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A Voice-Activated Small Office Automation and Security System using Raspberry Pi

Comfort Oluwaseyi FOLORUNSO[1], Wasiu Adewale RAHEEM[2*], Adebayo OKUTUBO[3], Oreoluwa AYININUOLA[4]

Systems Engineering Department, University of Lagos, Akoka.

[1]cfolorunso@unilag.edu.ng, [2*]wraheem@unilag.edu.ng, [3]adebayookutubo@gmail.com, [4]boluayininuola@gmail.com

Corresponding Author: wraheem@unilag.edu.ng, +2348038623569

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Abstract: *Humanity has benefited greatly from the emergence of automation systems. It has made life easier for the elderly, crippled, and infirm. The existing automation system has been enhanced to provide a secure system for use. This paper aims to provide a voice-activated small office automation and security system for office workers with a safe and stress-free atmosphere. This system includes both hardware and software. The hardware components are made up of some sensors and Raspberry Pi which serves as the central control, while biometric access was employed to give access to the credible user via the fingerprint scanner. The software is an intangible component which govern the system's connected devices and sensors. The developed system gives a satisfactory recognition accuracy of 89%. This paper offers a working prototype of a real-world office automation and security system that can be customised to match a variety of settings. This work was designed to fit into a small office, house or the likes.*

Keywords: *Automation, central control., office, raspberry pi, security*

1. INTRODUCTION

Automation has become a prominent issue in recent years due to the benefits it has given to the world of technology and indeed a source of comfort for humanity. It refers to the ability to control several appliances from a single location rather than having to go to each one's distinct control points or switches. On the other side, security is in high demand. Breaking into offices, buildings, and houses has long been a source of irritation for the residents and neighbours of the affected areas. Majority of people desire comfort and convenience. However, the concern for safety constrains their effort [1]. Hence, the need for a more enhanced method of security. The more the technology advances, the more hackers' device different means to break through, therefore every system should be designed with adequate measures for cybersecurity. An automation system is a system in which all the appliances are controlled by a central unit [1].

The Raspberry Pi served as the system's key component in this paper. All the appliances are connected together and then linked to the central control. This automation system has a security feature such that an access is required for the automation subsystem through the use of sensors and devices. Until the security subsystem gets access, there will be no automation. The security subsystem in this study was constructed in such a way that the automation may be turned on. The name given to this hybrid system is Voice-Activated Small Office Automation and Security System. This work was designed to fit into a small office, house or the likes.

Home automation is the process of automating the operation of all gadgets in a home so that they can all be managed with the touch of a button or a switch without the user having to leave their current location. A home automation system monitors and/or controls items in the home, such as appliances, climate control, lighting, and entertainment systems. It includes security features such as alarm systems and access control.

In order to achieve a well-secured home automation system, effective approaches have been employed. Among which is the usage of a mobile phone for home automation. Akinyemi *et al.* [2] demonstrated an automated home control system which utilised a mobile phone as a modem. Furthermore, Bodke *et al.* [3] and Murugadhas *et al.* [4] described the use of a mobile web-based application system for controlling household appliances without requiring the elderly or physically challenged to travel to the nearest control point. Also, the Raspberry Pi can be used alone or in conjunction with email to accomplish this objective. For instance, Jain *et al.* [5] as well as Suryawanshi and Annadate [6] made use of a couple of sensors, which include gas sensor, infrared (IR) sensor and passive infrared (PIR) sensor, to monitor the environment for

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faults or irregularities. The sensor signals were used to activate the actuators. The system sends an email to a designated email address informing the user of the current status of all devices connected to the Raspberry Pi. Also, the Raspberry Pi was utilised as the microcontroller by Venkatesh *et al*. [7]. The input and output ports of the microcontroller were used to connect the appliances. The Internet of Things (IoT) was used to automate the process, providing the devices and appliances to be controlled from anywhere in the world. The Raspberry Pi was connected to the internet via a Wireless Fidelity (Wi-Fi) connection. A webpage functioned as the automation system's user interface.

