RADIO FREQUENCY IDENTIFICATION (RFID) BASED CLASS ROOM ATTENDANCE SYSTEM WITH EIGENFACES FACTORS AUTHENTICATION

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Abstract:

Attendance is one of the most important elements of any educational institution because it explains the academic performance of a student and in relation to the NUC benchmark of 75% policy, it states the exact students and number that are eligible to write an examination thereby, acting as a guide in producing question paper. Based on these, a good system that accurately captures the attendance of students is of utmost need to any institutional administrator. Radio Frequency Identification (RFID) based class attendance system is a facial pattern recognition system that automatically captures the student's attendance. It coordinates the hardware and software design through handshaking the data communications between RFID tag and RFID reader whereby the student passes through a RFID reader with the tag on them or swipes the tag on the RFID reader for the web camera to capture the tag's electronic product code (EPC) and images respectively. It does eigenface pattern matching with the existing patterns in the database (MySQL) for proper validation and authentication. The tools used in achieving this system are C variant, Arduino based programming language (the programming languages for the microcontroller AT89C51 on Arduino development board), and the Arduino 1.6.5 IDE. Java programming language was used for the serial communication, eigenfaces training, detection and recognition, and the application interface. It provided security and privacy such that the product codes and identification were not compromised. The system performed better than the manual method and RFID with finger print in terms of time and accuracy.

Key Words: Radio frequency identification, Eigenfaces, Pattern recognition and matching

I INTRODUCTION

School attendance is a measure of the number of students who attend school and the amount of time they are present (Collinsdictionary, 2022). It is one of the most important elements of any educational institution because it explains the academic performance of a student (Munir, 2009; Ruel *et al*.,2021) and in relation to the NUC benchmark of the 75% policy, it is expected to state the names of the exact students and the number that are eligible to write an examination (Ugwuja and Onu, 2018), thereby, alleviating the issue of wastage in terms of excess examination question paper production.

The conventional method of taking attendance in the classroom in Nigeria is either by calling out names or manually signing the attendance sheet which are usually passed around during lectures. This method is inefficient because it is burdensome, time consuming, clumsy, brings about distraction on the part of students, does not accurately capture the students that actually came as some might sign for their friends and the lecturer is most likely to misplace some of the attendance sheets. The exact or near exact number of eligible students cannot be accurately ascertained in order to know the number of question paper to produce for an examination, the examination hall that best suits the number of students to take an examination and to guide the lecturer in explaining the academic performance of students.

Due to these, it became one of the major issues most higher educational institutions in Nigeria are facing today, thus, an utmost need for a good system that accurately captures the attendance of students is desired by institutional administrators.

In order to alleviate the problem of conventional attendance system, an automatic identification (AUTO-ID) approach is proposed. AUTO-ID is a broad set of technologies used to collect information from an object, image or sound without manual data entry (Techtarget, 2010). It is an automated process used in the identification and collection of data for storage, classification and analysis. Though it serves a wide scope of applications, it is primarily used for identification and validation, asset tracking and interfacing with other data systems (FEIG, 2022). Its advantages are reduction of cost of data entry, prevention of errors related to identification and data collection, speeding up the process of data collection, tracking facilitation and determination of an item's exact location.

II LITERATURE REVIEW

There is a wide variation of the actual technologies involved in AUTO-ID, the information obtained and the purpose of collection, that is, it is employed in a relatively broad spectrum of specific technologies such as Barcodes, Radio Frequency Identification (RFID), Biometrics, Optical Character Recognition (OCR) and Magnetic strips (Lim *et al*., 2009; FEIG, 2022)..

Barcode Reader

Barcodes consists of small images of lines (bars) and spaces affixed to retail store items, ID cards and postal mail to identify a particular product number, person or location. A barcode reader uses a laser beam that is sensitive to the reflections from the line and space thickness and variation. The reader translates information from the image to digital data and sends it to a computer for storage or for another process. Like a flatbed scanner, it consists of a light source, a lens and a light sensor for translating optical impulses into electrical signals.

Biometrics

This identifies people by using a specialized scanning process that compares biological characteristics such as iris or fingerprint. It samples the biometric features, extracts the unique features and converts tem into digital codes, and further forms these codes into feature templates. It is used in access control and even on personal mobile devices.

Optical Character Recognition (OCR)

OCR captures printed or written text characters by a computer. The process includes scanning the text character- by-character, analyzing the resulting character image and translating that image into a machine-readable character code, such as ASCII. This technology is used in the digitization processes of data such as documents and books, sort mail, and process cheques and mail-based payments by credit cards.

Magnetic Stripes

Magnetic stripes are typically seen on credit cards, debit cards, key cards and swipe cards. The stripe consists of iron-based magnetic particles in plastic-like tape. Each particle is a tiny bar magnet. Information is written on the stripe by magnetizing the tiny bars in either a north or south pole direction. The writing process is called flux reversal causes changes in the magnetic field that can be detected by a magnetic stripe reader. It can be swiped for immediate verification and are extremely common.

Radio Frequency Identification (RFID)

This technology involves capturing of the encoded digital data between mobile objects and an RFID reader via radio waves. It is an automatic identification technology used for retrieving from or storing data on to RFID Tags without any physical contact (Abdul and Jyothi, 2013).

The system in Figure 1 consist of the basic components (Lim *et al*., 2009): an antenna, transceiver (often combined into a single device), a transponder and data storage. The transponder is the RFID tag, when the scanning antenna and the transceiver combine, it is referred to as the RFID reader and the data storage is the Middleware and a Backend database. RFID Tags are uniquely and universally identified by an identification sequence that are governed by the rubrics of Electronic product code (EPC) global Tag Data Standard. A tag can either be passively activated by an RFID reader or can actively transmit RF signals to the reader.

