COST-EFFECTIVE RASPBERRY PI BASED SURVEILLANCE SYSTEM USING INNOVATIVE TECHNOLOGY

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Abstract

Home security is paramount. Criminals break into houses and cart away valuables and sometimes injure/kill the property owners. Though the existing home security system is effective however it is not affordable to the majority. Thus, due to the high cost of CCTV or IP camera systems alike, there is a need to develop a cost-effective surveillance system using innovative technology. This study develops and builds a prototype of a low-cost security system based on Raspberry Pi microcomputer. The Raspberry Pi will interface with Pi camera without interfacing the device with a PIR sensor, remotely send an email to a prescribed mail hub and also send SMS alert to the facility owner and or security agency.

Keywords: Motion detection, image processing, alert mechanism, security mechanism, home security, Raspberry Pi, the remote alert system.

Introduction

Over the years, security has been a prime concern globally due to the high increase in the crime rate.

The evolution of the security system begins after the creation of electricity. Then, there was the need to improve the security system. The electro-magnetic alarms were first introduced in 1853 for the wealthy resident and business establishment so they could secure their valuables. The magnetic contact is added to the doors and windows. When tripped, it sends a signal through the electromagnetic wiring and sounds an alarm. They were effective in detecting break-ins from occurring (perspecsys, n.d.).

Years later, major strides have been made concerning the surveillance system. After the alarm system, the analogue video camera and the video cassette recorder evolved. The digital video recorders evolved giving good quality of the image and enabling transmission of video signals through data networks and thus allowing remote monitoring (Osama, 2009).

The network video recorder was introduced later and they have the advantage of the DVRs. They provide network connections and more storage options. The type that uses the Cisco Video Surveillance Platform is the most superior version. They give secure remote access and control from anywhere, fail-safe redundant storage, easy integration with other systems and enterprise-class storage and support (Osama, 2009).

There has been a lot of break-ins worldwide. An example of such is that of the Enugu State Universal Basic Education Board (ENSUBEB) account department which happened in June 2012. According to (EDIKE, 2012), vital documents were removed from the account departments. Another case is that of Ilesha, Nigeria in 2016 where a man was remanded for conspiracy, burglary, and theft (Man,30, remanded for alleged burglary in Osun, 2016).

According to (2017 crime in the United States), burglaries are the second-most frequent crime behind larceny-theft in the USA. It occurs often, almost three every minute, i.e. about 3,757 burglaries a day, very unlike in the UK where a burglary takes place every 40 seconds (ITCC Locksmiths).

In 2005, a high number of burglaries were recorded in Russia. It was approximately 1.6 million offences. Though there is a gradual decrease, yet 756.4 thousand burglaries were registered in 2018 (Annual number of recorded burglary offenses in Russia from 2000 to 2018* , 2019).

According to (Appiahene-Gyamfi, 2005), the Nima division has a very low residential burglary compare to the Kpeshie division while the nonresidential burglary was highest in Accra Central. Again, Nima division has the lowest.

Criminals break into houses and cart away valuable (e.g. jewels, cash, sensitive documents, etc.). As this needs to be checked, there is a need to have a tool and applicable means to detect when an unauthorized person enters an environment. In this scenario, a security system with a camera and a modern alarm system that will alert the property owner and send information about the intruder to a security agency/property owner is needed.

There are many security technologies among which are:

Closed-Circuit Television (CCTV) Security System

The use of video cameras to transmit signals to a specific place with monitors is referred to as closed-circuit television (Kurdi, 2014). It varies from television broadcasting in that the signal is not broadcast publicly, although it may use point-to-point (P2P), point-to-multipoint, or mesh cable connections (Verman, 2005).

Remote Surveillance IP System

Remote surveillance IP system is a digitized and networked version of a CCTV. The IP camera records video footage and the resulting content is distributed over an IP network (IP Surveillance).

Arduino Based Home Security System

This system utilizes a built-in system consisting of an open software microcontroller (Arduino) and a Global Mobile Communication System (GSM) (Hareendran, 2014). When installed in homes, an interface intrusion-detector unit is connected to the microcontroller-based security system which incorporates a passive infrared sensor (PIR) for detecting motion.

