Construction of A Remote Home Automation and Security System Using Raspberry PI

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Abstract: **The needs for automation in home and offices have been so paramount in this era. Also, the subject of insecurity has become a big challenge in our society especially in Nigeria. In this study, construction and implementation of a home automation system was carried out based on Raspberry Pi. The system is based on the Internet of Things (IoT) architecture and sensor network. The Software for the system was written using Python programming language while the Smartphone mobile application was developed using Flutter Dart programming language. Result shows that, the Raspberry Pi which is the main controller reads sensor values like temperature, humidity, and motion from the sensors which includes Passive Infra-Red (PIR), Temperature and Humidity sensor which it publishes to the external clients (Smartphone Application) using Message queue telemetry (MQTT). Message commands for controlling devices and sensor data are exchanged between the system and external clients once a connection is established. If the System is scanned and motion is detected, an alarm is sounded.**

Keywords: **Raspberry Pi, message queuing, telemetry transport, internet of things, python programming, flutter dart programming**

I. INTRODUCTION

The most essential safety system required by the society is home security. This has become necessary due to the increase in crime rate, insurgency, robbery, kidnapping and fire outburst in Nigeria. Since, the awareness of security state of an environment is very vital, home security and surveillance system needs to be improved to address the increasing crime rate [1]. Home automation is the automatic control of electronic devices or appliances in the home. It may also encompasses a system that will be able to detect smoke, excessive electrical power usage, intruder or bugler attempts and alert you on any unauthorized movements [2]. Numerous individuals are at all times on the move from place to place and attached to their busy life style and household equipment are left without any level of monitoring. When some device is not properly monitored or controlled, they tend to consume a lot of energy leading to extra expenditure on electricity or cause disaster in the neighbouring environment. The idea of home automation (smart home) is good especially for the old aged and disabled persons for improved health care, allowing independence and improve comfort [3]. Home automation could embrace management of lighting, ventilation, heating and cooling system in order to produce upgraded convenience, comfort and security [4].

A home automation can be regard as "intelligent" because it can monitor many aspects of our daily life [2]. It can also provide a interface which can be remote to home appliances or the system itself, via phone, cables, wireless transmission which includes the internet, in order to provide control and monitoring via a smart phone or web browser [5]. The internet of things IOTs based architecture is very much relevant in many different ways which include monitoring system security, traffic signal control or controlling various application and also gives high level flexibility in communication and information [4].

Raspberry Pi is a device which is programmable and it can act as the hub of the home automation system. Sensors are connected to its GPIO pins and it collects data from the sensors. Computing Programmable Languages like python and scratch can be used on the device. Equipped with ARM cortex-A7 processor can be applied both in computer and electronics fields mainly for building Internet of Things, machine learning and computer learning projects [6]. The desire for adjustable light, temperature, ambient music automatic shading safety and security can be satisfied by home automation which is the latest fascination with housing mechanism. With the emergence of electronic technologies and their combination with older ones, smart home technology is fast becoming a reality [7]. Using adjustable mechanisms the home owner can enjoy his/her personalized heat, ventilation, lighting and other service at home [8].

According to Asadullah et al. [9] home automation is sub-divided into three (3) which are; power line, wired home and wireless home automation. Power line home automation system is inexpensive and doesn't require additional cables to transfer the information, but uses existing power lines to transfer the data. However, this system involves a large complexity and necessitates additional converter circuits and devices. For wired home automation system, all the home equipment are connected to a main controller (programmable logic controller) through a communication cable. The equipment is attached with actuators to communicate with the main controller. The entire operations are centralized by the computer that continuously communicates with the main controller. Wireless home automation is expansion and advancement of wired automation which uses wireless technologies like IR, Zigbee, Wi-Fi, GSM, Bluetooth, etc.

Various efforts in home automation design are referred back extensively during the literature search. For instance, Tan et al. [7] focused on internet-based system to allow monitoring from

a distributed control system (DSC) using a web browser. Liang et al. [10] and Conte and Scaradozzi [11] proposed multi agent concept architecture for home automation. However, all these systems has the disadvantage of bulkiness and not convenient to users especially mobile users and those without access to a computer screen and internet. Potamitis et al. [12] and Anamul Haque et al. [13] proposal a home automation system based on the use of speech command and timer to control home appliance. Such system has short range and applicable to real life operation at home through speech which may be ineffective in a noisy environment. Jawarkar et al. [14] proposed remote monitoring through mobile phones by using spoken commands. While Murthy [15] proposed the use of mobile web technologies to provide primary health care services to the rural area using GSM technology. This study focus on the GSM based home automation system which provides the controlling of home equipment's by an SMS to the GSM modem which makes the system less cost effective with limited features. Therefore, the objective of this study is to construct and implement a home automation and security system using a Raspberry PI. The scope covers simulation of a home automation system using python programming language, construction of a prototype on a Vero board and testing the output sensitivity, specificity and accuracy.

