Automated Attendance System using RFID, Face Recognition, and SMS

Roger H. Abucejo Jr[1], Jeffrey G. Bernadas[2], Abdul Fahad A. Pangandaman[3], Lucilyn C. Borja[4]
Surigao State College of Technology, Philippines
rabucejo@ssct.edu.ph, jbernadas@ssct.edu.ph, apangandaman@ssct.edu.ph, lborja@ssct.edu.ph

***Abstract*--This study is developed to create an Automated Attendance System that uses a Raspberry Pi 4B microcomputer to handle Face Recognition and RFID Reading to verify a student's identity. After a successful verification, the system will communicate with an API to record the attendance and send a text message to their parents through the GSM module. Additionally, it has a Web Application that lets administrators and students see their attendance record. The development is divided into four phases: REST API development using NodeJS, ExpressJS, and MySQL database; creation of a frontend web application with ReactJS and Redux that lets students see their attendance; the hardware development with an RC522 RFID Reader, SIM900A GSM Module, and Raspberry Pi microcomputer; and the Face Recognition functionality that uses several Python libraries. A System Development Life Cycle (SDLC) is applied in the first three phases to help plan the development, analyze the requirements needed to be accomplished, and ensure its maintainability after the implementation. The system successfully utilized and integrated the face recognition with RFID reading capabilities to identify students with an acceptable accuracy, resulting in a successful attendance recording, sending of SMS, and providing logs that can be seen in a web application.**

***Index Terms*—Automated, Face Recognition, RESTFUL API, RFID, Microcomputer**

I. INTRODUCTION

Attendance has been part of many institutions, specifically in the workplace and academe worldwide. It is a way to measure an individual's commitment to what they do. Over the years, the method of recording the attendance of an individual has drastically improved from writing, to QR scanning and biometrics giving birth to the idea of creating a full-fledged attendance system to track an individual's time, presence, and attendance information.

An attendance system helps provide time efficiency for every individual every day as it removes the need to write them, which is how the traditional way is done and enhances the security of an institution that implemented it. It is also a way to monitor if an individual is performing well and is committed to what they do every day.

In modern times, some organizations and schools already use automated attendance systems. Biometrics is one well-known usage for attendance monitoring. Specifically, biometrics uses fingerprints of individuals or employees to verify who is clocking in and clocking out of work each day. It is good and time-efficient; however, due to the never-ending threat of the Covid-19 virus, the researchers avoided using products that may involve any form of body contact. Thus, the researchers decided to use RFID and face recognition as a safe and robust primary and secondary verification for automated attendance monitoring.

The study is specifically developed to solve the problem in Surigao del Norte National High School – Senior High among parents, children, and teachers. The traditional way of recording attendance in this institution is through paper; however, it has several drawbacks aside from it being harder to maintain for an extended period of time. One is there is just no way of knowing fully if a student made the attendance as anyone can do it as long as they have the student's name and signature. Moreover, parents are still reluctant to have their child attend face-to-face classes as they will have no way of knowing if their child entered the school during that day. Additionally, teachers, students, and parents have no platform to monitor their attendance records. Lastly, the implementation of the "No Identification No Entry" policy should be stricter than ever to remove the risk of unauthorized entry into the school.

The researchers carefully developed an Automated Attendance System using RFID, Face Recognition, and SMS using a Raspberry Pi 4b microcomputer by carefully considering the above drawbacks. The system has several benefits for Surigao del Norte National High school as it provides efficiency and high-level verification attendance in the institution and assures parents and guardians of the children as it uses GSM Module that sends an SMS notification whenever the children enter the school premises. It also contains an online system platform that students and their parents can access to see their attendance logs. School teachers and staff can also access them to verify if the student indeed entered the school and their lecture during that day.

The researchers conducted this study and developed a functional end-project to cater the problems the academic institution, Surigao del Norte National High School is currently experiencing as they transition back to face-to-face classes again.

