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SYSTEM DESIGN AND IMPLEMENTATION OF A WEB-BASED RASPBERRY PI HOME AUTOMATION

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Abstract

Home automation is the use of one or several and varied electronic components to control some basic home appliances and other features remotely and automatically. Home automation is an interesting field of study especially using new technologies such as the Internet of Things (IoT) whereby homeowners can automate some basic home functions and features over the internet or IP connectivity. Homeowners in Ghana lack alarm systems or advanced security systems which account to burglary attempts against several homes. The purpose of this study is to design and construct a web-based home automation system using the Raspberry pi 3 as the main control device. The raspberry pi 3 is employed as an interface between the other hardware components and the software of the system which can be connected to several peripherals using the SD card slot, GPIO, USB ports, HDMI, the raspberry pi camera port and Ethernet or Wi-Fi connectivity. The designed flexible home automation system is configured with monitoring function, intruder alarm systems and control of devices remotely over the internet using a web browser from a computer or android smart phone. The results indicated that the homeowner can detect an intruder via email, view images of the intruder on the webpage, monitor activities in the house through the USB camera and switch a device from the webpage over internet. The designed raspberry pi 3 was able to provide a degree of security, safety, and comfort for homeowners.

Keywords: *Raspberry pi 3, Home automation, Passive Infrared, Internet of Things*

Introduction

Home automation commonly known as a "smart home", is the use of one or several and varied electronic components to control some basic home appliances and other features remotely and automatically (Lobaccaro, Carlucci and Löfström, 2016). The protection of homes and getting greater access has been a driving factor of communication. The theory of home automation started as far back in the 1970s (Jose and Malekian, 2015). Even though there has been a tremendous improvement in technology in recent years, homeowners continue to struggle when it comes to control, access and protecting their homes.

According to a study conducted by Greichen (1992), home automation is a field bedeviled with high manufacturing cost, high development costs, high installation costs, additional service and support costs,

lack of standards, consumer un-accustomedness with technology, and complex user interfaces. On the contrary, Palaniappan et al. (2015) and Gunge and Yalagi (2016) pointed out that with varied technologies in the implementation of home automation systems, challenges are being addressed with the introduction of new protocols, communication and interface standards. Recently, people spend more time at their work places than staying home. Hence, the need to acquire an alternative means of providing security and making the homes safe and secured.

According to the United State Department of Diplomatic Security (OSAC) report in 2013, the overall crime rate of Ghana is high (Anon., 2013a). Considering Accra in particular, the rate of burglary on a scale of 1-100, is at 46.05. Similar reports in 2014, 2015 and 2016 maintained the same high rate (Anon., 2016). OSAC reported that, there were burglary attempts in an expatriate residence, but perpetrators generally lacked the sophistication to overcome the home alarm systems and static security guards. Employing fulltime security personnel is expensive. This can cost $100 or more per month (Anon., 2016). This raised a question on how one without static security guards and limited budget can make home unsafe to live. In another study of crime incident by Anon. (2013b) from April to June, armed robbery recorded 10% out of the four crimes investigated.

According to the Ghana Police Service, 1, 235; 1,116 and 1,411 robbery cases were recorded in 2013, 2014 and 2015 respectively (Anarfi, 2016). Our smart homes should be sustainable and should give us signals of intruders. Home automation include remote mobile control, automated light, automated thermostat adjustment, scheduling appliances, mobile, email and text notification and remote video surveillance.

This study focuses on the design of Web-Based Home Automation System, with the use of the Internet to monitor and control some basic home devices. The system will aid homeowners to get greater access and control of their homes.

Literature Review

Home automation is the controlling of home appliances and domestic items and ensure its safety by the use of remote access through the Internet. (Gunge and Yalagi, 2016). Home automation cuts across several technologies from Raspberry pi, Arduino microcontroller, web-based, email-based, Bluetooth-based, X10 (Jose and Malekian, 2015), Ultra-wideband (Obaid et al., 2014), GSM-based, ZigBee based (Kumar and Singh, 2014), Dual Tone Multi Frequency-based, cloud-based, Z-wave (Knight, 2006 and

Amaro et al., 2011) Insteon (Bhatia, Bajaj and Roja, 2014), LonTalk (Jose and Malekian, 2015), and the Internet (Gunge and Yalagi, 2016). However, Bluetooth (Ryan, 2013; Kanma et al., 2003), WiFi (ElShafee and Hamed, 2012), and ZigBee are the popular choice for the backbone of such systems (Lobaccaro, Carlucci and Löfström, 2016;Palaniappan et al. 2015; Gill et al., 2009;).

Obaid et al. (2014) designed a voice controlled wireless smart home system for the elderly and disabled people using ZigBee. Sriskanthan. Tan and Karande (2002) implemented home based security system using Bluetooth technology. The development is in line with finding solutions to the challenges we encounter in our security systems.

