Education Support System Using Indoor Position Information and Physical Activity

Ryoichi Sekiguchi, Masaki Kawakatsu, and Minoru Ohyama
Tokyo Denki University, 5 Senju-Asahi-cho, Adachi-ku, Tokyo 120-8551, Japan
20jkm17@ms.dendai.ac.jp, kawakatu@mail.dendai.ac.jp, ohyama@mail.dendai.ac.jp

Abstract. In this paper, we propose an education support system that offers two functions: attendance management and advance notification. Attendance management is paramount in the field of education as the attendance of a large number of students needs to be accurately checked in a short time. The proposed system uses Wi-Fi indoor positioning to quickly and accurately determine a student’s indoor location. This system can manage attendance as well as late entries and early departures. Advance notification function prompts students to move from their current location to their destination. The proposed system uses a user’s physical activity and indoor position. This system measures the travel time between classrooms using the user’s smartphone. Based on the collected travel time and the current position of the student, a notification of the start of travel is made at an optimal advance notification time. This prevents students from being late for lectures.

1. Introduction
Attendance checking takes a long time in university lectures. This is because instructors have to call out the names of the students one by one. The greater the number of students, the more time the instructors spend in checking student’s attendance.

In this paper, we propose an attendance management system using Wi-Fi indoor positioning. In this way, there is no need for students to have the Radio Frequency Identification (RFID) card read by a reader mounted on a wall or the like [1]. A method using a QR code or BLE beacon has been proposed, but a method using Wi-Fi does not require new equipment [2], [3]. A student’s attendance is automatically checked based on whether the student’s Personal Computer (PC) is running during the lecture. Instructors can check their students’ attendance status in real-time using a web browser during lectures.

Students take many lectures a week. At times, they may have a long interval between lectures. In such cases, they manage the lecture schedule using Google Calendar or Microsoft Outlook. Google Calendar allows users to receive advance notification on their smartphones by setting the advance notice time. However, this advance notification time needs to be fixed by the user, and it does not consider the current location of the user. Depending on the current location of the user. Depending on the current location, the predetermined advance notification time may be too late or too early.

In this paper, we propose an advance notification system for Android devices that pre-notifies the schedule registered in Google Calendar according to the user’s current location. The travel time between the two lecture classrooms is automatically measured in advance using the Wi-Fi indoor positioning and user’s physical activity estimated by the sensors mounted on the smartphone. In consideration of the travel time, the timing of the push notification urging movement before the lecture
starts is changed according to the user’s current position. This prevents students from getting delayed for lectures or ignoring premature push notifications.

2. Related Works
Reference [4] is a Wi-Fi-based attendance management using the instructor’s terminal as an access point. If students can receive the access point signal of the instructor’s terminal, it is interpreted that students are attending the lecture.

Reference [5] is attendance management using Quick Response (QR) code. Using their smartphones, students check the attendance by reading the QR code displayed on the large screen. In this study, a dedicated application is used, and face recognition is required before QR reading; this helps prevent spoofing attendance.

Reference [6] is attendance management using RFID tags. Students register their attendance by holding their RFID tags over RFID readers.

Reference [7] is attendance management via Global Positioning System (GPS) using an Android application. The application identifies whether the students are within the designated area on the basis of the latitude and longitude, and sends their attendance data to the server.

Attendance management systems by reading QR codes or RFID tags do not enable continuous attendance management. Furthermore, with RFID readers, attendance checking takes a long time if the number of students is high.

Attendance management using GPS cannot identify classrooms in a university. Therefore, even if students are not in the designated classroom, they will be considered to have attended the lecture if they are in the university premises. Furthermore, the system cannot be used on devices without a GPS, such as PCs and tablets.

In the method of detecting the access point using the Wi-Fi tethering function of the instructor’s smartphone, it is difficult to correctly check the attendance as the radio wave is effective around several classrooms.

In this study, indoor positioning is performed using Wi-Fi, which can be used on smartphones, tablets, and PCs. Many educational institutions are now equipped with Wi-Fi networks. The educational support system that we have developed comprises a continuous attendance management system during lecture hours and a lecture schedule advance notification system that takes into account indoor position information.

3. Position Estimation
3.1. Collection of Wi-Fi Data for Learning
Wi-Fi Finger Printing [8] is used for indoor positioning. Wi-Fi data for learning was collected in advance in a total of 70 rooms—35 rooms each of Building No.2 and Building No.5, Tokyo Denki University, Senju Campus. The Wi-Fi data used to create the estimation model was collected 1500 times per room using the terminals shown in Table 1. Table 2 shows an example of Wi-Fi data obtained by one collection. The Basic Service Set Identification (BSSID) data is partially hidden.

| Table 1. Terminals for Wi-Fi data collection |
|-----------------|-----------------|
| PCs             | VAIO S11(2015), MacBook Pro (Mid 2012) |
| Smartphones     | Arrows M04, Xperia A4, Nexus5X           |

| SSID | BSSID | RSSI [dBm] | Frequency [MHz] |
|------|-------|------------|-----------------|