Review of Related Literature

Salim et al. (2018), proposed a method of developing a comprehensive embedded class attendance system using facial recognition with controlling the door access. The facial recognition is done by implementing Local Binary Patterns (LBP) and Haar Feature-based Cascade algorithm, images are then detected and cropped for its region of interest.[3].

To Nimithka K et al. (2017), attendance begins by the facial recognition process; divided into two main parts: processing

before detection where face detection and alignment take place, and afterwards recognition occurs through feature extraction and comparison. The captured image is sent to the PIC controller where it matches the obtained image with the image stored in the database; if the image and ID number match the student is marked as present. ID number is used for security purposes [36].

For Okokpujie et al. (2017), described biometrics to have an epic range of applications and more inventive ways of using it thus it keeps on emerging. All biometrics are distinctively unique in features and in individuals. These led them in creating a face recognition-based attendance system with GSM notification. In this study, attendance starts by setting-up a camera as an input device. During registration, Viola-Jones algorithm was used to detect faces. On the other hand, fisherfaces algorithm was utilized for creating templates for the captured faces. A database stored the created templates along with other particulars unique to the users enrolled. During verification, the camera acquired images of faces detected were compared with face templates stored in the database for any match. The number of verified face images formed the basis for attendance taken by the attendance algorithm. Attendance information taken is passed via a cellular network to authorized devices [7].

To Zaman et al (2017), they interfaced the Arduino Mega, SD card, Shield, RFID Reader, Wi-Fi module and a LCD Display Shield. The controller compares this two information and if they match, it takes the attendance and saves that time and also shows it in the LCD display that attendance was taken in order to inform the user. However, if these two information do not match it shows that the user is not registered in the LCD display [19].

Murallo (2015), he formulated an electronic attendance and logging system with the utilization of RFID as students' gate pass and SMS with an integration of an online management portal with a database server that provides reliability and security of data. In this study, daily SMS are sent to parents informing them on the entry and exit time records of their students. In addition, the system also has the capability to provide electronic reports of student's attendance for specific purposes. The study was implemented in Lyceum of the Philippines – Laguna [14].

To conclude, all previous literature and studies have similar features to the current project; the use of RFID, Face Recognition, SMS Notification, and Attendance systems through Software or Web Application for viewing the attendance record. However, no project offers all mentioned features; one study offers RFID verification and SMS notification but does not have face recognition for further verification. Thus, the researchers decided to bridge the gap between the past and present trends in attendance systems.

Conceptual Framework

The researchers used a waterfall model that describes the entire flow of the study depicted in Figure 1.

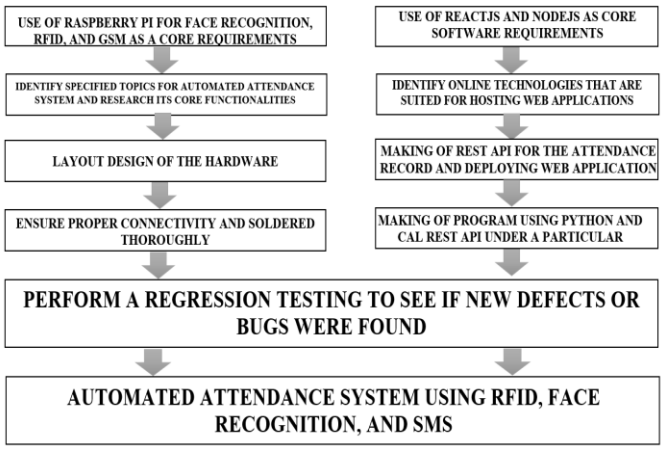

Fig. 1. Conceptual Framework of the Study

Objectives

The objective of the study is to develop an Automated Attendance System that uses an RFID to read the student's tag, a REST API to record the attendance, and Face recognition to identify an individual. At the same time to send text messages to their parents whenever they enter the school's premises. Students will be able to see their attendance records on an online website. Specifically, this study focused on the following:

1. To design and fabricate an Attendance System using RFID, Face Recognition, and SMS Notification and send attendance data to the web using a REST API.
2. To design and deploy a ReactJS, NodeJS, and MySQL-based Web Application to let students see their attendance record.
3. To test the speed and accuracy of the system when reading RFID tags, Face Recognition, and recording of the attendance.
4. To implement the project in Surigao del Norte National High School - Senior High School.

