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Indoor positioning system using BLE beacon to improve knowledge about museum visitors

Andreas Handojo[1], Tanti Octavia[2], Resmana Lim[3], Jonathan Kurnia Anggita[4]
[1,4]Informatics Department, Faculty of Industrial Engineering, Petra Christian University, Indonesia
[2]Industrial Engineering Department, Faculty of Industrial Engineering, Petra Christian University, Indonesia
[3]Electrical Engineering Department, Faculty of Industrial Engineering, Petra Christian University, Indonesia

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ABSTRACT

Generally, a museum has many locations and artifacts collection that display for visitors. Museum manager often have difficulty in obtaining information on visitors behavior such as, is there are particular locations/artifacts in the museum that are frequently/rarely visit by museum visitors, how long visitors spend their time in particular locations/artifacts, etc. The purpose of this study is try to build a suitable system in order to improve knowledge about the behavior of museum visitors by identifying the position of visitors in the museum. This study uses Bluetooth Low Energy (BLE) Beacon that place around the museum. The visitor mobile phone will detect BLE beacon signal, then the mobile phone application will calculated the visitor's mobile phone position using the signal strength from the BLE beacons that are detected. The application then sends it to the computer server to display it in as museum visitor heat map. From this information, the museum manager could find out the visitors behavior movement and know which areas/artifacts that frequently/rarely visit by museum visitors. According to distance error testing which compare real location and position of the calculation, it is show that the average of distance error is around 140 cm. So, it can be concluded that the information obtained is sufficient enough to represent the position of museum visitors.

Corresponding Author:

Andreas Handojo,
Informatics Department,
Faculty of Industrial Engineering,
Petra Christian University,
Siwalankerto 121-131, Surabaya, East Java, Indonesia.
Email: handojo@petra.ac.id

1. INTRODUCTION

Indonesia is a country that has a long history. Starting from the ancient kingdom history, the history of resistance to invaders, the history of fighting for independence, and others. This history left a lot of historic relics such as temples, statues, historic buildings, furnitures, weapons, metal equipment, and others. Most of this relics are located in the museums. Indonesia has approximately 400 museums scattered in various places throughout Indonesia [1]. Seeing the important role of the museum in preserving culture and becoming an educational medium for the future of the nation, the Indonesian government has carried out museums revitalization with the aim of creating attractive museums for visitors in accordance with international museum standards [2]. The government has also organized the "Visit Indonesia Museums" program on seven provinces

in Indonesia with the aim of increasing the public's visit to the museum which is expected to increase people's understanding and love of the nation's history.

In presenting the information, the museum presents historical heritage by using displays and showing media. The layout of historic relics is very important so that it can provide important and interesting information for visitors. Especially considering the number of artifacts in the musuem that can reach thousands items, such as the National Museum Indonesia which has around 141.000 artifacts [3]. The problem that arises is how the museum administrator could find out which area and which artifact that interesting to the visitors. How long the visitors will spend their time to a particular area/artifacts. It's any change that needed to be done to improve visitors experience and interest in their visit to the museum [4].

First objective from this study is to build a museum visitors behavior information by constructing location mapping to provide an analysis which museum area that visit by visitors, how long they spend times in particular locations, which areas and artifacts that favorite to the visitors, etc. This information will displayed on the museum visitor's heat map that displays the visitor movement in particular times and locations. Another objective from this study is to apply Internet of Things (IoT) technology to Indonesia Museums. How to find suitable IoT technology for Indonesian museums. Considering that Indonesia museums consists of a wide variety of objectives, budget size, various display models, the level of museum manager's ability to adopt technology, etc.

To achieve this objectives, this study builds a visitor behaviour mapping using the Indoor Positioning System (IPS) by utilizing Bluetooth Low Energy (BLE) beacons. This BLE signal will be detected by Bluetooth that are already installed on the visitor's mobile phone. This study proposed to use BLE beacons because its size is very small so that it is easy to place on the shelf or museum artifacts without significant interference. BLE beacons also easy to install and only require low energy consumption so they only require a small battery and only need to be replaced in one or two years. BLE beacons also cheap so they can be bought by any level of Indonesia museum (small to large museum budgets). BLE beacons also have a medium range coverage signal so it can cover small to large spaces in the museum.