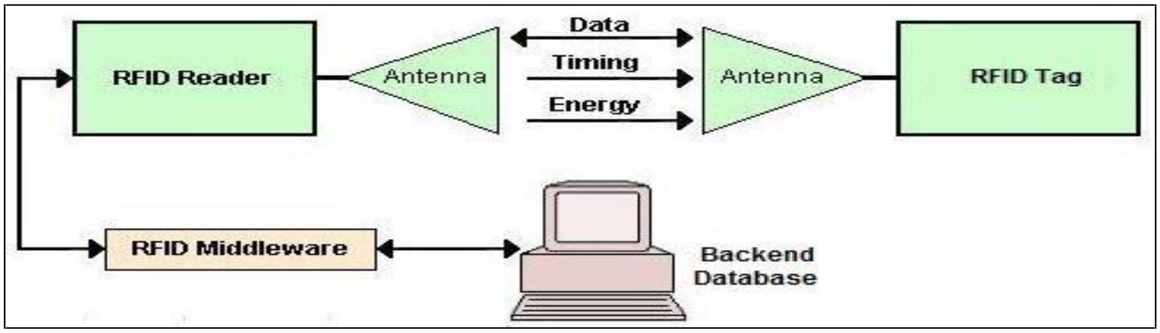

Figure 1: Radio Frequency Identification **syste**m (Lim *et al.*, 2009)

The antenna transmits a signal that activates the transponder which then transmits data back to the antenna. The tags are read/write devices that are more reusable and rugged as they are protected by a plastic cover. The reader whose effective range is based on its operational frequency is designed to operate at a certain frequency. The operational frequency of the reader ranges from 125 KHz - 2.4 GHz (Amin *et al*., 2014). The Middleware encompasses all those components that are responsible for the transmission of germane information from the reader to the backend management systems. It can include hardware components like cables and connectivity ports and embedded system software like Assembly language and embedded C that monitor and control the communication between the hardware and the computer system. The backend database stores individual tag identifiers to uniquely identify the roles of each tag. The data is used to notify a programmable logic controller that some specific action should occur.

RFID technology can carry large data capabilities which can all be programmed to the tag. The system is interdependent on its core components to achieve maximum efficiency and optimum performance of the application. This technology contain high level of security (data can be encrypted, password protected or set to include a "Kill" feature to remove data permanently, once set up; it can be run with minimal human participation. Due to its high degree of flexibility, the system can be easily adopted for an array of applications ranging from small scale inventory cabinets to multifarious and highly agile supply chain management systems. Although, the cost of incorporating this technology has restricted its outreach, the technology promises to have untapped potential.

It is similar to barcoding in that data from a tag or label are captured by a device that stores the data in a database. However, it has several advantages over systems that use barcode asset tracking software. The most notable ones are RFID tag data can be read within a range and without a direct line-of-sight (that is, it reads outside the line-of-sight), whereas barcodes must be aligned with an optical scanner and the tags of RFID can be read at a much faster rate than barcodes and can be read at the same time (Hinz, 2012).

NEED FOR IMAGE PROCESSING AND RECOGNITION IN RFID

The conventional personal identification techniques like passwords, keys, barcodes and smartcards have a major drawback: they don't check who is entering or holding an information. They only check if the correct information is presented to the system. Such systems can easily be deceived because any person who has the ID card or knows the password can easily claim the identity of the person. Other drawbacks for such systems include: the person has to remember the password or the burden of carrying an ID card. In barcode system, line of sight reading is required.

Biometrics based personal identification systems eliminates most of these drawbacks. Alice *et al*. (2007) defined biometrics as the automated recognition of individuals based on their behavioral and biological characteristics. Fingerprint, hand geometry, face, iris scan, retinal scan, signature, gait, voice are some of the well-known biometric characteristics. Biometric systems are more reliable because biometric characteristics cannot be easily stolen, duplicated or lost, does not require memorization of the password or need to carry ID cards about.

Though the use of biometrics systems offer a lot of advantages, they are still limited in their range of usage or application. The finger prints and hand geometry based systems fail to identify the individuals if the finger or hand is injured or dirty. Retinal and iris scan are very much susceptible to diseases that change the characteristics of the eye. For obtaining the retina scan, laser light must be directed through the cornea of the eye. Iris based systems need a specialized camera which is very expensive and also, the photo should be taken very close to the subject. Voice based systems might not work properly if the voice of the person changes due to flu or throat infection. Any noise in the background also affects the performance of the system. Face recognition based systems have many advantages due to the following reasons (Zhao, 2003):

i. Easy to deploy as one can use existing image capturing devices (webcam, security camera, IP camera)
ii. Unlike fingerprint, it does not require user cooperation. It is contact free process (people can be identified without their knowledge).
iii. It is easier to obtain a photo rather than a finger print or iris scan.

IMAGE PROCESSING AND FACE RECOGNITION SYSTEM

Image processing implies a set of computational techniques for analyzing, enhancing, compressing and reconstructing images (Prahlad *et al*., 2008). A face recognition system (Figure 2) is made up of a camera which take the photos of individuals and a computer unit which performs face detection (locating faces from the image removing the background information) and recognition (identifying the persons) (Turk and Pentland, 1991). It is a method for computing fast approximations to support vector decision functions in the field of object detection.

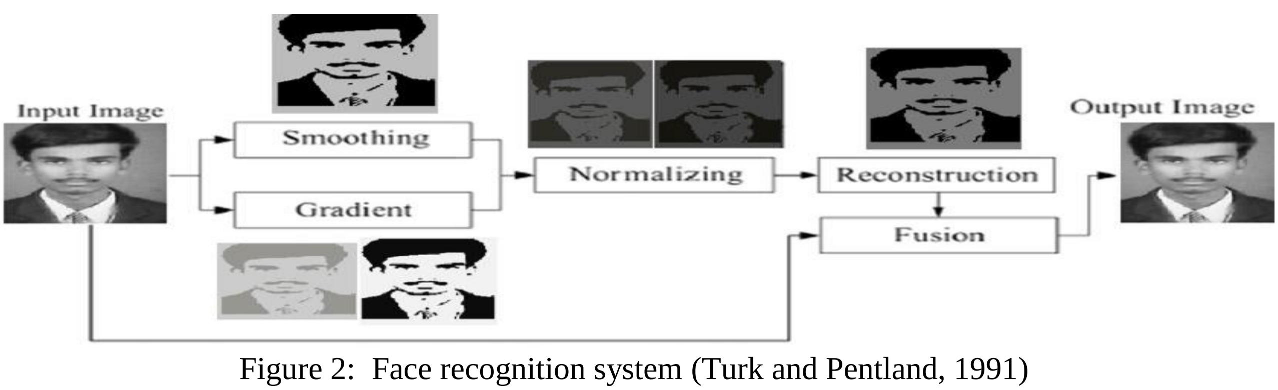

Figure 2: Face recognition system (Turk and Pentland, 1991)

RESEARCH OBJECTIVES

In order to alleviate the problems encountered with the conventional system of capturing attendance, the following objectives were considered:

a) propose an AUTO-ID technology based attendance system.

b) extract the face features to reduce high dimensionality in the data set and generate eigenfaces for classification of faces.
c) select an appropriate microcontroller.
d) develop the proposed system.
e) evaluate the system performance capability in capturing accurate attendance.