Table 2. Example of Wi-Fi data obtained by one collection
3.2. Collection of Wi-Fi Data for Learning

From the collected Wi-Fi data, an estimation model for each room was created. The estimation method was examined via Extreme Gradient Boosting (XGBoost) and Support Vector Machine (SVM). The data used to create the estimation model is one part of the collected data. XGBoost and SVM each created an estimation model by increasing the number of Wi-Fi data per room up to a maximum of 500 by 25. Each created estimation model was verified with Wi-Fi data that was not used for model creation. The number of datasets for verification were 2301 per room. Figure 1 shows a graph of the estimation accuracy rate. Using 25 Wi-Fi datasets per room for model creation, XGBoost and SVM showed an accuracy of 91.5% and 69.5%, respectively. Using 375 Wi-Fi datasets per room for model creation, XGBoost and SVM converged at 98.5% and 73.4%, respectively. Based on these results, we decided to use XGBoost.

As a matter of fact, we used 3000 Wi-Fi data per room for model creation. The data necessary for model creation was supplemented by data that was obtained by adding noise to the original collected data. The addition of these data has a positive effect on estimation accuracy.

A web server with the created estimation model was prepared, and an indoor positioning server was installed. From the Wi-Fi information sent from the client terminal, the server estimated the room where the user was located, and returned the result.

![Figure 1. Comparison of XGBoost and SVM of accuracy](image)

4. Attendance Management System

4.1. System Configuration

This attendance management system acquires Wi-Fi data from the user’s terminal throughout the lecture, and continuously checks attendance. The acquired Wi-Fi data is sent to the server. The instructor can check the return value (student’s indoor position) to see if the student is present. Figure 2 shows the configuration of the attendance management system.

The user logs in to the server. At that instance, the user receives a random integer between 0 and lecture time [minutes] divided by 10 as the return value from the server. Let the received integer be x.
Consider that the student’s attendance is checked five times during a lecture. The first attendance checking will be made $x$ minutes after the start of the lecture. With this random value of $x$, the frequency of accessing the server can be reduced. The user’s client application automatically sends Wi-Fi data to the server when the time comes. The server returns the estimation result (room name). A terminal sends Wi-Fi data five times and the server returns the estimated room name five times. This is because if the estimation result is considered only once and is found to be incorrect, the user is judged to be absent even if the user is in the lecture classroom. The estimation is performed five times in order to reduce this type of error, and the estimation error can be reduced by taking a majority vote among the five results. As a result of the majority decision, if a particular classroom is the majority, the client application sends an attendance request. In addition, during the lecture time [minutes], the majority vote flow is repeated five times for the purpose of checking lateness and early departure. Figure 3 shows the sequence diagram of the attendance management system.

4.2. Evaluation Experiment 1
Assuming that many students request the attendance to the server at the same time. We investigated the maximum number of people who can use the attendance management system at the same time. The computer specs used for the server are shown in the table. Increase the number of requests to the server by 10 every five seconds, and check if there is a response from the server within five seconds. Increase the number of requests until there is no response from the server, and check the upper limit of the number of simultaneous connections to the server. For the experiment, we used four MacBook Pros as clients. As a result, the server was able to process 850 requests at the same time. When more requests were sent to the server, the server took
more than 10 seconds to respond. By using this system, the server processes are divided into 10 in a 100-minute class. In other words, 8500 students can confirm attendance at the same time.

Table 3. The computer specs used for the server

| OS            | Windows10 Home |
|---------------|----------------|
| CPU           | Core i7-6700 3.40GHz |
| RAM           | 8GB            |

4.3. Evaluation Experiment 2

Using this system, attendance was checked during an actual lecture. Table 4 shows the terminals used; all the terminals correctly checked the attendance five times in a single lecture. Table 5 shows the attendance result for one student who uses ThinkPad. This was during a lecture on “Computer Mathematics” that was offered from 15:40 to 16:30 hours. This student was late for this lecture and was present at 16:00 hours.

Table 4. Terminals using attendance checking

| VAIO S11 (2015) | Let’s Note | ThinkPad |

Table 5. Attendance for the lecture on “Computer Mathematics”

| Time             | Attendance count |
|------------------|------------------|
| 2019-12-11 16:01:51.30 | 2               |
| 2019-12-11 16:11:51.67 | 3               |
| 2019-12-11 16:21:52.25 | 4               |

5. Classroom Movement Timing Notification System

5.1. Space considerations

The classroom movement timing notification system provides advance notice of the movement timing on the basis of the user’s lecture schedule acquired using the Google Calendar Application Program Interface (API), according to the user’s current position acquired from Wi-Fi indoor positioning. Figure 4 shows the configuration diagram of the inter-classroom movement timing notification system.

Figure 4. Configuration of Classroom movement timing notification system

5.1.1. Measurement of Travel Time. It is necessary to measure the travel time between classrooms in order to give advance notification considering the current location. Therefore, travel times between two rooms the user has visited, including classrooms and laboratories, need to be automatically collected from the user’s daily life.

