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IOT-Based Farmland Intrusion Detection System

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Abstract
As crop vandalization with conflicts between farmers and herdsmen become recurrent in Nigeria, existing farm intrusion prevention methods such as fence mounting and placement of farm guards can no longer guarantee farm security. This is because intruders either jump over the fence or attack guards on duty without visual evidence. Therefore, a complementary approach using computer technologies for effective detection is required. This paper presents an IoT-based farm intrusion detection model using RFID and image recognition technology. RFID sensor as well as cameras are placed at entrances of a fenced farmland for simultaneous identification. The sensor reads workers' tags for identification, while cameras capture images of users for further identification as captured images are sent to Convolutional Neutral Network (CNN) for recognition. A user whose image cannot be recognized is flagged as an intruder and an intrusion alert with visual evidence is sent to the farm owner. The system showed a high level of effectiveness with an accuracy of 90%, Precision of 70%, and 80% Recall rate and effectively controlled the rate of illegal encroachment into farmland

Keywords: Buzzer; Convolutional Neural Network (CNN); Internet of Things (IOT); Microcontroller; PIR Sensors; Radio Frequency Identification (RFID)

Abstrak
Perusakan tanaman dengan konflik antara petani dan penggembala menjadi berulang di Nigeria, metode pencegahan intrusi pertanian yang ada seperti pemasangan pagar dan penempatan penjaga pertanian tidak dapat lagi menjamin keamanan pertanian. Ini karena penyusup melompati pagar atau menyerang penjaga yang bertugas tanpa bukti visual. Oleh karena itu, diperlukan pendekatan pelengkap menggunakan teknologi komputer untuk deteksi yang efektif. Makalah ini menyajikan model deteksi intrusi pertanian berbasis IoT menggunakan teknologi RFID dan pengenalan gambar. Sensor RFID serta kamera ditempatkan di pintu masuk lahan pertanian berpagar untuk identifikasi simultan. Sensor membaca tag pekerja untuk identifikasi, sementara kamera mengambil gambar pengguna untuk identifikasi lebih lanjut saat gambar yang diambil dikirim ke Convolutional Neutral Network (CNN) untuk dikenali. Seorang pengguna yang gambarnya tidak dapat dikenali ditandai sebagai penyusup dan peringatan intrusi dengan bukti visual dikirim ke pemilik tambak. Sistem menunjukkan tingkat efektivitas yang tinggi dengan akurasi 90%, Presisi 70%, dan tingkat Recall 80% dan secara efektif mengendalikan laju perambahan ilegal ke lahan pertanian.

Kata kunci: Buzzer; Jaringan Syaraf Konvolusional (CNN); Internet of Things (IOT); Mikrokontroler; Sensor PIR; Identifikasi Frekuensi Radio (RFID)

I. Introduction

Virtually every country in the world relies on agriculture to survive, not just because it is a source of food but it is also connected to the production of most basic human needs. In Nigeria, agriculture remains the leading non-oil sector of the country's economy, providing about 70% of the nation's population with jobs. It is a major source of livelihood for those in rural areas as they depend on the proceedings from their farm harvest to cater for their family.

However, the sector has suffered a major setback with persistent cases of intruders; human and animal alike causing serious damages to crops by stealing, eating, and trampling on crops. In recent times, the destruction of crops has aggravated with the incessant conflicts between herders and farm owners arising from illegal encroachment of cattle into farmlands. Usually, mounting of fences round farmland, engaging farm guards, use of repellants, among others are used as means to wade off invaders. Though relatively effective, these methods can be less than ideal and are sometimes prohibitively expensive to put in place [3]. Moreover, with the herders- farmers conflict, the existing security measure cannot completely guarantee safety as several farm guards have been killed and fence been jumped over without visual evidences. In order to overcome these challenges, there is need to build a system that will alert farmers of any intruder and also repel animals away from the farm. The aim of this paper is to detect and prevent intruders from entering into the farm land by implementing an IoT based intrusion detection model for farmlands using RFID technology and image recognition technique. Radio Frequency Identification technology is a technology which uses radio waves to automatically identify people or objects. Currently, this technology is dramatically increasing the use of wireless technology in many areas such as healthcare, transport, military, textile, and agriculture. Unlike barcode systems, RFID systems reflect better result in industrial applications like baggage tracking, access/vehicle control, animal tracking, etc. Apart from traditional usage of RFID technology, another innovative research path of RFID is integrating RFID technology with mobile devices such as mobile phones and PDAs [14].

This automation can provide accurate and timely information without any human intervention, access to such information where one can individually identify each one of the tagged items uniquely; help in improving your processes and also to make informed decision. Radio Frequency Identification (RFID) technology is an automatic identification system consisting of a tag and a reader which can communicate with radio waves [11]. In this way, a lower costs more efficient process management and monitoring is provided.

The remaining of this paper is organized as follows: Section 2 provides the related works. Section 3 describes the proposed system architecture and the methods applied to actualize the system. Section 4 explains how the system was implemented, while Section 5 provides the evaluation of the system. Section 6 presents the conclusion.