Obaid et al. (2014) and Zanella et al. (2014), wrote about the popularity of the Home automation systems inrecent times. ElShafee and Hamed (2012) implemented home automation system using Wi-Fi technology. Sarthak, Anant and Goyal (2014) used Raspberry pi to design home automation system. Piyare and Tazil (2011), used Bluetooth technology to design a home automation system. Palaniappan et al. (2015) carried out a literature survey of home automation systems. Jose and Malekian (2015) provided a comprehensive literature survey of the home automation system and technologies from a security point of view. Raspberry pi 3 combines the power of PC, communication and multimedia technologies to manage and control systems without human intervention (Ganesh and Khan, 2015). Ganesh and Khan (2015), compared Raspberry pi home automation system with available commercial home automation system and concluded it is better than the commercial type. Rao and Uma (2015) combined Raspberry Pi and smart phone to control door sensor, light switches and camera to stream live video. Maslekar et al. (2015) considered smart lighting system with the use of Raspberry Pi.

In another study, Navedeti et al. (2016), designed patient monitoring system parameters using Raspberry Pi. Hadwan and Reddy (2016,) implemented a smart home control system by using Raspberry Pi and Arduino UNO. The system has been established to be less expensive and scalable and therefore applicable to many monitoring systems.

Methodology

Hardware Design Concept

The hardware design consists of the block diagram of the Raspberry pi 3 Web-Based Home Automation System and the description of the various components. The block diagram of the design is shown in figure 1. The Raspberry Pi 3 is interfaced with a motion sensor, a camera and a relay.The raspberry pi 3 serves as a client which is interfaced with the raspberry pi camera, Passive Infrared (PIR) motion sensor, one

channel relay and USB Camera. The main purpose is to serve as the control unit running on a python program. It runs on a Raspbian Operating System (OS). The Raspbian OS is a set of basic programs and utilities that make the Raspberry pi 3 to execute commands.

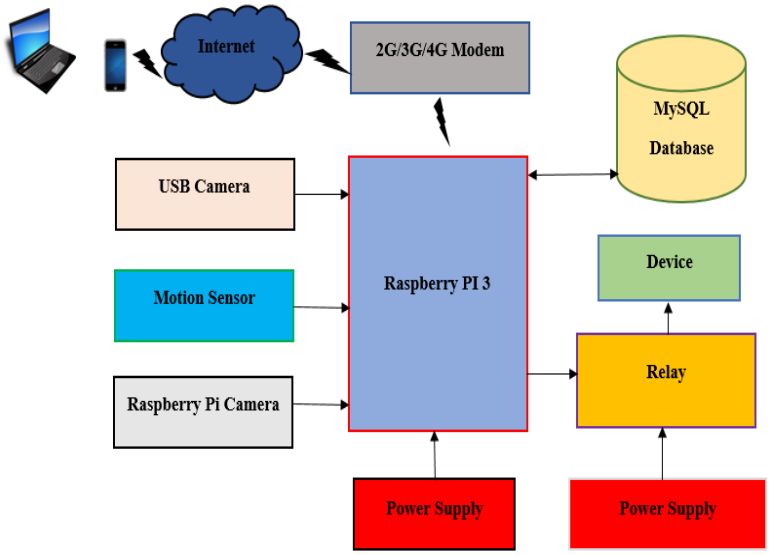

Fig. 1: Block Diagram of Raspberry Pi 3 Web-based Home Automation System

Description of Components

This section gives the description of the components used.

Raspberry PI 3

The raspberry pi 3 is a third generation of the raspberry pi. Figure 2 shows the board. It has a 1.2GHz 64-bit quad-core, ARMv8 CPU and 802.11n wireless LAN. Raspberry pi is a series of credit card-sized and a single-board computer (Sarthak, Anant and Goyal, 2014). Several generation of the Raspberry PI have been released which include the Raspberry PI 1, model A and B, A+, B+, PI 2, PI 3 and the PI zero.

Basically, all these models have a Broadcom system on a chip with an Advanced Reduced Instruction Set Computer (RISC) Machine known as the ARM, compatible Central Processing Unit (CPU) and a chip Graphic Processing Unit (GPU). The CPU speed ranges from 700MHz - 1.2GHz for the PI 3 and on board memory range from 256MB – 1GB RAM. It has a Secured Digital Card which is used to store the Operating System (OS) and program-memory, the "High Capacity Secure Digital Card" (HCSD).The chip

specifically provides High Definition Multimedia Interface (HDMI)and most boards have between one and four Universal Serial Bus (USB) slots.