II. METHODS

Research Design

The researchers used an iterative process and approach to understand its complex structure and solve problems it may encounter along the way, wherein a Plan-Do-Check-Act (PDCA) criterion is used as its model in finding a solution. After collecting relevant information and knowledge from various planning stages, the researchers assessed and converted them to factual data before postulating a pragmatic end-product. Figure 2 shows the schema of the study.

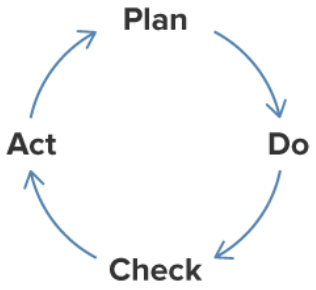

Fig. 2. Schema of the study

A. Plan

The researchers used a Raspberry Pi 4 Model B, a full-fledged tiny and affordable computer with a high-performing 64-bit quad-core processor, dual-display support at resolutions up to 4K via a pair of micro-HDMI ports, hardware video decode at up to 4Kp60, up to 4GB of RAM, dual-band 2.4/5.0 GHz wireless LAN, Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE capability. This will handle all operations of sending and retrieving data from the REST API and the face recognition functionality. An RC522 RFID Module, an inexpensive RFID that can communicate with a microcontroller at a maximum data rate of 10Mbps is also used for communicating and reading RFID tags given to the students wherein the attendance recording is done.

In addition to the two, a 1.3inch OLED Display with 128x64 dot matrix and I2C is used to display a set of instructions and the current status of the system when an RFID tag is scanned. Finally, a SIM900A GSM Module is used to send a text message to the number of a student's guardian notifying the arrival of the student on the school's premises [14].

For the face recognition functionality, the researchers used Python v3.10.4 to be the main language for the creation of the face recognition script and a 1280x720p USB Camera. A package installer called pip is also used to install packages that are needed for the development.

Furthermore, the researchers created a Web Application that will let students see their attendance record and give administrators a way of managing students in the database. Users will have to login using the credentials given by the administrators after registering them in the database.

Moreover, the researchers created a Representational State Transfer (REST) API that will be consumed by both the created Web Application and the Raspberry Pi to access and modify information in the database during attendance recording and student registration.

B. Do

During the development, the researchers used the following technologies to develop all functionalities and features present in the Automated Attendance System using RFID, Face Recognition, and SMS; both hardware and software:

1. **Python with Thonny IDE,** used for coding all parts connected in the Raspberry Pi and Face Recognition.
2. **ReactJS, Redux, MantineUI,** primarily used for the Frontend of the Web Application.
3. **NodeJS, ExpressJS, Postman,** used for building the REST API.
4. **Sequelize ORM, MySQL database,** for creating SQL queries and the database.
5. **Heroku, Netlify,** for hosting the Web Application and REST API in the web.

The researchers used Python language in the Raspberry Pi as the main development language for every part present in the hardware such as the RFID, SIM900A, and OLED. Additionally, pip package installer is used to install libraries needed for the face recognition such as dlib that includes machine learning techniques and tools for writing complicated software, cmake for testing, OpenCV, and face-recognition package for manipulating faces and the recognition of them. A Histogram Oriented Gradient (HOG) algorithm is used which is the basis of the recognition functionality that works by locating faces in an image that are then converted into grayscale images [32]. In order to recognize faces, the image is compared to the HOG patterns that are extracted from the trained faces to the most common pattern with the known pattern and marked.

In the frontend of the web application, ReactJS is used for building its UI as it is easier to maintain and use. MantineUI is also utilized to make use of its ready-made UI components for faster development and design. Furthermore, React Redux, particularly Redux Toolkit, is incorporated with it to manage states and data received in the database during API calls. Other NPM packages are also installed such as Axios for handling API requests, FullcalendarJS for the Calendar UI, DayJS for dates formatting, Git for version control, and Github where the code is hosted for better collaboration and continuous deployment.