II. MATERIALS AND METHOD

A. Materials

The materials and their specification that were used for the construction of a remote home automation and security system using raspberry pi Includes; Camera, passive infra-red sensor, servo motor, LED, Temperature and humidity sensor, relay module, Message Queuing Telemetry Transport, Fan, Battery, Alarm, and Raspberry pi. The pin out of the raspberry pi is shown in Figure I.

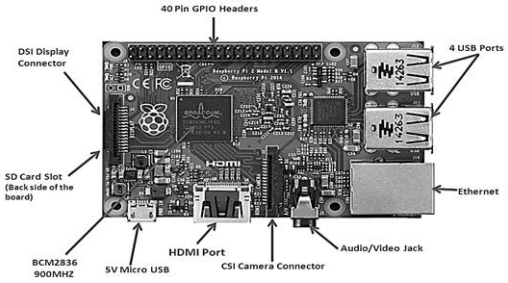

Fig. I Raspberry Pi 3B model [6]

B. Methods

The method adapted in this study is in two parts which include simulation, construction and testing methods. The simulation method includes the software development and flowchart of the system while the construction involve developing the prototype device and testing is to ensure the proper functionality of the system.

B.1 Simulation Method

The simulation method involved the development of software and flowchart for the operation. The flow chart is as shown in Figure II. The basic software program is written using the python 3.7, Python programming language. The choice of python 3.7, Python programming language is chosen because it is more compatible with the Raspberry pi software:

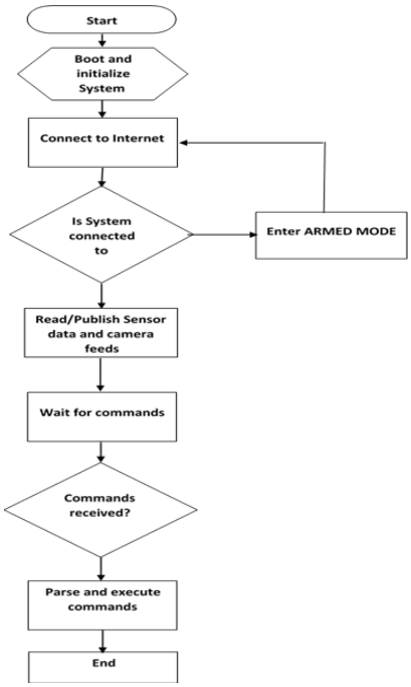

Fig. II Flowchart of the proposed System

B.2 Construction Method

The hardware construction was a simple step by step construction of the various units following a block diagram. Raspberry Pi 3B being a micro-processor based board is generally tailored for this type of application owing to its advanced features. The construction of the prototype was carried out two parts which include component temporary assembly and placement on a bread board and then transfer of the components on a Vero Board for permanent soldering. The device was tested for accuracy and sensitivity to ensure optimum performance. The block diagram of the system is shown in Figure III.

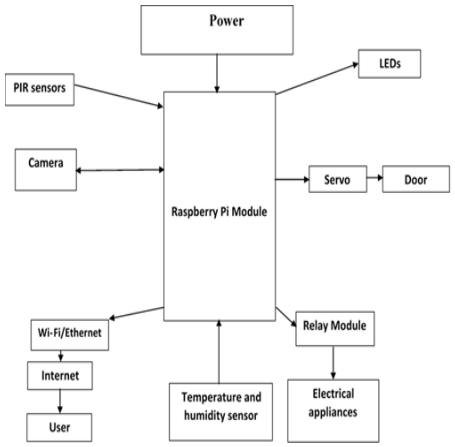

Fig. III Block diagram of the proposed System

1) *Power Unit:* This is the power supply unit. The system will be powered from a 5volts DC battery pack, which is the amount of voltage required by the Raspberry Pi.
2) *Control Unit or Raspberry Pi Module:* This is the main controller/hub of the system and it requires only 5volts DC from the power source up to currents of about 2.3amps. The Raspberry Pi 3 model B which is the latest model of the module will be used in this study. It has 40 GPIO pins which other devices and peripherals can be attached to.
3) *Important Pins:* The Raspberry Pi board has number of pins which other modules can be attached to. The pins are categorized into General Purpose input/output pins (GPIO), communication pins and power pins. The notable pins on the board which are relevant to this study are presented in Table I.

