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Design and Implementation of a Microcontroller Based Community Surveillance System

[1]Uhagh Louis, [2]Nentawe Y. Goshwe, [3]Jonathan A. Enokela
Department of Electrical and Electronics Engineering
[1,2,3] Joseph SarwuanTarka University, Makurdi, Nigeria

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ABSTRACT: Security of lives and property is one of the major factors that contribute to the growth and development of any nation and it is the primary responsibility of the Government. In recent times, Nigeria has been threatened by numerous security challenges leading to very many loss of lives and property without appropriate intervention to mitigate it. Where the security agencies respond, sometimes the intervention comes late due to lack of intelligence at the crime scene. This research, which designs and builds a Community Surveillance System, seeks to provide support to the security agencies and residents through early warning signs to improve on the response time. The system uses Passive Infrared sensors that detect human motions by sensing the infrared radiations from the body of non-residents when they are 6 meters away or nearer to the sensor. A detected intruder will trigger the UART camera to send the image footages through the GSM/GPRS to a cloud database and trigger an alarm for 2 minutes so as to attract the attention of nearby persons. In addition, the system sends SMS and email alerts to the residents, relations, the local vigilante, the police and any other preconfigured telephone numbers and emails that are in the database. An Application Programming Interface is provided to the vigilante groups and other security stakeholders who have security credentials to track the live footages of the intruder. The test results of the implemented system returned SMS and email notifications within 20 and 40 seconds respectively and seamless remote monitoring of live footages from the database. Under poor network conditions the worst returned time was 5 minutes and 2 hours for SMS and email delivery respectively. The system offers the advantages of live monitoring and retrieval of stored footages from the database as early warning signs; a user friendly concurrent access of the footages from remote points using internet enabled devices and email/SMS notifications. These multiple benefits make the system a reliable tool for use in homes, shops, warehouses and supermarkets to aid security agencies to investigate a crime that has been committed, to intervene in real time in a crime that is being committed, and to be proactive in taking decisions about a crime that is yet to be committed.

KEYWORDS: Electronic Surveillance, Microcontroller, Cameras, PIR Sensor, Database, Website

I. INTRODUCTION

Security has been defined as the establishment of measures for the protection of persons, information and property against attacks to enable citizens to go about their daily activities without any threat to lives or property (Adegbami, 2013). It is designed to safeguard the resources of individuals, groups, businesses and state assets. A community is secured when citizens have predictable daily life, protected from crime, and institutions are provided as safety nets. Therefore, security is supposed to be the primary responsibility of the government because therein lies its prosperity.

Nigeria is presently witnessing an unprecedented level of insecurity that is making national security threat and crimes to be a major issue that the public expect government to tackle. The trust in the security apparatus to guarantee safety and security of lives and property is dwindling every day because the threats remain unabated. According to 2017 records of crimes by the Nigerian National Bureau of Statistics, there were a total of 122,040 reported crimes against properties and humans which comprised 68,579 cases of reported property crimes and 53,461 reported crimes against persons. The crimes against property include 3,527 armed robberies; 32,348 theft/stealing; 2,167 burglaries; 3,212 house breaking; 1,873 store breaking and 1,086 arson

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cases across the country. The reported crime against persons in the same corresponding year were 3,219 murder; 120 manslaughters; 771 attempted murder; 11,191 grievous harm/wounding; 24,025 assault; 345 child stealing; 2,279 rape/indecent assault and 1,134 kidnapping cases (National Bureau of Statistics, 2017).

To reduce the incidence of these crimes and insecurity, governments are allocating huge national and state budgets to security, embarking on criminalization of terrorism by passing the Terrorism Prevention Act in 2011 (Terrorism Prevention Act, 2011), improving on surveillance system, and taking physical security measures to disrupt potential attacks (Umego, 2019). Despite these efforts, the level of insecurity in the country is not improving as Nigeria still globally ranked low in the Global Peace Index (GPI, 2020).

Technology has been used in dictating and preventing unauthorized intrusion into premises using Intrusion Detection System (IDS). An intrusion detection system (IDS) is a system that monitors network traffic for suspicious activity and alerts when such activity is discovered (Lutkevich,2020). Such security systems are used in commercial, residential, industrial and military properties for protection against burglary (theft), house breaking, shop breaking, arson or other crimes against property as well as protection against intruders

Intrusion Detection System (IDS) can either be a software or hardware device that automates the process of monitoring and analyzing of events. The device can be activated when an intruder is detected in some reserved area that is planned to be secured. The IDS is normally equipped with an alarm system that will alert institutions and individuals to intervene during security breach. Whenever an intruder is detected, the IDS sounds an alarm that runs for a pre-determined time and also sends an SMS to the owner informing him of the intrusion. Conventional security systems keep owners and their property safe from intruders by alerting property owners using an alarm. A lot of interesting research works have been done on IDS. Elfasakanyet al. (2011) developed a system that triggers an alarm and also alerts the owner via a mobile text message if the house has been opened or an attempt has been made to open it illegally. The system featured two different forms of activation/deactivation and automatically opened or closed the door for the user. The system however had no means of identifying the person who attempted to open or who succeeded in opening the door since no camera was used.

Mutlaget al. (2012) implemented a modern security system based on mobile phone intended to protect important places by calling the place owner
through a mobile phone to notify him that the place is being penetrated. The system however used hard disk
(which is susceptible to theft or damage) for storing images instead of using the cloud which is much more secure.

Rothkrantz (2014) proposed the use of sensor networks for military surveillance and environmental monitoring applications to reduce the amount of data to be processed. This system is too complex as it requires several human operators and high tech video camera systems.

Khotet al. (2015) proposed a smart video surveillance system capable of enhancing situational awareness across multiple scales of space and time. It described mobile based remote control and surveillance architecture. The system however, does not have cameras to detect any intruder. Secondly, no alarm system was used to alert anyone of any intrusion

Tarus (2017) designed a PIR sensor-based home security system which used Raspberry pi and PIR sensor. The project was designed to assure home security through surveillance. The major drawback of this work was that images and videos were not saved on the web making it difficult to access in real-time. The overall cost of the system was very massive.

