



## DEVELOPMENT OF REAL TIME HOME AUTOMATION SYSTEM WITH SMS ALERT ON NIGERIA GSM NETWORKS

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### Abstract

The comfort and security of homes are continuously being challenged by the needs for monitoring and controlling some domestic devices. Previous researches on real time home automation used microcontrollers for appliances switching and access control, on the world-wide-web, android applications and emails for transmission of information without consideration for the cost and time which are essential factors in automation. This study has developed a simple real time home automation system for door control and electrical appliances management. Camera, relay, servo motor and electrical power sensors were interfaced with Raspberry pi-3 board for image capturing, switching, door control and electrical power monitoring respectively. The captured image was processed for recognition using a CNN based model for access control. A keypad provides an alternative means of entry for authorized person who is not a regular home user to input a one-time-pin (OTP). Information about entry to the house and the electrical power status were transmitted via SIM800L GSM module as SMS to the house owner over Nigeria GSM networks. The research was tested; the electrical appliances switched autonomously when door opens or closes, the circuitry shot down when the supply voltage is less than 161Vac or above 240Vac. At the point and time of transmission, SMS transmission speed was found to be fastest (average of 5.4 sec) on MTN to MTN network in Nigeria. This research has shown a simple way of implementing a real time smart home system capable of providing security, efficiency and convenience at minimum cost.

**Keywords:** Automation, Network, Raspberry pi, Access Control, Real-Time

### Introduction

A peep into the future has shown that most homes will autonomously manage themselves in the nearest future (Abubakar et al., 2020). Automation will soon become an essential facility just like electricity in residential buildings because of the continuous quest to do things faster and smarter. The need for timely information and control of home activities with adequate security are other areas demanding automation. From the rural to urban areas, the world is becoming very busy with clumsy activities in which the home is not excluded; these activities involve appliances switching, access control, security, monitoring of sensitive devices and energy management (Iqbal et al., 2021). Due to stress and fatigue, organizing and ensuring that these activities are efficiently carried out are fast growing beyond human capacity. The need to regularly move around the house for switching and monitoring are too cumbersome for

children and older people who spend more time at home than the active middle age who are incapable of controlling the appliances effectively (Abubakar et al., 2020; Majeed et al., 2020). While many have adopted the use of domestic servants, house maids and home managers; apart from the high cost, the attendant dangers as seen in Nigeria and other countries range from theft, kidnapping, careless handling of responsibilities just to mention few (Azu, 2023). The solution to these and other problems is in the implementation of home automation whose main goals are Security, Economy, Convenience and Efficiency (Siddig 2017).

Home automation is the adoption of electronics system for the control of household features, appliances and activities via a network to ensure security, cost and time saving (Xfinity, 2019). It is an assembly of hardware, communication and

electronics interfaces that work to bring household devices to relate with each other over a network. Each device has a sensor that monitors changes in the physical parameters like temperature, illumination and presence or motion of objects. The outputs of the sensors go to the processor where signals are sent to the actuators to control the devices (Sowah et al., 2020).

Several existing systems have been used for home automation purposes such as microcontroller based, wired and wireless systems as well as IoT technology, but they are mostly very expensive with accessibility and coverage limitations. The study in which IoT was used to implement a smart home and security system presented a wireless control system and accessibility into a home environment for authenticating people only. The system uses a Passive Infra-Red (PIR) motion sensor and camera for motion detection and image capturing respectively. These were interfaced with Raspberry Pi-2 for image processing and transmitted via Transmission Control Protocol/Internet Protocol (TCP/IP) as email to the controlling authority who determines accessibility using a smart phone (Anwar and Kishore 2016). Othman and Aydin (2018) carried out a research which led to the development of a method for face recognition in the internet of things IoT for security application in smart homes and cities. The study aimed at protecting homes and offices through a real time automation system. The captured of the approaching persons were processed for recognition on the Raspberry Pi-3 project board. The images and notifications were sent to a smartphone based IoT (Othman and Aydin 2018). While these systems were able to identify the residents, they are not completely autonomous since they are incapable of making decision and also have no provision for controlling the home appliances. Harpreet et al., (2018) used the open source microcontroller Arduino Uno Atmega with Android application, Bluetooth HC-05 module with Gas and Temperature Sensors to implement an IoT based automated home/office system. Although, most of the appliances were controlled but the work made no provision for access control (Harpreet et al., 2018). Divyashree and Sujatha (2020) used object and temperature sensors on LPC2148 microcontroller to design an automated energy management system for home. The system switches and controls the fan based on the temperature of the room. Likewise the light intensity was controlled based by the number of persons the room. The results shows that this system reduces energy consumption considerably though it has no provision for protection against electrical surge or fire (Divyashree and Sujatha, 2020). Studying the application of intelligence to home automation, Majeed et al., (2020) prototyped a design of an