The REST API is built around NodeJS and ExpressJS frameworks together with Sequelize ORM to easily write SQL queries for accessing the MySQL database. Additionally, the frontend web application is hosted in the internet via Netlify and Heroku for the REST API. This makes the application accessible by anyone around the web.

Finally, the face recognition functionality and RFID scanning are integrated to each other as it is the main security needed to be met to create the attendance of an individual in the database.

C. Check

After identifying what pins are needed to be utilized for every hardware component based on the created schematic diagram, they are then prototyped on a breadboard to see if every component is working properly before they are carefully connected to the Raspberry Pi and attached to the created enclosure. The deployed frontend web application and REST API were also checked to see if they are all working the way they are intended and is accessible in the web by anyone. The face recognition and RFID scanning are also checked if they are both running simultaneously when the codebase is executed.

D. Act

System Testing

The researchers first tested the created REST API as it is the backbone of attendance recording and the frontend web application using Postman. All HTTP methods created are all tested to see if they are all working the way they are intended, as well as its security for possible data leaks. Upon reaching a desirable result during the test, it is then connected first to the Web Application to check every functionality, and debugged the code when an error and vulnerability is recognized.

The researchers then tested the functionality of the face recognition to check its accuracy and speed when recognizing an individual. The algorithm and codes of the functionality are progressively tweaked to reach a satisfying end-result. The REST API is then consumed by the Raspberry Pi for the RFID attendance recording to check if every creation of the attendance inside the database works, and an SMS is sent to the number of a student's guardian. Furthermore, the face recognition functionality and RFID integration are checked as

it is the main security feature of the attendance recording before the attendance recording operation is executed.

The researchers kept track of all functionality test results to easily debug and troubleshoot them if an error is recognized. Finally, the frontend of the web application is hosted in a Github repository to keep track of every changes done in the codebase and easily maintain it.

III. RESULTS AND DISCUSSIONS

This chapter discusses all results presented in the research methodology. It showcases all results related to the objectives of the study and the process of making the output.

3.1 To design and fabricate an Attendance System using RFID, Face Recognition, and SMS Notification and send attendance data to the web using a REST API

The researchers fully designed and fabricated a functional end-product that does all its features based on the first objective. Figure 2 shows the entire setup of the project, where the entire hardware parts are located on the left side of the figure inside its acrylic enclosure. Figure 3 shows how the REST API is connected to both the web application and Raspberry Pi for manipulating the database. Figure 4 shows the circuit diagram of the whole project.