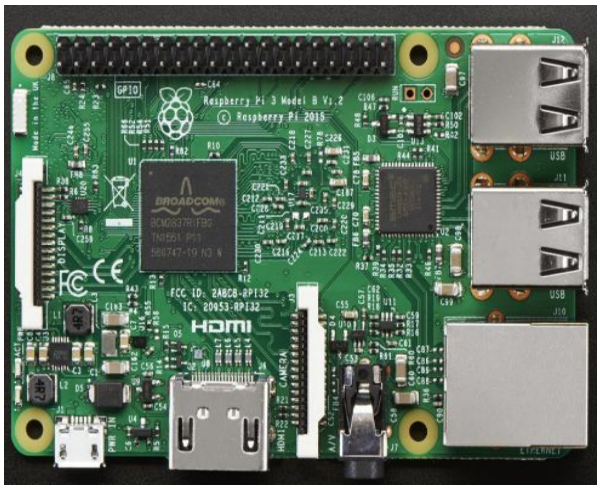

Fig. 2: The Raspberry PI 3 Source: Sarthak, Anant and Goyal, 2014

It also has a phone jack for audio and a lower level output which is provided by a number of General-purpose Input and Output (GPIO) pins. The B models have an 8P8C Ethernet port and the PI 3 has onboard WIFI 802.11n and Bluetooth. The Raspberry PI promotes python and scratch as the main programming language. It also provides Rasbain, Debian based Linux distribution for download as well as third party Ubuntu, Windows 10 IoTcore and RISC operation system.

— The Raspberry PI 3 board contains a single 40-pin expansion header labelled as J8 providing access to 28 GPIO pins and also has the power, ground UART, I^2, SPI, and GPIO.

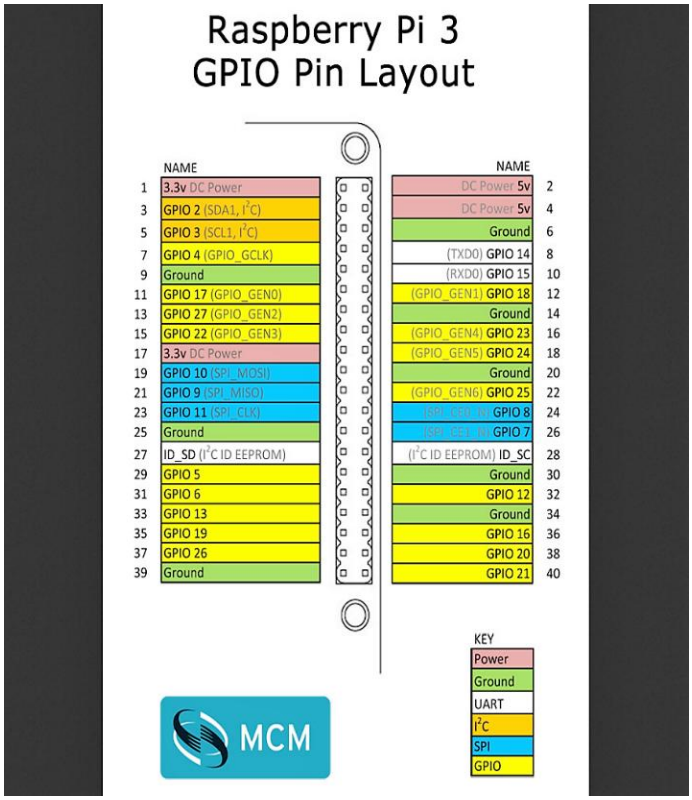

Fig. 3: General Purpose Input/Output Layout of the Raspberry Pi 3

Source: (Gregory, 2016)

— **Power**: It pulls power directly from the Raspberry PI 3

— **Ground**: They are the pins used to ground the devices and they are all connected to the same line **Universal Asynchronous Receiver and Transmitter (UART):** These are serial pins that are mainly used to communicate with other devices.

— **Inter-Integrated Circuit(I^2C)**: are the pins that allow the system to connect and communicate to hardware modules that support I^2C protocol.

— **Serial Peripheral Interface Bus (SPI)**: are the pins that connect and communicate to hardware modules that support SPI protocol.

— **General Purpose Input and Output (GPIO)**: Standard pins used to turn devices on and off.

— **BCM2835**: It is the Broadcom chip used in the Raspberry PI.

— **Wiring Pi**: It is a PIN based GPIO access library written in C for BCM2835 used in the Raspberry Pi. This can be programmed as either digital outputs or inputs.

Secure Digital Card (SD Card)

The SD card is used to store the operating system of the (Raspbian OS) needed to run the raspberry pi 3 and also store the sever codes and python codes used to control the objects connected to it.

PIR Motion Sensor

The passive infrared (PIR) sensor detects motions of intruders in the detection range. It consists of a Fresnel lens, an infrared detection and supporting detecting circuitry. The function of the lens is to detect an infrared radiation present around it. The sensor detects a motion and the feedback is sent to the user via email.

Female to Male and Male to Male Jumper Wire

They are commonly used with the breadboard which transfers electrical signals from the breadboard to the main controller (raspberry pi 3) are used to interface the components to the Raspberry pi 3.

One Channel Relay

Relays are electromechanical devices that give the raspberry pi 3 the ability to control high voltage devices.

USB Camera

The USB camera is used to stream live video or monitor activities in the house. The Raspberry Pi camera is used to take pictures of the intruder as the motion sensor detects an intruder.

Raspberry PI Camera

Android studio is the official Integrated Development Environment for Android application development, used to develop the Remote-Control application to access the Home Automation System over the internet.

Software Design Concept

This section discusses the development stages of the software design. The software architecture was implemented as shown in figure 4.