II. Related work

[15] carried out a Survey on Animal Detection Methods in Digital Images and observed that animal in image processing have been an important field to numerous applications. They narrowed the applications to three main branches, namely detection, tracking and identification of animal. They identified the efficacy of applying computer vision in image processing for animal detection, use of transformation function such as the Fourier transform, Face Detection Approach and Thresholding Segmentation Method. They identified lighting problem and changes of natural environment from day to night at outdoor surveillance system as two problems that need to be considered in developing an animal detection algorithm.

There are copious numbers of researches undertaken to improve the old system of securing farmlands. [5], a smart farmland using raspberry pi for crop vandalization prevention and intrusion detection system was developed. They showed how Passive Infrared Sensors (PIR) was used to detect motion of human body, once the employed PIR sensors detect motion the cameras capture an image and start recording the video, the owner of the farmland gets notified about the intrusion. This information along with the captured video is stored onto cloud from where the administrator /farm owner can access it once he receives the message. RFID tags was used to differentiate between the authorized person and the intruders, if the person is an authorized one then no action is taken by the system. System uses two mechanisms to ward off animals namely: the rotten egg spray and electronic

firecrackers. Their system requires no human supervision, hence saves a lot of time and energy. The system works in real time to detect the animals in the field, in addition the farmers can access the view of their fields remotely. However, the use of fire cracker can cause damages to crops, while rotten eggs spray can result in crop diseases.

[12] worked on an animal detection system using ultrasonic sensors to detect the movement of the animal and send signal. This signal is transmitted to GSM and which gives an alert to farmers and forest department immediately. However, the system can only detect the animals but cannot prevent them from destroying the crops.

Kaluti et al. (2018) developed an IoT Based Wireless Sensor Network for easy detection and Prevention of wild animal's attack on farming lands. In their study, they showed how sensors such as PIR motion sensor, sound recognizing sensor, and web cameras were used to collect data. Aurdino mainly the raspberry pi, acts as master node and collects the data from the sensors which sends those data to the server for further processing. The server processes the data and sends signals to the speakers to produce sound in order to stop the animals by crossing the forest boarder, and also sends message to the mobiles of the nearer villagers, farmers, and the forest office to take the safety precautions. Their system was helpful to the farmers in protecting fields and save them from financial losses and also saves them from unproductive efforts that they endure for the protection of their fields. However, in this work the stealing of RFID tags can give intruders access into the farmland.

[6], worked on human-animal conflict using PIR Sensors and camera as first round of security where the animal movement is detected using the sensor and the sensor in turn triggers the camera to take the picture of the animal and transmit the image for processing via microcontroller i.e., through WSN. The microcontroller transmits the image from the camera to the PC in the command center where the image processing and classification of animal is done. Once the animal is found to be a threat the PC will send the signal to the repellent system via microcontroller to take appropriate action. However, the system results in crop diseases.

In Cherukat et al., (2014), a farm field protection using sensor networks, due to the fact that fields nearer to the forests were facing problem of attack of wild animals on the crops. To this effect, they designed a smart field that is on low cost, low energy consuming, small sensor nodes. They showed how sensor nodes are deployed in groups, this group of nodes is connected to a common node and common node to the main node. The three parts of sensor deployment is primary, secondary and tertiary. The primary node controls the network, secondary nodes passes data from tertiary to primary node. By including more sensor nodes more farm areas can be covered. Except the node in primary all other nodes are connected with PIR (Passive Infrared) sensor. Their system helped to protect farmlands from wild animals. It was a self-managing, cost effective and energy efficient system. However, any failure in one of the nodes results in failure of the whole system.

Koik et al., (2016), in their research, did a comprehensive analysis on Animal Detection Methods in Digital Images. The study was carried out in order to design a system that uses digital image processing for animal detection. They showed how digital image processing system was built up by the use of power spectral in trying to test animal presence in the image, Fourier transform by transforming from spatial domain to frequency domain, Animal Detection Based on Thresholding Segmentation Method in which if the threshold is greater than a pixel of gray that value is set to white and others are set to black. The system helped to detect the exact animal that entered the field. However, this work cannot be suitable for fast detection of animals.

[8] developed an intruder recognition in a farm through wireless sensor network, this came as a result of the struggle farm owners go through for top yield in varied ways after which, their yield may be curtailed due to the interference of animals and unauthorized humans. Due to this, many farmers sleep in field area to save their crops risking their lives if wild animals attack their fields. Animal attack on the crops could also cause infections to the buyer when the crops are sold in the market due to the

animal poison. Hence, it is much essential to monitor the boundaries of the farm to discover movement of unauthorized entries into the farm. They therefore aimed at designing a WSN in border surveillance and intrusions detection that is cheaper for the farmer. They showed how the system is implemented to detect intrusion of animals in farms using wireless sensors and buzzers which detects the animals and produce acoustic sounds. At various locations around the farm, motion sensors are placed where certain distance is maintained between them and one of the motion sensors is made as the centralized from where we can operate all other sensors. The sensors which are present frequently sense the movement and pass it to the Coordinator through RFID. An Arduino board is placed near the centralized sensor to which GSM module is interfaced along with buzzers and RFID transmitter. Animals are being detected by the motion sensors in the agricultural area. When an animal or human is being detected by the sensors in the agricultural area, the sensors are activated through RFID transmitter and the system produces sounds through the buzzer and will give a very minor shock to the animal. This sound irritates the animals and they cannot accommodate it at that place and due to minor shock animals will fall. However, the system was not able to provide video processing.