automated home system that used sensors on raspberry pi and relay circuits, data were classified with support vector machine. A mobile application was also developed to facilitate an online monitoring and control of the home appliances. Experimental and real life tests show that the system works, replicable and may be cost effective though it is incapable of ensuring security. (Majeed et al., 2020). Iqba et al., (2021) in research into home automation using intelligent electricity dispatch investigate the usage of home automation to solve the problem of electric power shortfall and the troubles caused by sudden outages. Microcontroller and sensors were used for physical control of appliances while they are controlled remotely through web-based and app-based automation. The results of this study show average accuracy of 88.7, 88.5 and 88.6 for physical automation, web-based automation and app-based automation respectively (Iqba et al., 2021). In this research, open source, cost effective raspberry pi based home automation was designed and implemented using GSM network.

This study on Raspberry pi based home automation using GSM alert was designed and installed with capabilities for decision making. It is able to know when the home electrical services like lightings, air conditioner and television should be put ON or OFF, thus enhancing energy management. It was designed to recognize who is authorized to enter the house. The door which is equipped with a camera scans the image of an approaching person, sends to the processor where it is compared with the image of the stored face. If the faces are the same, the door opens and the room light switched on, the door closes after 10 seconds, air conditioner and the television are switched ON after 5 minutes. They remain ON even if he leaves the room for 5 minutes after which they automatically go off. Likewise the light bulb remains on for 5 minutes after he has left the office. The house owner generates a one-time pin (OTP) that a person he sends to take or do something in the house can use for access. GSM transmitter sends message once the door senses a shaking or bang to signify the presence of an intruder. The house electrical network are monitored continuously, therefore this system sends short message system SMS alert when high current/voltage is detected and simultaneously switch off the electrical network.

### Methodology

The research methodology focused on the identified limitations of the previous designs to provide access control, electrical system management and cheap real time information transmission. This section consists of the system architecture, hardware and software design, implementation and testing. The home automation system was designed and implemented following

“Bottom-Top” approach. Bottom-Top approach is the piecing together of systems to give rise to more complex systems, thus making the original systems sub-systems of the emergent system (Schothborgh et al., 2006).

### System architecture and circuit design

The architecture which is the framework upon which the home automation system was built consists of the following main components; sensors, actuator, storage, network protocols and layers in phases which allow the administrator to manage and support the system. The architecture ensures that data is obtained from the right sources, processed correctly and transmitted to where they are needed. There is no globally accepted standard architecture for automation, every system is

research: Perception, Processing, Transport and Application layers.

The hardware components: camera, voltage and current sensors, ultrasonic sensor, servo motor and GSM transmitter were interfaced in modules with raspberry pi-3 board. The modules were connected based on the system architecture and circuit diagram into a complete system. Each module was first assembled and tested on a project board before permanent fabrication and interfacing with the processor. This research work was built with a BCM2711 a 64-bit quad-core processor on Raspberry Pi 4 board. The complete circuit diagram of the design which is shown in figure 2 was drawn on Proteus-8 professional electronics prototyping software.