Table I. Important Pins For The Raspberry Pi Module

Pin	Pin No.	Category	Function
GPIO4	7	GPIO	Input pin for Temperature and humidity sensor
GPIO23	16	GPIO	Input pin for Motion detection sensor
GPIO17	11	GPIO	Output pin for LED
GPIO27	13	GPIO	Output pin for LED
GPIO22	15	GPIO	Output pin for LED
GPIO26	37	GPIO	Input pin for Motion detection sensor
GPIO19	19	GPIO	Servo motor control pin
CSI Port			Port for Camera
	1	Power	3.3volts power pin
	2	Power	5volts power pin
GPIO16	36	GPIO	Output pin for Buzzer
GPIO20	38	GPIO	Output pin for relay

4) *PIR Motion Sensors:* This block/unit represents the Motion detector sensors that will be deployed by the system as one of its security capabilities. HC-SR501 Pyroelectric Infrared modules were used in order to detect motion or intrusion. The PIR motion sensor has three pins, two pins are for power (5volts/3.3volts and GND) and the Centre pin which is the OUT or DATA pin is attached to GPIO23 (pin 16) of RPi. On detecting motion or intrusion, the OUT pin changes its state to HIGH which is sensed programmatically via RPi pin.

B.3 Testing Method

The hardware constructed was tested to ensure proper functionality of the system. We carried out sensitivity, specificity and accuracy tests.

1) Sensitivity Test: This test helps determine how sensitive the raspberry pi is with cameral and the internet. The ability of the system to correctly detect intrusion. This is calculated as follows:

$$Se = \frac{TP}{TP+FN} * 100 \quad (1)$$

2) Specificity Test: This test is the ability of the system to correctly identify NO intrusion. This is calculated as follows:

$$Sp = \frac{TN}{TN+FP} * 100 \quad (2)$$

3) Accuracy Test: This test determines how accurate the system is in its detection for intrusion coming from the front and back of the house. This is calculated as follows:

$$Acc = \frac{TP+TN}{TP+FN+FP+TN} * 100 \quad (3)$$

III. RESULTS

A. Construction Result

The system was constructed as shown in Figure IV. The system was switched on and results were obtained in various stages to ascertain functionality and effectives.

Fig. IV Constructed device

The system is fully booted up and the power LED is on. All the components are fully initialized and it has read and transmit data to its external clients. The system after this is ready to send and receive commands and also monitoring the environment. The results are presented from the Figures V and VI respectively:

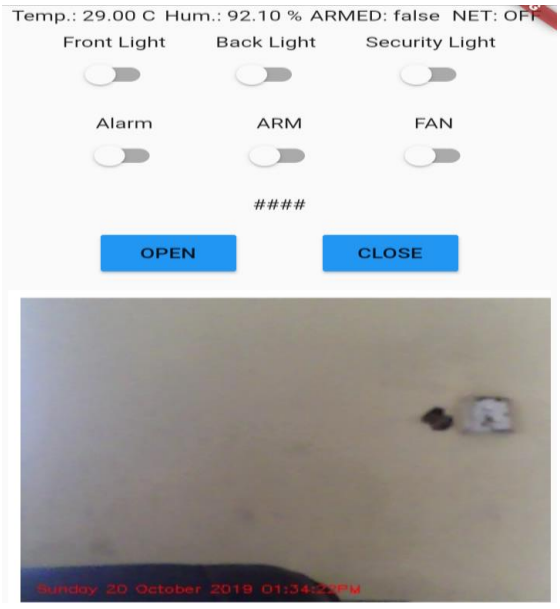

Fig. V Android Mobile app showing received Sensors' data

The interface of the android mobile application which can be used in controlling the system. The Mobile application successfully received the sensors' data and can send commands to the system.

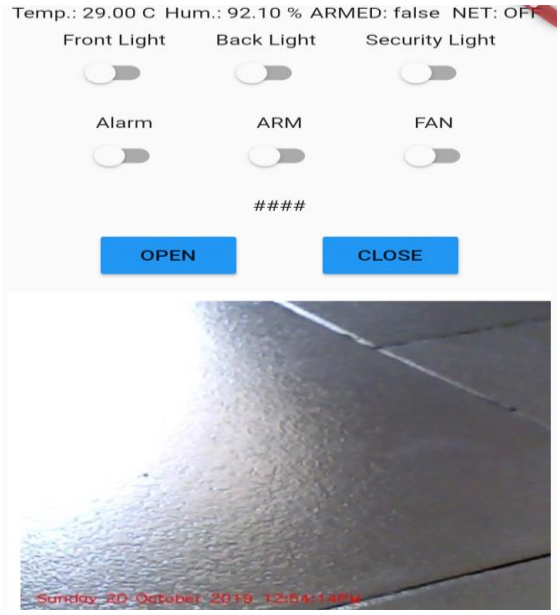

Fig. VI Android Mobile app showing received Sensors' data

The Figure VI clearly shows the real time camera feed on the mobile app. The position of the camera can be controlled from the mobile app.