Arduino Uno Microcontroller

The Arduino Uno is an ATmega328 based microcontroller board. It has 14 input and output pins which are digital (including 6 as PWM outputs), 6 analogue inputs, 16 MHz oscillator crystal, USB connection, energy jack, ICSP header, and reset button. It includes everything you need to help the microcontroller by merely linking it to a USB cable laptop or powered by an AC-to-DC adapter or battery. The Uno varies in that it does not use the FTDI USB-to-serial driver chip from all previous boards. Rather, it features the programmed Atmega 8U2 as a USB-to-serial converter. It has 32 KB and 2 KB SRAM as well as 1 KB EEPROM (Rozita Teymourzadeh, 2015).

Passive Infrared Sensor (PIR Sensor)

The passive infrared sensor is a pyroelectric electronic device that measures infrared (IR) light radiating from objects. When an object, like a human being, passes in front of the background, such as a wall, the temperature in the field of view of the sensor will rise from room temperature to body temperature, and then back again (How Infrared Motion Detector Components Work, 2013). The sensor transforms the resulting shift in incoming infrared radiation into a shift in output voltage, which causes detection.

GSM Module

GSM module is a specialized type of modem which accepts SIM card and operates over a subscription to mobile operators. There is communication over the mobile network when the GSM modem and computer are interconnected. Although these GSM modems are most commonly used for mobile internet connectivity, SMS and MMS messages can also be sent and received (Bangali, 2013). This device receives and processes GSM signals from virtually all GSM bands as well. This modem can be used to interact and create integrated apps using its RS232 (Saidu, 2013).

Raspberry Pi Based Surveillance System

The raspberry pi can be used to implement as a security system with motion detection, image processing, and alert mechanism. Furthermore, there are image processing (image Blurring and grey scaling), object detection and tracking, background subtraction method (foreground detection), real-time background

subtraction and shadow, template matching, shaped based, optical flow method.

The Raspberry Pi based surveillance system requires the use of an intruder detection system that will help identify and report any intrusion. The intruder detection system is designed to reveal intrusion once an intruder enters a premise.

In Nigeria, for example, due to its lower power consumption, this system can work best, particularly in remote locations where electricity supply is a challenge. The system is fully automatic, i.e. it monitors and controls without human intervention. This makes it effective.

Nowadays, QoS is getting improved by automation and IoT (Internet of Things). IoT is an ongoing Internet development concept through which everyday objects have communication capabilities that enable them to send and receive data through wireless or wired connections and distinctive systems for creating fresh applications/services and achieving a common objective. IoT seeks to exploit environmental state information to customize it and adapt the environment to user preferences. IoT technological development is for smart houses to provide intelligence and to improve the quality of life (Piyare, Rajeev, 2013). Application-based on IoT can be used remotely to view the activity and be notified when movement is identified.

There is a wide range of surveillance systems that researchers and developers have come up with that are used for remote monitoring, alerting as well as controlling tasks. Security cameras with seemingly many function preferences are many. These monitoring devices are accessible in a broad variety.

RELATED WORKS

Padmashree A. Shake and Sumedha S. Borde presented a cost-effective alerting system based on small motion detection. Their system helps to monitor the household activities in real-time from anywhere and based on a microcontroller which is considered nowadays as a limited resource and an open-source solution compared to SBC (Eseosa, 2014).

D. Jeevanand designed a system based on Raspberry Pi SBC that worked in a real-time situation. Contrasting to other embedded systems, their real-time application offers client video monitoring with the help of the alerting module and SBC platform (Dickson, 2015).

Sneha Singhd and his team aimed at developing a system that captures real-time images and displays them in the browser using TCP/IP. The algorithm for face detection is being implemented on Raspberry Pi. This algorithm enables live video streaming along with the detection of human faces. The research did not include any surveillance reactions (Sneha, Feb.2015).

Mahima F. Chauhan and Gharge Anuradha designed and developed embedded internet server video monitoring system Raspberry PI B+ Board. Their system has low cost, good openness, and portability. The system could be used for security in banking halls, industry, environment and military arts (Leela Krishna Gunnemeda1,Subhash Chowdary Gadde2, Harshith Guduru3,, 2018).