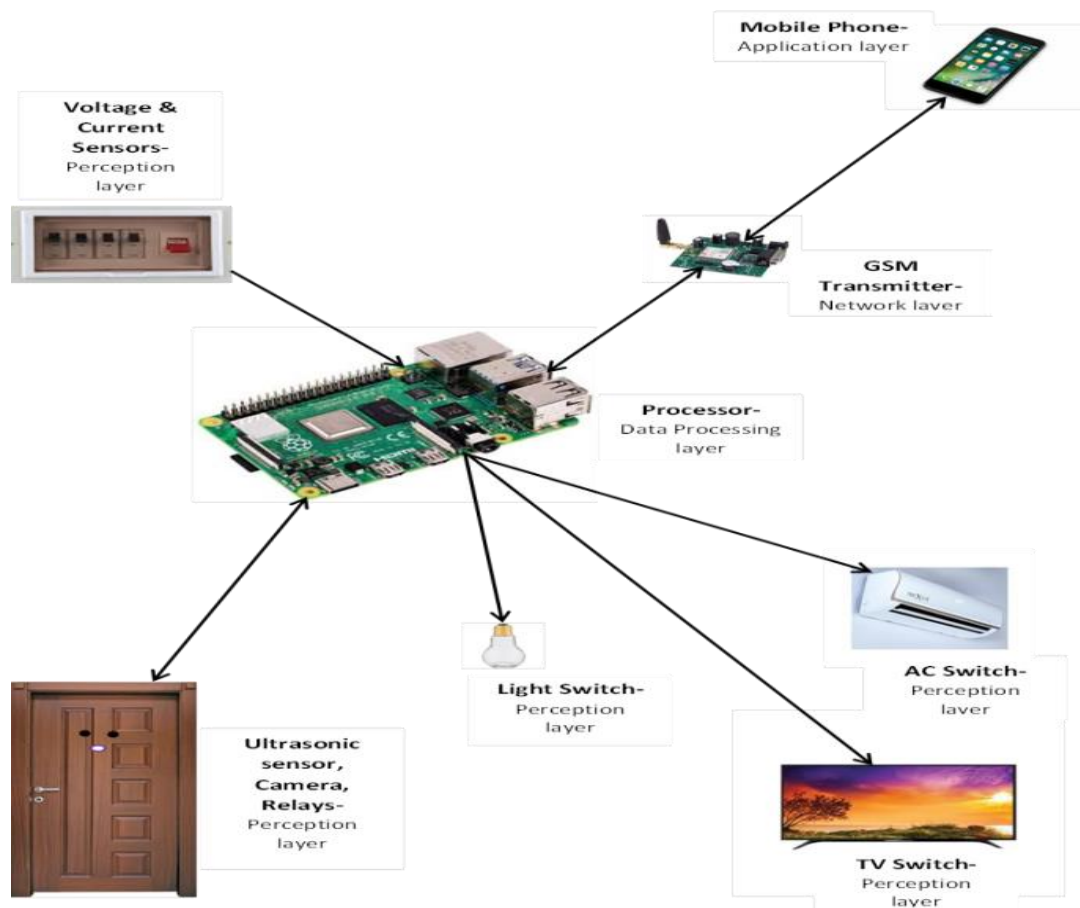


Figure 1: The architecture of the home automation system

designed based on the intended solution it aims to provide. As shown in figure 1, there are four basic layers recognized in the architecture of this