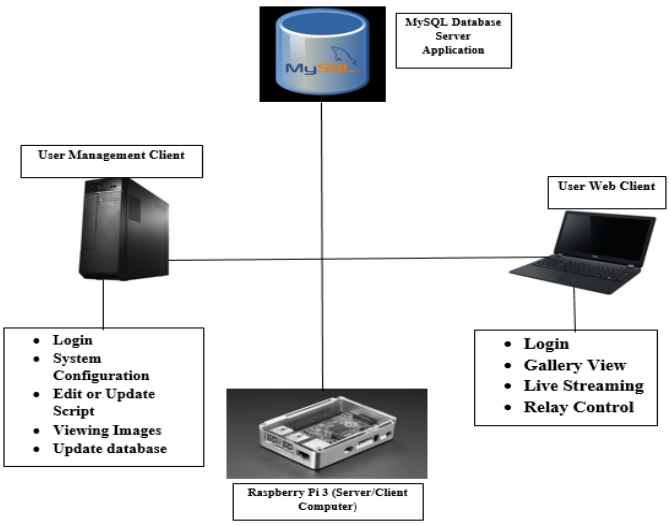

Fig. 4: Software Architecture

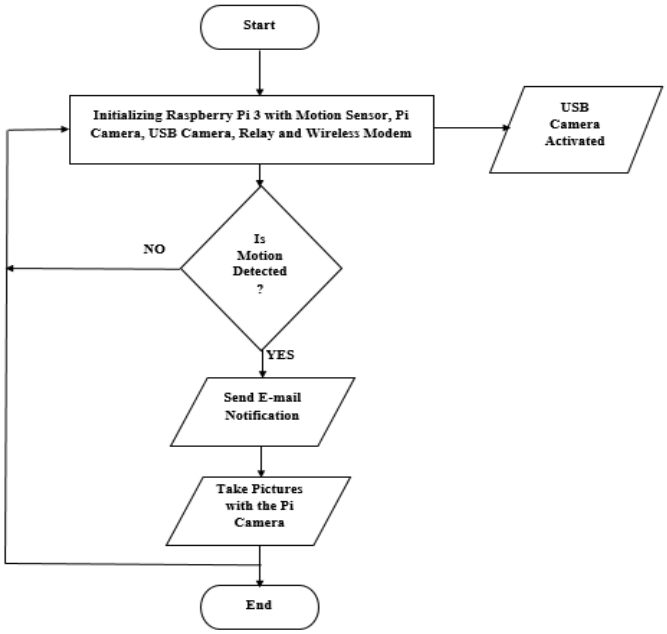

Fig 5: Operation of Detection Devices

The flowchart of the detection devices is shown in figure 5. The remaining sections describe the software and programming languages used for the study and processes that are involved in the setting up of the Raspberry PI 3.

The raspberry PI 3 is hooked up with its necessary peripherals such as the USB camera, PIR motion sensor, Power supply, one channel relay and Raspberry PI camera.

Configuring the Raspberry PI 3

Configuration is done on the raspberry pi 3 to carry out its functions. These include installing the raspbian operating system, configuring of the raspberry Pi camera and USB camera, configuring the database and configuring the raspberry pi 3 web server.

Software Used for the Study

Android Studio: Android studio is the official Integrated Development Environment for Android application development used to develop the Remote-Control application to access the Home Automation System over the internet.

Notepad ++: It is used to write the code for the Home Automation System Web design and saving the codes in default extension ('.php', 'index.html')

IDLE Python: Integrated Development Environment or Learning Environment for writing Python codes and running the codes.

RealVNC viewer: It is Virtual Network Computing software for sharing graphical desktop remotely to control another computer. It controls the raspberry pi 3 remotely and view the graphical desktop interface of the raspberry pi 3 on the computer.

HTML5: It is the fifth version of the HTML Standard for structuring and presenting the content on the webpage (worldwide web).

PHP Programming Language: It is originally derived from Personal Home Page Tool which is Hypertext Preprocessor. It is the server scripting language for creating the dynamic webpages of the system.

Apache Web Server: It is designed to create the web servers that have the ability to host one or more HTTP-based websites.

MySQL Database: MySQL is an open source relational database management system that uses structured query language to store information in tables, thus tables for the username and password and the relay switch of the system.

JavaScript: It is a full-fledged dynamic programming language applied to the HTML document to provide dynamic interactivity on the website. It is also used to develop the android application base on the system.

The relay control of the system over the Web interface is illustrated in figure 6.