[2], Animals from wild area were continuously attacking crops for so many years and the protection of these crops field from wild animals was a serious issue. The wild animals face shortage of water and food as a result of which they move towards the agriculture area which creates great loss to the crops and annual income of farmers. When wild animals enter in a farm there is a need for an alert system to prevent crops from being damaged by wild animals. The developed a system and their objective was to prevent the loss of crops and protect the area from intrusion of wild animals which causes major damage to the agricultural area. Their system has a wireless sensor network (WSN) consisting of a large number of autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. The WSN consists of various clusters connected with the sink node. Each cluster has number of sensor nodes having one Master node capable of collecting the data from remaining nodes, web camera and GSM connected to the raspberry pi kit. Camera is used to detect the motion of wild animal and ones it gets detected it captures its image and distinguishes its features as dangerous or not, if it is dangerous then it sends instant message to the farmer. It saves farmers from unproductive efforts that they endure for the protection of their fields. However, the system is expensive and require high maintenance.

[1], implemented an intelligent security system for farm protection from wild animals in order to provide food requirements of the people and produce several raw materials for industries as animal interference in agricultural lands has resulted into huge loss of crops. Hence, they developed a prohibitive fencing to the farm, to avoid losses due to animals. They showed how fencing wire is used as a sensor. When animals come in contact with this open cable the circuit will be grounded and we get initial input signal that indicates presence of animals at fencing. After getting that initial input signal followed by amplifier circuit passing it for further processing, then, it will be given to the microcontroller and their system will be activated, immediately buzzer will be on, at night time, flash light will be on and message will be sent to the farmer. Continuous monitoring can be done because it works on Solar panel. However, damages still occurred during storms, thunder and lightning which is still a risk of dangerous shocks to farmers.

Therefore, the development of an Internet of Things farmland intrusion detection system with automatic facial recognition module for effective security and safety of both crops and farm owners aimed at tackling the shortcomings pointed in the reviewed literatures has become imperative.

III. Methods

Based on the proposed system architecture in Figure 1, the RFID reader, camera, and Buzzer are all connected to a microcontroller placed at the entrance of the farmland. The RFID tags unique identification number is configured with the staff information stored in the database. At the entry point

into the farm, the tag is brought closer to the reader for staff identification as the staff tag is cross-checked with the staff information in the database. While confirming staff ID, the microcontroller will activate the camera to capture facial image of staff. The image is then fed into face recognition module for further prove of identification. This process is carried out simultaneously to prevent intruders using authorized tag into the farmland. If any of these actions should fail, an intruder alert message is sent to the administrator's system or the farmer's smart phone, and the buzzer will produce a loud irritation noise.

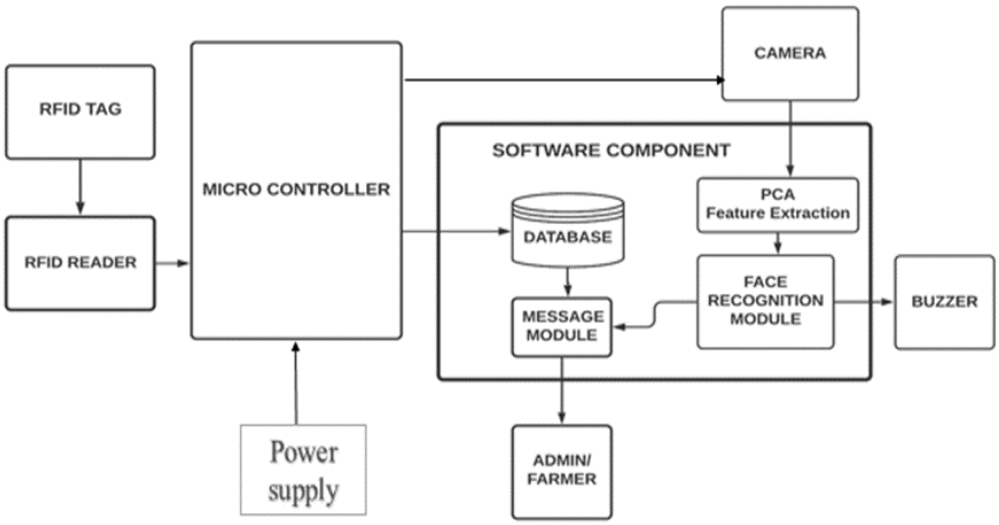

Figure 1. IOT-Based Farmland Intrusion Detection System Architecture.

The The detection of an authorized person with a valid RFID is estimated using the frequency of signal reading received by the reader. The signal power measured at the receiving node (RFID reader) is known as RSSI (Received Signal Strength Indicator), the RSSI received is translated from reader's antenna into frequency of signal reading which is displayed by the reader. The RSSI transmission power for the person is expressed mathematically as:

$$p(R) = p(T) - 10n\log\left(\frac{R}{T}\right) - B \qquad (1)$$

$$B = \begin{cases} q * p & if\ q < c \\ c * p & otherwise \end{cases} \qquad (2)$$

where n is the attenuation factor, p(T) is the signal power at the reference distance T, R is the distance between the transmitter and the receiver for the tag, q is the number of obstacles between the transmitter and the receiver, p is the attenuation factor of the farm, and c is the maximum number of obstacles between the transmitter and the receiver. The signal strength is converted into frequency of signal from the reader's antenna and displayed by the reader. The transmission frequency increases with proximity of the RFID reader with the reference tag. The signal power in RSSI is converted to distance by using the Euclidean equation which is stated as:

$$E = \sqrt{\sum_{n=1}^{N}(A_n - B_n)^2} \qquad (3)$$

where E is the relative position of the reference tag A and unknown tag B, A_n represents the signal strength of the reference tag, B_n is the signal strength of the unknown tag received on the reader, N is the number of times the measurement is taken.