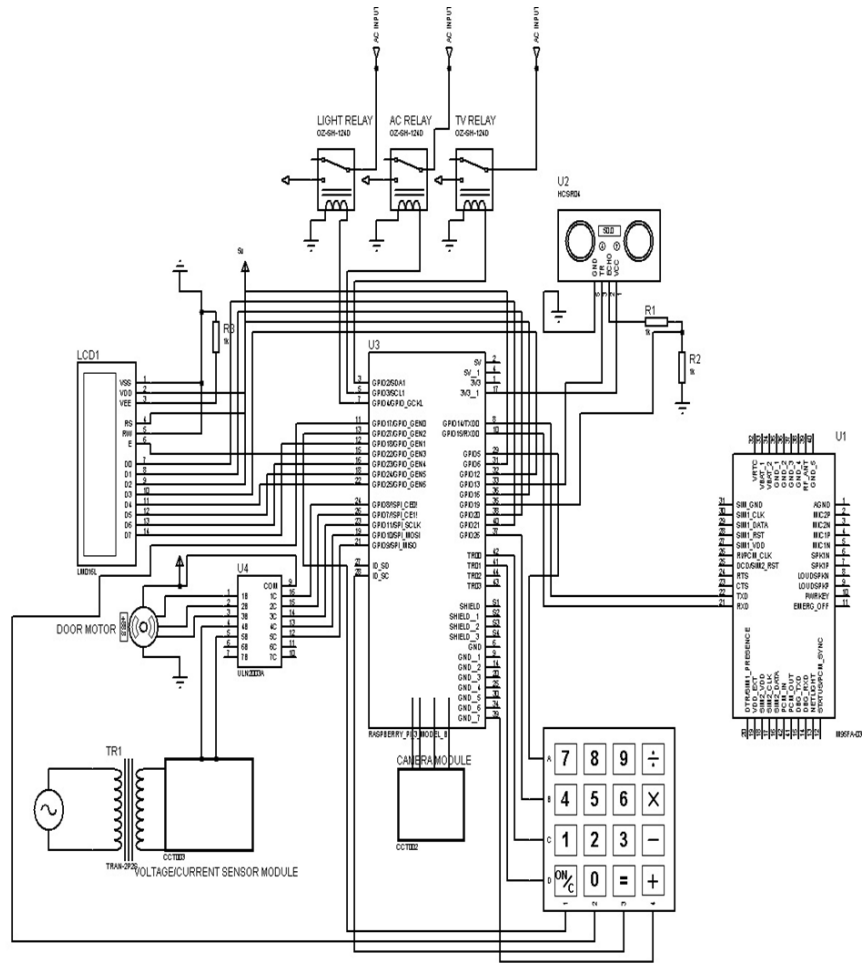


Figure 2: The complete circuit diagram of the home automation system

Information about entrance to the office and electrical power status were transmitted as short message system SMS to the designated mobile phone through the global system of mobile communication GSM transmitter SIM800L. A SIM card registered with a Nigerian GSM service provider and activated was inserted into the SIM slot of the GSM module was wired to the raspberry pi board.

The assembling and soldering actions of the hardware were done module by module. For each module, the components were first assembled on a temporary project board and tested. These were later transferred carefully to a vero board for permanent rigid fixation. Following the block and schematic circuit diagram carefully, modules and interconnecting components were fixed through the non-conducting side of the board with their pins projecting through the perforation to the conducting copper side. The soldering was done using highly conductive alloy soldering lead with a 20 – 40 w adjustable power soldering iron. The hardware

components were connected and soldered into a permanent system and the whole assemblage after testing was housed in a transparent room-like plastic chassis.

### Program design and integration

This research made use of two major software; the face recognition model linked with a custom software developed on python IDE as the control software for the system. A face recognition model; Convolution Neural Network CNN was built on TensorFlow; a deep learning platform developed by Google Brain team as an open source library built in Python language. Tensorflow was used because of its compatibility with Python environment, low power consumption and speed of training (Simplilearn, 2023; Daniel, 2023). The face recognition model was developed using transfer learning approach. The face recognition model was the CNN based FaceNet, downloaded from Keras and saved as *facenet\_keras*. Necessary libraries and dependencies were imported with the model:

### Data Acquisition

Two hundred images of two classes of persons to be recognized were obtained using a digital camera as shown in figure 3.

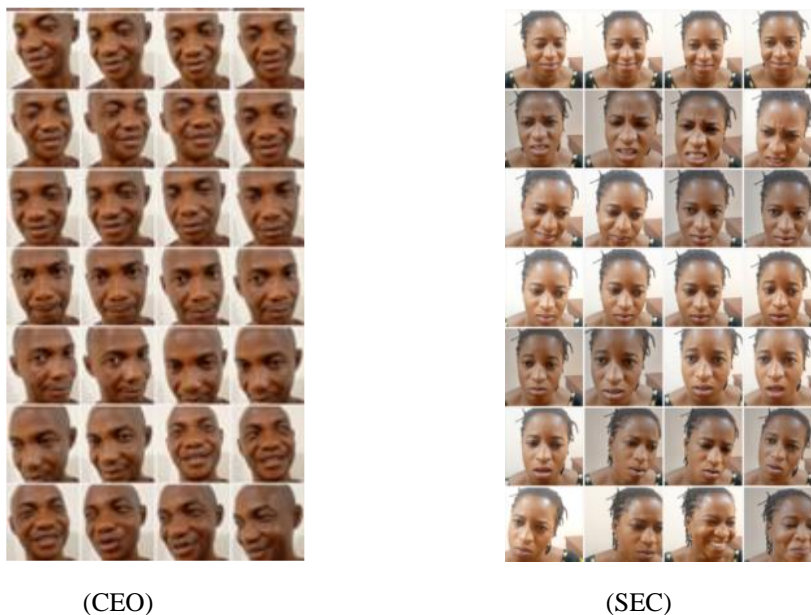


Figure 3: The screenshot of some of the images used to train the model

Each class containing 200 images were preprocessed and labeled as **CEO.** and **SEC.,** 160 of the preprocessed images of each class (making a total of 320) was used in re-training the model. Transfer learning was used for training the model using CNN for good performance, accuracy and fast facial recognition. It begins with labeling which is a process of saving and naming the pictures in different folders which the model can recognize. The next step was the training of model. The labeled image folders were imported into the model to train with before classification.

