Performance Analysis of Automatic Integrated Long-Range RFID and Webcam System

Minh-Duy Tran¹,² · Kha-Tu Huynh¹,² · Van-Hieu Pham¹,² · Anh-Tu Phan¹,² · Quoc-Khanh Nguyen¹,² · Xuan-Phuc Phan Nguyen¹,² · Tu-Nga Ly¹,²

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Abstract
In the academic environment, checking attendance can help lecturers better evaluate students’ performance in university. Traditional attendance checking has some disadvantages, which are wasting time and effort. The automatic attendance monitoring system, on the other hand, not only can help us solve these drawbacks but also bring a high-accuracy result compared to manually checking. The method uses ultra-high-frequency (UHF) RFID technology with four circularly polarized antennas, combined with the high-definition camera system used for face recognition that allows the system to recognize students’ faces. The system will check the attendance of students in offline classes through an RFID reader and camera which are set up in classrooms. In the case of online study in which students learn from home, the system can use students’ cameras directly from their laptops and smartphones to recognize their faces and check attendance. The web-based information system has real-time updates with attendance monitoring that allows the lecturer to review or determine the student’s attendance status. In the event of unexpected issues on the student side, the system enables lecturers to check attendance manually after receiving the student’s request. Our system, furthermore, can automatically generate a weekly report about student’s learning status in each class and provide the overall proportion of students’ commitment to attending classes for the lecturer. This paper brings some initial simulations of the system to give a more detailed picture of how the new system works and interacts. Besides, this manuscript provides a detailed performance analysis about the system with RFID and camera, then has an evaluation based on class’ learning outcome. The time, precision, and accuracy of our system are considered.

Keywords RFID · Face recognition · High-definition camera · Attendance monitoring · Web-based system · Real-time information system · Statistics · Analysis

Introduction
Based on [1, 2], the class attendance level of students can represent the class’s quality and student performance. Participating in class allows students to interact with each other and with lecturers, which can produce the influence,
better in studying and utilizing the information, lecture on course and in their future career. That is the reason why many universities require using students’ class attendance level as a criterion in assessment and performance evaluation. Traditional attendance monitoring produced manually by checking students directly face to face or using forms in class have some remaining weaknesses that can be improved and advanced with an automated information system. This proposed attendance system reduces the resource and time expense for class management [3, 4].

Recently, multiple methods, technologies and equipment have been used to develop an automated attendance system [5, 6]. First, RFID technology used for attendance monitoring [5] has been proven efficient in performance that delivers high speed, high accuracy, and user friendliness without a high cost in installation, operation, and maintenance phases. Unlike short-range low-/high-frequency RFID, QR code or Barcode, UHF RFID uses its output data to generate localization functionality for checking student signals [7, 8]. Our recent research proposed developing long-range UHF RFID technology with the high-definition camera to automate attendance monitoring system from 1 to 3 m range in real-time database (see Figs. 2b and 5 in [6]).

Compared to the system proposed in [6], our system has combined face recognition technology as a biometric authentication method. By that way, it can bring us a more advanced system with higher accuracy and provide more data for monitoring and analyzing. In addition, the system brings students more active in checking attendance using the camera system directly in class for offline learning [9–11] or their camera on their laptops, smartphones for online learning [2], which is more convenient and adapts to the current COVID-19 situation that many courses are produced through online platforms.

Our main contributions are the following: first, a set of training images that contains student’s faces is collected to feed the system. A set of collected student faces is used to compare with the one captured on camera, then mark it as attendance if they belong to the same person. According to our information system in [6], second, we continue to analyze the performance of the learning outcomes to show with automatic RFID which is useful to improve the quality learning; To reach our current goal for teaching online or security-based face recognition, thirdly, the integrated RFID and webcam is deployed. We apply Histogram of Oriented Gradient (HOG) technique to detect [12] and Convolution Neural Network (CNN) to recognize [13] the face student. Finally, the time and the precision of our system are measured.

All related works are presented in “Literature Review”, where the authors will review previous research and lay the foundation for this system. In “Proposed System”, executions from hardware attribute measurement to software development are demonstrated. The results of the experiments using the established system are produced in “Simulation Results”. Finally, the authors give a conclusion including completed work and suggest future improvements.