B. Circuit Simulation Result

After the circuit was constructed with Raspberry pi 3 model B, the program used in the Raspberry pi was written in python programming language and flutter dart programming language was used in developing the mobile application. In this study the use of internet, MQTT publish and subscribe functionality to ensured security and reliability on the system software was used to simulate so as to check its workability. Figure VII shows the final circuit design from the simulated output. At the start, the Raspberry pi 3 model B is initiated and passive infrared sensor is to detect any Motion across the sensors that will be deployed by the system as one of its security capabilities. HC-SR501 Pyroelectric Infrared modules were used in order to detect motion or intrusion. On detecting motion or intrusion, the OUT pin changes its state to HIGH which is sensed programmatically via RPi pin. The process keeps looping at every end of a particular process of entrance or exit. The buzzer alarm can be manually/automatically triggered when necessary. A 5volts piezo buzzer was used in this unit and it was attached to GPIO16 (pin 36) and controlled programmatically from the Raspberry Pi module. The internet is to receive and send commands to its external clients, the system uses the internet protocol to achieve this. In order words, data transfers are over the internet. The Raspberry pi is equipped with WIFI functionalities which it can used to connect to access points or the Ethernet port.

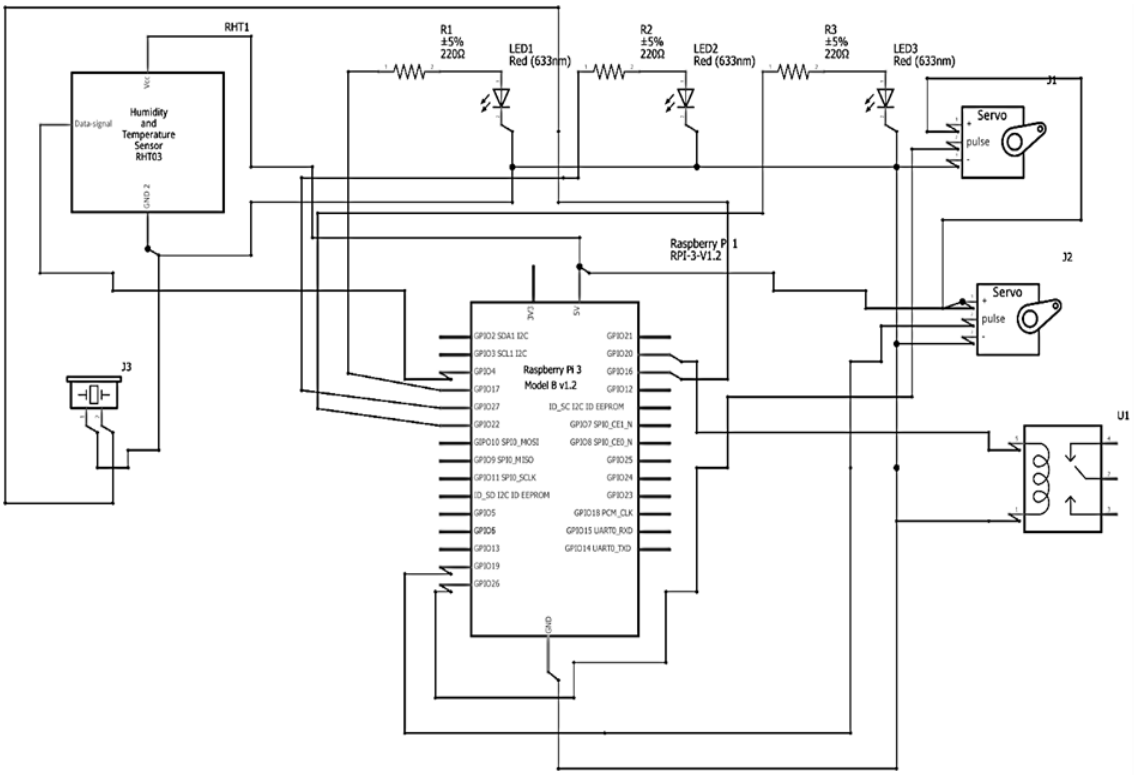

Fig. VII Simulated home automation circuit with Raspberry Pi 3 model B

C. Output Test Analysis Result

A performance evaluation tests was carried out with forty (40) trials with different people who volunteered to act as intruders and the number of times the system detected an intrusion, undetected intrusion and wrong output were recorded and presented in Table II. Then using equations (1), (2) and (3) the specificity, sensitivity and accuracy of the system were calculated.