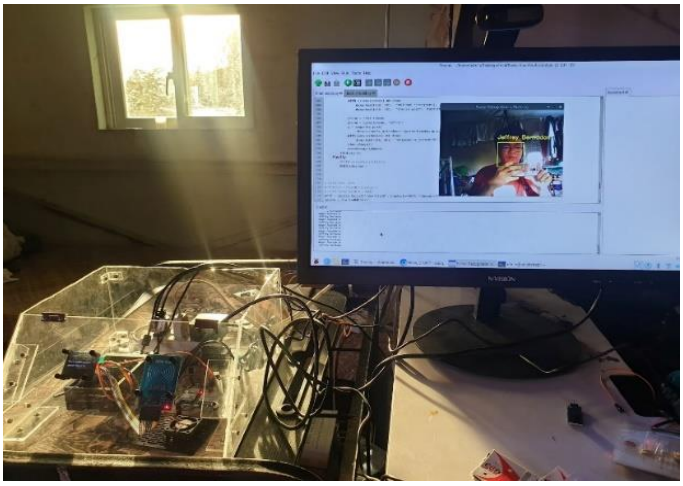

Fig. 2. Face Recognition and RFID Attendance System

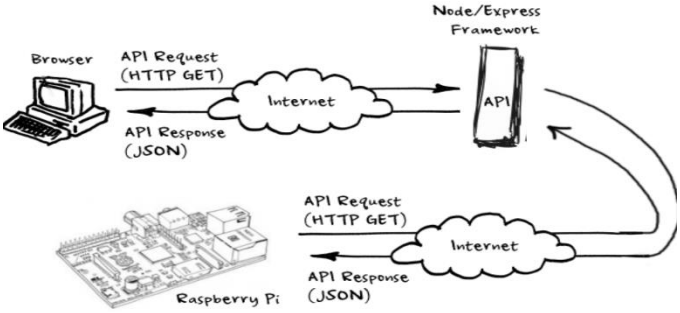

Fig. 3. REST API connections for both the Web Application and Raspberry Pi

A school administrator will first register students for Face Recognition during its operation using the Raspberry Pi. Upon executing the code, a Command Line Interface (CLI) inside the Thonny IDE is operated by an administrator. They will first be prompted if they want to register a student. If 'y' is pressed on the keyboard, the administrator will have to input the student's name that they wanted to register to check if they are already in the record. If not, the Raspberry Pi will open the camera and require five copies of still images of the student. After capturing of the images by pressing the "space" key on the keyboard, "ESC" key must be pressed to exit the capturing window. The Raspberry Pi will next train the captured images to be used in face recognition. The RFID tag registration will follow, where it will ask for the student's name to be embedded in the RFID. The names inputted on both registrations should match as they will be used for a condition before creating their daily attendance. On the other hand, if "n" is pressed, it will open the camera and ready the face recognition functionality and RFID scanning for attendance recording seen in Figures 5 and 6.

Administrators must also register the student through the Web Application created, wherein the RFID tag registered earlier is bound to the student's account for attendance recording inside the application before giving them the RFID tag and their login credentials to access their attendance record in the web app.