In 2014, Jadhav G. J implemented a cost-effective surveillance system. In the work was adopted an ARM core as a basis processor of the system. PIR sensor was used to detect motion while vibrating sensor is used to sense any vibration events such as the sound of breaking. The proposed intruder detection technique used the PIR sensor that detects motion and triggers a system of alerting and sending short message service through the GSM module for a specified phone number. (Bangali, 2013).

In 2014, Sanjana Prasad and his colleagues developed a mobile smart surveillance system based on SBC of Raspberry Pi and PIR motion detector sensor. Their development enhances the practice of portable technology. And this offers vital safety to daily life and home security and even control use. In their work was developed a mobile smartphone home

security surveillance system based on the information capturing module combined with the transmitting module that is based on 3G technology fused with web applications. (Sanjana Prasad, 2014).

Uday Kumar worked on the implementation of a low-cost wireless remote surveillance system using a camera with Raspberry Pi. The images acquired are to be transferred to the dropbox using a 3G internet dongle.

Notwithstanding, the need for a reliable and effective intrusion system needs to be emphasized, considering the frequent security threats gotten as a result of rampant burglary cases. This affecting both private homes and offices, thus there is a need for the affordable intrusion system with an alarm system. The proposed surveillance system would be designed using a raspberry pi and motion-detecting camera to send alert to the user through email once an intruder is detected. Though this system may not wholly replace the role of CCTV and IP surveillance cameras especially in large environments like industries, it is easy and affordably cheap for home users to use it to monitor their homes. The Raspberry Pi is a complete Linux credit card-sized low-price affordable computer that can provide all functionalities of a computer/laptop, at even low power consumption. It has easy support and documentation (The Raspberry Pi Education Manual, Dec 2012). The raspberry pi is used because, unlike CCTV cameras, it is cheaper and gives high resolution and low power consumption features. Image processing is a term that indicates image or video frame processing that is taken as the input. The processing outcome set may be a set of related image parameters (sheshai, 2016).

METHODOLOGY

An embedded real-time surveillance system must have at least three functions for effective monitoring and alerting. The functions are detection, image processing, and alert mechanism. Designing the raspberry pi security system is divided into two main parts which are the hardware and the software. For hardware design, the entire system consists of the following components:

- Raspberry Pi3 Model B+ controller - This model was chosen for this project as it has both higher clock speed and an onboard Wi-Fi with built-in Bluetooth. Raspberry pi 3 runs at 1.2 GHz and has an upgraded power system as well as four USB ports. It is an improved model from the previous versions and is based on the Broadcom system-on-a-chip (Figure 1).
- RJ45 Ethernet connector
- Micro SD card
- Pi camera module
- USB powered cable

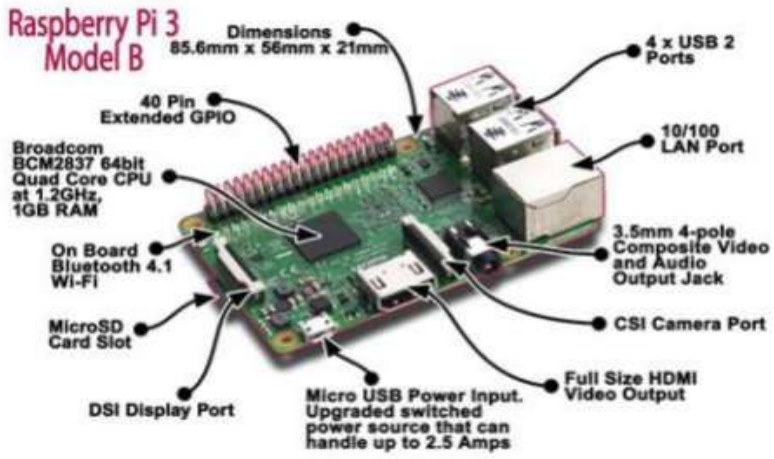

Figure 1. Raspberry pi 3 Model B

Installing MotionEyeOS Into the Raspberry Pi

The SD card was formatted to remove libraries that may conflict with the new package to be installed. Thereafter, the OS was installed on it. The MotionEyeOS image file was burnt on the SD card using disk imager.