Cermenoet al. (2018) proposed to add a module based on machine learning and global features bringing adaptability to the video surveillance solution, so that problematic situations can be recognized and given the right priority. This system however, did not incorporate a database where information on problematic environments could be stored.

The design presented in this work offers advantages over existing systems in the following ways. The system has a wireless camera for proper identification of intruders. A cloud database which has more storage space is used for storing images of intruders and these images can be accessed in real-time. A website was designed for viewing the captured images of intruders. An alarm system was incorporated to scare away intruders and also notify the neighborhood of intrusion. Finally, SMS and email notifications which notify the owner, his/her relation, the local vigilante and the police were adopted.

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II. METHODOLOGY

This section will discuss the design procedure and the basic theory of components used for this work.

2.1 HARDWARE DESIGN

The major components involved in the hardware design include;

- The STM32F103C8 microcontroller
- The Spinel SC20MPC Series Camera
- SIM800L GSM/GPRS Module
- Liquid Crystal Display
- PIR Sensor
- Buzzer

2.1.1 The STM32F103c8Microcontroller

This microcontroller belongs to the family of ARM cortex STM32F103XX (STMElectronics, 2018). The STM32F103C8 microcontroller is the heart of this system and it handles the processes involved in the system design.

2.1.2 The Spinel SC20MPC Series Camera

The camera is a device which capture images and videos. In this project, the camera has been used to capture images when an intruder is detected. The camera chosen for this work is Spinel SC20MPC series Camera. It is a highly integrated serial camera module which can be attached to any host system that requires a JPEG compressed still pictures for embedded imaging applications (Spinel, 2018).

2.1.3 GSM/GPRS Module

The Sim800L GSM module which uses a RS232 to connect to the microcontroller has been used. SIM800L is a compact GSM/GPRS module that offers 2G GSM/GPRS data and supports SIMCOM enhanced AT commands. Because it uses the serial communication method, it is easy to interface with the UART of almost all popular microcontrollers (SimCom, 2013).

2.1.4 Display Unit

The liquid crystal display used for this work is a 16 x 2 module (Shenzhen Electronics, 2021).

2.1.5 PIR Sensor

The Passive Infrared (PIR) sensor is the startup point of the system. The PIR sensor operates on the principle of infrared radiations emitted from the human body. Different materials emit different Infrared (IR) radiations at different wavelengths. The human body usually emits infrared radiation with wavelengths ranging between 0.7 and 300 micrometers. This makes the PIR sensor distinguish other movement from human motion. The PIR sensor in the design has a range of 6 meters and an angle of 110°. Once the motion is detected, a signal is sent to the microcontroller.

2.1.6 Buzzer

A buzzer or beeper is an audio signaling device which may be mechanical, electromechanical or electronic (All Electronics, 2021). The buzzer was programmed to beep for two minutes when the PIR sensor detects motion.

2.2 SOFTWARE DESIGN

This section covers the Integrated Development Environments (IDE) used for the design of the website, database and microcontroller programs. The software design is segmented into microcontroller software (IDE), the Website Design software/IDE and Database Design Software/IDE.

2.2.1 Microcontroller Software/IDE

Microcontrollers are programmed to execute the tasks which they are assigned. They are usually the brain behind embedded systems. The Microcontroller used in this work is the STM32F103C8 microcontroller while the software used to program the microcontroller is the Arduino IDE 1.8.13.The command <SIM800L.h>was used to initialize the SIM800L driver with an internal buffer of 200 bytes and a reception buffer of 512 bytes**.** The GSM/GPRS module SIM 800L has three pins named Transmitter (Tx), Receiver (Rx) and Reset (RST). In this work, Transmitter (Tx), Receiver (Rx) and Reset (RST) were assigned to Pins 5, 6 and 12 of the microcontroller respectively. The Liquid Crystal Display (LCD) was initialized using the <LiquidCrystal.h>. The Register Select and Enable were assigned to PB4 and PB5 while Data Pins 4 to 7 were assigned to PB6, PB7, PB8 and PB9 respectively.

The output port of the PIR Sensor was assigned to pin PA4 of the microcontroller. The input and output ports of the Spinel SC20MPC Camera named Transmitter (Tx) and Receiver (Rx) were assigned to pins PA4 and PA5 respectively while the Buzzer/Transistor Base input port was assigned to PB3.When the Microcontroller received a signal from the PIR sensor, it detects the specific sensor and sends a message to all the registered numbers and email addresses based on the programmed message for the particular sensor. For example, PIR sensor 1 (displayed as Node 1) was registered to a location "Plot 6969 NgokumaGede Street'. The GSM/GPRS Module sent a message. " Attention; Intruder is detected at

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Plot 6969 NgokumaGede Street!" once the microcontroller received a signal from PIR sensor 1.

Similarly, PIR sensor 2 (displayed as Node 2) was also registered to a location "Plot 4745, AgakuIkyogen Street". The GSM/GPRS Module sent a message. "Attention; Intruder is detected at "Plot 4745, AgakuIkyogen Street"' when the sensor became active. The Flowchart of the system is shown in Figure 2 and the steps of the program execution are shown as follows:

Step 1: Test for connection
- Do HTTP POST communication with 10s for the timeout
- Check for reception buffer at the Rx Pin for data size
- If data received on the serial greater than or equal 512 bytes, display " HTTP POST successful "
- If data received is less than 512 bytes, display " HTTP POST failed"

Step 2: Activation of PIR Sensor and Detection of Intruder
- Send a voltage of 3.3V to PA4 (PIR Output) to activate the sensor
- Check PA4 for signal from PIR Sensor
- If signal received is greater than 3.3V, it indicates a logical HIGH (Intruder detected)
- If signal received is 0 V, it indicates a logical LOW (No Intruder detected)

Step 3: Sound Alarm
- Send 3.3 V for 120 seconds to base of transistor to activate the buzzer.

Step 4: Capture Images and save on SD card
- Send Command (Hex) to Take Image
- Send Command (Hex) to Read Data.
- Save image on SD Card

Step 5: Send SMS
- Send AT Command to SIM 800 to send SMS to registered number through TX Pin PC4.

Step 6: Post image to Cloud
- Send Command (Hex) to read image length and size
- Send Command to send JPEG image to TX Pin PA4 from transmission to cloud.