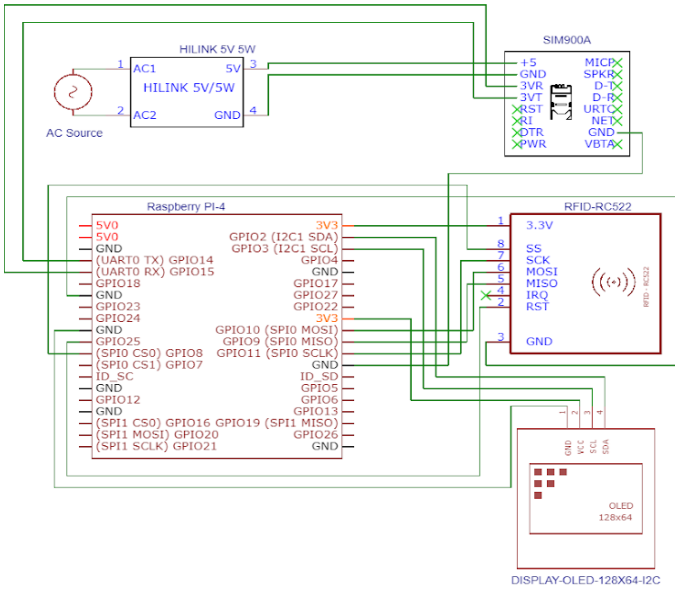

Fig. 4. Automated System Circuit Diagram

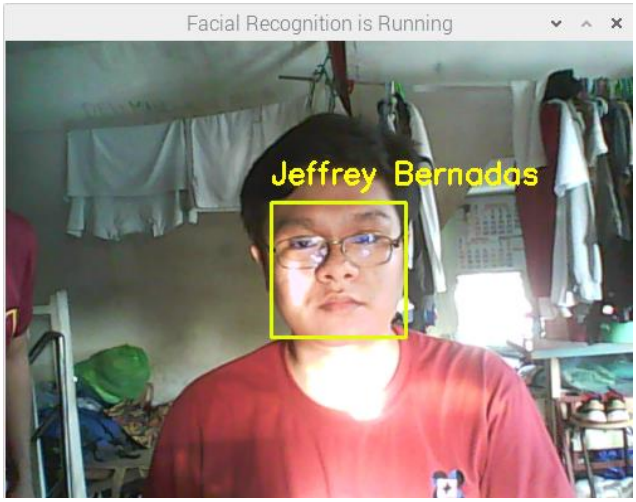

Fig. 5. Face Recognition Running

Fig. 6. OLED Display message when RFID Scanning is ready

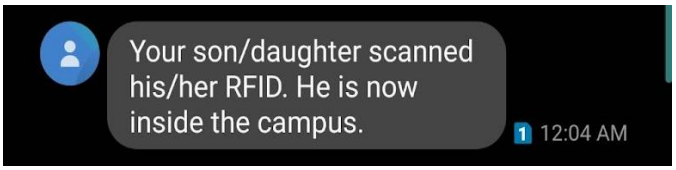

Fig. 7. SMS sent to the student's guardian

3.2 To design and deploy a ReactJS, NodeJS, and MySQL-based Web Application to let students see their attendance record

The researchers fully designed and deployed a functional web application that anyone can access in the web. It also communicates with the created REST API to access data in the database. After a student successfully scanned their RFID and created the attendance in the database with the date it was scanned, then it will appear as "Present" on their Attendance Calendar shown in Figure 8. Administrators can also see a

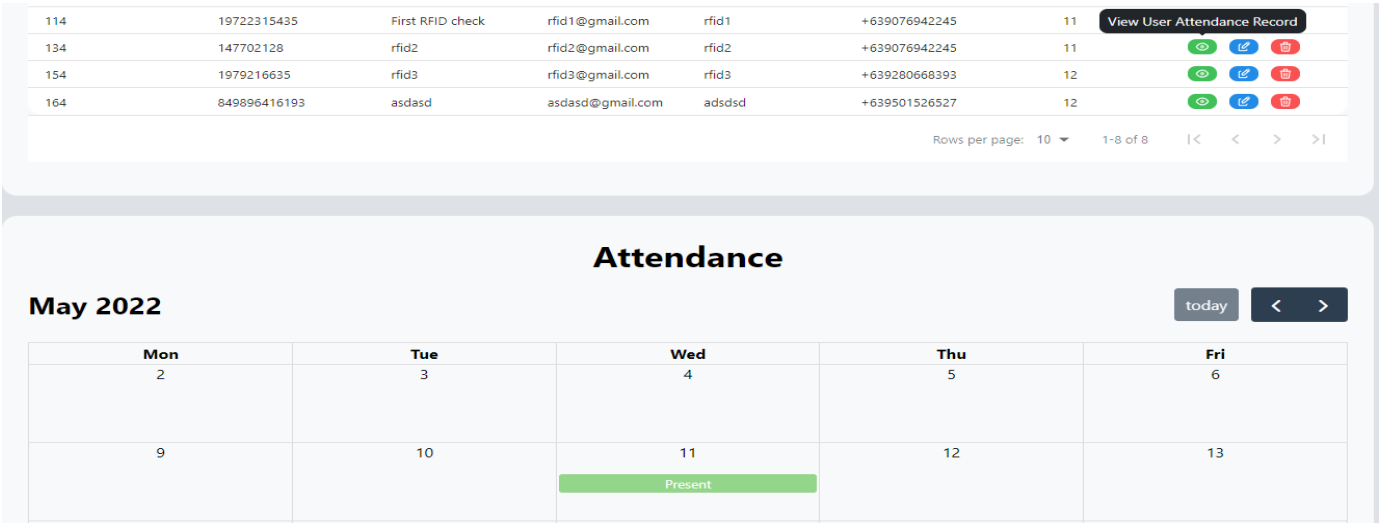

Fig. 8. A student's attendance record accessed by an administrator

The student must first pass through the face recognition during its actual operation to see if they are registered. After their name appears on the screen, they will have to scan their RFID tag in the reader. The algorithm will first check if the name shown during face recognition matches the RFID scanned. If they match, then the attendance recording operation executes where a series of multiple messages are displayed in the 1.3inch OLED depending on the current process the system is undergoing. The raspberry will first fire a GET request in the API to check if the scanned RFID is bounded to a student. If an RFID tag is not registered in the database through the web application, the OLED will display "RFID not recognized, register it to the admin". If they exist in the database, the OLED will display and welcome the verified user. The system will then communicate with the API to create the attendance record of the student. Additionally, a text message will be sent to the phone number bounded to that student which strictly belongs to their guardian. Figure 7 shows the text message sent to the guardian after a successful attendance recording.