Booting Up the Pi Model

After the burning, the SD card was slotted into the Raspberry Pi, the Ethernet cable was connected to the Raspberry Pi to remotely access and control it Connection to the Raspberry Pi can also be made via Wi-Fi. Putty, an SSH client, was then started and the default static IP address of the Raspberry Pi was typed into the hostname field. While doing this, windows PC was set to manual IP configuration. This was to allow for communication with the Raspberry Pi.

Setting Up Internet Connection on The Pi

Internet connection makes Raspberry Pi communicate over the network protocols and thus allows the installation of various packages. When using a router, it is necessary to change the IP address of the Raspberry Pi from static to dynamic because the router uses DHCP (Dynamic Host Configuration Protocol). Necessary changes were done by editing the network interface file using the following command:

Sudo nano /etc/network/interfaces

Enabling the Pi Camera

This camera is specifically for Raspberry Pi, and it is on one of the two tiny sockets on the upper surface of the board connected to the Raspberry Pi. CSI-2 dedicated electric port is used specifically to interface the camera. To configure and enable the camera, the following commands were used:

Sudo apt_get update

Sudo apt_get upgrade

Sudo raspi-config

To test that the camera is well configured, the following command is executed

Sudo raspistill –o image.png

This command automatically takes a picture and saves it.**Software Design**

The flow chart (Figure 2) describes the series of events starting from the intrusion event up to the point when it sends out an alert. This algorithm was implemented using a Python script.

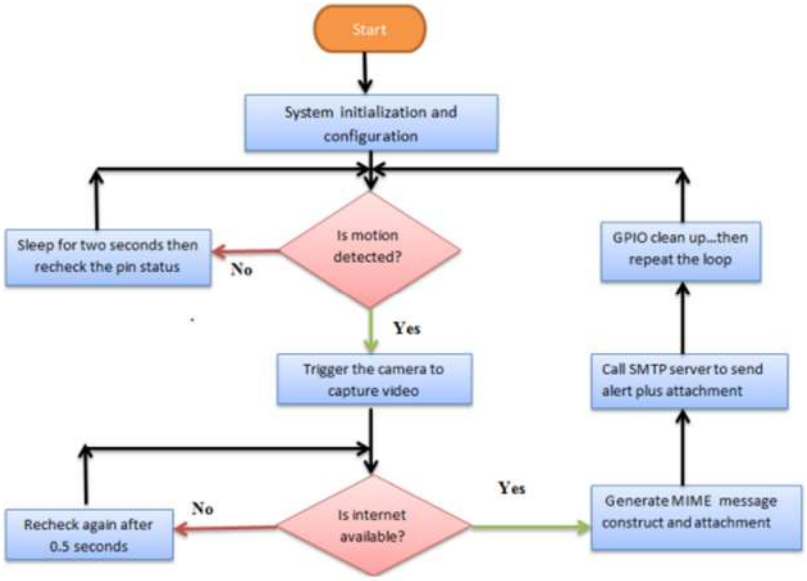

Figure 2: Flowchart of the security system

After the device has boot up, the IP address of the Raspberry Pi was typed on the browser to get to the MotionEye login page (Figure 3).

Figure 3: MotionEye web login page

After login, the Pi module was detected and the live image was shown.

All configurations were done on the web user interface (Figure 4). For the first login, there were some basic initial steps taken, and they were:

- set a password for both admin and the user; this was done by going to the three bars menu to open the general settings and enable advanced settings and make the necessary changes to the admin username and password.
- set the correct time zone for the region
- to enable the wireless connection, if there is one
- configure video device(s) (framerate, resolution, etc.).
- configure the file storage, if there is one
- enable still images and/or motion movies if there is a need for any information to be recorded

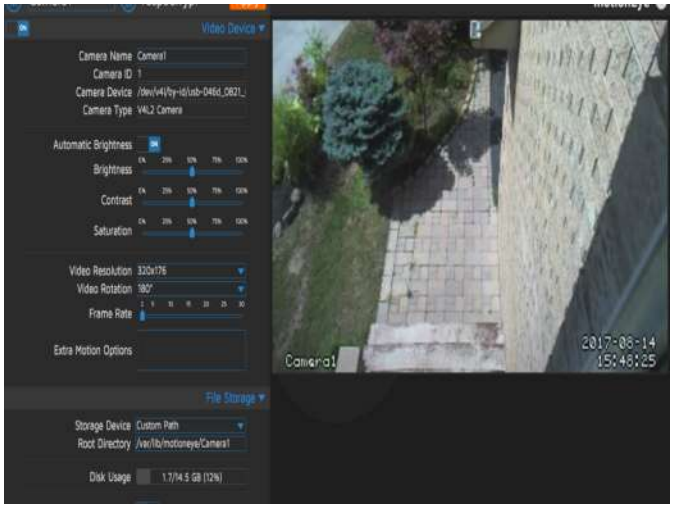

Figure 4: Example of the main screen of the MotionEye (Vázquez, 2018)