However, the microcontroller activates the camera to take snap shot of the person. Captured images were preprocessed by way of image value normalization and feature extraction. Image value normalization involves bringing images into a range of into a range of intensity value that is normal. This is achieved using equation (4)

$$output_{channel} = 255 * \frac{(input_{channel} - I_{min})}{(I_{max} - I_{min})} \quad (4)$$

where 〖output〗_(channel)is the normalized image, input_channel is the image to be normalized, I_max is the maximum pixel value, and I_min is the minimum pixel value. Thereafter, global features were extracted from normalized image using principal component analysis (PCA). PCA involves computing the eigenvalues λ and eigenvectors μ of the data correlation matrix C =X^T X, where X is an n*q data matrix of n number of samples and z features using equation (5):

$$(C - I\lambda_i)\mu_i = 0 \mid i = 1,2,3, \dots, q \quad (5)$$

where q is the total number of eigenvalues. The k numbers of eigenvectors μ having the largest eigenvalues λ were picked as principal components (PCs) based on a given threshold value as defined in equation (6)

$$\frac{\sum_{i=1}^{k} \lambda_i}{\sum_{i=1}^{q} \lambda_i} * 100 > threshold \quad (6)$$

where threshold value specifies the percentage of information to be retained, k∈q represents the number of eigenvalues whose corresponding eigenvectors to be retained. PCA extracted features were fed into CNN model for recognition. CNN takes the preprocessed input image vector x=(x_1, x_2,x_3,…,x_n) with an assigned class c_l which are the images of farm staff. At the convolutional layer, images are convolved to extract features that forms feature maps f_m using equation (7)

$$f_m = tanh(wx_i + b) \quad (7)$$

Where b represents the bias term, w represents weight matrix, and x_i is the input vector. Thereafter, the feature maps f_m is passed to the max-pool layer where max-pooling operation is applied to each feature map to obtain the most significant features by selecting features with the maximum value as expressed in equation (8)

$$f_m = \max\{f_m\} \quad (8)$$

where f_m represents the downsized features. The obtained features f_m is fed to the fully connected layer which contain the softmax function that will classify the image data as intrusive or non-intrusive as in the equation 9.

$$y = soft\max(w_o f_m + b_o) \quad (9)$$

Where y represents the output, w_o represents the output weight, and b_o represent the output bias. If the recognition model give a recognition rate below 70%, it triggers an irritation alarm and subsequently send alert to the administration's system (base station) and the owner's smart phone

IV. Results and Discussions

This section presents the implementation of the Internet of Things farm land intrusion detection system, using RFID technology and image recognition technique to prevent unauthorized person into the farmland, and a safe defensive mechanism using irritation noise to scare away intruders. RFID reader was mounted at the entrance of a farm to read the tags of farm workers for identification purpose. The microcontroller, the RFID reader, tags, the buzzer, the camera and application software which includes the user interface design. The tools used in the development of the software part are as follows:

- Personal computer with 64 bit Operating System and Processor Intel® of 2.20GHz.
- PHP, MySQL, HTML, CSS and JavaScript programming languages.
- XAMPP Apache Local Server.
- Python Programing language for the image recognition algorithm.

A. User Interface Design

A user interface is the portion of a program with which a user interacts with the computer system. The user interface of the farm land intrusion detection system contains:

1. Login Page

This is the default page that appears when the application is launched. This page enables the farm owner to access its features. Figure 2 shows the system interface. The system contains three major parts, farmers login, farmers face identity prediction, farm worker enrolment. They are shown below:can be presented with tables or figures. Results and discussions must also interconnect with theory that used. Avoid excessive use of citations and discussion of published literature