**Testing the model**

The remaining 80 images were used to test the performance of the model. The preprocessed test images were fed into the retrained FaceNet to generate embeddings which are the high dimensional feature vectors that captures the essential characteristics of each face image. Euclidean distance (equation 1) was used to compute the distance or similarities between the embeddings of different test images.

Euclidean distance:

$$d = \sqrt{[(x_2 - x_1)^2 + (y_2 - y_1)^2]} \tag{1}$$

where,  
 (x<sub>1</sub>, y<sub>1</sub>) are the coordinates of one point.  
 (x<sub>2</sub>, y<sub>2</sub>) are the coordinates of the other point.  
 d is the distance between (x<sub>1</sub>, y<sub>1</sub>) and (x<sub>2</sub>, y<sub>2</sub>).

**The control program**

The control codes were written in Python while the libraries and image recognition model were included. The control software drives the system as represented in the flow chat in figure 4. The ultrasonic sensor detects an object. Once the object is within 0.6m range, the camera is activated and snaps the picture which goes into the image processing model, then compared with the reference images with which the classifier has been trained. The output enters a conditional statement; **If image is True** (that is; does the image captured match the reference image(s)?). If yes, signal is sent to the motor to open the door and relay to switch on the light while delaying 5 min before signal goes to the air conditioner and television switch. However, if the captured image does not match the reference image(s) (that is **NO**), the software will check the one-time pin OTP record to compare input OTP with the stored one in another conditional statement; **If OTP is True** (that is; does the approaching person provide OTP that matches what has been stored?). If yes, signal is sent to the motor to open the door and relay to switch ON the light only. Consequently a “I entry” message goes to the GSM module where it is transmitted to the designated phone. If no OTP is provided (that is; access denied) or entry has been made, the software goes back to the object sensor output and it continues as a loop.

Simultaneously, the voltage and current sensors read the supply power entering the electric distribution board and output to a conditional statement; **If Power is True** (that is; are the supply voltage and current normal?). If yes, the current  $\leq 1$  A and voltage is within 160 – 220 v ac, it goes back to voltage and current sensor output as a loop. If **NO**; high current and or voltage, signal is sent to the relay, switches OFF the distribution board and sends “**abnormal power detected, Power shut down**” message to the GSM module where it is transmitted to the designated phone and goes back to the voltage and current sensors output as a continuous loop.

switches which indicate how fast the appliances are switched and door opening was tested as image was detected. The voltage read by the sensor was compared with the actual value to determine its accuracy. The percentage accuracy of the training of model and its face recognition was also computed. The speed of SMS delivery of the GSM transmitter was tested by transmitting through MTN (in the GSM module) to the four main GSM service providers in Nigeria at the same time in the same place. That is MTN-MTN, MTN-Airtel, MTN-Glo and MTN-9mobile in the same place, at the same time and using the same type of mobile phones. The data obtained from the evaluation were