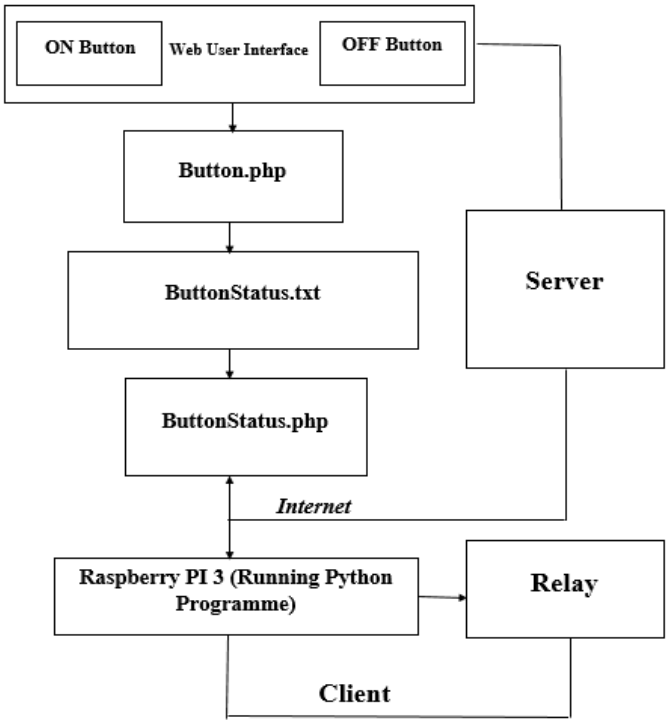

Fig 6: Relay Control over Web Interface

Results and Discussions

Figure 7 shows the login interface of the webpage of the system access through its IP or localhost on a computer. The users would have to insert a username and a password to access and get control of the system.

Figure 8 shows the home page of the system thus the dashboard where the user can get access to the menu or the control; relay switch, video stream and the images taken by the Pi camera during the detection of intruder by the PIR motion sensor.

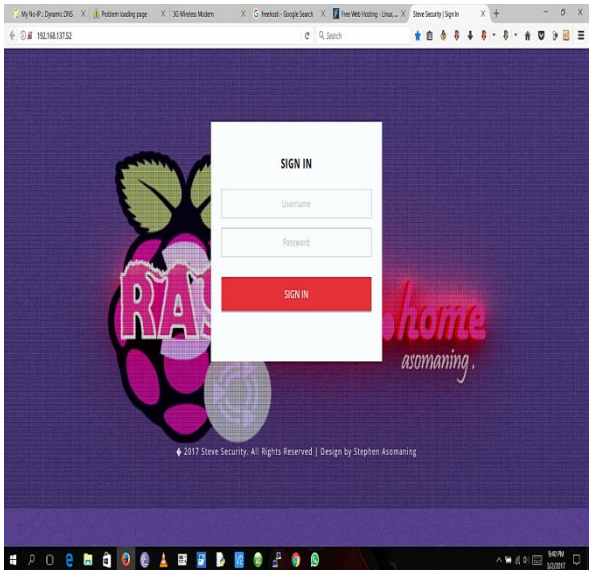

Fig.7: Image of the login interface of the system

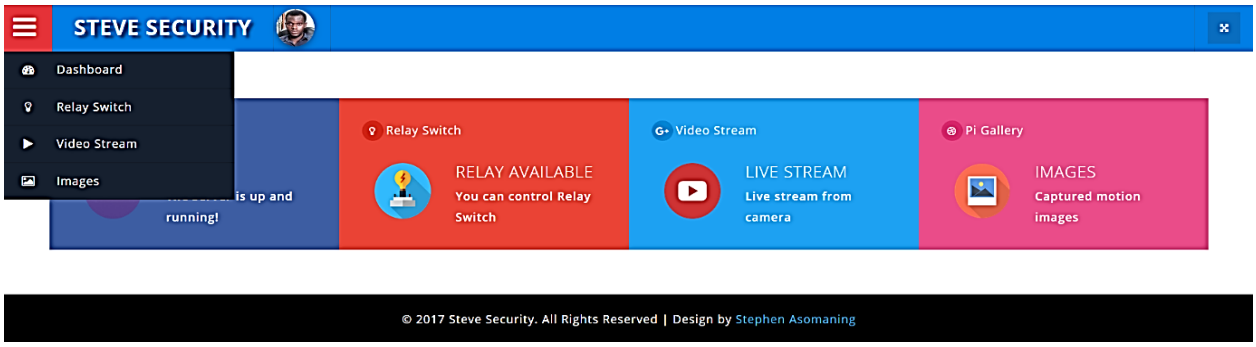

Fig. 8: Homepage of the System

Figure 9 shows the images taken from the Raspberry Pi 3 camera during the detection of the intruder. The images are stored on the system and can be accessed over the webpage of the system.

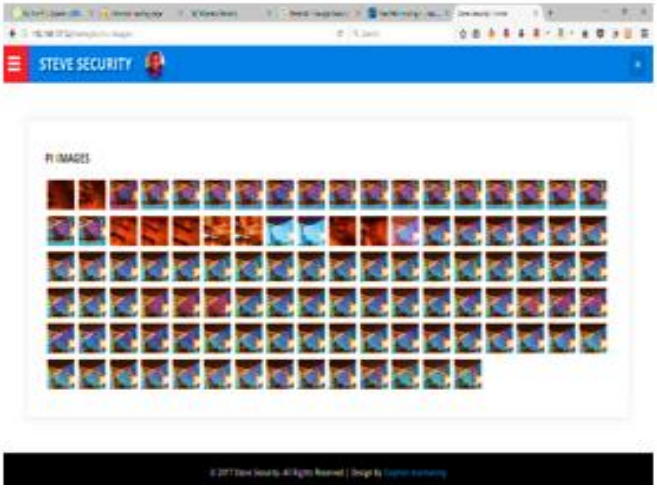

Fig. 9: Pictures taken for the Raspberry Pi Camera

Figure 10 and figure 11 show the interface of the relay switch from the web page which is connected to the database. The user controls the device over IP or Internet by turning on/off the light.