First, museum visitors are asked to install the museum information application (through Google Playstore) that was made in the previous study [5], through this application visitors can access any information about artifacts in the museum (in text, video, image, audio). After detecting bluetooth signal from BLE beacons, the mobile phone application will calculate the distance of the mobile phone location from each BLE beacon location using the signal strength from each BLE beacon that has been detected. This study use trilateration and kalman filter method [6, 7] to calculate the position of museum visitor. Information about visitor locations is sent to the server as visitor mapping data. The data is then managed as visitor mapping information starting from the location of the visitor at a particular time, the length time that visitor spend in particular location, and the number of visitors in the location.

2. RESEARCH METHOD

Research on the use of technology for tourism development (especially cultural heritage tourism) continues to grow as by Botturi et al. [8] that create mobile games for learning cultural heritage, Meiliana et al. [9] that build mobile smart travelling application on android for Indonesia tourism. Handojo et al. [10] that using mobile phone and GPS features to build interactive game and information city heritage on mobile phone. McGookin [11] that developed a mobile application for cultural heritage. Rolando and Scandiffio [12] that use mobile phone technology, QR code, Geographic Information System (GIS), and Global Positioning Systems (GPS) as interactive tools for tourists visiting various cultural heritage sites in the city. Handojo et al. [13] also used mobile phone and GPS technology to guide tourists in a visit in the city of Surabaya to follow the history of the battle for Indonesian independence.

Several attempts also have been made in order to create an interactive and interesting museum. Chivarov et al. [14] create an interactive presentation using mobile phone to create digital exhibits in the museum. Turan and Keser [15] created museum guide in classical car museum to create interactive information. Some modern museums have used technological tools to create a more attractive museum for visitors. For example, the Smithsonian American Art Museum uses virtual reality to create a virtual experiences for museum visitors [16]. Another example is the Cleveland Museum of Art which uses the augmented reality facility to provide facilities for visitors to enjoy the art offered [17]. From various research and implementation efforts, it can be concluded that it is very important to make museums more interesting, interesting to visit, and interactive information using various types of information technology.

It is a challenge to create a museum that suits the needs of visitors. Therefore, it is very important for the museum manager to be able to know what museum visitors need and what visitors learn while in the museum [18]. It is important for museum manager to find out the needs of their visitors which areas or exhibition that interesting to them [19]. Therefore, this study tries to help museum managers to see which areas

or museum artifacts that have seen by museum visitors, how long visitors spend their time there, etc. This study use Indoor Positioning System Technology to mapping user location on the museum at a certain time.

Research on Indoor Positioning System (IPS) in order to determine user location in a room (indoor) has been developed by many researchers. IPS uses received signal strength indicators (RSSI) that obtained by ultrasonic wave transmitters/beacons. The transmitters/beacons locations usually have been predetermined. Some studies use WiFi (access point), radio frequency identification device (RFID), ultra wideband (UWB), and bluetooth low energy (BLE) as transmitters/beacons. Each equipment has its own specifications. Some devices have a long range such as WiFi which has a distance of 100 meters to 1 kilometer [20, 21]. Some equipment also has short range such as common Bluetooth that have 7-10 meters range and RFID which has a range of only around few centemeters to 1 or 2 meters [22].

Some studies use WiFi as IPS transmitter devices, such as Narzullaev et al. [23] which uses WiFi fingerprint as IPS to track assets and equipment in companies such as warehouses, factories, and hospitals. Yeo et al. [24] use WiFi fingerprints at shopping malls in South of Kuala Lumpur, Malaysia. Firdaus et al. [25] which use WiFi fingerprints based on user orientation to improve IPS. Another studies used Bluetooth (BLE) as transmitter, such as in Handojo et al. [5], Asmus [26], Davies [27], Skårberg and Sletten [28], and Setiawan et al. [29] that use it on the museum. Huh and Seo [30] and Thamm [31] that use Bluetooth on department store.

Every transmitter will have their own advantages and disadvantages ranging from price, size, range, energy consumption, installation difficulties, etc. This study chose to use BLE beacons (WEMOS LOLIN32 Lite) because (low) price consideration. So it's suitable to be implemented in various museums (small/big funds) without large cost necessity, considering not every museum has large funds. BLE beacons Figure 1 also have a small size (13x5 cm) so that they can easily be placed in various places in the museum space without disturbing the artifacts on display. In addition, BLE beacons also have easy installation so they are easily duplicated when needed [32]. In terms of energy consumption, BLE beacons have used Bluetooth 4.0 technology so that it only requires low energy. So, it is requires minimal battery maintenance can last up to more than 1 year). Meanwhile, to do location calculations, this study using the Trilateration method Figure 2 and Kalman Filter.