Literature Review

Attendance System-Based RFID

Referring from [1–3, 5, 6], there are some common approaches where the RFID component is used for the management system to roll call. There are several studies and research that could be automatically indicated web-based [5, 6]. Based on the technique [5] for the employee identification purpose, the research team created a real-time RFID system that includes an RC522 card reader, a web-based interface stored on a server, and a database behind. The team set up the distance of the card reader to be roughly 5 cm in this case. In a similar vein, the authors [1] give a method for estimating average reading time and automatically computing student attendance percentage based on gathered and saved data.

Analyzing and processing the data can be considered a potential and crucial part for the class management system. Proposed RFID-based attendance systems [3] have analyzed and assessed for system functioning as well as the major results for future research areas. These technologies have been achieved as programming languages and frameworks in web development; however, they perform poorly in terms of real-time and optimized data traffic aspects. For the same purpose, but the proposed system in [6] prefers using more complex technologies and frameworks, such as NodeJS and MongoDB, that can improve the system’s performance [14]. The author [2], meanwhile, suggested some recommendations to improve e-learning acceptance and learning outcomes of students in Vietnam via five factors including university support, students’ computer competency, infrastructure, content and design of courses, and student collaboration.

Our recent research [6] introduced an automated attendance system based on radio frequencies with long-distance ranges (1–3 m) with adjusted power from 18 to 24 dBm (see Fig. 3b [6]). This leads us to examine the student’s status by displaying the student’s name in real-time in case of card fraud and remind students of the number of lessons via email (see Fig. 10 [6]) so that they are more aware of the situation and more inclined to visit class, as well as automatically digitizing and visualizing the sessions for the teacher in terms of statistics (see Figs. 8 and 9 [6]).
Integrated RFID and Face Recognition

The use of RFID for roll call does not ensure that the person who uses the card for roll call is the person who is calling. To overcome these concerns, the research from [2, 9–11] integrated the face recognition into the RFID for roll call.

An automated checking attendance approach with face recognition can be referred to the study [10]. The paper describes a method using the webcam for getting training sets and testing sets, and the Principle Component Analysis (PCA) algorithm for learning. The system also provides log file maintenance keeping records of each student over the overall system time. With a 98.7% detection rate and 95% recognition rate, the archived performance is quite good at the publication time. The required distance for face checking is extremely short (50 cm); however, it is difficult when applied in reality.

In the study [9], the author has proposed a method based on the combination of facial recognition and RFID tags for the office checkup task in a surveillance monitoring system. The technology is specifically connected to a SQL Server database, which provides greater synchronization than standard surveillance management solutions. With a short-range RC522 card reader, this system scanned tags and confirmed from 200 to 300 photos with 93.5–95.3% accuracy. Furthermore, for processing facial data for checking, they have presented two methods including the Viola–Jones method for detecting face objects in images and the Local Binary Patterns Histogram (LBPH) algorithm for facial identification [3]. The author tested 11 samples using RFID cards with modest distance, ranging from 1 to 4 cm. Meanwhile, the author [2] analyzed the learning outcome of students in Vietnam by e-learning acknowledgment that was influenced by five factors including university support, students’ computer skill, collaboration, infrastructure, content, and design of courses. Another author [11] proposed integrating deep learning face recognition and RFID technology, then analyzed traditional face recognition technology with deep learning neural network recognition technology.

Proposed System

In this study, our team proposes a fully developed system that utilizing the Impinj R2000 reader, C# Win-form [15] for desktop middleware, Node.js and Express.js for back-end, MongoDB [16], Mongoose for database, and React.js, Ant Design for front-end part. Supporting RFID, using Face Recognition is the new feature deployed in our system to check the attendance of students in class. The core component of the algorithm is a deep neural network module named OpenFace with the trained models. The result from this model will be returned as a REST API which connects with this system.

System Architecture

Figure 1 presents the attendance system architecture using long-range RFID and webcam. The system architecture uses client–server architecture. The client is an attendance desktop middleware app (C# Winform) that a computer installed it to receive tag data and read from the reader and the student’s image taken from camera. The reader and camera are placed in a position that is suitable to capture students’ tags going in and out of the classroom (the recommended position is determined in the section of “Tag reading range”). Three of them must be connected to a Local Area Network (LAN) of the university. The middleware desktop app is also considered as the system’s client where it can be used to transmit the information from the user to the web server.