student's attendance calendar and the guardian of the student given that they know the credentials of their children. Additionally, the researchers conducted several trials in the created Web Application tackling the success rate of requests and operations done in the admin dashboard to the REST API shown in Table 1. Compatibility with devices that have smaller screens was also conducted and depicted in Table 2. Additionally, error handling was put into consideration and was implemented to avoid any API-breaking bugs. Figures 9 and 10 shows the error when an RFID and Email that is already bounded to a student is used again during updating a new student as both of them must be unique.

Table 1. Web Application API Requests Success Rate Test Result

No. of Trials	(GET) Fetch all Students	(GET) Fetch Student's Attendance Record	(POST) Add Student	(PUT) Edit Student	(DELETE) Delete Student
	Success Rate (100%)				
1	100%	100%	100%	100%	100%
2	100%	100%	100%	100%	100%
3	100%	100%	100%	100%	100%
4	100%	100%	100%	100%	100%
5	100%	100%	100%	100%	100%
Avg.	100%	100%	100%	100%	100%

Table 2. Web Application Compatibility and Functionality on various screen sizes

Screen Sizes (pixels)	Compatibility	Functionality
1980x1080p	YES	YES
1366x768p	YES	YES
320x658p	YES	YES

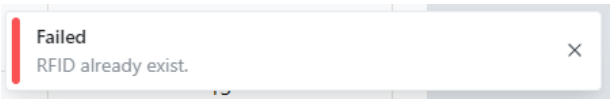

Fig. 9. Error Message when the inputted RFID value in adding and updating student modal is already bound to another student

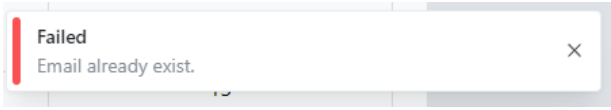

Fig. 10. Error Message when the inputted email value in adding and updating student modal is already bound to another student

3.3 To test the speed and accuracy of the system when reading RFID tags, Face Recognition, and recording of the attendance

The researchers did several testing procedures to determine the speed and accuracy of the features implemented in the project. Table 3 shows the tabulated result of the first test tackling the speed and accuracy of the RC522 Reader when an RFID tag is scanned through it.

Table 3. RC522 Reader Speed and Accuracy Test Results

No. of Trials	Speed	Accuracy
1	0.6 seconds	100%
2	0.4 seconds	100%
3	0.4 seconds	100%
4	0.5 seconds	100%
5	0.6 seconds	100%
Average	0.5 seconds	100%

Based on the results seen in Table 3, the RC522 takes an average of 0.5 seconds to read an RFID tag with 100% accuracy which is suitable for reading RFID tags of the student. Table 4 shows the tabulated result of the second test tackling the total time when the entire operation is triggered, from scanning the RFID tag to creating attendance and texting an SMS to the student's guardian, which took an average time of 14.28 seconds to finish the entire process. This can be lessened by eight seconds by making the delays in the codebase smaller; however, it is not ideal as it would make the messages being displayed in the OLED disappear very fast, making them not readable at all. Additionally, all trials conducted showed a 100% attendance recording in the web application and SMS sent to the phone number attached to the account.

Table 5 shows the test results of face recognition in terms of its speed and accuracy. The face recognition speed is based on the time it took to 100% recognize the subject; this means that in trial 1, the subject is recognized after 1.18 seconds. Meanwhile, the accuracy is based on how accurate face recognition is when the subject faces the camera. In trial 1, after 1.18 seconds, the face recognition displayed the subject's name accurately (no other subject names were displayed).