METHODOLOGY

a) The RFID AUTO-ID technology based attendance system was proposed due to the nature of the problem (information to be obtained and purpose of collection) and its advantages over related technologies.
b) The face feature extraction was done using Principal Component Analysis (PCA) . The reason was to find the vectors which best account for the distribution of face images within the entire image space.

i) First, we acquired the initial training set (face images). The face images were captured using webcam and the database (collection of faces in different poses) was created.

Based on Turk and Pentland (1991), the captured training images with dimensions N*N were read and converted to N^2 dimensional space, thus, obtaining a training set of N^2*M dimensions, where M is the number of sampled images.

Let the training set of the face images = $\Gamma_1, \Gamma_2, \ldots, \Gamma_M$

ii) Calculate the eigenfaces (the set features which characterize the global variation among face images) from the training set (retaining only the highest eigenvalues). These can be recalculated as new faces are encountered. The M images define the face space.

Each vector is of N^2(linear combination of the original face images). Since the vectors are eigenvectors of the covariance matrix corresponding to the original face images and they are face like in appearance, then they are called the eigenfaces.

The Average face (image) set which gives us a good example of a face that is the representative of the category of faces is then calculated:

$$\psi = \frac{1}{M} \sum_{i=1}^{M} \Gamma_i \qquad \ldots(1)$$

where $\psi =$ average image, $M =$ number of images and $\Gamma_i =$ image vector.

From equ. (1), the difference Φbetween the average image and image vector in the training set is then calculated as:

$$\Phi_i = \Gamma_i - \psi \qquad \ldots(2)$$

This set of very large vectors is then subject to PCA, which seeks a set of M orthonormal vectors, u_k , which best describes the distribution of data.

The kth vector is u_k, such that:

$$\lambda_k = \frac{1}{M}(u_k^T \Phi_n)^2 \qquad \ldots(3)$$

The vectors u_k are the eigenvectors while the scalars λ_k are the eigenvalues of the covariance matrix C.

$$C = \frac{1}{M}\sum_{n=1}^{M} \Phi \cdot \Phi^T \qquad \ldots(4)$$

$$= A \cdot A^T \qquad \ldots(5)$$

Where the matrix $A = [\Phi_1, \Phi_2, \ldots, \Phi_M]$ and the matrix C is $N^2 x\ N^2$.

Whenever the number of data points in the image space is $M(M < N^2)$, there will be only $M - 1$ meaningful eigenvectors instead of N^2. The eigenvectors can be determined by solving much smaller matrix of the order $M^2 x\ M^2$ which reduces the computations from order N^2 to M pixels.

Therefore, to construct matrix L

$$L = A \cdot A^T \qquad \ldots(6)$$

Where $L_{mn} = \Phi_m^T \cdot \Phi_n$ and we find M eigenvector u_l of L.

These vectors determine linear combination of the Mtraining set face images to form the eigenfaces v_l.

$$v_l = \sum u_{lk} \cdot \Phi_n \qquad \ldots(7)$$

Where $l = 1,2, \ldots, M$

iii) The next step is to identify and classify faces. The eigenfaces span an N^2-dimensional subspace of the original A image space. The M' significant eigenvectors of the L matrix are chosen as those with the largest associated eigenvalues.

A new face image (I) is transformed into its eigenface components and projected into the face space by:

$$\Omega_k = v_k^T(\Gamma_k - \Psi) \qquad \ldots(8)$$

Where $k = 1,2, \ldots, M'$

This describes a set of point-by-point image multiplications and summations. The obtained weight vector:

$$\Omega^T = [\Omega_1, \Omega_2, \ldots, \Omega_M{}'] \qquad \ldots(9)$$

The vector is used to find which of the number of predefined face classes, if any describes the face best. Here, the face class k that minimizes the Euclidean distance is selected.

$$\varepsilon_k = \| \Omega - \Omega_k \| \qquad \ldots(10)$$

A face classified to a class k when the minimum ε_k is below a certain distance threshold θ_ε.

The distance threshold is half the largest distance between any two face images:

$$\theta_\varepsilon = \frac{1}{2} max_{jk}\{\| \Omega - \Omega_k \|\} \qquad \ldots(11)$$

Where $j, k = 1,2, \ldots, M$

The face recognition and classification were based on:

$\varepsilon \geq \theta_\varepsilon$: input image is not a face

$\varepsilon < \theta_\varepsilon, \varepsilon_k \geq \theta_\varepsilon$: input image is an unknown face and rejects attendance

$\varepsilon < \theta_\varepsilon, \varepsilon_{k'} = \min\{\varepsilon_k\} < \theta_\varepsilon$: image contains face of individual k' and accepts attendance

c) The microcontroller AT89C51/52 was found suitable for this.
d) The proposed system (Figure 3) was developed using arduino C variant language.

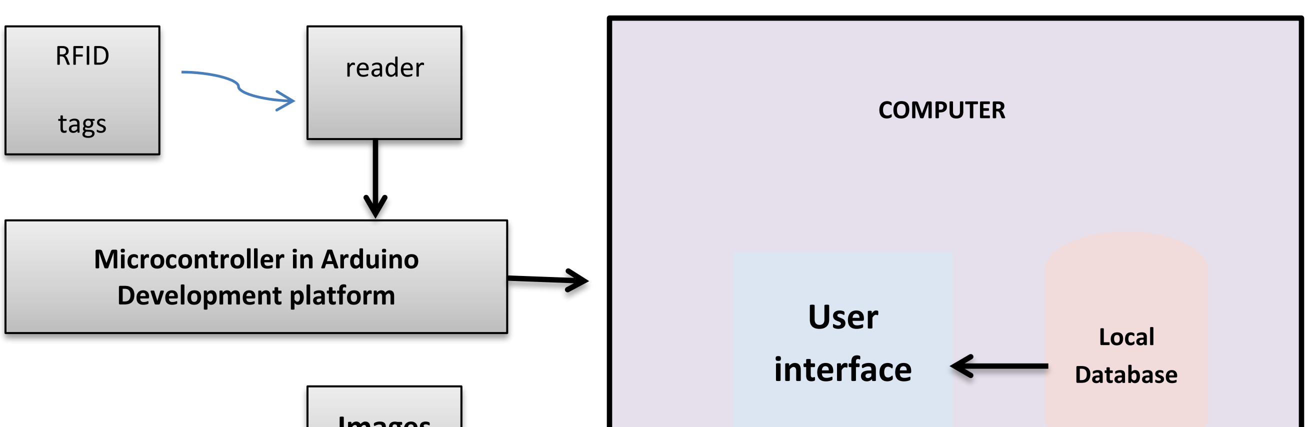

Figure 3: RFID based attendance system

The eigenface identification codes were built into the microcontroller AT89C51/52 in arduino platform. The system will send alarm to indicate that an individual passed through the RFID reader with another person's tag. It will process the incoming images and EPC tag from students, recognize and match them with the preregistered ones in the database.