The travel time is defined as the time from the current location (stop state) to the stop state at the destination. To measure this time, it is necessary to estimate the user’s physical activity. Therefore, the physical activity of the user is estimated every second by the processing shown in Fig.5 and Fig.6.
When indoors, three physical activities of the user need to be considered: stopping, walking, and being in an elevator or on an escalator. In this system, it is paramount to know whether or not the user is moving, so walking and climbing stairs are considered to be the same. Moreover, user movement is estimated using data from the phone’s acceleration sensor and atmospheric pressure sensor; if it is determined that the user is moving, the server is not accessed because indoor positioning is not required, thereby reducing the load on the server.

In the stop state, indoor positioning is performed and it is determined whether the obtained location is a lecture classroom. If the result is not a lecture classroom, the positioning result is used as the starting point. If the result is a lecture classroom, then the lecture classroom is set as the arrival point, and the time elapsed since when the departure point was last acquired as the result of indoor positioning is recorded as required time. In this measurement result, if the time taken is 30 seconds or more, the value is rounded up to one minute. This is because Google Calendar does not provide advance notification function in seconds. The measured travel time between the two rooms is stored in the format shown in Table 6.

![Figure 5. Algorithm for physical activity estimation](image)

```
Algorithm 1 Algorithm for Physical Activity
1: StopCount = 0
2: LOOP Process Every Second
3: if (√(Acc_x^2 + Acc_y^2) > 3) then
4:     movingstate = Walking
5: else
6:     if |Pressure(t - 1) - Pressure(t)| ≥ 0.07 then
7:         movingstate = Elevator or Escalator
8:     StopCount = 0
9: else
10:     if movingstate == Walking then
11:         IndoorPositioning
12:     else
13:         StopCount++ = 1
14:     if StopCount == 5 then
15:         StopCount = 0
16:     IndoorPositioning
17: else
18:     movingstate = Stop
19: end if
20: end if
21: end if
22: Wait(1 second)
23: end if
```

![Figure 6. Pseudo code of Algorithm for physical activity estimation](image)
5.1.2. Measurement of Advance Notification Timing. Each user pre-registers how many minutes before the lecture they want to arrive in the lecture class. This registration time is called an offset. After performing indoor location positioning and obtaining the user’s current location, the system extracts the travel times data from the user’s current location to his/her lecture classroom, as in Table 5 and then calculates average travel time. The time obtained by subtracting the offset and travel time from the lecture start time is registered in the system as the advance notice time of the lecture schedule of Google Calendar by the Google Calendar API. As a result, the push notification of the schedule can be received at the timing according to the current position.

5.2. Evaluation Experiment
We checked whether the lecture schedule registered in Google Calendar was properly pre-notified. The terminal used was Nexus5X. The lecture classroom was classroom 2302 on the third floor of Building No.2 and the departure point was a laboratory on the 10th floor of Building No.5. Table 7 shows a part of the data on travel time between classrooms extracted from Table 5, in advance, by the algorithm of this system.

| Table 6. Travel time between the laboratory and classroom 2302 |
|---------------------------------------------------------------|
| Laboratory → Classroom 2302 | 3 m 33 s 41 |
| Laboratory → Classroom 5301 | 2 m 20 s 23 |
| Classroom 2302 → Laboratory | 4 m 6 s 61 |
| Classroom 5301 → Classroom 2302 | 2 m 10 s 23 |
| Laboratory → Classroom 2302 | 3 m 28 s 64 |

| Table 7. Travel time between the laboratory and classroom 2302 |
|---------------------------------------------------------------|
| Laboratory → Classroom 2302 | 3 m 33 s 41 |
| Classroom 2302 → Laboratory | 4 m 6 s 61 |
| Laboratory → Classroom 2302 | 3 m 28 s 64 |

The advance notice reached the time when the offset and the average travel time were subtracted from the lecture start time. In this case, the average travel time of accumulated data in Table 6 was rounded off to four minutes. The user wanted to get to the lecture classroom five minutes before, so the offset was set to five minutes. In other words, the advance notification arrived nine minutes before the lecture start time.

Nine minutes before the start of the lecture, the user received advance notification and went from the laboratory to classroom 2302, which took 3 minutes and 43 seconds. The user arrived at classroom 2302 before the lecture started. The advance notification of this system functioned properly.

6. Conclusion
We developed an attendance management system and a classroom movement timing notification system as an educational support system using location information and physical activity.

In the attendance management system, continuous automatic attendance management was realized. In the classroom movement timing notification system, advance notification was given in consideration of the travel time of the lecture schedule in indoor, using Google Calendar. The travel time was recorded using the user’s physical activity and indoor positioning. This function can also be used for faculty meetings within the university. Furthermore, besides education, it is possible to give advance notification of company meetings and to analyze the periods during which elevators are congested from the history of moving conditions, and to shift the end time of meetings. In addition, it
is possible to give advance notification considering the travel time outdoors by extending to the outdoors.

In the future, we will examine whether the attendance management system can be operated correctly by confirming the attendance by a large number of people. The classroom movement timing notification system adds a function that allows advance notification even though the user is outdoors.

7. References

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