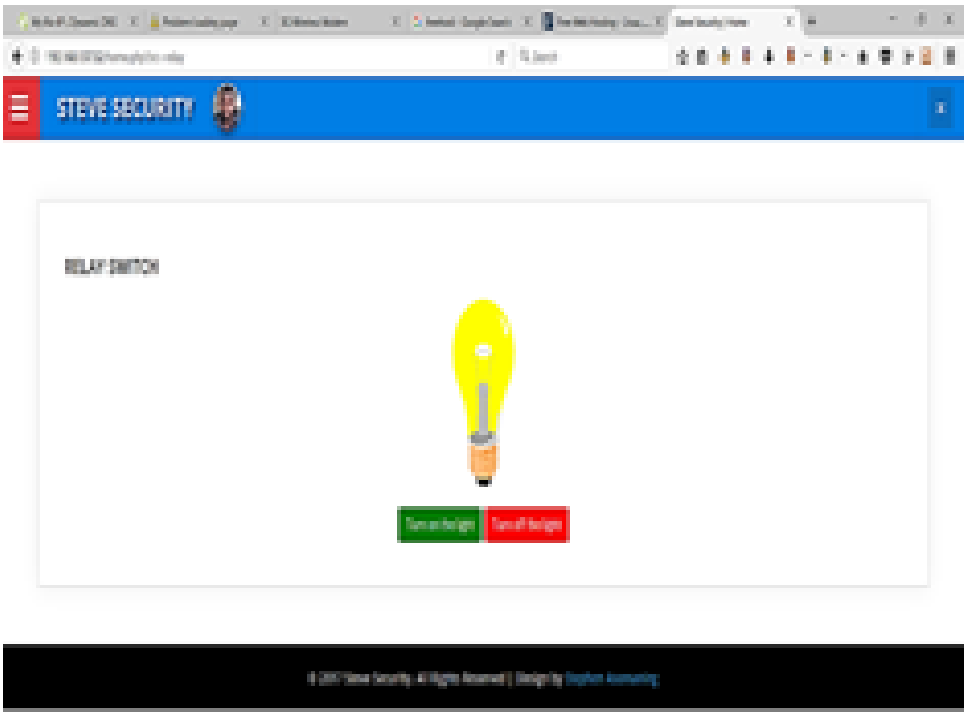

Fig. 10: Relay Switch at its on State

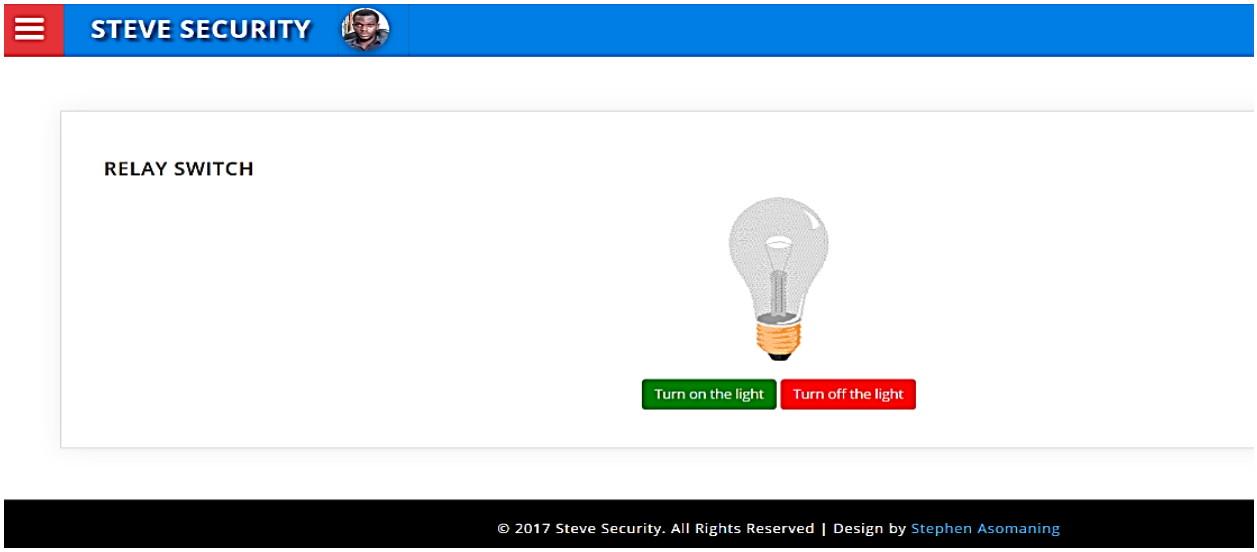

Fig.11: **R**elay Switch at its off State

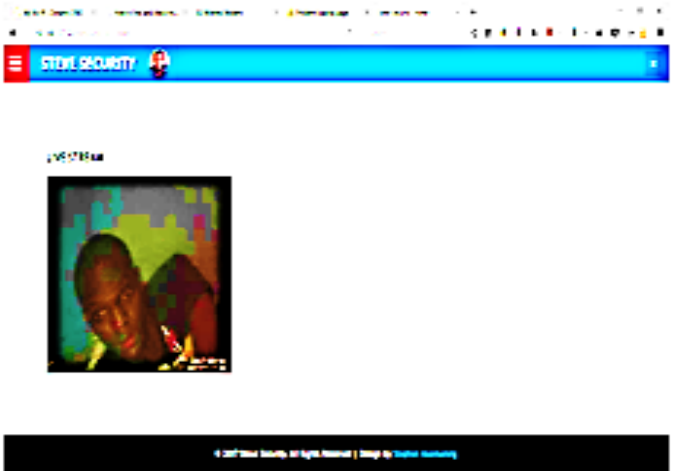

Fig. 12: Live Stream from the USB Camera Connected to the System

Figure 12 shows the live stream from the USB camera connected to system. This function enables the user to monitor activities in the house through live stream over IP.

Fig. 13: User Interfaces of the Webpage of the System Using Android Application on Android Phone

The image in figure 13 shows the interfaces of the webpage accessed for the mobile application on the android phone where the user can get control over the relay switch, view images of the PI camera as well as the live stream.

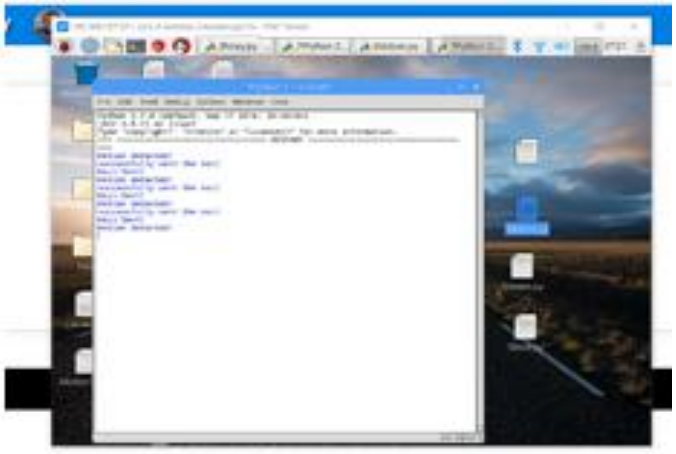