The research was conducted on a sample of 4 enrolled PhD Computer Science students with 4 RFID tags uniquely assigned to each student. On point of registration, the students images were captured, the ID/EPC of the tags were uniquely assigned to each student. Based on this, attendance acceptance was strictly on the students using the exact assigned tag.

The system has an interactive interface designed with net bean (Java programming language) that can enable lecturers register the students, view, edit and print out student's attendance records weekly, monthly and at the end of each semester.

THE SYSTEM MODE OF OPERATION

The system coordinates the hardware and software design by handshaking the data communications between RFID tag and RFID reader as shown in Figure 3. It is based on passive RFID tag. The RFID reader and camera that connects to the class room computer or the lecturers' laptop are mounted at the classroom entrance door. The stored information are the students' trained images, tag id/electronic product code, student name, student registration number, date of birth, course name, course code, date, time, and class room location. Each student will hold a unique RFID tag to enter the RF receiver zone, the attendance will be registered automatically with proper image matching with the prerecorded images attached to that particular EPC. The transmitter will hold a unique address which will be transmitted by the means of radio frequency to a particular region. The 2.3GHZ transponder will continuously respond to the incoming data and will gather the data from the transmitter. The ATMEL 128kb microcontroller on arduino board takes inputs from the RFID reader and the webcam, processes and sends them for EPC based image pattern matching and verification. Here, the data image is changed to eigenfaces by the eigen factor present. These eigen faces go through face detection, training and recognition before matching with the preassigned face data in the database and positively records the attendance of that particular student if it matches.

The system algorithm:

i. Step1. RFID card was initially sensed by the reader.
ii. Step2. RFID reader starts to match the string which ask available on the card with the database entries as
RFi .RFi . T= I, RFi .RFj . T= 0 RiRF + tagEPC of individual.
iii. Step 3. Web camera capture image send to permanent database for matching the patterns which were in the database entries as RFi .RFi . T= I, RFi .RFj . T= 0 RiRF+ image of individual.
iv. Step 4. Using hardware perform the filtering operation to remove unwanted field and extract and attach tag EPCs and images to the student bio identity.
v. Step 5. Search student tags EPC in permanent database with incoming RFID student's tags.
vi. Step 5.1 search for the images in the permanent database with the new captured image, image matching will be analyzed with face recognizer if it recognized FPi .FPi . T= 1, FPi . FPj T=0. The image pattern is pre-processed and is converted into a binary pattern as: B(i)=1 if I(i) ≥ T = 0 I(i)
vii. if found go to step 5.2 else go to step 4.
viii. Step5.2. Search class room id, if found go to step 5.3. else go to step 4.
ix. Step5.3. Search course id, if found go to step 5.4. else go to step 4.
x. Step5.4. Search student id, if found go to step 6. else go to step 4.
xi. Step6. Compare detected student's image and tag EPC with class time table and if match found than go to step 7 else go to step 3.
xii. Step7. Check person type and mark the presence.
xiii. Step.8 Repeat step 3 to step 7 for all present RFID tags and images.

THE SYSTEM UNIFIED MODELING LANGUAGE DIAGRAMS:

For the development of the application module, the unified modelling language (UML) diagrams were designed. The sequence diagram was used to design the registration module (Figure 4), the attendance capturing (Figure 5) and the overall face recognition process (Figure 6).