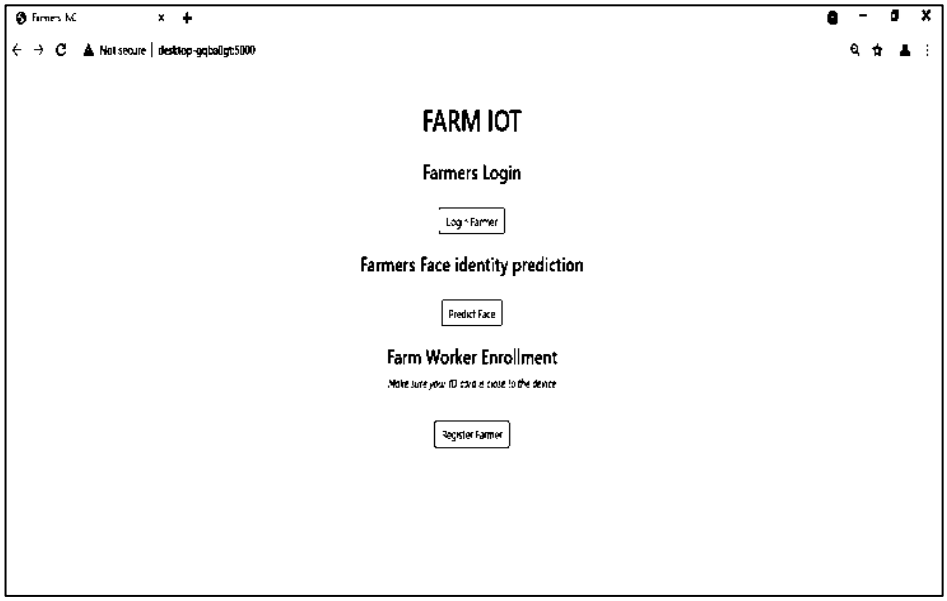

Figure 2. User Interface Design

Figure 3. Signing in of a farm owner

2. Farmer's Face Identification Prediction

The image identity checking module contains an image upload module for uploading an image which would be used to check if the face is authorized to enter into the farm. The module activates when an object or a person attempts to enter into the farmland via the entrance points. This is to prevent the possibility of an intruder using a worker's tag. Figure 5 shows the identity checking module.

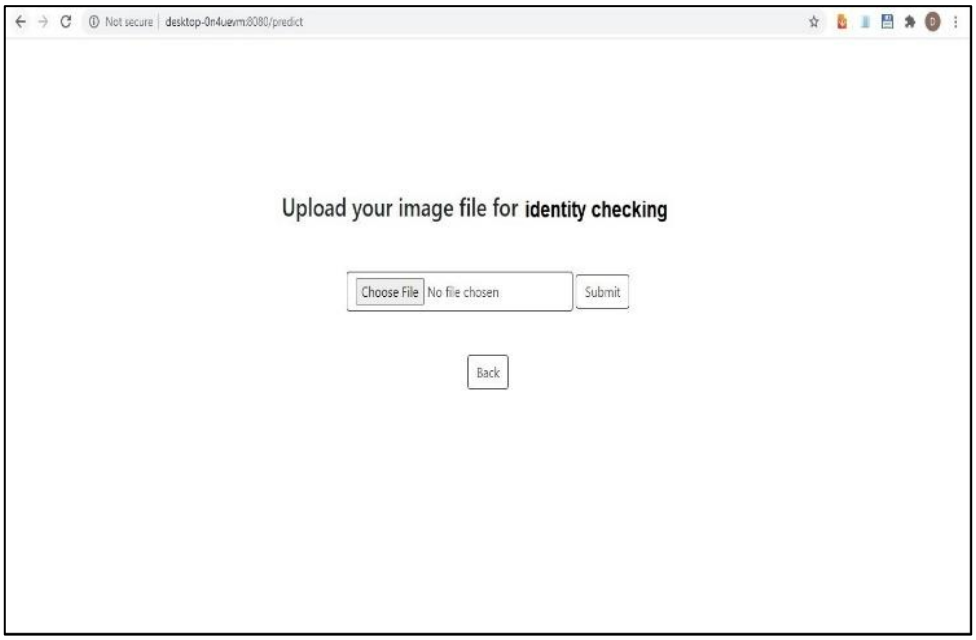

Figure 5. Identity checking interface

3. Farm Worker Enrolment

The system takes the required data and save in the database, the system wait for the farm owners to click on proceed and then put the RFID tag close to the RFID reader. Figure 6 shows the unique RFID tag number and the login details to be provided by the farm owners.

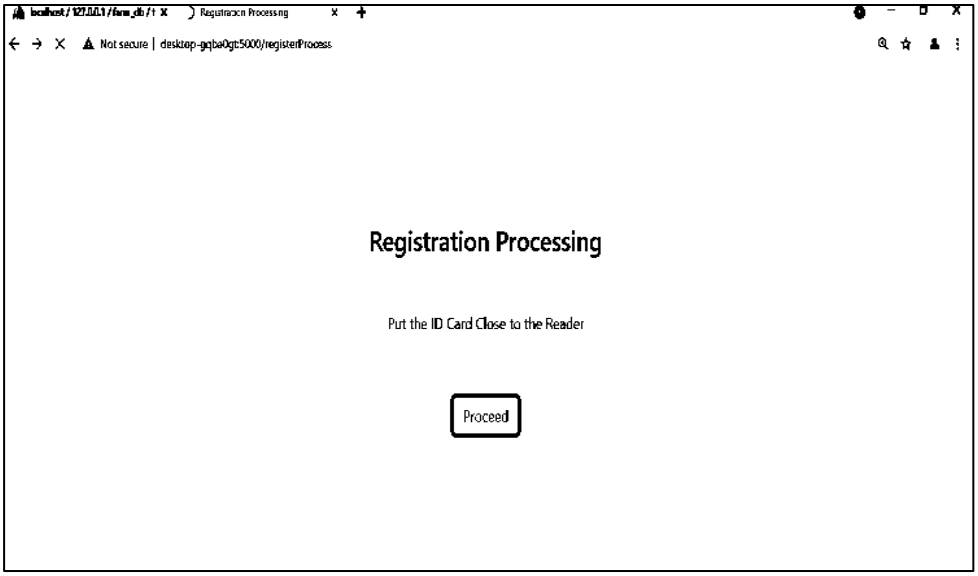

Figure 6. Registration of a farm owner

Figure 7 shows the unique RFID tag number and the login details to be provided by the farm owners:

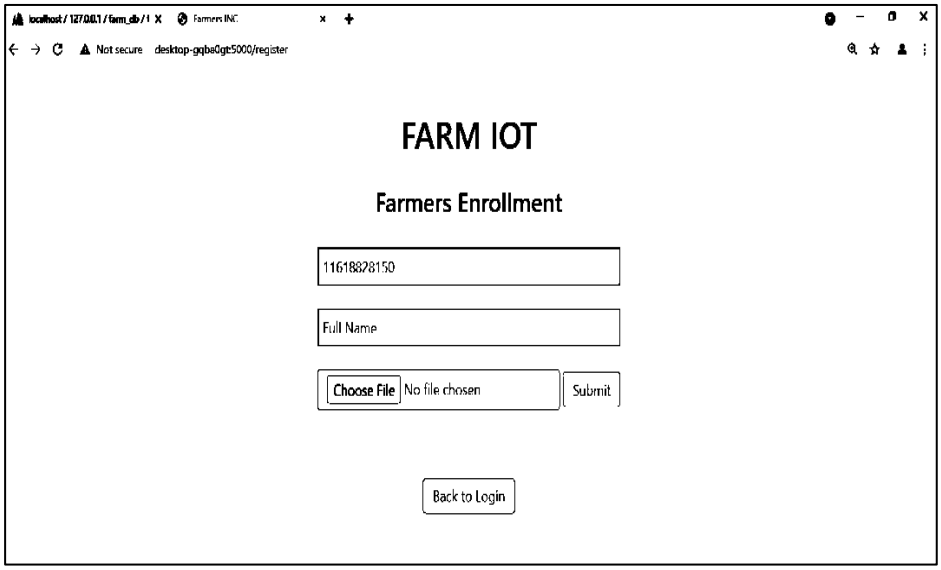

Figure 7. Registration of a farm owner

Figure 8 shows the data of the farm owner has been successfully uploaded.

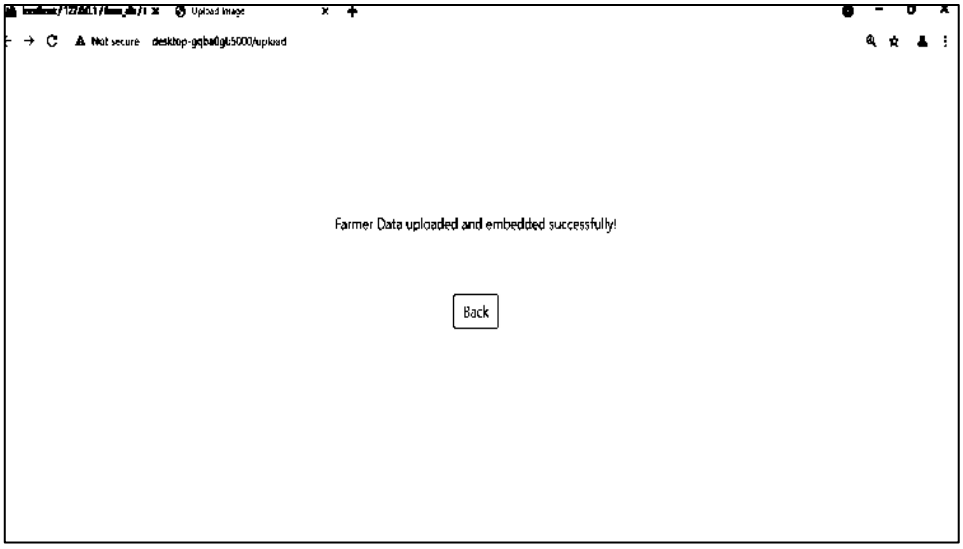

Figure 8. Successful of a farm owner

4. Face Recognition with Camera

Captured images will undergo different pre-process steps such as image value normalization, image enhancement, and feature extraction.