Fig. 14: Motion detection Code Running in Python Shell

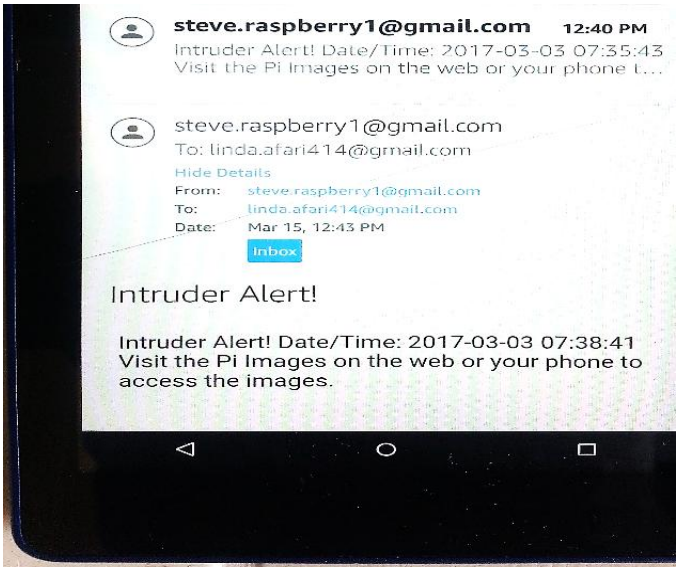

Fig. 15: Intruder Alert Notification through Email

As the motion sensor detects motion, an email notification is sent to the user email address (figure 15) and the PI camera takes pictures and stores it in a folder which can be accessed over the webpage of the system.

The relay code running in python shell and the connection to the database of the system where the relay switch can be controlled over the web interface is shown in figure 16.

Figure 17 shows the Raspberry Pi 3 system with the PI camera, PIR motion sensor, USB camera and the one channel relay connection. The image shows the off state of the relay when controlled over IP or Internet from the webpage.