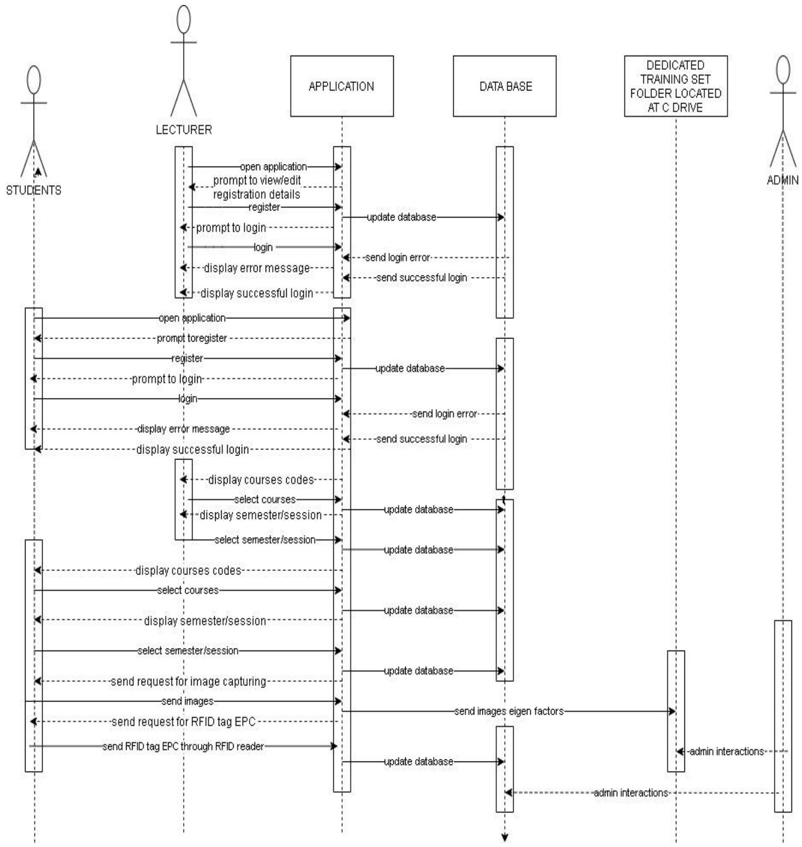

Figure 4: Registration Module

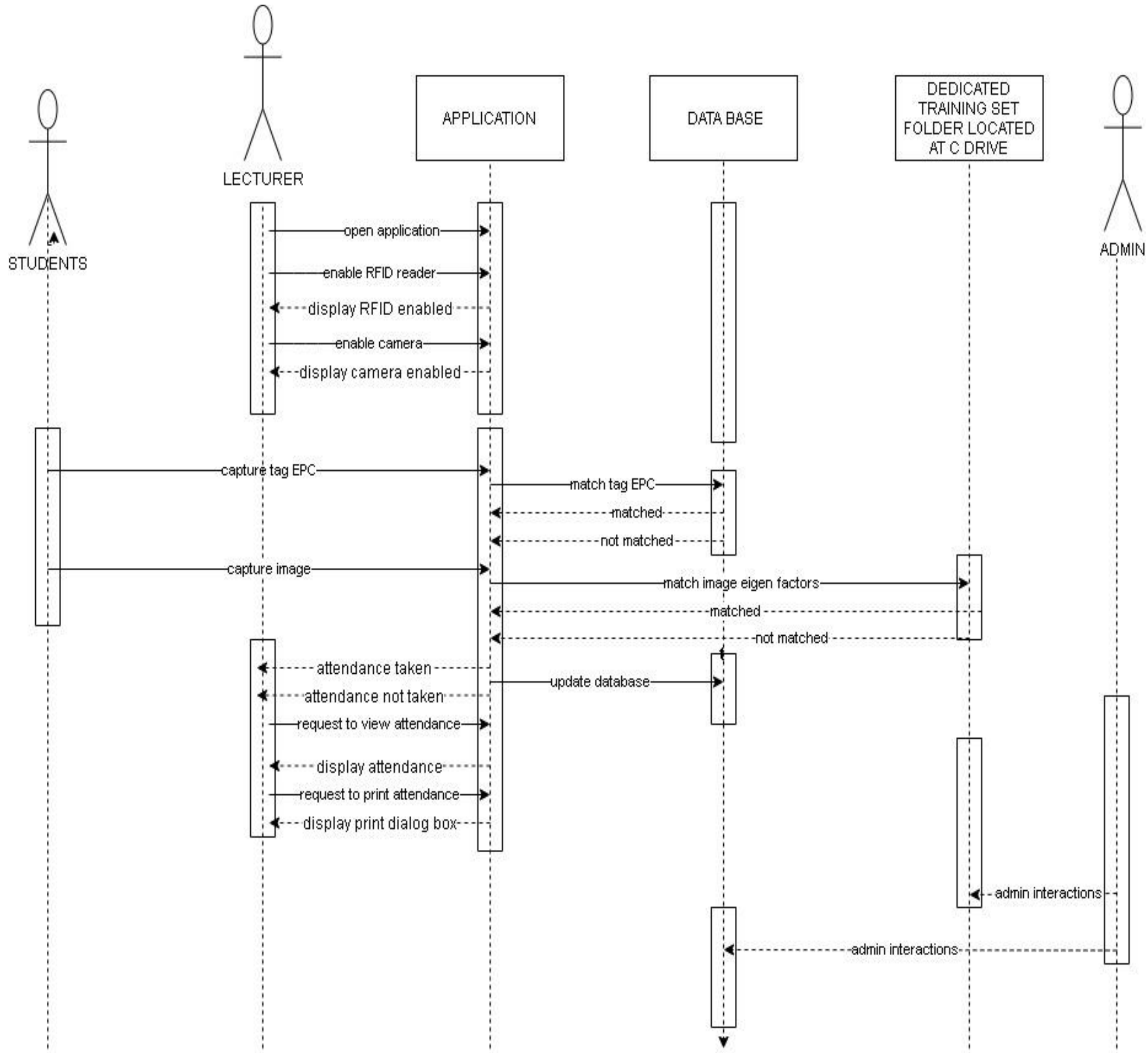

Figure 5: Attendance Capturing Module

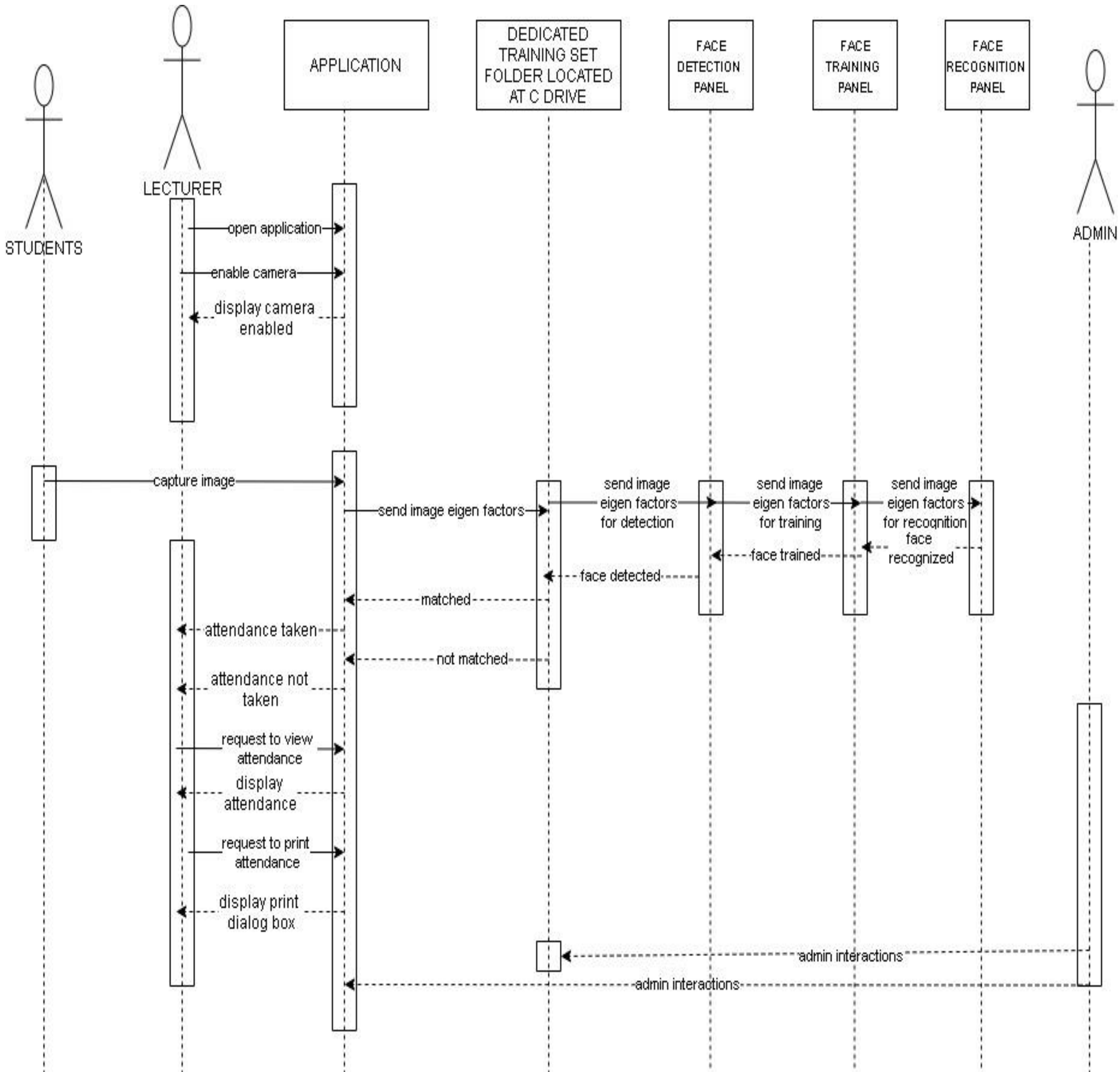

Figure 6: Overall Face Recognition Process

APPLICATION MODULE

We designed the application module with Java net bean. Figures 7- 9 depict the Administrator's login and the port serial communication in arduino and application interface respectively. For the application to establish communication with the hardware via USB, a form for selection and connection to the hardware must be designed. In the design, we used the list control for selecting the buad rate (the bandwidth at which the serial converter must be before it can communicate). The highest bandwidth (9600) for fast data transfer to and from the hardware was chosen. The