Table II. Performance Evaluation Test Result

No. of Trials	No. of Motions Detected	No. of Motions not Detected	No. of No Motions but Detected	No. of No Motions not Detected
40	25	7	-	8

$$Sp = \frac{7}{7+0} * 100 = 100\%$$

$$Se = \frac{25}{25+8} * 100 = 75.76\%$$

$$Acc = \frac{25+7}{25+8+0+7} * 100 = 80\%$$

From the performance evaluation test, the specificity was 100%, sensitivity 75.76% and accuracy of 80%. Performance evaluation was also carried out with 10 trial each to test how the system responds to commands sent from the external client. The test was carried out for door opening, door closing, ON/OFF light, and alarm activation and the result is presented in Table III:

Table III. Commands Simulation Result

Command	**No. of Commands Sent**	**No. of Successful Execution**
Open door	10	7
Close door	10	8
On/off light	10	10
Activate alarm	10	10

From Table III, the system reaction to various commands sent from external client shows that Out of 10 trials each, the system accurately executed only 7 for door opening, 8 for door closing and 10 for others. The failure to execute some commands might be attributed to network issues or the system being busy when the commands arrived.

IV. DISCUSSION

The result obtained from the system clearly shows that the system is quite efficient. The data from the sensors were promptly published to its external client using MQTT as the bridge. Appliances depicted as LEDs were also controlled using commands from the clients. Various test carried out on the constructed device have revealed vital information that ascertain its functionality. The continuity test revealed that the circuit was continues with no short circuits along the paths, or broken conductors, or damaged components, or excessive resistance along the circuit. While the power ON test shows that, the voltage at the different terminals was according to the requirement and specification of the simulated circuit. This is similar to that of Alheraish [16] who design and implemented home automation system based on GSM technology using a microcontroller, Bhaskar and Uma [17] who worked on Raspberry Pi home automation with wireless sensors using smart phones, Conte and Scaradozzi [11] who viewed home automation systems as multiple agents' systems involving home appliances and devices that can be controlled, monitored and maintained, Das *et al.* [18] who designed a home automation and security system for mobile devices, Malik *et al.* [19] who worked on SMS based wireless home appliance control system (HACS) for automating appliances and security, and Patel *et al.* [20] who developed a system for home automation using ARM based Raspberry pi.

For the performance analysis on the device, Findings from this study has revealed that the sensitivity is 75.76% and the specificity is 100%. This implies that the constructed device will correctly identify about 76% of intrudes to the house, but it will also fail to identify 24% of them. The device will also correctly identify 100% of No intruders to the house, meaning that the device cannot give a false alarm when there are no intruders. Findings has also revealed that the accuracy was about 80%, which implies that the design conforms to the correct value specifications of the circuit and that intrusion detection using the constructed device is close to that of a standard or ideal case and we are 80% sure. However, of all the previous work reviewed, for example Hamed [2], Alheraish [16], Bhaskar and Uma [17], Conte and Scaradozzi [11], Das *et al.* [18], Malik *et al.* [19], Patel *et al.* [20], Delgado *et al.* [21], Javcile *et al.* [22], Jawarkar *et al.* [14], Bepay *et al.* [23], etc. none of them were able to calculate specificity, sensitivity and accuracy in their work. This reveals the additional contribution of this work to the literature.

The prototype was able to identify intrusion to the house with great accuracy and reliability. However, the major weaknesses of the device is that; for it to work perfectly there has to be internet supply at home and at the external client end. With calculated accuracy of 80%, means the device is very accurate and highly reliable. Therefore, using ARM based microprocessor devices like Raspberry Pi for home automation can be of great importance in home security and managing homes remotely.

V. CONCLUSION

Remote home automation and security system provides high level of security and comfort to homes and offices since it can be used to detect intrusion and as well control our home appliances. The use of Raspberry pi for home automation is a welcoming idea since it can be interfaced with a microcontroller for basic programming and fast switching action. Its ability to monitor intrusion remotely can be useful in this era of high level of insurgency, kidnappings and banditry actions, since it can keep the external client alert. In terms of comfortability, it can be very helpful for the old aged and disabled person since they can control their appliances at their comfort without any stress.

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