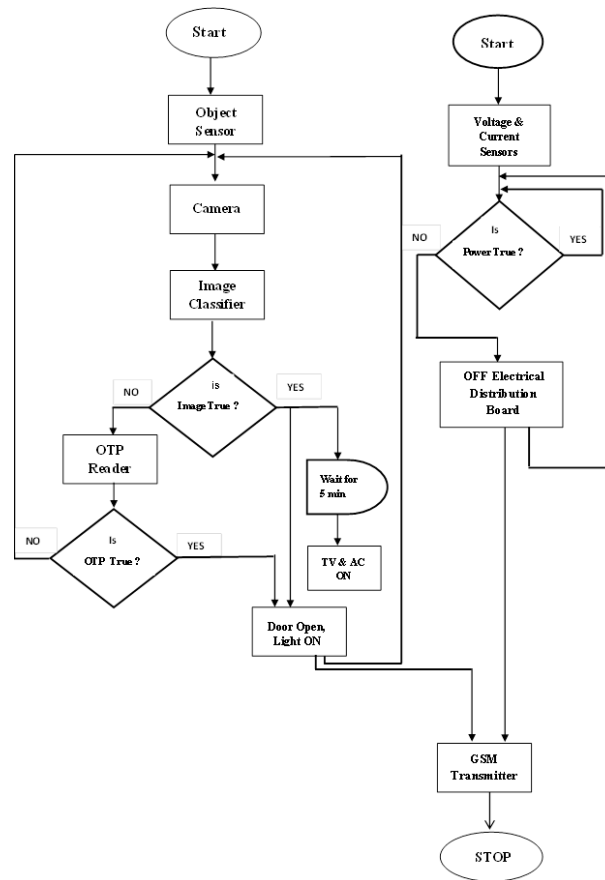


Figure 4: The flowchart of the software design

**Results and Discussion**

The research was evaluated by conducting systematic test of the whole work to determine the level to which the objectives have been achieved. All electrical connections and wirings were tested with a continuity tester to ensure strong contact. The estimated distance of detected objects of the ultrasonic sensor was compared with the actual distance of objects at different distances from the sensor in other to evaluate the accuracy. The angle and the distance of best image was also tested for the camera. The response time of the relays and

computed and discussed as results. The whole assemblage was neatly packaged in a transparent house-like chassis as shown in figure 5.

**Results of test on the electric power monitoring module**

The electric power monitoring unit was tested for its ability to sense the supplied current and voltage level. A high precision SUNTEK-3000 variac that smoothly adjust the AC voltage in the arrange of 0-300vac was used for the testing and the parameters obtained tabulated in table 1.



Figure 5: The complete system housed in a transparent chassis

Table 1: Results of test of the power monitoring module

S/N	Voltage Range	Power Status	SMS Alert
1	1 – 20	OFF	IRREGULAR SUPPLY: Power shut down
2	21 – 40	OFF	Nil
3	41 – 60	OFF	Nil
4	61 – 80	OFF	Nil
5	81 – 100	OFF	Nil
6	101 – 120	OFF	Nil
7	121 – 140	OFF	Nil
8	141 – 160	OFF	Nil
9	161 – 180	ON	NORMAL SUPPLY: Power restored
10	181 – 200	ON	Nil
11	201 – 220	ON	Nil
12	221 – 240	OFF	IRREGULAR SUPPLY: Power shut down
13	241 – 260	OFF	Nil
14	261 – 280	OFF	Nil
15	281 – 300	OFF	Nil

The communication layer of the system was based on GSM network for short message system SMS alert. The image captured by the camera goes to the classifying model where it determines if it matches those it has been trained with. If the image matches, the Raspberry pi sends signals to the servo motor to open the door, the light switch to ON the light and the GSM transmitter to send a report message to the admin. The power status and entry information are transmitted through the SIM800L GSM module to the user's phone as SMS alert as shown in figure 6. The none home user who

is sent to pick something also gained access through one time pin OTP sent from the office user's phone to the person and the raspberry pi (Through the GSM module) as SMS simultaneously. Using the keypad, the visitor inputs the OTP which if it matches the one received and stored in the raspberry pi memory the door opens. The performance of the transmission and reception of information through the SIM800 GSM module was tested. MTN SIM card was used for the transmitter because it has more subscribers than all other mobile phone service providers in Nigeria.

Test was carried out with for main GSM SIM cards. That is, with MTN in the home automation system, MTN, GLO, AIRTEL and 9mobile were tested with mobile phone for ten hours (7:00am-4:00pm) and the results shown in table 2.

The speed of SMS delivery was computed and tabulated as shown in table 2, and plotted in graph (figure 7).

Out of the four networks tested, MTN to MTN recorded the highest SMS delivery speed with latency of less than 10 seconds (average of 5.4seconds). Since the transmitter and receiver are in the same mobile network, the same (which is the nearest cell mast) cell tower acts as the transmission and reception tower. For other networks, the transmitted signal first goes to the nearest MTN mast where it is routed to the nearest Airtel or Glo or 9mobile mast to the receiver.



Figure 6: The image of the information transmitted as SMS to the admin mobile phone.