Website Design Software

The designed system is implemented using two nodes with each node having specific users. The system is designed in such a way that a user in a particular node can only access images in that node. This means that a user in node 1 cannot access and view images in node 2 and vice versa. The website was designed using PHP at the frontend. While PHP and Python were used for the backend. Figure 3 is the Use Case Diagram which explains how users interact with the website.

Database Design Software

A database is a collection of information that is organized so that it can be easily accessed, managed and updated. It could also be defined as a collection of data or information that is specially organized for rapid search and retrieval by a computer. For this system, a database was designed using MySQL to save the personal information of all the users and the footages of intruders for node 1 and node 2. The captured images are stored in a database and can be retrieved when the need arises. Figure 5 shows the screenshots depicting how images are stored for both nodes.

III. OPERATION OF THE INTRUDER DETECTION SYSTEM

The IDS for community surveillance constructed in this work has three subsystems: the intruder detection subsystem; the notification subsystem and the image detection subsystem. The intruder detection subsystem is activated using an SMS "Activate Security" from a mobile phone of the owner to screen the intruders from the residents of the community. The PIR sensors detect human motions by sensing the infrared radiations from the body of non-residents that are 6 meters away or nearer to the sensor. Once an intruder is detected, the sensor sends the intruder's signal to the microcontroller. The microcontroller triggers the UART camera to get the footages of the intruder and sends the footages through the GSM/GPRS to cloud database. The footages tracked and captured are saved in the cloud database with date, time and address stamps.

The microcontroller triggers an alarm for 2 minutes to attract the attention of nearby persons while the web application sends SMS and email alerts to the residents, relations, the local vigilante, the police and any other preconfigured telephone numbers and email addresses that are in the database. An Application Programming Interface (API) is provided to the vigilante groups and other security stakeholders who have security credentials to track the live footages of the intruder. This community surveillance IDS offers advantage of live monitoring and retrieval of stored footages from the database, concurrent access of the footages from remote points using internet enabled devices and email/SMS notifications. These multiple benefits make the system more user friendly and reliable in reducing crime that is yet to be committed, intervene in a crime that is being

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committed or investigate a crime that has been committed.