Figure 9. Sample of pre-processed images

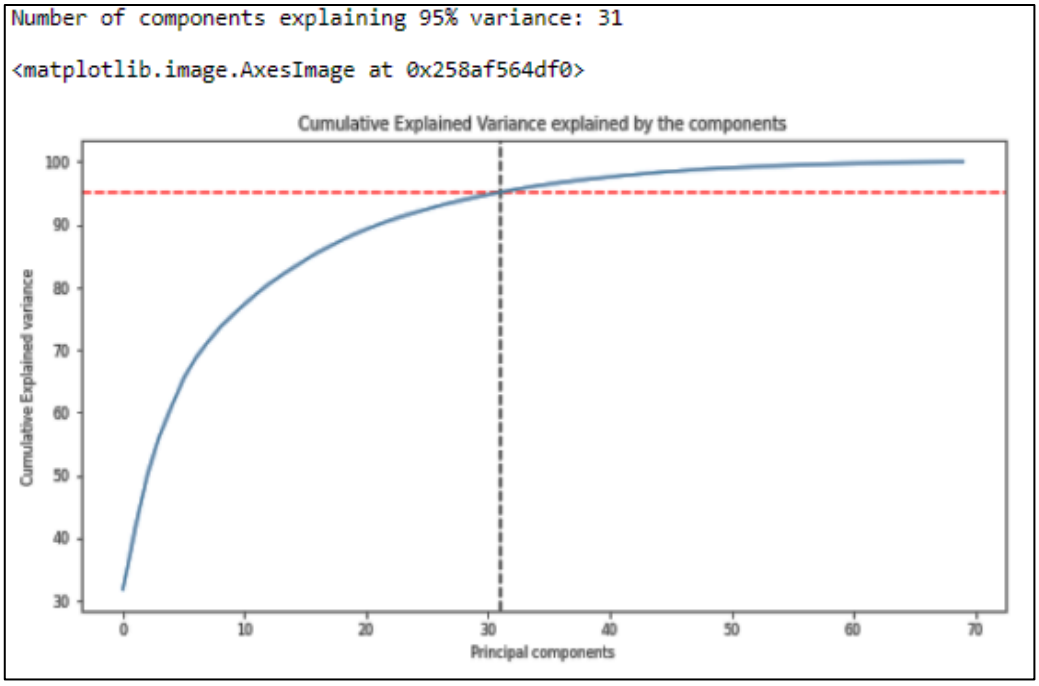

Figure 10. Scree Plot for PCA

These are the output of the pre-processed images

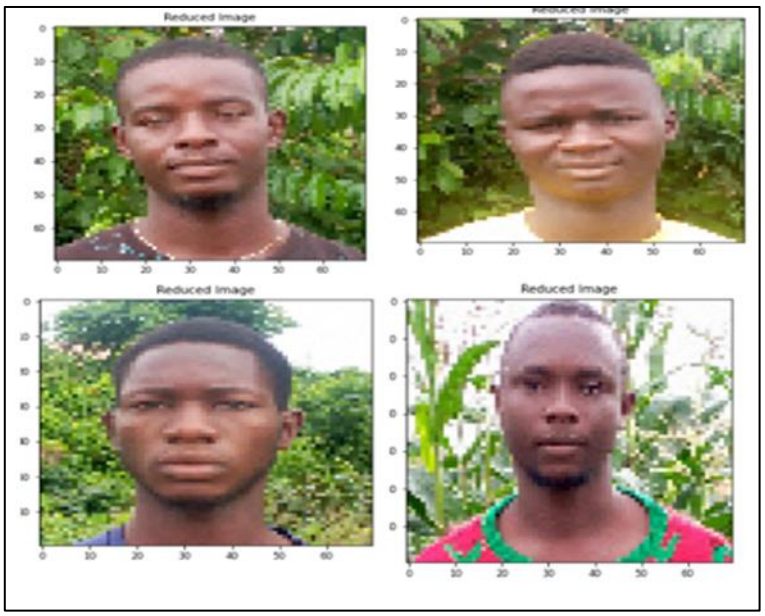

Figure 11. PCA Reduced Images

Figure 12 Shows the face recognition operations indicating authorized and unauthorized farm owners.

Figure 12. Face Recognition Operation

Figure 14 shows a layout of the system database showing farm owners that is been recognized by the system.