COM port through which the hardware must communicate was selected from non-busy ports in order to establish communication.

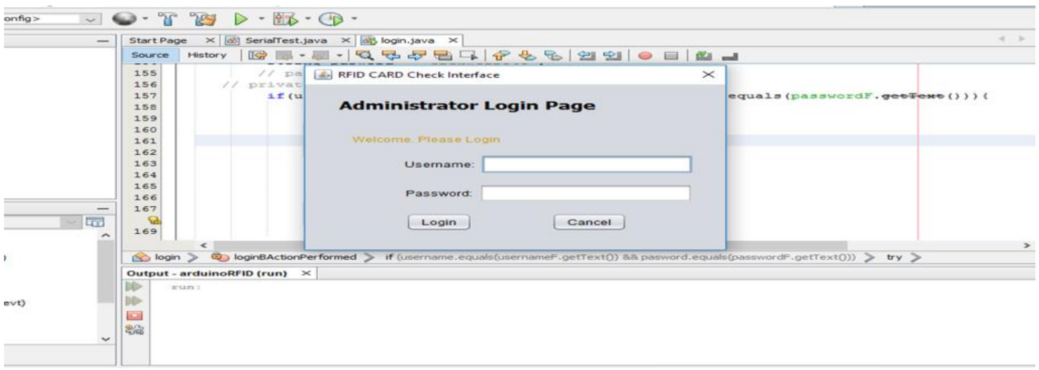

Figure 7: Administration login

Figure 8: Serial Communication Establishment in Arduino

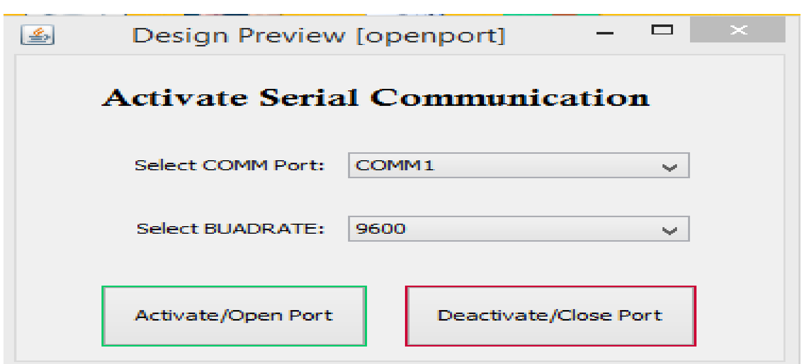

Figure 9: Serial Communication Establishment in the Application Interface

FACE RECOGNITION MODULE

The face recognition module involved four major parts: the training, detection and recognition. The first form in this module was initiated through the training set editor. Here, the images were captured into the editor through the camera during the registration (Figures 10 and 11). Figure 10 shows the registration interface and Figure 11, the captured student's registration.