This middleware is at least able to fetch current course data of the classroom from and send attendance checking requests to the backend application and display the attendance results to students. As the improved performance [14], the Nodejs server is hosted on the Heroku cloud, connected, and manipulates data on the MongoDB cloud storage, and sends report emails to both students and lecturers. The frontend application is written with ReactJS, decorated by Ant Design, while the middleware is developed by C#. The webpage serves the Admin, who manages the course, and student data, and lecturers, who manage their courses’ attendance. To be more specific, we will have the middleware receive data and then send these through the REST API. The REST API is responsible as the server to receive every signal that was sent to them by the client. To verify the identity of the face student, the webcam is used for face-recognition. Our new updated system structure is shown in Fig. 1.

Hardware Placement

The new system has an integration with the webcam for face recognition so the team decided to keep the placement for the RFID system and find out the suitable placement for the webcam which can work smoothly and obtain positive results.

First about the RFID placement, the transceiver distance of the RFID reader is measured from the center of the hardware and a full 360° circle with the center as the reader’s antenna. Each different measurement angle will record the best position to calculate the average value that the reader can identify student attendance cards quickly and accurately as shown in Fig. 2. The reason for this measurement is because we want to consider when students approach the card reader in many different directions how the signal will
be received, thereby choosing the most suitable power for the reader.

We keep the long-range RFID card reader with a circular polarization antenna arrangement including 4 antenna bars arranged on four square sides, each antenna bar having dimensions of 7.2 cm x 2.3 cm (see Fig. 2a). These four antenna bars are divided into two parts at the antenna input: the left-hand two circular polarization (LHCP: left-hand circular polarization) antenna bars and the right-hand two antenna bars (RHCP: right-hand circular polarization).
Each classroom requires a UHF RFID reader as shown in Fig. 2b to be mounted on top of the door or mounted on a 1.65 m-high rack next to the door. For a UHF RFID reader, placement is important for it to read tags effectively in a determined range under any circumstances [17].

As in our previous study [6], we keep placing the mount within the range of 1–3 m so that the reader can read the card when the student has just opened the door and entered the classroom. Here, we introduce how to place the webcam in our integrated system shown in Fig. 2c. Moving to the webcam place plan for the face recognition part, the core library used in the face checking system, has the best performance when catching up the human’s face. A camera with a 90° viewing angle, therefore, needs to be placed on the ceiling facing the door. This setting allows the camera to capture the face of any student entering the class.

Software Analysis

The ambiance of the RFID system, if presented with a high volume of metallic and liquid components, can cause a destabilized electromagnetic condition [18]. Therefore, regulation is required to ensure successful attendance monitoring. For a student to check attendance, see Fig. 3, he/she is obligated to carry his/her RFID student card separated from metal objects (vacuum flask, phone, etc.), liquid, and other RFID cards as these can reduce the reading sensitivity. The student can walk past the reader and wait for their result to appear on the screen. The server requires the course’s ID and the student tag’s ID from the middleware to determine if the student is registered for the course or not. If the student registered, the server stores the attendance data in the database and responds successfully to the middleware. The result is then displayed on the web application authenticated by the classroom teacher.

To enhance the security and reliability of the system, the student is required to check attendance by webcam. While the system receives the signal from their student's card, the webcam will automatically take the student's image and send it back to the server for the recognition process. Then the system will double-check with the student card signal and the face recognition data to ensure that the student present in the class.

Face Recognition

In this subsection, we briefly introduce two phases for recognition of the human face. The first is face detection [12] and face recognition based on HOG and CNN, respectively.

First, two models of dlib’s face detector are HOG [12] is less accurate but faster on CPU and CNN [13] is more accurate with GPU/CUDA acceleration. We apply HOG model due to its low latency and quick response, suitable for application in a classroom environment, see Fig. 4. It is a feature descriptor used in computer vision and image processing for the purpose of object detection. It counts incidences of edge directions in a local neighborhood of an image. This detection task is performed by applying dlib’s HOG and Linear SVM in the acquired images. Dlib face detector is built out of 5 HOG filters: a front looking, left looking, right looking, front looking but rotated left, and finally a front looking but
rotated right one.\(^1\) All detectors are trained on labeled faces in the wild dataset.\(^2\)

The HOG approach is currently the most used feature of computer vision to describe the local texture of an image. In design, the local area orientation gradient histogram in the image is calculated. To form facial features. After obtaining the HOG feature vector in the image, it is common to combine the SVM classifier for image classification. At first, SVM and HOG were widely used in pedestrian detection.