In the last trial, with the subject name "Jeffrey Bernadas", the face recognition functionality took more than four (4) seconds to recognize the subject successfully as it mistakes to be another one; this is because of the face positioning of the subject not directly looking at the camera, which is opposite to the stored images and dataset of the subject. Moreover, the face recognition's functionality is sensitive to light, making the recognition process slower and inaccurate. Finally, an individual who is not registered in face recognition will be named "Unknown", shown in Figure 11.

Table 4. RFID Attendance System Testing Results

No. of Trials	Total Processing Time	Attendance Recorded and can be seen in the Web Application	SMS Status
1	13.4 seconds	Yes	Sent
2	13.9 seconds	Yes	Sent
3	13.2 seconds	Yes	Sent
4	14.8 seconds	Yes	Sent
5	16.1 seconds	Yes	Sent
Average	14.28 seconds		

Table 5. Face Recognition Speed and Accuracy Test Results

Face Trial	Recognized Face	Speed	Accuracy
Roger Abucejo		1.18 seconds	100%
Jeffrey Bernadas		1.52 seconds	100%
Roger Abucejo		0.86 seconds	100%
Jeffrey Bernadas		2.24 seconds	100%
Roger Abucejo		1.91 seconds	100%
Jeffrey Bernadas		4.09 seconds	33.33%

Fig. 11. Unrecognized individuals will be labeled "Unknown"

3.4 To implement the project in Surigao del Norte National High School - Senior High School

The project will be implemented in Surigao del Norte National High School specifically in Senior High School. The project's ideal location would be in the school gate or the entrance where senior high school students go in.

IV. CONCLUSIONS AND RECOMMENDATIONS

After a series of multiple and thorough testing processes conducted by the researchers, the fabrication and development of the Automated Attendance System using RFID, Face Recognition, and SMS were found and proved to work effectively and efficiently with good maintainability as hardware parts are available locally. The website application is also in a Git repository with continuous deployment enabled.

Conclusions

The researchers were able to design and fabricate an Attendance System using RFID and Face recognition for student verification, sending of SMS to the parents of the student, as well as saving attendance records to the database via REST API. During registration, the inputted names for both face recognition and RFID must be similar as they will be matched before the attendance is recorded. The tag must also be registered using the Web Application as it will be the basis of creating the attendance record in the database. No RFID tag in the database means no creation of the attendance. The development of REST API for communicating with the database also proved to be beneficial as it lets other application in different platform access the database as long as they have the correct credentials for using it.

Moreover, a MERN (MySQL, ExpressJS, ReactJS, NodeJS) stack-based Web Application were deployed to the web using Netlify for the frontend and Heroku for the backend API as the hosting providers to let students see their attendance record and history. The web application is also mobile responsive, meaning every functionality that it has are compatible and can be used in devices with smaller screens.

Furthermore, the use of a Raspberry Pi 4B as the main microcomputer of the project played a huge role in the accuracy and entire processing speed of the entire system especially on Face Recognition. The positioning of an individual during face recognition must also be the same to the dataset or images captured from them during the registration to easily and accurately recognize the individual.

The functionalities of the Automated Attendance System using RFID, Face Recognition, and SMS were all met and is functioning correctly, due to this, it is planned to be installed and implemented in Surigao del Norte National High School particularly in the Senior High sector.

Recommendations

Since the developed project has limitations, the researchers recommend to the future researchers to redesign the system to be more flexible in terms of the following aspects:

1. The ability for the system to reset the GSM Module when no signal is detected and RC522 if it reaches the inactivity state.
2. Integrate a login-logout functionality to it and create a GUI using Tkinter for the registration part of the project instead of the CLI in the Thonny IDE.
3. Use a Raspberry Pi Touch Display instead of a computer monitor, a Raspberry Pi Camera for better image quality, and a better computer or microcomputer as image processing requires a lot of memory resources.
4. Use a better or upgrade the hosting provider for both the Frontend Web Application and the REST API instead of using a free tier plan.

V. ACKNOWLEDGMENTS

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