Figure 1. Bluetooth Low Energy Beacon

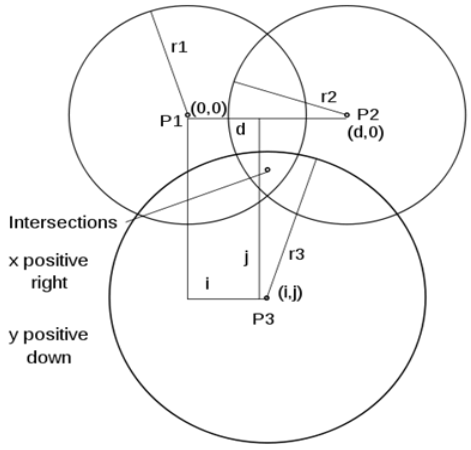

Figure 2. Trilateration

The research method of this study can be described as follows Figure 3. Some BLE beacons are placed in certain locations in the museum rooms. The coordinates of each BLE beacon are stored on the server.

- Each BLE beacons will broadcast their identification (UUID) using bluetooth signal. The museum application on user mobile phone will detect the beacon id that's around it
- Then, the application will then send the beacon id to the server. The server will send the location of the beacon on the museum.
- Based on this information, the application will calculate the user's location by calculating the BLE beacon strength signal (RSSI) using Trilateration dan Kalman Filter.
- The user location then sent to the server periodicaly

This data will be stored in a database on the server. The server will use this data collection to mapping the visitor's heat map. This visitor's heat map then could be use to improve knowledge about museum visitor's

interests. Where museum visitors spend their time in the museum, how long the museum visitors stay in the particular locations/artifacts. Using this information the museum manager could find out the patterns of visitors when visiting the museum. Then, the museum manager could reorganize the placement of museum artifacts or the layout of the museum to provide interesting display information for museum visitors.

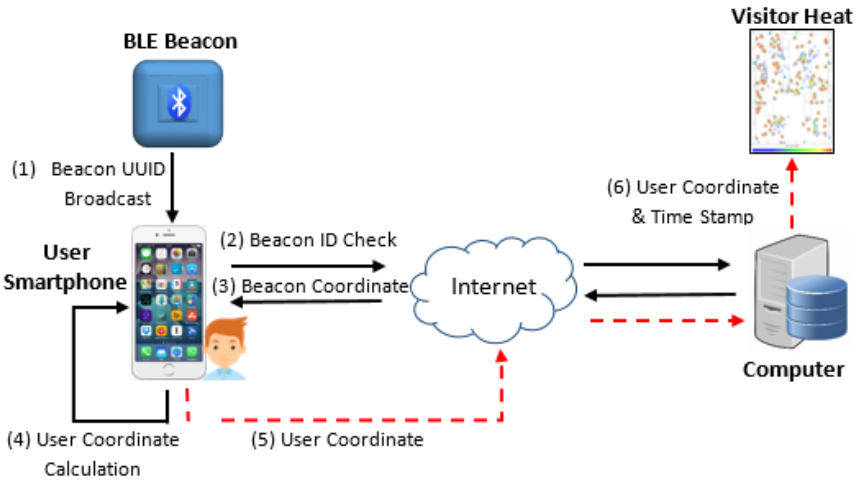

Figure 3. Bluetooth Low Energy Beacon

3. RESULTS AND ANALYSIS

As a place for testing, this study uses Trowulan Museum that located in the city of Mojokerto, East Java, Indonesia. Trowulan Museum is a museum that stores the relics of the Majapahit Kingdom (1293-1500 AD). Majapahit Kingdom was one of the largest ancient country that rule most of Indonesia, Singapore, and parts of Malaysia. The museum holds such as statues, war equipment, glassware, daily live tools, and others. This study try to cover 3 rooms in Trowulan Museum, namely the Metal Room (metal equipment, arms, etc), the Terracotta Room (contains glassware, jars, roof tile, etc), and the Sculpture Room (contains statue, sculpture, etc). Each room has a different area of 5x12 meters, 17x12 meters, and 21x21 meters. The Metal Room and the Terracotta room are both surrounded by walls, but the Sculpture Room is an open space room with a roof.