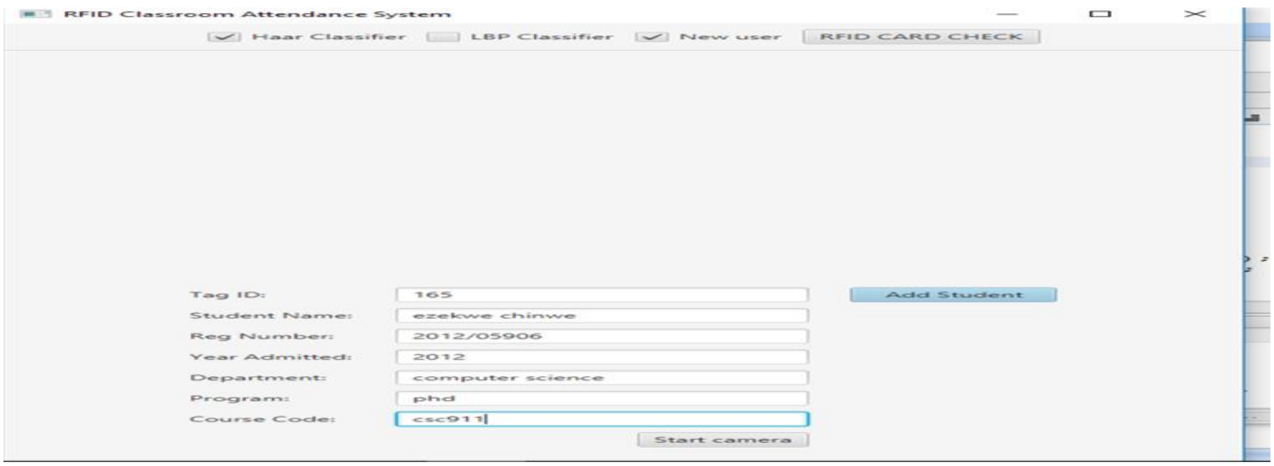

Figure 10: Students' registration

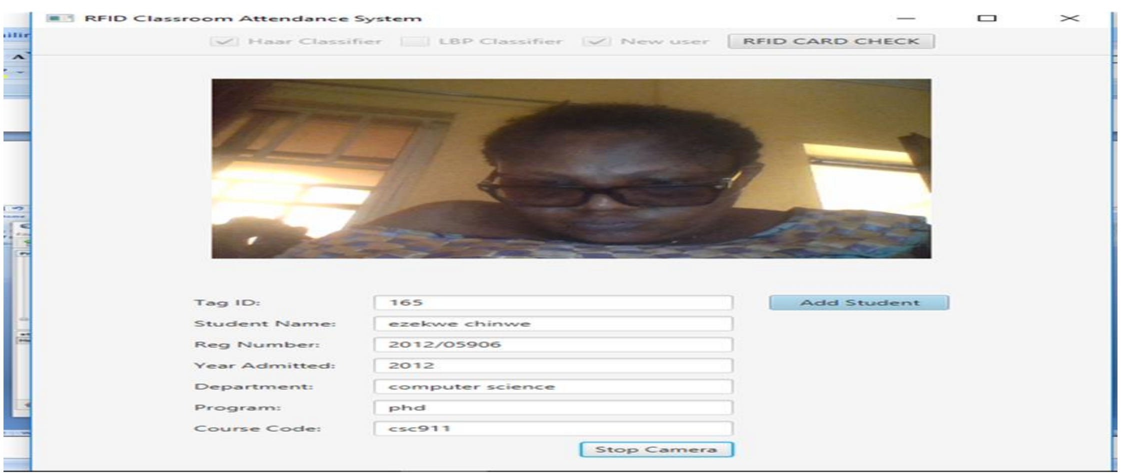

Figure 11: Captured Student's Registration

Training of image (photo) begins after it has been captured. Figure 12 depicts the interface for student's photo training. This procedure must be carried out on every image for the attendance so that the system can recognize and match the image while taking the attendance no matter how the image came during the attendance process. Figure 13 shows the eigenfaces of the captured image.

Figure 12: Face Training Interface

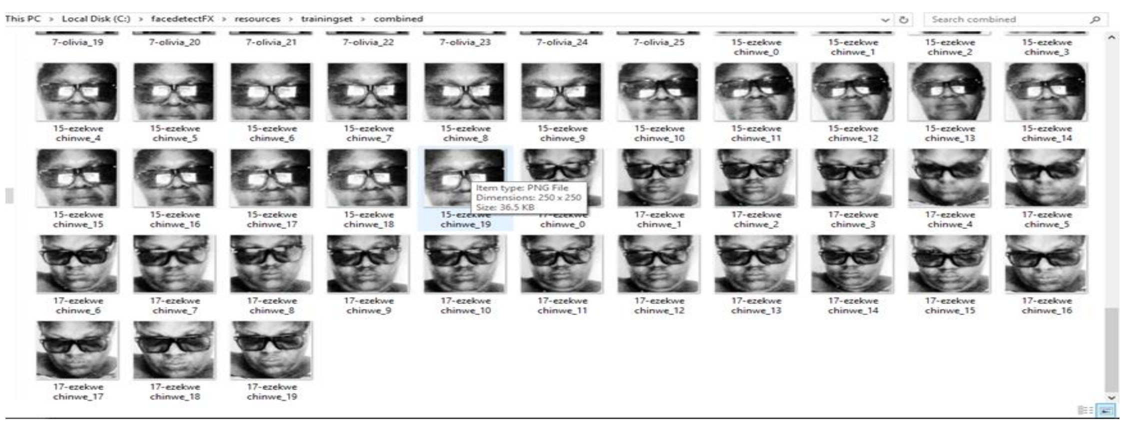

Figure 13: Eigenfaces of the Trained Image

For the detection and recognition of faces, the trained images are matched with the incoming images during the attendance processing and recorded on the attendance interface (Figure 14). If the incoming images and the EPC tag matches the prerecorded ones, attendance is taken else it is rejected (see Figures 15 and 16 respectively).