The block diagram of the system is shown in figure 1

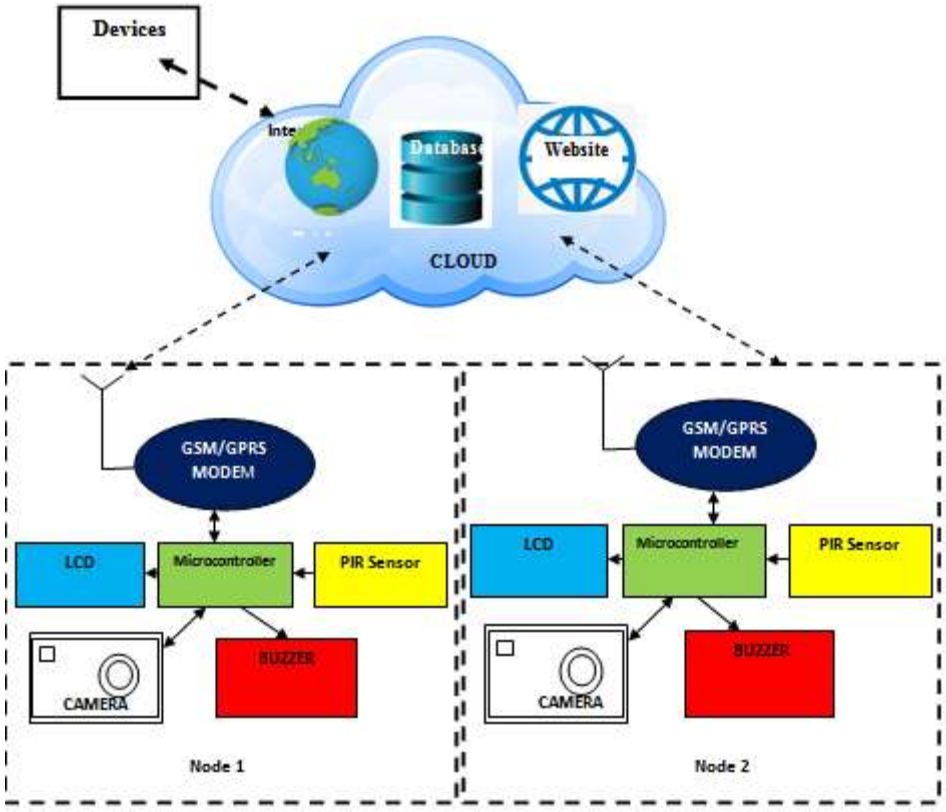

Figure 1: Block Diagram of the Intruder Detection System

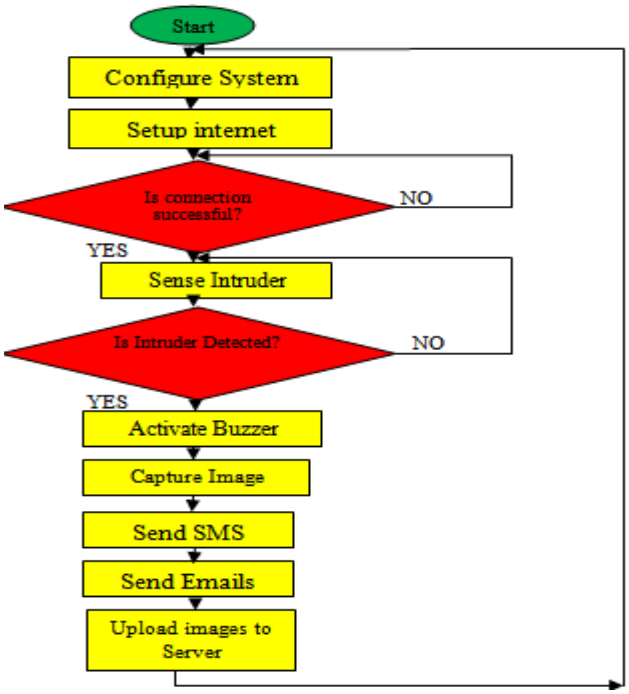

Figure 2. Flowchart of the System

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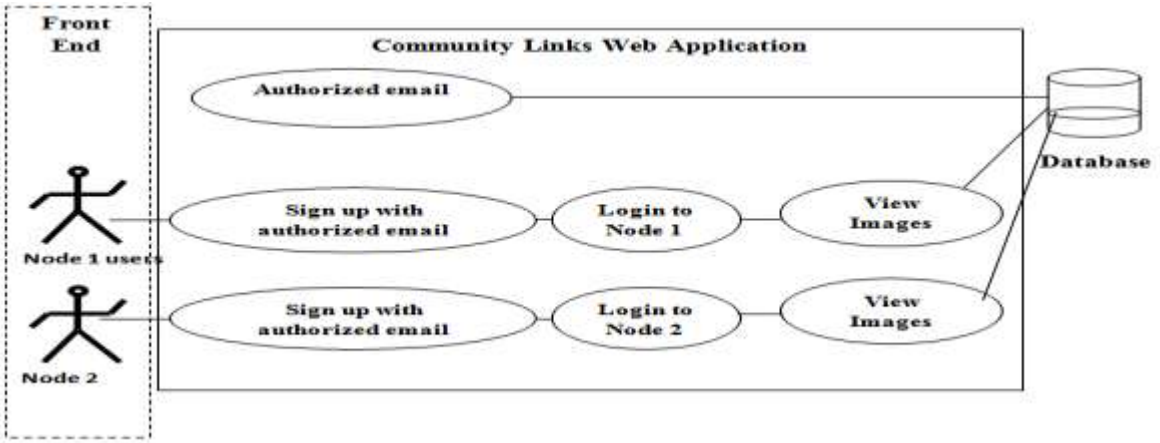