This study places a number of BLE beacons in each room. This BLE will provide a signal to detect the movement of museum visitors in the museum and detect how long they spend their time on each location. For implementation, this study place around 25 BLE beacons and records their location coordinates on computer server. This study also build a feature on the application that facilitate museum manager to simulate coverage range for each BLE beacon Figure 4. This will help the museum manager to find a suitable location for the beacon to cover all areas in the museum (using trilateration method).

The results of visitor mapping can be seen on the visitor's heat map Figure 5. Museum managers can find out the movements of museum visitors in the museum and how long they spend at each location. The red color means that many visitors are in a certain location and spend time there in a long period of time. With this data, the museum manager can analyze how many visitors come to visit a particular room or particular exhibits and how long they spend there. Using that knowledge, museum manager can conclude which room/artifact is rarely/frequently visited by museum visitors.

This study also tested the accuracy of location calculations for museum visitors. The test is done by comparing the real location data with the calculation position and taking 3 data of the highest BLE beacon signal strength that was successfully detected from the user's mobile phone. As shown in Figure 6 and Table 1 this this test is to estimate the pretinence in BLE beacons placement conducted in the terracotta room. Calculation of user location distance error is around 70-200 cm with average error distance of about 140 cm. From the tests conducted, it appears that the placement from the BLE beacons have a big influence on the accuracy of the user's location calculation. Where it emerged from testing number 1, 4, 5, and 8 Table 1 that have a low level of RSSI (around -100) also has a considerable error distance which is around 1.5 to 2 meters. Therefore, the application facilities for beacon laying simulation Figure 5 has an important role in estimating the range of each beacon and the coverage requirement for each room.