Clicking on the menu button located at the top corner (Figure 4) will pull up options for effecting various settings like changing the username and password as well as the surveillance password, setting time zone, also hostname (Figure 5). Surveillance users can only view the cameras but cannot change settings.

Figure 5: Screenshot of the menu

Preference Sub-Menu

At the Preference sub-menu can be configured the quality and image preview of the camera.

Video Device Sub-Menu

After adding the camera, the video device sub-menu allows the user to change the name of the camera., rotate the camera, set automatic brightness and specify the frame rate that has a direct impact on the performance of the system (Figure 6).

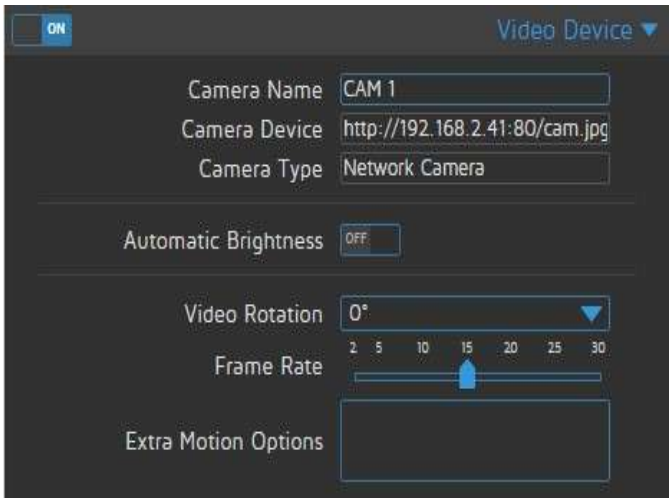

Figure 6: MotionEye Video Device Sub-Menu

Still Images sub-menu

This option allows MotionEye to record (Figure 7).

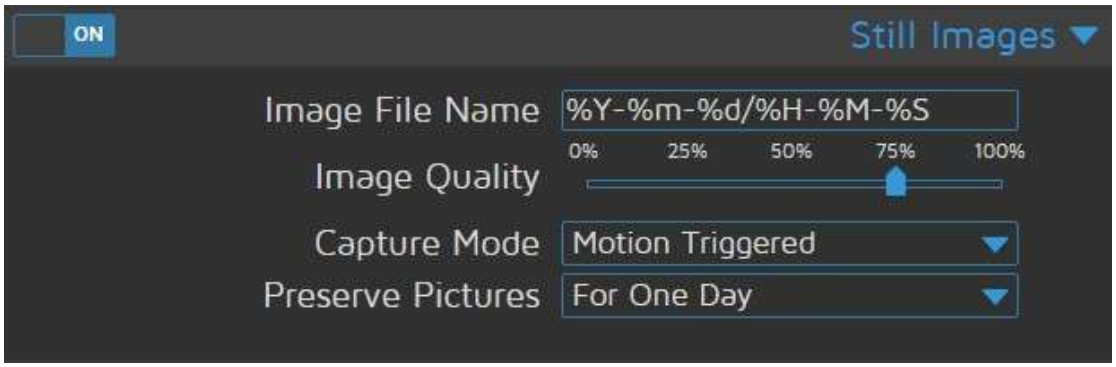

Figure 7: MotionEye Still Images Sub-Menu

Movie Sub-Menu

This sub-menu is enabled to allow recording of movies in MPEG format. It is very similar to the image sub-menu. However, there is an option for maximum movie length.