Figure 3: Use Case Diagram showing Users Interaction with Website

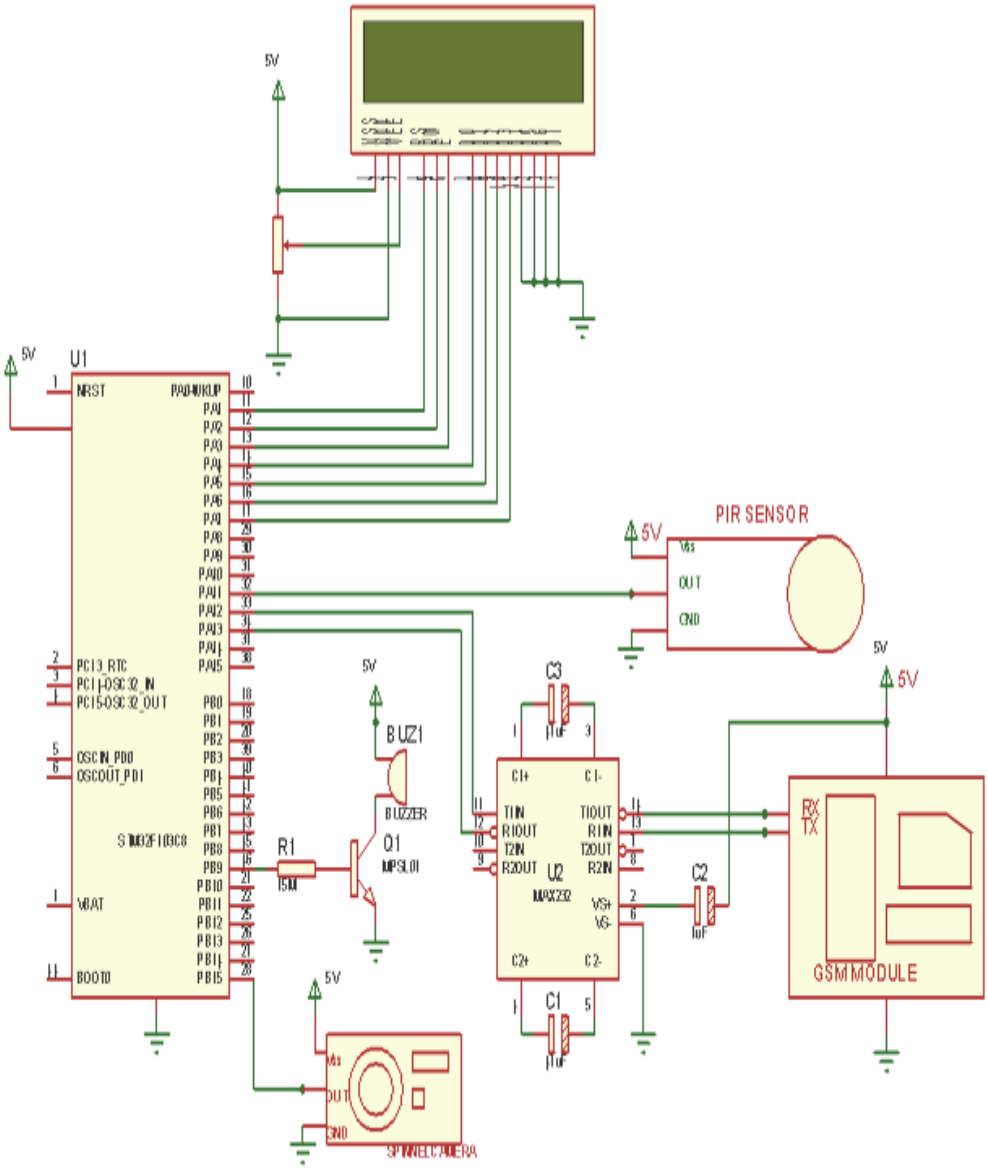

Figure 4: Schematic Diagram of the Intruder Detection System

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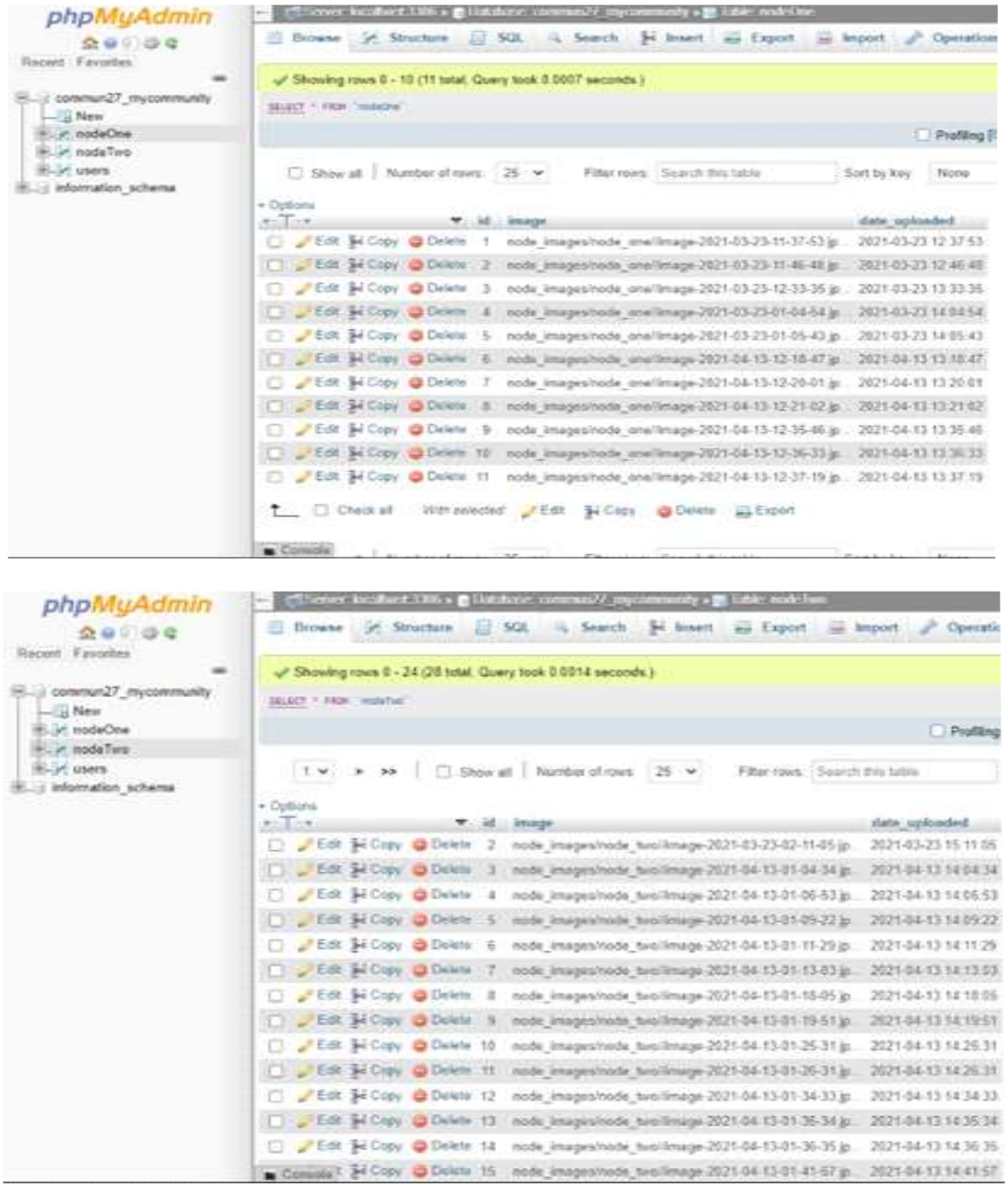

Figure 5: Image Storage Database for Node 1 and Node 2

IV. RESULTS AND DISCUSSIONS

Node 1 is at a location 'Plot 6969 Ngokuma Gede Street' and a PIR sensor is registered to the location. Once the sensor at the location was active, the camera captured images of the intruder and send it to a cloud database which can be viewed using the URL www.community-links.com.ng.The GSM/GPRS Module sends a message to owner " Attention!!! Intruder is detected at home"; sent another message "Attention!!! Intruder is detected at your relation's house" to the relation. The local vigilante and police get the message "Attention!!! Intruder is detected at Plot 6969 Ngokuma Gede Street" once the microcontroller received a signal from PIR sensor. Similarly, emails are sent to designated email addresses for owner, with messages similar to those sent to the GSM numbers of relation, local vigilante and Police. The system does the same for all nodes connected to it. The screenshot of SMS and emails notifications for node 1 and node 2 are shown in Figure 6 and Figure 7 respectively.

Similarly, Node 2 is at a location Plot 4745 Agaku Ikyogen Street' and a PIR sensor is registered to the

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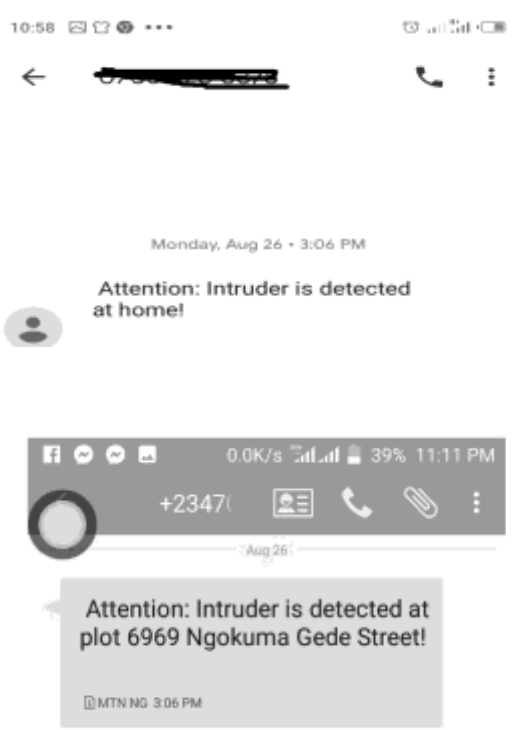
location. Once the sensor at the location was active, the camera captured images of the intruder and sent it to a cloud database which can be viewed using the URL www.community-links.com.ng.The GSM/GPRS Module sends a message to owner " Attention!!! Intruder is detected at home"; sends another message "Attention!!! Intruder is detected at your relation's house" to the relation. The local vigilante and police get the message "Attention!!! Intruder is detected at Plot 4745 Agaku Ikyogen Street" once the microcontroller received a signal from PIR sensor. Similarly, emails are sent to designated email addresses for owner, with messages the same to those sent to the GSM numbers of relation, local vigilante and Police.