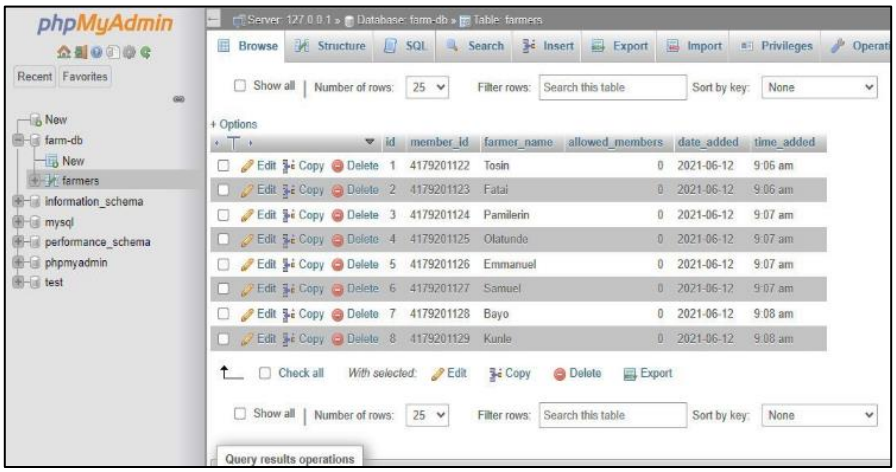

Figure 14. A layout of the system database

Figure 15 Shows typical messages sent to the Farm owner's mobile phone

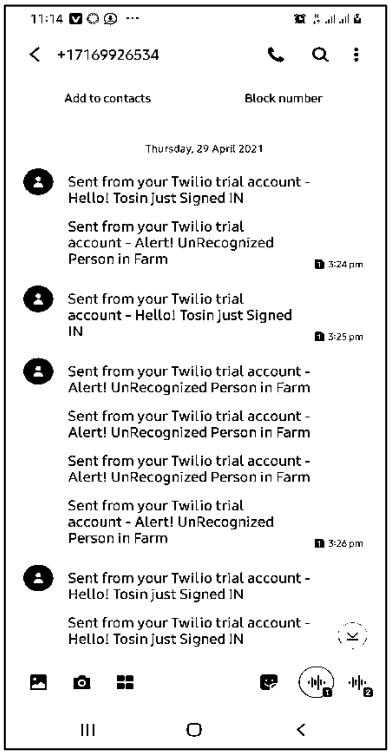

Figure 15. Sample of received message on farm owner's mobile phone

5. Evaluation

Confusion matrix table (shown in Table 1) was used in this study to describe the performance of the recognition module on a set of test data for which the true values are known. In this study, 20 image test data were used of which 15 were authorized farm workers and 5 were regarded as intruders. The true positive (TP) represents the number of correctly detected intruders. True negative (TN) represents number of correctly recognized farmers. False positive (FP) represents the number of farmers that were incorrectly recognized as intruders, while false negative (FN) represents intruders that were incorrectly recognized as farmers.

Table 1. Confusion Matrix of system recognition module

		Prediction Class	
		Intruder	Farmer
Actual Class	Intruder	4	1
	Farmer	2	14

$$Accuracy = \frac{4 + 13}{4 + 12 + 2 + 1} = 0.9$$

$$Precision = \frac{4}{4+2} = 0.7$$

$$\text{Recall} = \frac{4}{4+1} = 0.8$$

The system shows a high level of effectiveness with an accuracy of 90%, Precision of 70%, and 80% Recall rate.

6. System Performance and Evaluation

Table 2 shows the comparison of recognition accuracy score of the developed system with existing farm intrusion detection systems, while Table 4 depicts the comparison of the developed system with existing system using other metrics such as efficiency, technology used, operations performed by the system and platform used.

Table 2. Comparison of Recognition Rate of Developed System with Existing Systems

Performance Metrics				
	Vinaya et al (2018)	Saieshwar et al. (2018)	Sachin et al., (2017	Developed System.
Accuracy	87.35%	54.32%	82.5%	90%

Figure 17 is the chart showing the accuracy of the previous work and developed work.

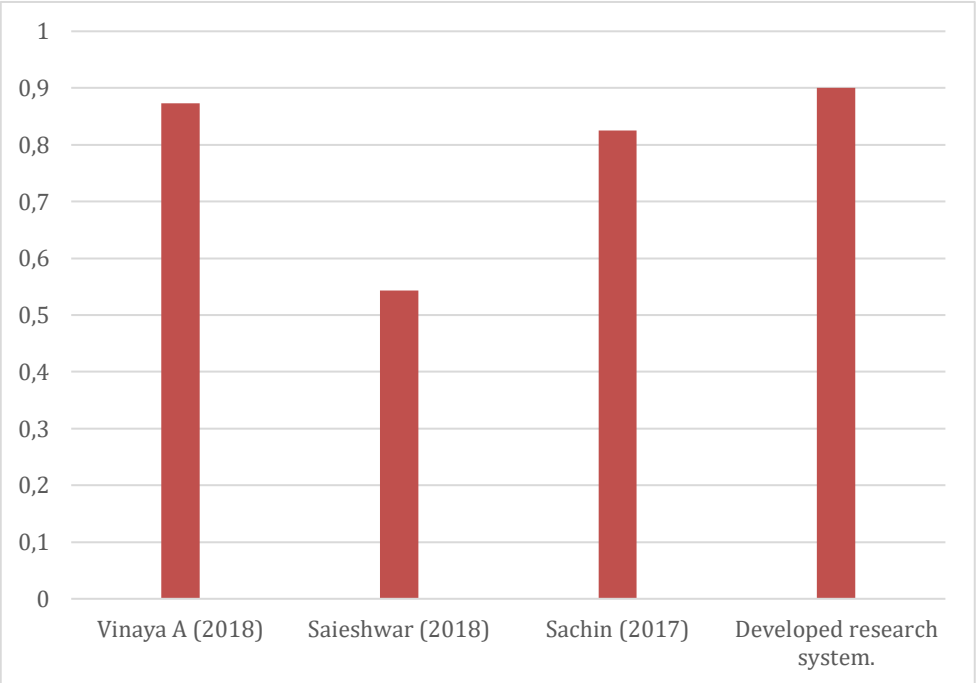

Figure 17. Accuracy Chart

V. Conclusion

This research has established an effective farmland intrusion detection system using RFID technology and image recognition technique to prevent unauthorized person into the farmland, and a safe defensive mechanism using irritation noise to scare away intruders. RFID reader was mounted at the entrance of a farm to read the tags of farm workers for identification purpose, therefore, the system proceeded by taking face images of the workers for further identification. The capture images were

preprocessed and salient features were extracted using PCA algorithm. Extracted features were fed into the recognition module driven by CNN for recognition. The system was implemented using programming language, and other packages such as flask 1.0, PyTorch, MySQL. The result of the system shows a recognition score of 90% accuracy, precision of 70% and 80% recall rate, while existing system shows the accuracy of 87.35%, 54.32% and 82.5% respectively. Hence, with the objective of developing an IoT farmland intrusion detection system using sensors and CNN, this research therefore has succeeded in controlling the rate of illegal encroachment into farmer's farmland.

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