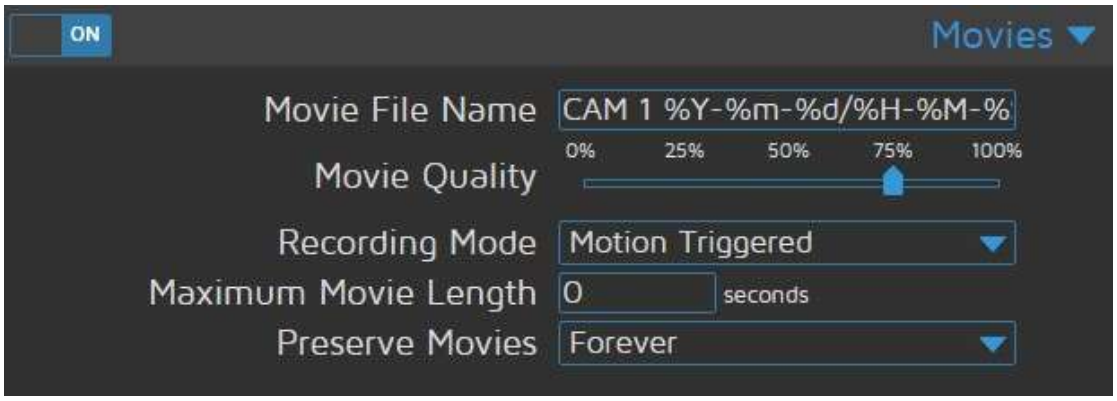

Figure 8: MotionEye Movies Sub-Menu

Motion Detection Sub-Menu

Motion detection in this study is done using program motion. Several parameters are considered as the movement which triggers the detection and subsequently other actions like sending notifications, recording a video and or capturing an image (Figure 9).

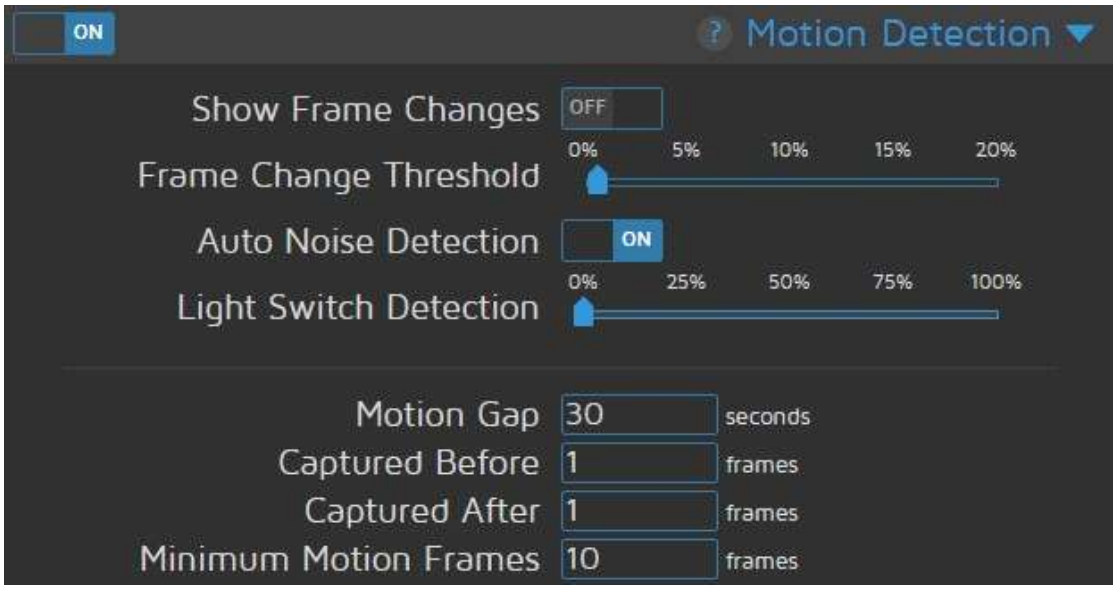

Figure 9: MotionEye Motion Detection Sub-Menu

Motion Notification Sub-Menu

This is responsible for enabling certain notifications to be sent once there is detection. There are various types of possible ways in which notification can be configured, including email to which is attached to the image(s) taken when the motion was detected (Figure 10).