The captured images are stored on the database. These images are stored based on time hierarchy where each image on the database was stored based on the time it was sent and labeled according to the location of the Node which captured the image. The images were arranged in a single row and contains subsets such as date, time and view image. The Website (named "Community links") has an interface where the user has to sign up and login to get access. The website was accessed using Firefox, Google Chrome, Opera and UC Browsers without any problem. The screenshot of the Website interface is shown in Figure 8 while Figure 9 shows how images are accessed on the website.

V. CONCLUSION

The system was built and tested successfully. All modules worked properly and both the SMS and emails were received by all concerned persons. The website was accessed and all captured images from the nodes were viewed. The research was completed successfully. Further research could incorporate facial recognition and machine learning in identifying the intruder.



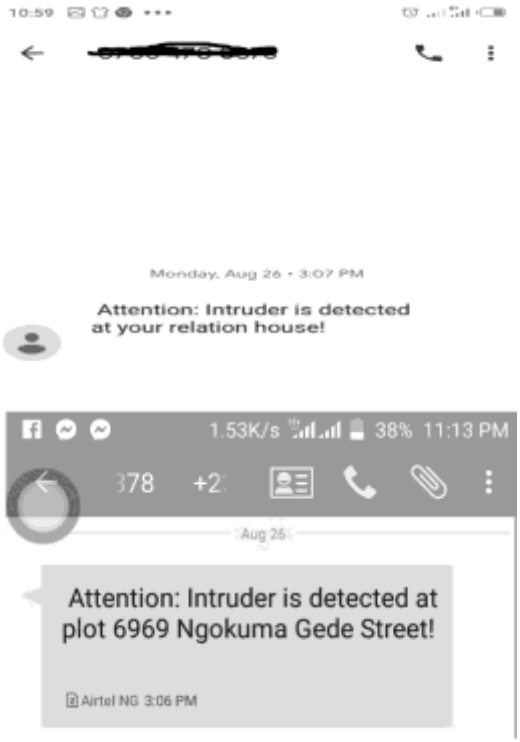


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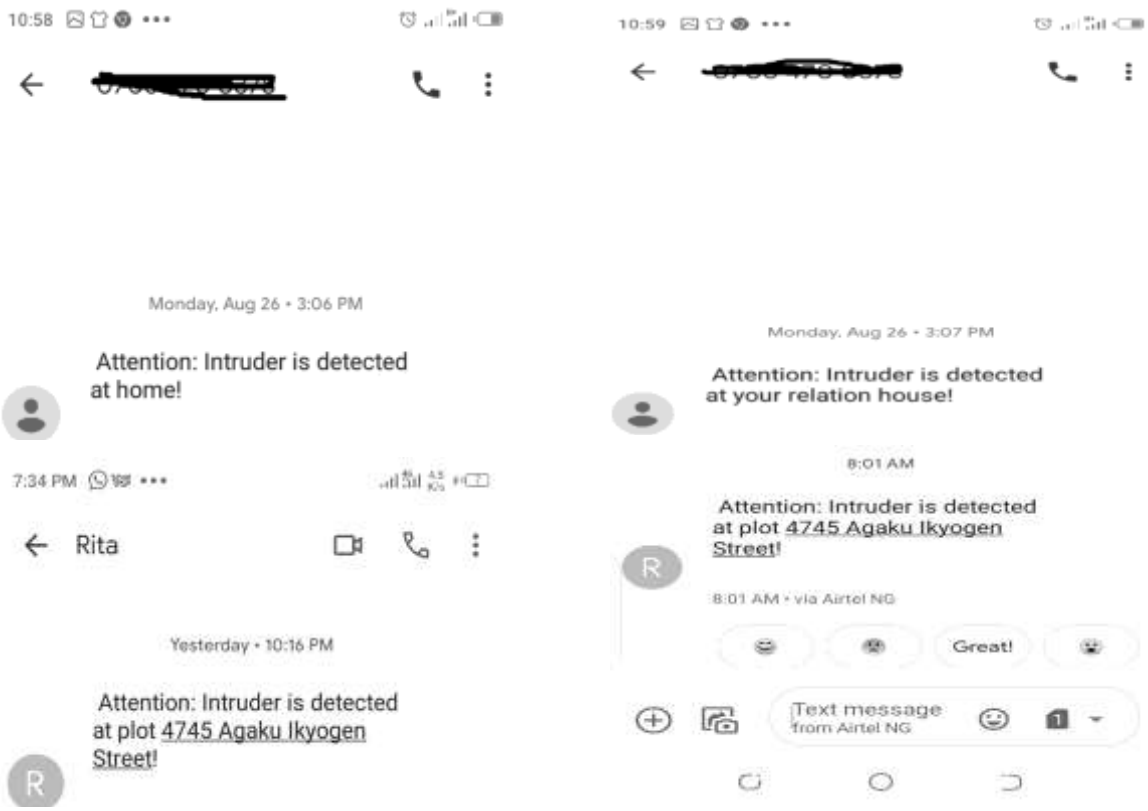
Figure 6: Screenshots of SMS and emails Notifications for Node 1