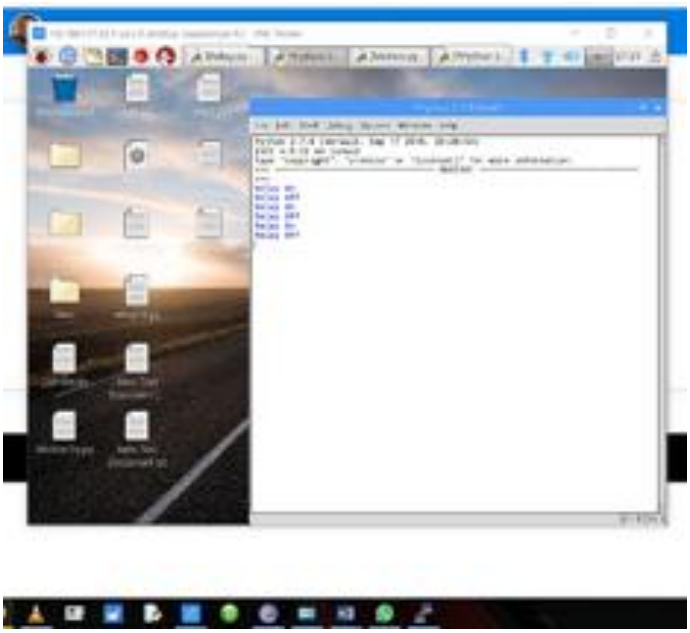

Fig. 16: Relay Code Running in Python Shell

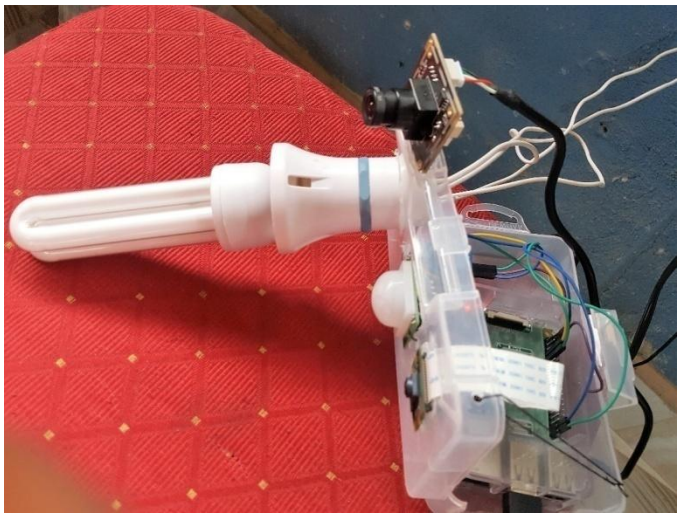

Fig. 17: Image of the System Showing the Bulb's off State

Figure 18 shows the on state of the relay attached to GPIO of the Raspberry Pi 3 when controlled over IP or Internet from the webpage of the system

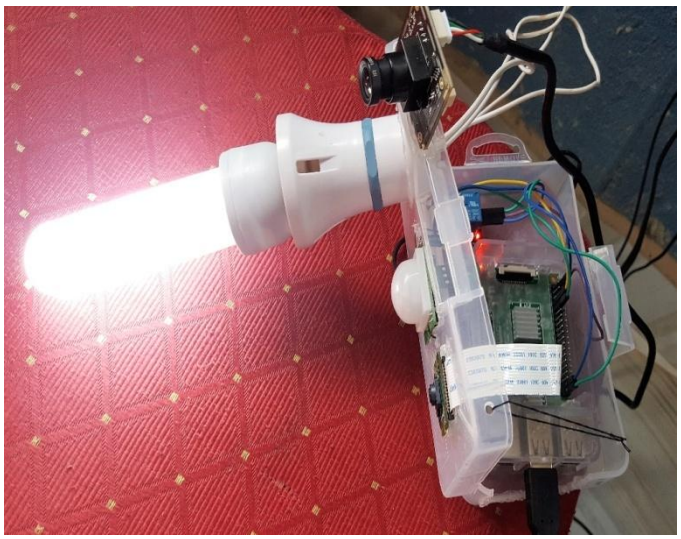

Fig. 18: Image of the system showing the on state of the bulb

The study employed the Raspberry PI 3 Web-Based Home Automation System to help homeowners monitor the activities of intruders. The system is able to capture images and video of intruders in the home. This is in agreement with earlier works by Rao and Khan (2015) and Maslekar et al. (2015). Hadwan and Reddy (2016) also used Raspberry Pi in monitoring and for data collection applications.

The Raspberry Pi 3 system was able to control a device in the home over the internet. This is illustrated in figure 12, figure 17 and figure 18 respectively.

In accordance with an earlier study done by Prasadet al. (2014), the design captures information of the intruder and sends it through a mobile network by applying web application, to the smart phones of the user.

Conclusion

The study has successfully designed and implemented a web based raspberry pi 3 home automation system which is able to detect an intruder, sends feedback to the user and takes pictures of the intruder simultaneously. The system stores the pictures of the intruders.

The system is able to send feedback to the user's email address, and stream live video with the USB camera over the internet. The images or pictures of the intruders are also accessible over the Internet

through the webpage with login interface of the system. These measures are in line to strengthen the security system and enjoy a sound life.

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