Second, our face recognition uses dlib’s ResNet model v1 as a face recognition algorithm. ResNet, standing for residual network\(^3\) was first introduced in 2015 and came first in the ImageNet detection, ImageNet localization, COCO detection and COCO segmentation in the ILSVRC and COCO competitions of 2015\(^2\). This Dlib’s face recognition model maps human faces into 128D vectors where pictures of the same person are mapped near to each other, and pictures of different people are mapped far apart.\(^3\) After encoding both the training dataset and the test input image, a Euclidean distance function is used to compare the similarity between 2128-dimensional face encodings. The smaller the distance, the more similar the face is. There are 3 types of results:

(i) Has face on camera and the closest distance < 0.45: mark as attendance, return id and accuracy (one distance).
(ii) Has face on camera and the closest distance > 0.45: request to capture again and return accuracy.
(iii) Has no face on camera: request to capture again.

**Database**

For a MongoDB database, a collection contains documents, which is similar to a table containing rows of data in a SQL database, see Fig. 5 (the next page). Each row of data requires an elicit primary key in SQL database, as for MongoDB, each document is generated with its ObjectId, thus requiring no primary or foreign key. Both users, admin, and lecturer have their table, which stores the name, email, and encrypted password. Lecturer also has information about courses that they are teaching. Each student has an RFID tag’s ID. During testing, 200 tags are used, and the tags’ IDs are stored in the database to create and update students more easily. A course, or a class, contains the time and location of the class to help determine where and when its sessions will be held. Each attendance record stores ObjectIds of the course and student, and the check times store the times the reader reads the student’s tag. Check-in, check-out, and leave for a break can be determined via the CheckTimes attribute. Here, our new designed attendance field and student field are modified with check Face, check RFID, a faceID, respectively, compared with Fig. 7 \(^6\). Referring to Fig. 1, the table Webcam Recognition system is used to store all the images captured by the webcam, and then the system will process the data from the webcam and compare it to the RFID’s data to identify the student.

**Advantages and Disadvantages**

To compare the effectiveness and efficiency of using an RFID system for student attendance (from our study on \(^6\)) with the use of an integrated long-range RFID and Webcam, there are some considerations points as follows:

**Advantage For RFID system:**

(1) All the work concerned with the data is automatically done by the system. It helps to save time when running.
(2) The lecturer is able to know exactly about the attendance circumstance within the class section.
(3) The student will receive an email to remind them about his/her attendance status if they nearly overcome the allowed day-offs.
(4) The lecturer will receive an email to notify the attendance status of the class weekly.
(5) Less cost when applying for the entire university.

**For RFID system with the help of webcam for face recognition:**

(1) High authenticity
(2) Relatively low pay per class
(3) Convenient in moving the device, easy to set up

**Disadvantage For RFID system:**
(1) Security is not high, fraud occurs when students ask their friends to take attendance.
(2) High cost if just applying for a few classes.

For RFID system with the help of webcam for face recognition:

(1) Currently the system does not automatically recognize when students enter the class, must go through the manual image confirmation step.
(2) Students need to enter the correct webcam to get the best recognition results, to avoid the system failing to detect the student's face.

Simulation Results

Setup RFID and Webcam System

The placement of RFID reader and camera equipment, Fig. 6 shows label A is the distance from the student to RFID reader (width of 60 cm), label B is the distance from the student to the camera, which the width is about 70 cm. Also, the distance between the RFID reader and the Webcam is roughly 10 cm (label C). The reader is tested with various arrangements, such as no tilt or 45° tilt, at distances ranging from 0 to 100 cm. The reader is tested with various layouts, such as no tilt or 45° tilt, at distances ranging from 0 to 100 cm. With a slanted degree, the reader can perform well for both check-in and check-out periods; without a tilt, check-out performance is less effective than check-in, and with a decent distance from the door, the reader cannot scan tags that are beyond the border, outside the room, or near the entrance. The arrangement is primarily based on the authors' experience because it is dependent on the construction of the room, the thickness and material of the walls and doors, other equipment inside the room, the number of students and RFID tags in the affected area.

To determine the recognition range based on angle, by integrating a webcam for face recognition, the system will conduct automatic facial recognition of students when they step into the webcam's range, see Fig. 7. The webcam is located next to the RFID reader so that card reading and face recognition can occur simultaneously. Our experiment shows that with a wide camera angle (78°), the camera can detect
students up to about 4 m away and still obtain excellent and stable quality images.