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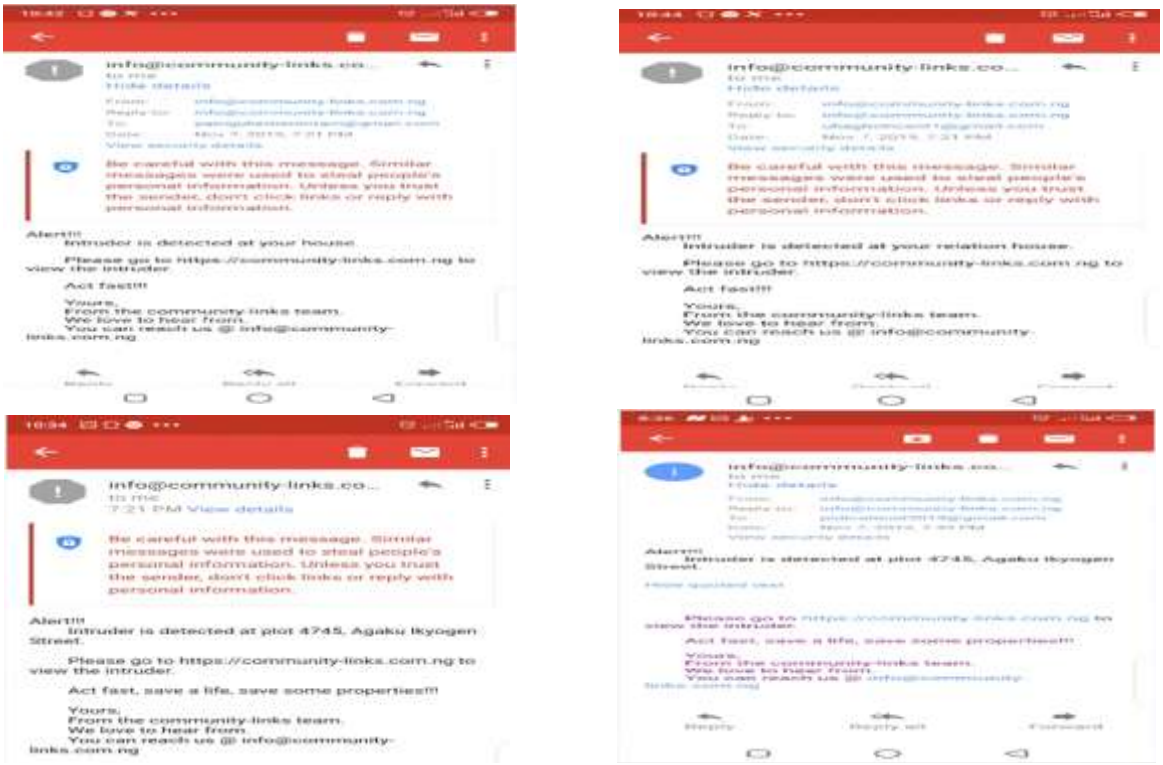
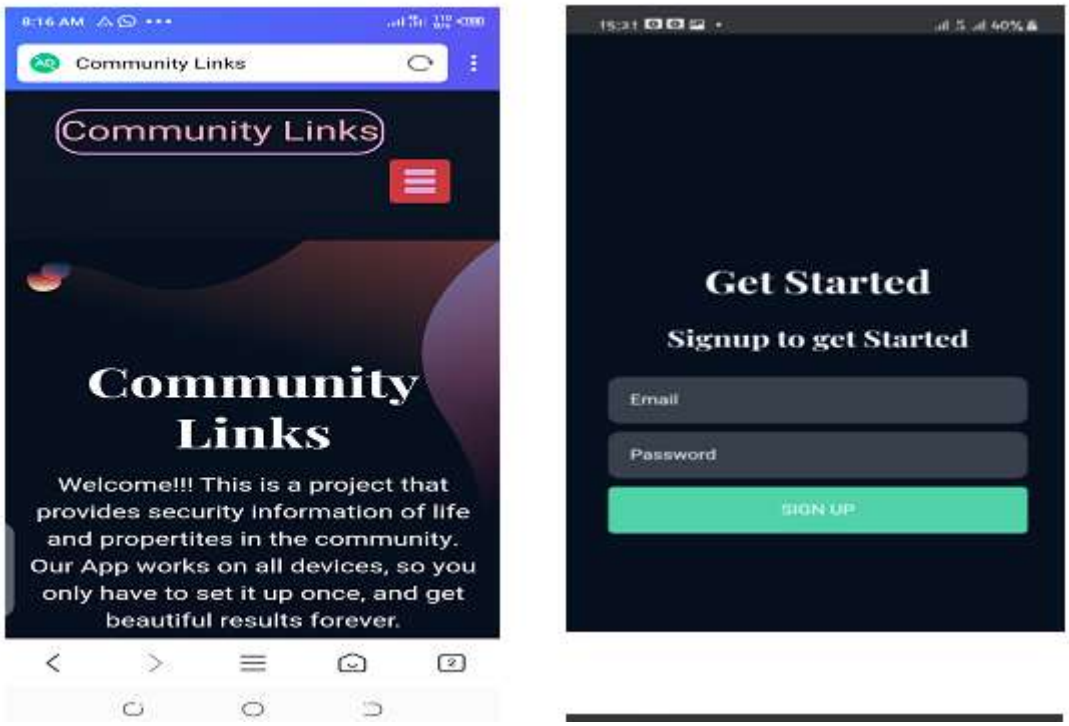