In addition, Internet of Things (IoT) can be used for smart home automation. Arun *et al*. [8], for instance, looked into the application of IoT for home automation. IoT for this purpose differ from prior systems in that it allows the user to monitor the device via the internet from anywhere in the world. Ali and Awad [9] investigated various security threats faced by IoT-based smart homes. For appropriate clarification, real-life concerns were stated. For each threat and risk, practical solutions were presented. An essential solution suggested was an awareness program for smart home system users to become more conscious of home security and safety. Furthermore, Dinakar *et al.* [10] and Kumbhar *et al*. [11] presented an IoT-based automation system with appropriate sensors to prevent intruders from obtaining access to the building as well as sending an email to a predetermined email address.

Other systems, like those developed by Chatterjee [12], Isa and Sklavos [13], and Kaur *et al*. [14], used Arduino-compatible microcontrollers for automation. However, Chatterjee [12], used the Facebook Artificial Intelligence (AI) Chatbot and Google Assistant to operate the appliances from anywhere as long as the central Arduino system has an internet connection. The importance of a home automation and security system cannot be overemphasised as technology improves and people seek easier control of their home appliances as well as enhanced security for their lives and properties.

2. METHODOLOGY

The proposed solution aims to address the security issue that comes with building automation. The approach prioritises physical security threats (break-ins and intrusions) over cyber security dangers. Raspberry Pi, camera module, proximity (distance) sensor, fingerprint scanner, USB Microphone, keyboard, mouse, four-channel relay, LCD, sockets, light bulbs, and a five volts (5V) power supply were among the components utilised in the build. The correct connectivity of these components would result in a system that could control devices using voice instructions received through the microphone.

The system's purpose is to translate spoken commands into understandable and actionable directives. Furthermore, the system is designed in such a way that automation can only take place after the security system has allowed access. Fingerprint sensor, camera module, and distance sensor make up the security system. Once a credible user has been granted access to the system, the appliances connected to it can be readily automated according to the user's preferences. The block diagram of the system is shown in Fig. 1.

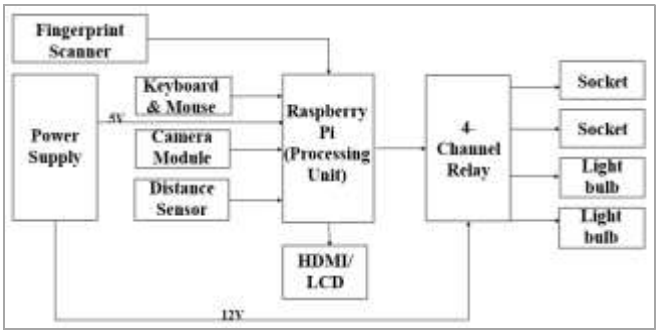

Figure 1: Block diagram of proposed system

Raspberry Pi 3B

The Raspberry Pi is a mini-computer, in form of a small board. It requires external mouse, keyboard, monitor and other important computer peripherals for operation. This model of Raspberry Pi uses a Broadcom BCM2837B0 SoC to allow the Pi run at low voltage to reduce the level at which power is consumed. It monitors and controls the temperature of the chip. It operates with a 1.4GHz 64-bit quad-core ARM Cortex-A53 processor, with 512 KB shared L2 cache. It has forty GPIO pins, and other devices for proper connection. It also has other ports to include USB, CSI camera connector, HDMI port, OTG port for power supply, MicroSD Card slot and 3.5mm audio jack. Raspberry Pi runs with Raspbian, which is an operating system that runs in the Linux environment. It can also run with Ubuntu MATE, Snappy Ubuntu Core, Windows 10 IoT Core and RISC operating system [15].

Camera Module

The camera module is called Pi Camera. The exact camera used was built to fit Raspberry Pi 3B model. It has 160-degree wide angle, focal length of 2.1, 1080p sensor resolution. The size of the camera is 25mm x 24mm with four screw holes at the four corners. It provides 3.3v power output. The camera is connected directly to the Raspberry Pi using the camera CSI port on the Pi [16].