**Table 2: Speed of SMS delivery to the four major GSM network**

Time	MTN – MTN (ms <sup>-1</sup> )	MTN – GLO (ms <sup>-1</sup> )	MTN – AIRTEL (ms <sup>-1</sup> )	MTN – 9Mobile (ms <sup>-1</sup> )
07:00am	0.250	0.125	0.125	0.100
08:00am	0.333	0.143	0.090	0.056
09:00am	0.200	0.030	0.111	0.037
10:00am	0.143	0.018	0.090	0.031
11:00am	0.143	0.047	0.066	0.033
12:00noon	0.143	0.025	0.010	0.013
01:00pm	0.167	0.011	0.033	0.001
02:00pm	0.167	0.125	0.056	0.035
03:00pm	0.200	0.111	0.067	0.029
04:00pm	0.250	0.111	0.067	0.022

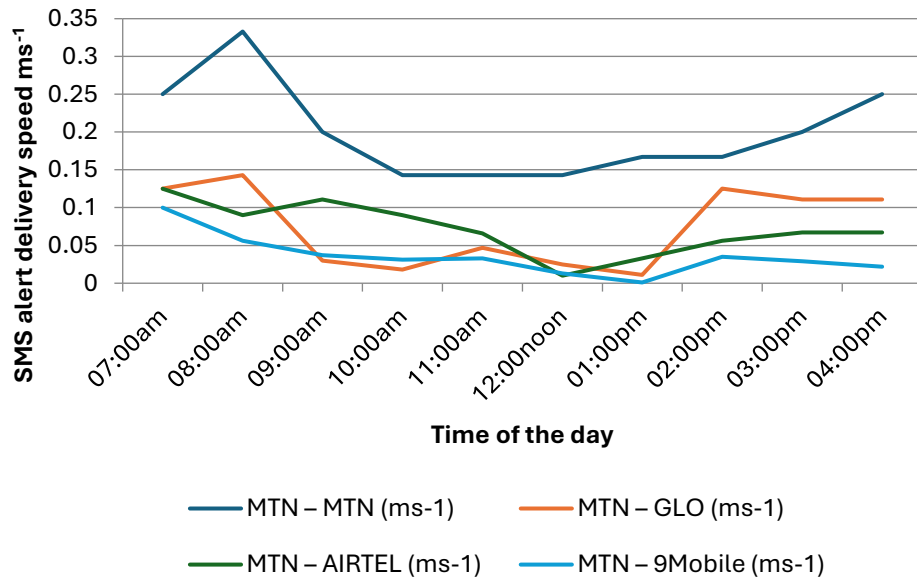


Figure 7: Graph of transmission speed of the SMS alert of the system

Table 3: The area of automation and information transmission delay of existing design as compared with the current study

S/N	Author(s) Year of Publication	Means of Transmission	Areas of Automation Covered	Transmission Delay
1	Alsaad & Hussien (2021)	GSM	Security only	20.5 Sec.
2	Anwar & Kishore (2016)	Email	Security only	-
3	Toubidul <i>et. al.</i> (2023)	GSM	Security & Economy	-
4	Olaniyan <i>et. al.</i> (2020)	GSM	Efficiency only	10 min
5	Noora & Baswaraj (2019)	Email	Convenience & Security	15 Sec.
6	Abubakar <i>et. al.</i> (2020)	GSM	Convenience only	19 Sec.
7	Current Study (CNN Enhanced Secured Smart Executive Office)	GSM	Security, Efficiency, Economy & Convenience	5.4 Sec.

This research was compared with existing models and related studies. The result as stated in table 4 shows that the speed of transmission of information which is an important factor in automation is higher in this research in that a 64% improvement in the speed of information transmission. Also, this research is the only one that covered all the areas of automation.

**Conclusion**

The study into home automation with SMS alert on Nigerian GSM network has been designed and

implemented by interfacing ultrasonic sensor, camera, current sensor, voltage sensor, relays and GSM module with Raspberry pi-3 board and house in a chassis in form of a home. A convolutional neural network model CNN was used to provide security. Information was transmitted as SMS alert on four GSM networks in Nigeria but found to be fastest on MTN to MTN. The SMS alert system used made this design very versatile and could be operated even in rural areas of Nigeria where there are no internet connectivity. As shown on table 4, whereas previous designs only covered one at most

two areas of automation, this research covered all the areas of automation in a single unit. When tested, transmission of information in this research was faster than those of resent related designs. This study has produced a simple hardware prototype that is easy to assemble and operate. The system could be scaled up to provide real time automation for homes, schools and offices.

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