Now, we measure the time of our system. First, the time of RFID-recognition is nearly real-time, meaning that it is very small. Leading to our system just consider to measure the time of face-recognition. According to Fig. 11, the time of capture face student is about from 0.47 to 0.51 s for one person. Based on our experimental, the time to capture face-recognition and ID student in manual attendance is about 1 s per person. With checking one person, therefore, the time of our method is better than the manual attendance approach. Moreover, the manual attendance does not reliably detect all cheating attempts. With a bigger number of attendees and more cheating attempts, manual approach does not effectively catch up.

The Performance of Face Recognition

Figure 7 shows the test cases that the group has made based on collecting personal photos from the team members, then conducting the train and using the webcam to identify the comparison with the trained images. To expand the stability as well as the image quality obtained, the group proposed transformations from the webcam of individual laptops to using Logitech C922 webcam to improve performance and increase the accuracy of the system.

We conduct student face recognition in a home classroom environment for testing purposes, with medium–low light conditions, and the image recognition distance is close to 0.3–0.6 m, the accuracy we obtained at the five different angles (see Fig. 7) and about 55–68%. When conducting face recognition of students in the actual classroom, meanwhile, the lighting conditions are good. The detection distance is also about 0.3 m to nearly 0.6 m, similar to the home study room; the results have significantly improved. The accuracy has been enhanced by about 25%. The average accuracy falls from about 80% to about 92% (see Fig. 8a).

Conversely, when the collected data do not match, if the signal from the RFID tag and the face recognition result return not the same person, the system will print a small message for the user to recognize (see Fig. 8b).

In addition, there are still some invalid cases where the system cannot detect the student's identity, that is, the student image is captured at an angle of 180°, not directly towards the camera. When the image data obtained will not be enough to compare the compatibility with the available data set, the information system will display a small message to remind the user to try again (see Fig. 8c).

To verify the accuracy of the algorithm as well as the flexibility of the webcam, the research team has added the measurement methods of error, calculation accuracy, and image recognition time to improve the system's performance. We did a little experimentation that compares the resulting images with pre-trained images, and the results are like the confusion matrix below.

The results from the confusion matrix are very usable shown in Fig. 9. It indicates out of 100 available records, the algorithm’s prediction success rate is up to 58.24% of the total via Eq. (1):

\[
\text{Precision} = \frac{TP}{TP + FP}
\]

where TP and FP are True Positives and Fail Positives, respectively.

Final, Fig. 10 confirms that system has received enough authentication data from both the RFID and the face recognition, it will then verify the student's attendance and record their authentication time.

The Performance of Attendance with and Without RFID

In addition to analyzing the data of classes that use the RFID system to take attendance in each class, the group study also included a dataset of classes in the same course but not equipped RFID system for comparison, from which it is possible to clarify the visualization and benefits of the RFID system.

Based on the study [21], each class's raw data or report will be cleaned before processing to analyze them. Initial data was obtained from the International University and contained the Computer Architecture (CA) and Artificial
Fig. 8  

a Set up the system and capture images of student—SUCCESS case.  
b Set up the system and capture images of student—fail case.  
c Set up the system and capture images of student—exception case.
Intelligence (AI) class's attendance data from the years 2020–2021. The data is obtained as a CSV/Excel file and is cleaned by a manual process. For these students, a record time during a class session will be marked as 1; otherwise, the missing values were replaced with 0, indicating that the student was absent. By collecting the attendance data from both AI class and CA class, we construct Table 1 to review the way that RFID systems have an impact on the student's presence.

Besides, through the inheritance from [6], attendance data of the classes in the same course are also included for the purpose of comparing and evaluating the final learning results. For classes that do not use the RFID system for attendance, the assessment and scoring of the process is conducted by assessing the students' practice scores through each lab test.

In order for the assessment of students' progress to be fair, classes that are not equipped with an RFID attendance system will be counted by completing two-thirds of...
the lab exercises; in other words, students must get a lab score of at least 70 points above, and the student will be considered to be in that session. The marking of 2 out of 3 labs is because during the lecture, for exercises at a low level of reading comprehension and application, the lecturer will give detailed instructions to students about the practices; that is, getting the total score depends on whether the student is willing to attend the class to listen to the lecture or not. From the charts in Fig. 12b, it can be witnessed that most of the students attending the AI lab class completed the minimum score of the subject. The same is true for CA lab classes, where student participation in these classes has also remained steady.