Fingerprint Scanner

This has been a commonly used material in Scientific Fiction (Sci-Fi) movies for about a decade and more. And it is already a reality in developed countries, and in some urban areas in under-developed countries. It is used to read fingerprints. A fingerprint is a pattern on the outer skin of a finger. Each fingerprint is unique for every individual as no two persons has the same fingerprint. Due to this uniqueness, it is a very good means of security against intruders or unauthorised users. On the device, there is a glass surface, where the finger is placed. The sensor has within it, a red LED that is involved in capturing the pattern of the finger that is on it. The image is what is processed by the fingerprint sensor and is then sent as a signal to the Raspberry Pi. The fingerprint scanner is connected to the USB module. The VCC pin (on the fingerprint scanner) is connected to 5V (on the USB module), RX (on the fingerprint scanner) is connected to TX (on the USB module), TX is connected to RX and GND is connected to GND. The connections between the pins are done using female-to-female jumper cables [17].

Ultrasonic Sensor

This device senses human presence within its range. It has a range of up to 10 meters. More than just sensing human presence, it can also measure speed and direction. It is also used in humidifiers and ultrasonography. In this system, the ultrasonic sensor measures the distance between the object (person) and itself. An ultrasonic sensor is a device that uses ultrasonic sound waves to detect the distance to an item. A transducer is used in an ultrasonic sensor to emit and receive ultrasonic pulses that communicate information about the proximity of an item [3].

The sensor has two parts: transmitter and receiver. The transmitter releases a sound wave called ultrasonic sound. The sound wave is inaudible to the human ear. Sound wave can be obstructed or interfered by an object. After the wave has been emitted, the nearest object would reflect the sound wave. The return signal is received by the receiver. Then the sensor calculates the distance by the time difference from when the wave was sent and the signal received. The formula for calculating the distance between the object and the ultrasonic sensor is shown in Eq. 1.

$$s = (t * v) / 2 \quad (1)$$

where s is the distance between the object and the sensor, t is the time the sound waves travelled and v is the speed of sound which is approximately 340 meters per seconds.

The sensor has four pins: VCC, Trig, Echo and GND. The ECHO pin is rated at 5V. In order to step it down, voltage divider law is used. After stepping it down to 3.3V through the use of resistors, the pin is then connected to GPIO pin. ECHO serves as GPIO input. Next, TRIG is connected to any free GPIO pin. It serves as the GPIO output. VCC pin is connected to 5V power supply on the Raspberry Pi. Then, the GND pin is connected to the GND pin on the Raspberry Pi [3].

USB Module

A USB module can also be called a USB to TTL converter. As stated earlier, the fingerprint scanner is interfaced with the USB module for easy connection to the Raspberry Pi. It is not compulsory in the whole setup of the system, but it gives the work a neater look by reducing the number of wires or jumper cables that are connected to the Raspberry Pi. There are four pins on this module: 5V, RX, TX and GND. The pins on this module are connected to the fingerprint scanner, as is explained above. The connected devices (the fingerprint scanner and the USB module) are connected to the Raspberry Pi, using the USB port. The USB point on the USB module is fitted into the USB port on the Pi. Thus, the connection between the Raspberry Pi and the fingerprint sensor is established using the USB module.

USB Microphone

In the most basic sense, a USB microphone is a microphone with a USB output. So, a USB microphone is a microphone with a built-in digital audio interface that can be connected directly to a computer (or any other digital audio device) through USB. This microphone operates under the simple principle: plug and play. It has the necessary workings within it. It has a sensitivity of -67 dBV/pBar, -47 dBV/Pascal +/-4dB. It is interfaced with the Raspberry Pi by plugging it directly into any of the USB ports on the Pi. It is very useful in this project because it filters out external noise. Also, the neck of the microphone is easily bendable. This enables it to be adjusted to any way the user would desire [18].

Relay

This is an electrically operated switch. It is used to pass signal from one device to another. It does the job of switching ON and OFF sockets through the use of electromagnet. To interface the relay with the Raspberry Pi, the pins on the relay are used for connection. The type of relay that was used is a four-channel relay. There are six pins on the relay to be connected to pins on the Pi using female jumper cables. On the input side, the pins are GND (ground), IN1, IN2, IN3, IN4 and VCC.

The VCC is connected to the 5V pin on the Raspberry Pi. The input pins on the relay (IN1, IN2, IN3, IN4) are connected to GPIO pins on the Pi. And the GND pin is connected to the GND pin on the Pi. On the output side, the load (appliances) to be automated are connected to the negative and positive terminals. On this type of relay, there are four groups of terminals. Each group contain the positive and negative terminals for the load[19].

