuracy will be improved through the study of changing and improving the applied filter and minimizing the diffuse reflection of radio waves.

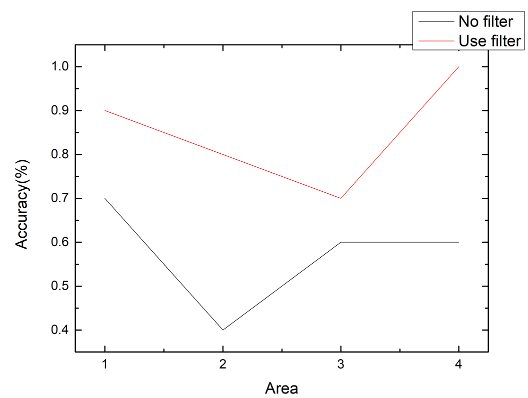


**Figure 8** Env1 position prediction accuracy

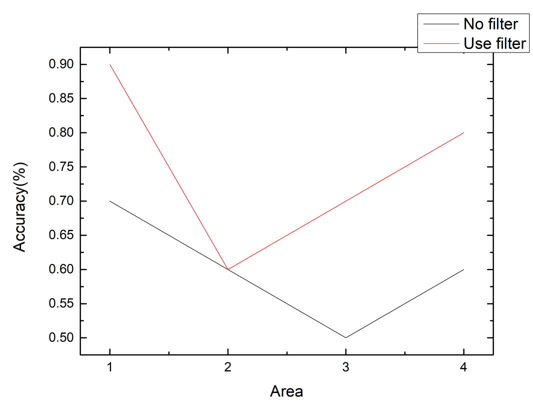


**Figure 9** Env2 position prediction accuracy

## 4. CONCLUSION

In this study, we developed an algorithm to predict the location of a worker using a BLE beacon. As a result, when simple data and IQR filter data were applied to the system, the results of simple data predicted many inaccurate locations, resulting in lower accuracy. On the other hand, it was found that the accuracy was improved when the filter was applied. In conclusion, it was confirmed that the BLE beacon technology in the livestock environment can show strength in the location-based service part in the livestock environment as it develops in the future.

## AUTHORS' CONTRIBUTIONS

Young-Woo Choi is responsible for all of the calculations, figures, writing, and large portions of the text. Na-Eun Kim and Gun-ho Lee helped during the data collection. Jeong-Hoon Song and Seok-Gun Hong prepared the setup for the experiment and Hyeon Tae Kim reviewed and edited the manuscript as well as guided the experiment.

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