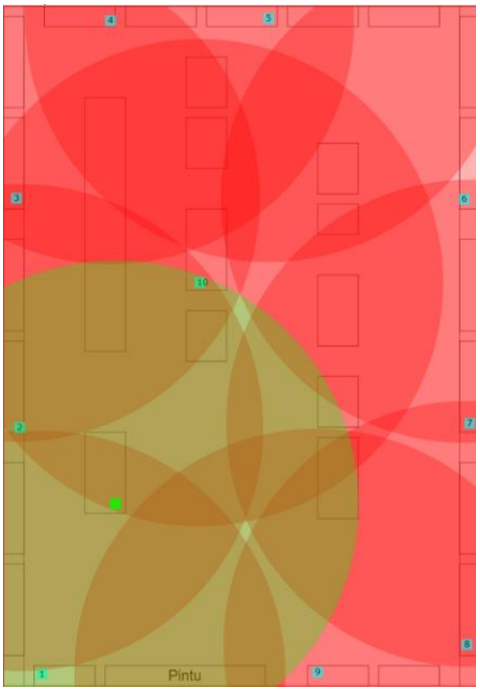

Figure 4. BLE Beacon coordinates map

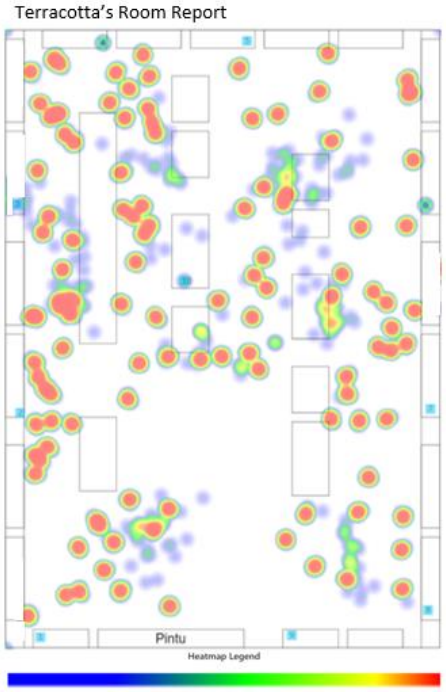

Figure 5. Museum visitors movement heatmap

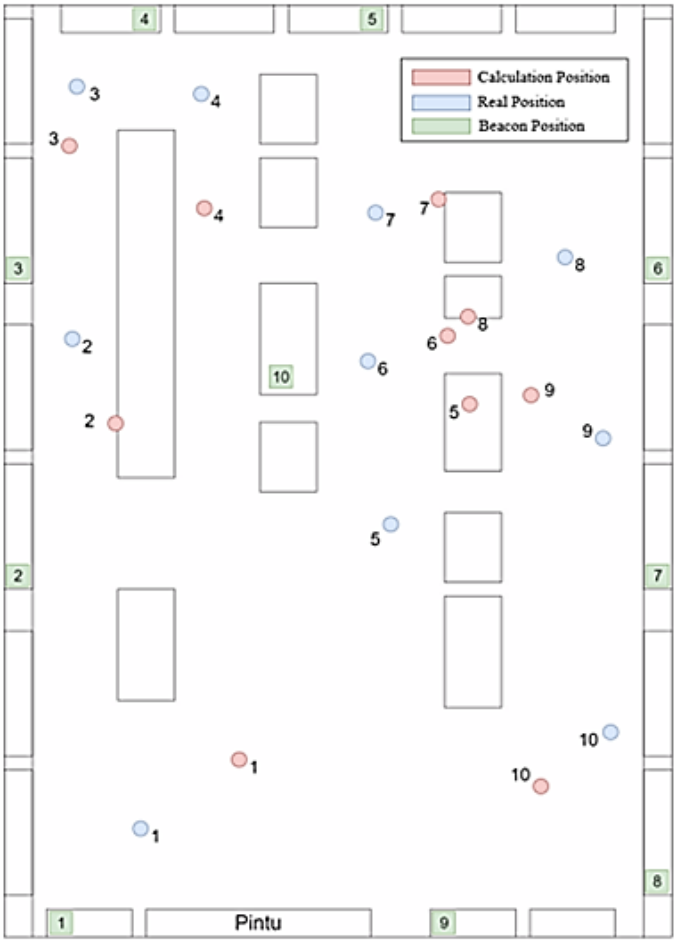

Figure 6. Visitor Position Calculation Testing

Table 1. Testing of position accuracy

No	Real Position		RSSI Beacon (Strongest Detected)			Calculation Position		Distance Error (cm)
	X	Y	1	2	3	X	Y	
1	226.67	1466.67	-95.87	-100.00	-100.48	400.00	1342.67	154.12
2	106.67	586.67	-84.23	-84.53	-91.59	182.67	738.67	130.94
3	114.67	133.33	-84.00	-89.07	-89.09	101.33	242.67	72.14
4	333.33	146.67	-100.07	-92.23	-102.00	338.67	352.00	195.40
5	666.67	920.00	-100.31	-103.88	-106.40	805.33	704.00	203.28
6	626.67	626.67	-100.84	-99.52	-108.53	766.67	581.33	147.16
7	640.00	360.00	-95.89	-92.00	-93.39	750.67	336.00	69.24
8	973.33	440.00	-92.48	-103.51	-108.24	802.67	546.67	185.26
9	1040.00	765.33	-99.35	-102.55	-98.33	913.33	688.00	138.41
10	1053.33	1293.33	-94.67	-98.47	-102.09	930.67	1390.67	106.59
Average								140.59

4. CONCLUSION

This study tries to mapping the visitor location in the museum and how long visitors are in a particular location in the museum. This mapping uses indoor positioning system using BLE beacons. BLE beacons are placed in particular places in the museum room. The signals emitted by beacons are detected by the application that installed on the museum visitor's mobile phone. The application will calculate the location of visitors using trilateration method and kalman filter. The application then sends this information to the server computer. The data is then mapped on the museum map using a website application to find out the location and how long visitors are at a particular location in the museum. This information is displayed in the form of a heat map. Based on this information, museum managers can find out which locations are often/rarely visited by visitors and how long visitors spend at that particular location. Using this visitor mapping information, the museum manager can analyze whether there are any particular locations in the museum that museum visitors rarely pass, how many visitors enter each museum area in a particular time, which museum areas/artifacts that often visited by visitors, how long they spend time in each area and which artifacts get a lot of attention and time from visitors, whether each artifacts display placement is suitable to the museum's needs. With this information, the museum manager can rearrange display artifacts, manage the flow of visitors' routes, etc. With this information, the museum manager is expected to be able to evaluate the layout of the items on display.

Based on the accuracy testing of visitor location information in real locations compared to the calculation of the visitor location using signal strength of BLE beacons. The results showed that the error distance is around 70-200 cm with an average of 140 cm. So it can be concluded that the information obtained is sufficient enough to represent the position of museum visitors. This error distance level is obtained at locations where RSSI beacon detection is not in good condition. So, it can be concluded that the laying of beacons is very decisive in getting the expected data accuracy. This accuracy could be improve by redeploy particular beacon to another place.

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