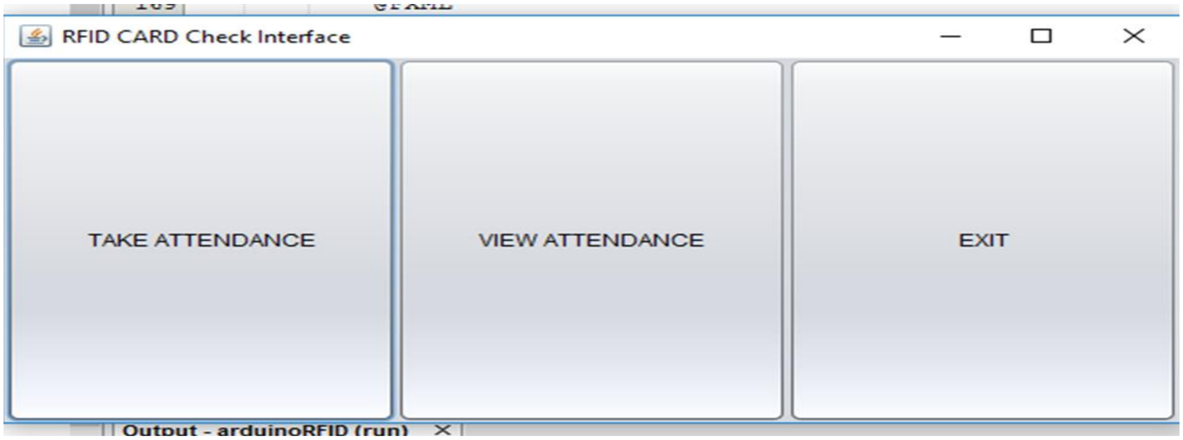

Figure 14: Attendance Interface

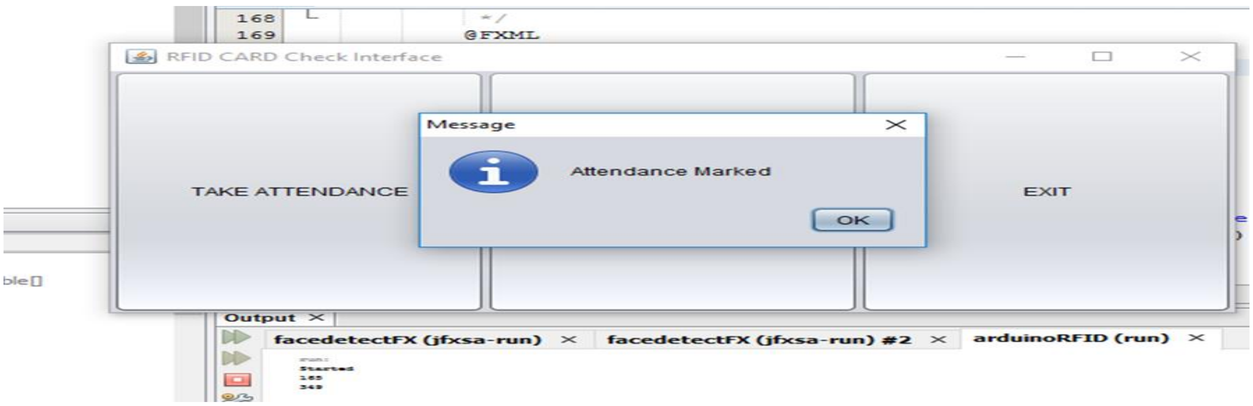

Figure 15: Attendance taken due to matched images

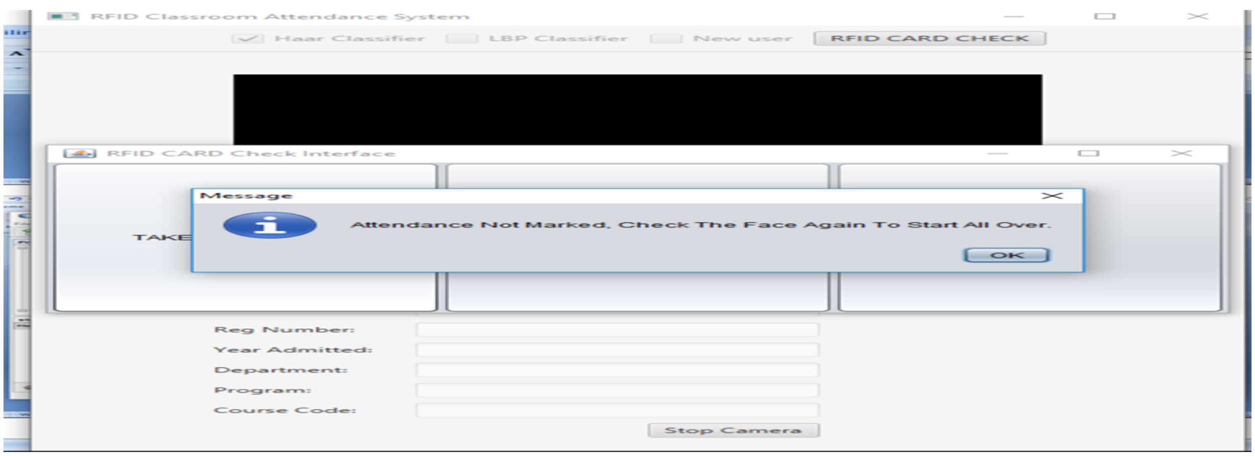

Figure 16: Rejected Attendance due to mismatched image

RESULT

Performance evaluation was designed to test the system and compare it with other existing systems like the manual method and RFID with finger print. It was based on speed. Table 1 shows that the time taken to take an attendance using RFID with image performed better than the manual method and RFID with finger print as the finger print scanner might take time to accurately capture some finger print images. Figure 17 shows the time graph of the three methods.

Table 1: evaluation of attendance systems

Method	Total Number of Students			
	1	10	60	100
Manual Entry	10 seconds	100 seconds	600 seconds	1000 seconds
RFID with finger print	5 seconds	50 seconds	300 seconds	500 seconds
RFID with image	0.2 seconds	2 seconds	12 seconds	20 seconds

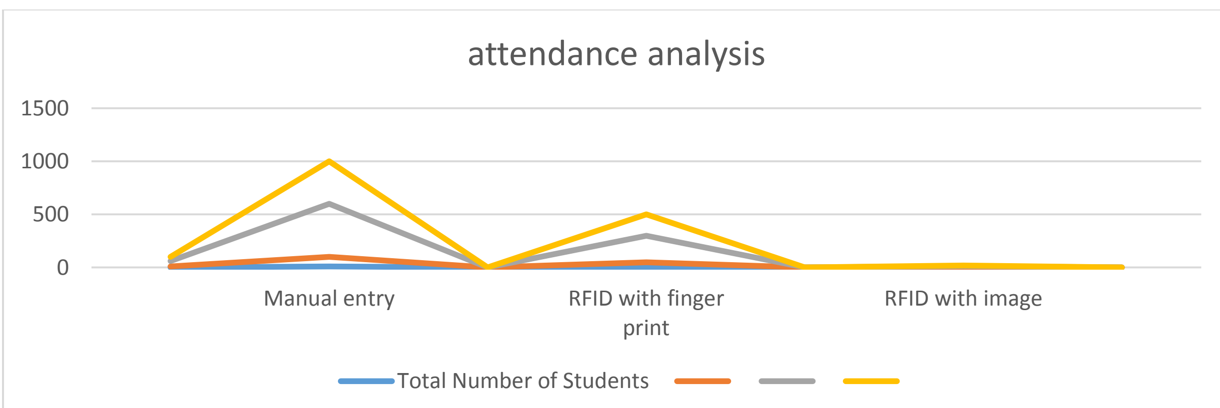

Figure 17: Attendance evaluation graph

CONCLUSION

The Radio Frequency Identification technology (RFID) based class attendance system with eigenfaces factor authentication significantly improved the current manual process of students' attendance recording especially in a university environment. The system was able to promote a fully-automated approach in capturing the students' attendance using their tag Electronic product code (EPC) and their images. At the completion of this work, the overall objectives were achieved.

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