Mode of Operation

The mode of operation of the system is described in the flowchart presented in Fig. 2. Software requirement include local server (raspberry pi), python, pyQt 5, tinyDB, several other python libraries. The user interface was written in python with

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the pyQt framework - a GUI framework for designing desktop apps in python and tinyDB - which is a json based database for storing user registration data. The user interface consists of a login/registration page (which includes fingerprint registration) and a main page.

The core control aspect of the system was written in python using various class libraries to access the sensors, camera, alarm and fingerprint functions. Twilio and mime class libraries were used for the voice call and mailing features of the system respectively.

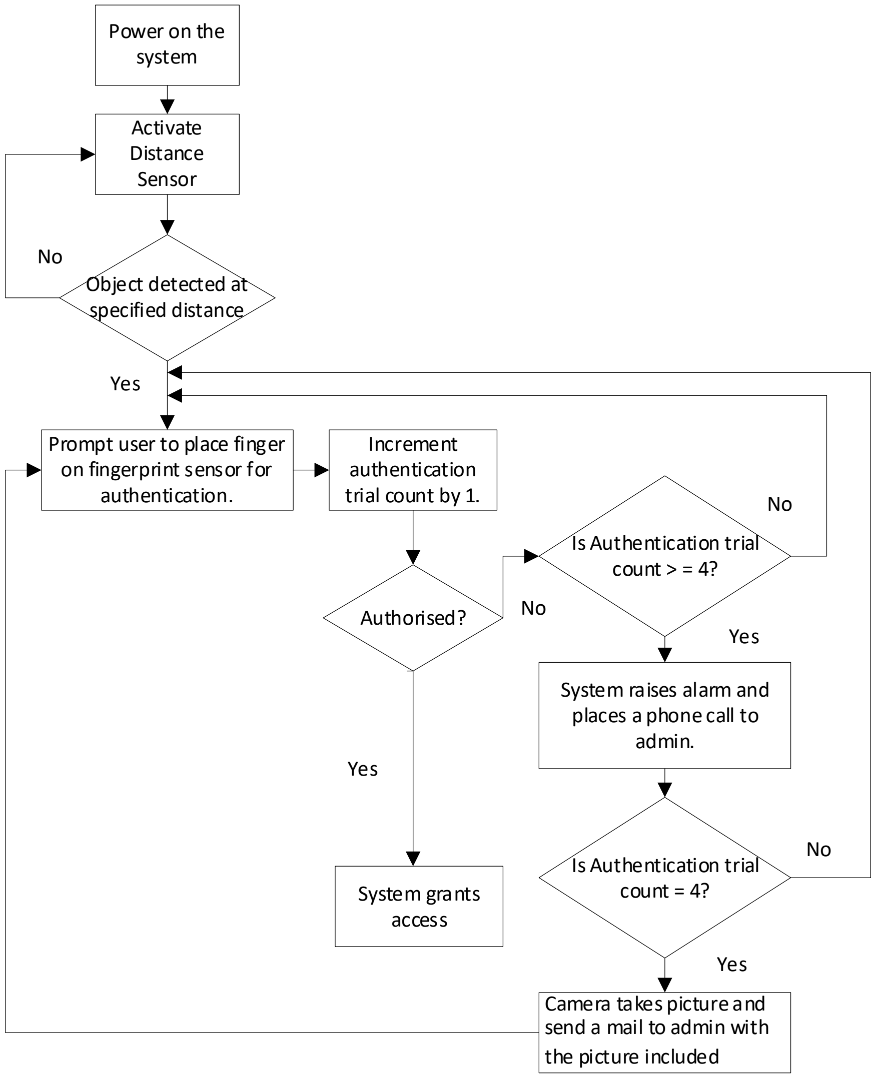

Figure 2: Flowchart describing mode of operation of the system

3. RESULTS AND DISCUSSION

The system functions properly due to the established connection between all of the system's components. First and foremost, the system's operating program was created in Python on the Raspbian operating system. The code was copied to a MicroSD card and plugged into the Raspberry Pi's MicroSD port. To allow the user to interact with the system, an interface was created. This allows for the addition and removal of credible users, as well as the enrollment and deletion of their fingerprints. The interface is used to add a credible user and enrol the user's fingerprints into the system for the first time. The user gets registered as an admin on the system, via an interface as shown in Fig. 3, this interface accepts credible user details to create an account for the user. Figure 4 shows a successful login page.