Figure 7: Screenshots of SMS and emails Notifications for Node 2



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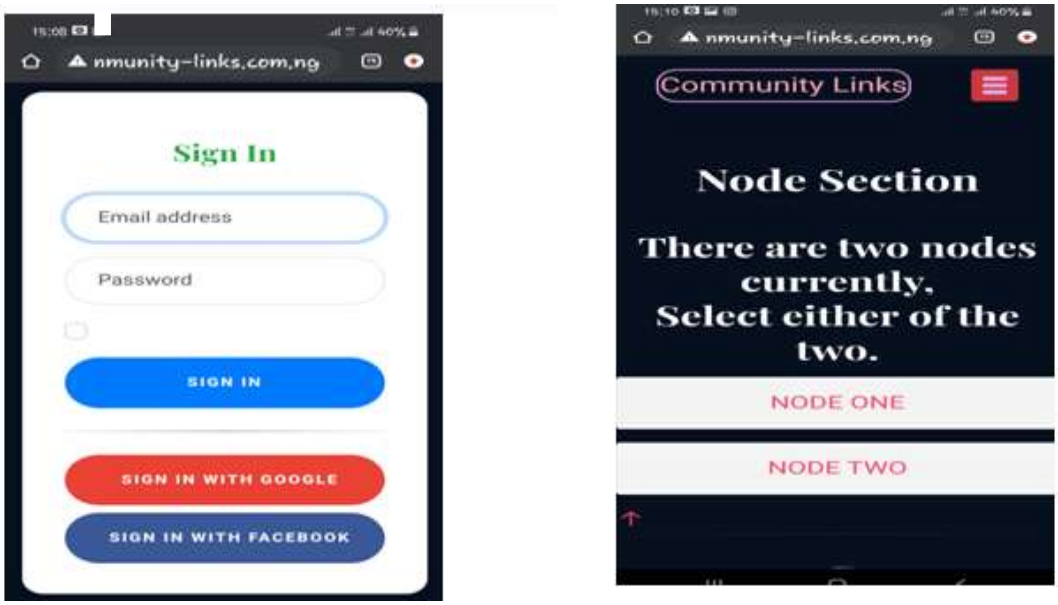
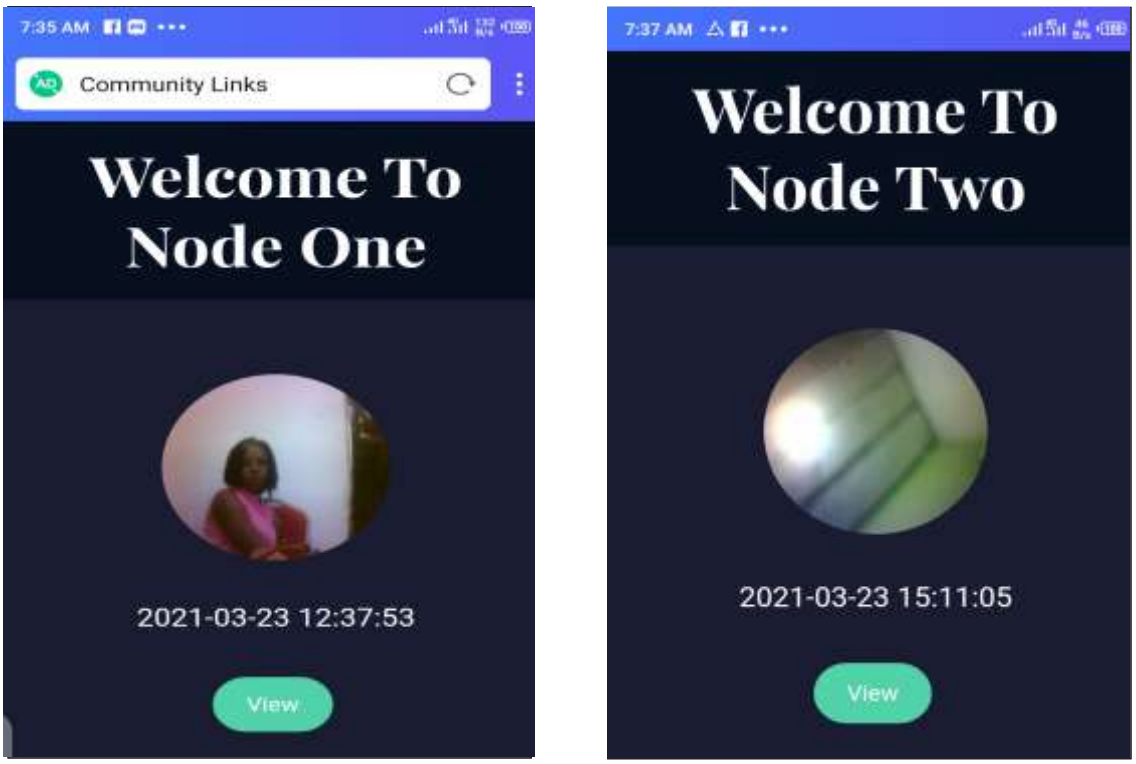


Figure 8: Screenshots of website Interface



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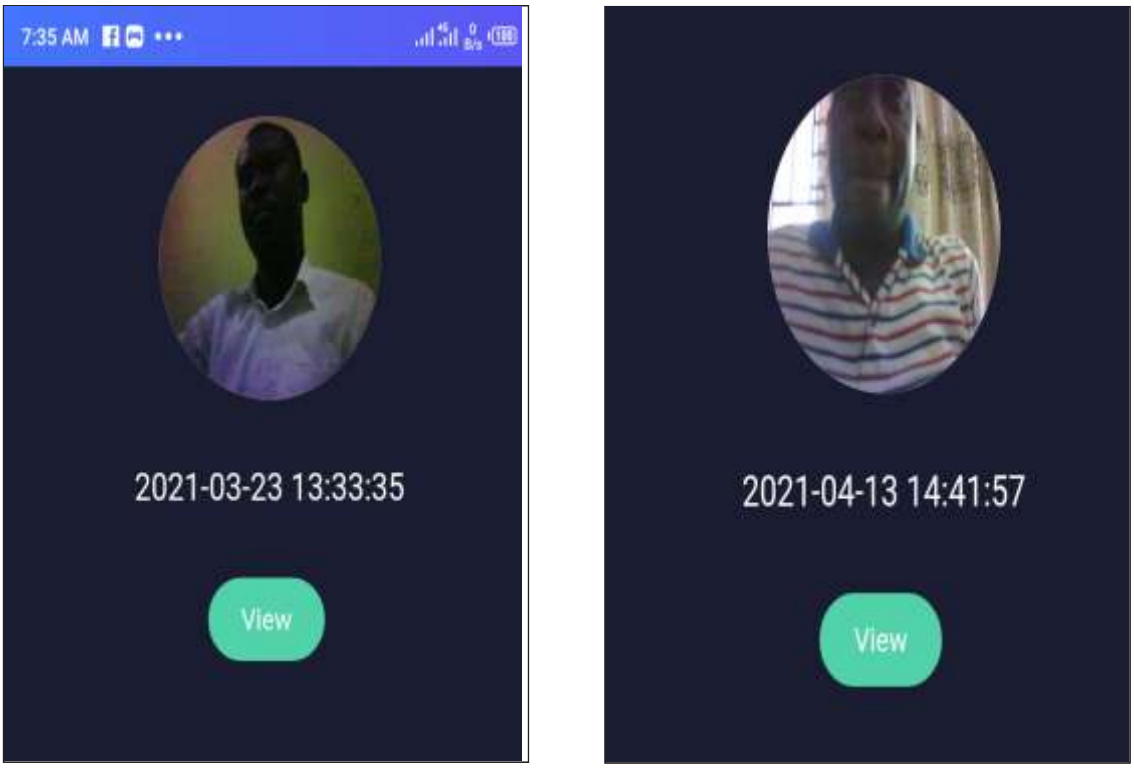

Figure 9: Screenshot of Images Stored on database as accessed via the website.

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