Thanks to the study of [22], Fig. 11 shows us the boxplots of classes that use the RFID system to take attendance, the graph shows how the parameters of students in classes participating in classes behave. As explained in Table [5], we construct this boxplot based on data obtained from Computer Architecture (CA) and Artificial Intelligence (AI) classes from the academic year 2020–2021. Each class will have a unique ID for identification; for instance, AI-1 is the first AI class, and the same marking is also applied to CA classes. The correlation between these classes that use the RFID attendance system has been expressed in granularities from the above chart. Since then, it can take specific measures to improve and maintain the stability of students attending the classroom.

In addition, to analyze the effectiveness of using the RFID system in the classroom, the team proposed to use the final score of the lab classes for assessment. It aims to see how different students’ attitudes and learning outcomes are when the course is equipped with an RFID attendance system and vice versa. Combining the results from Fig. 12a, b, it can be witnessed that, for most students from different classes but equipped with the RFID system, their average Final Score is mostly higher than 80 points. And especially, there are no dropouts in these classes. In contrast, for these classes that are not equipped with an RFID system, the average Final Score of these classes ranges from 60 to about 85. In general, we can see more stability in terms of scores of classes using RFID.

Compared to the students in the AI class, these students with a final score greater than 90 will be classified as the LO3; otherwise, they will be considered as the LO2 shown in Fig. 13. The chart from Fig. 13 clearly shows the trend of AI class using RFID and not using RFID. More specifically, for the class equipped with an RFID system for attendance, the percentage of students classified into LO2 is about 52%, and LO3 is 48%, respectively. Meanwhile, for classes not equipped with RFID, the percentage of students falling into the LO2 group is about 55%, and 45% for LO3.
For the CA Class, students with a final score above or equal to 90 will be classified into LO5, from 60 to less than 90 will be placed in LO4, and the rest will be placed in LO3. From that criterion, we constructed the line chart in Fig. 14; the group also conducted clean data. To get more accurate results, we removed students who dropped subjects from the data set; the results obtained most accurately reflect the students’ academic performance. Combining the graph (see Fig. 14) and Table 2, we have the following parameters, for the CA classes equipped with the RFID system for attendance, we obtain the proportions of the classifiers from LO3, LO4 to LO5 are 17, 48, and 35%, respectively. Besides, for the classes that are not equipped with RFID, we have students classified into the LO3 group at 18%, LO4 is 53% higher than the classes equipped with RFID, but LO5 is lower, only about 29%.

Based on the above parameters, the result can be easily obtained that for the classes equipped with RFID, the percentage of students classified as LO3 is higher than in the classes that are not equipped with RFID. While the same was true for students in CA classes, the percentage of students classified as LO5 is also higher than that in classes without RFID. This class achieved relatively high scores when equipped with an RFID system for attendance. In addition, the dropout rate of students in these classes is also much
lower than that of classes that are not equipped with RFID (see Table 2).

Conclusion

In this paper, our experiments and results reported here indicate that it is possible to construct and create an attendance system employing UHF radio identification with a circularly polarized antenna, an automated tag reading range of 1–3 m combined with face recognition through the camera system. This technology assists instructors and students in visualizing and automating time management in the classroom. The team provided a strategy for automatically raising and lowering the power of the RFID reader in an appropriate time based on the system’s operational distance measurement spectrum. The design findings of the circularly polarized antenna have been confirmed by experimental measurement of the axis ratio parameter to be satisfactory and in accordance with the specifications. In addition to taking attendance with student cards, students in each class must perform a second authentication step: face recognition. The system’s webcam will capture each student’s frame and return it to the server to conduct data recognition; after comparing the available data set and the received image, the system will return the result that the student is successfully recognized or not ask the student to try again. The team also offers a mechanism to avoid card fraud and methods to aid instructors in updating students’ attendance status when they lose or forget their cards. Stakeholders get email alerts with the findings of weekly reports. Finally, we compare the radiation patterns based on modeling and implementation to increase the antenna’s coverage distance for each situation. More features for improved user involvement can be added in the future, such as a mobile application allowing students to check their attendance and be alerted to forthcoming classes. To improve system architecture performance, difficulties of considerable data traffic and multiple data formats may be solved by constructing data streaming pipelines; an algorithm can be designed to automate power adjustment based on data from student check-in times. In addition, the system will be expanded to serve the purpose of online attendance, allowing students to use the computer’s webcam or camera system to submit facial data, which will help lecturers manage their classes well due to the epidemic situation and students cannot attend offline classes normally.

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Declarations

Conflict of interest The authors declare that we have no conflict of interest.

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