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Figure 3: Interface for register page

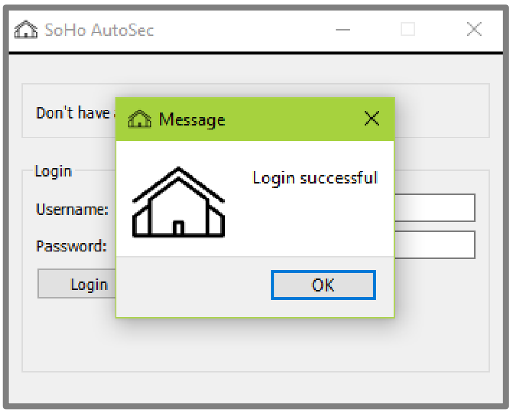

Figure 4: Successful Login

With the saved fingerprints, the user can access the system at any time. With all these preparations put in place, the system was ready to be used. Figure 5 shows login authentication error, which pops up when a user tries an invalid username or password. Figure 6 shows the login interface to prompt the user to login into his or her account.

Figure 5: Username Error on login page

Figure 6: Login Page

The ultrasonic sensor continually sensed for human presence. When anyone reached within its stated range, the camera module and the fingerprint scanner were activated. The LCD showed a prompt to place finger on the fingerprint scanner. At wrong attempts, the camera module began to capture images of the person who attempt to gain access. After four wrong trials on the fingerprint scanner, the authorised user of the system received an e-mail on his/her registered e-mail address with the system as shown in Fig. 7. The email contained a warning message and the captured image of the person trying to gain access. At the fifth wrong trial, a phone call is put forward to the authorised user to alert him/her that an unauthorised person is trying to gain access to the system and then an alarm is triggered.

On the other hand, at right attempt on the fingerprint sensor, access is granted into the system. Then, the user can make specific voice commands to activate or deactivate any appliance that is connected to the system. This was first depicted using light emitting diode (LED). Then it was further illustrated using sockets and lamp holders with bulbs. During the whole process, the Raspberry Pi had an already established connection to the internet through Wireless Fidelity (Wi-Fi). Figure 8 shows the complete system. The biometric access obtained 89% accuracy.

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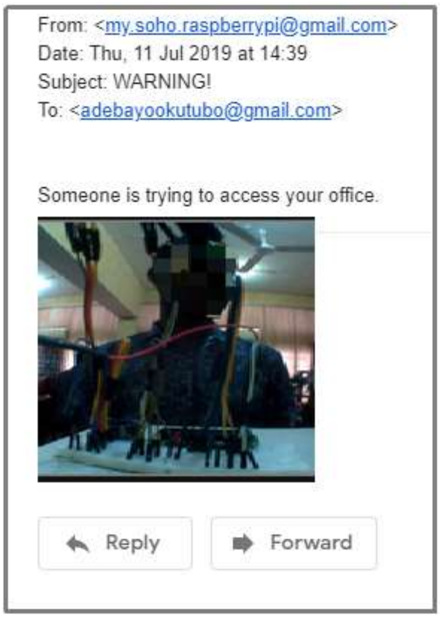

Figure 7: Screenshot of mail sent to user

Figure 8: A complete picture of the system

4. CONCLUSION

This research presents home automation with security features such as alarm systems and access control. Though the system is designed for a modest office, the research can easily be extended for larger rooms and structures using more advanced materials. The microphone should be omni-directional to be able to pick up spoken commands from any location in the automated area. The work presented in this paper was quite effective for small office home automation.

Security system has been included using fingerprint, such that access will not be granted to an unauthorised user while the automation is not activated. The strength of this paper is that the system gets credible user's and neighbours' attention almost immediately (placing a call and triggering an alarm) to enable quick response to the intrusion. Also, intruder's image is sent via email. In contrary, no full featured web interface is included in the research. In addition, weak or poor internet connection may truncate real-time generation of report via email and phone calls.

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