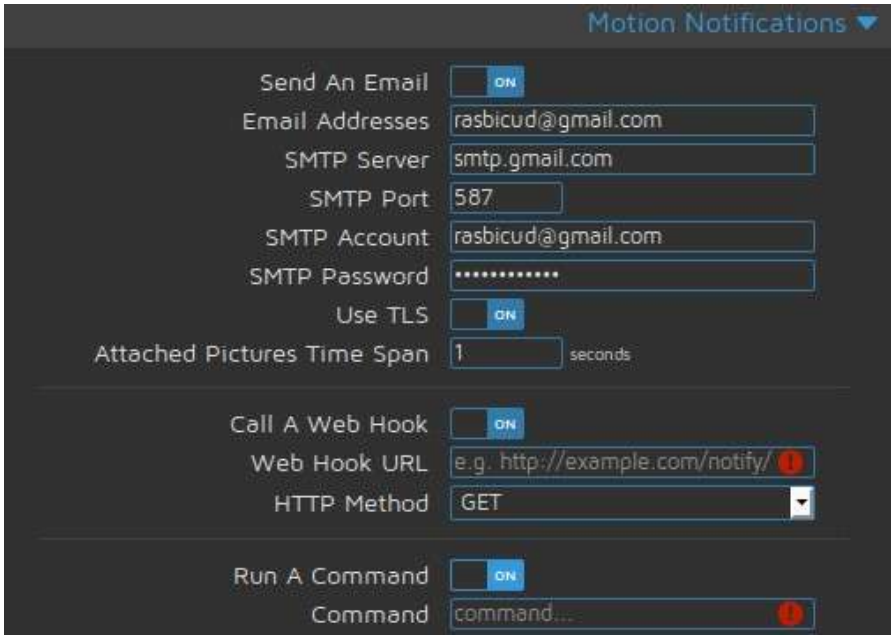

Figure 10: MotionEye Motion Notification Sub-Menu

Working Schedule Sub-Menu

This sub-menu is used to determine a daily schedule per week in which motion detection is enabled. This allows the configuration of motion detection in a particular timeframe (Figure 11).

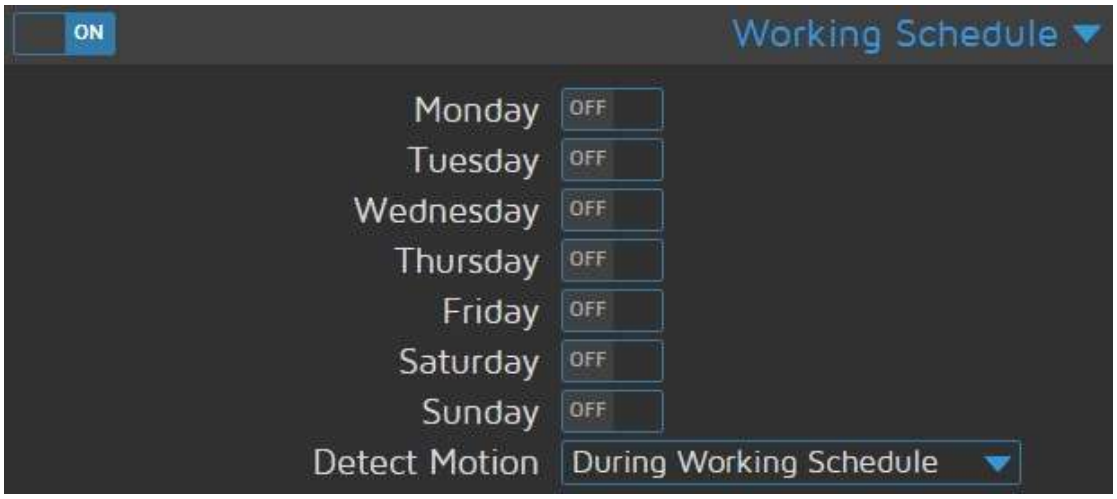

Figure 11: MotionEye Working Schedule Sub-Menu

The wireless network could also be enabled and configured accordingly. Raspberry Pi is portable and connection via Wi-Fi makes it easy to be placed anywhere within the Wi-Fi coverage.

TEST AND RESULTS ANALYSIS CONSTRUCTED DEVICE

After a successful design of the intruder detection system, using the Raspberry Pi and Pi camera module.

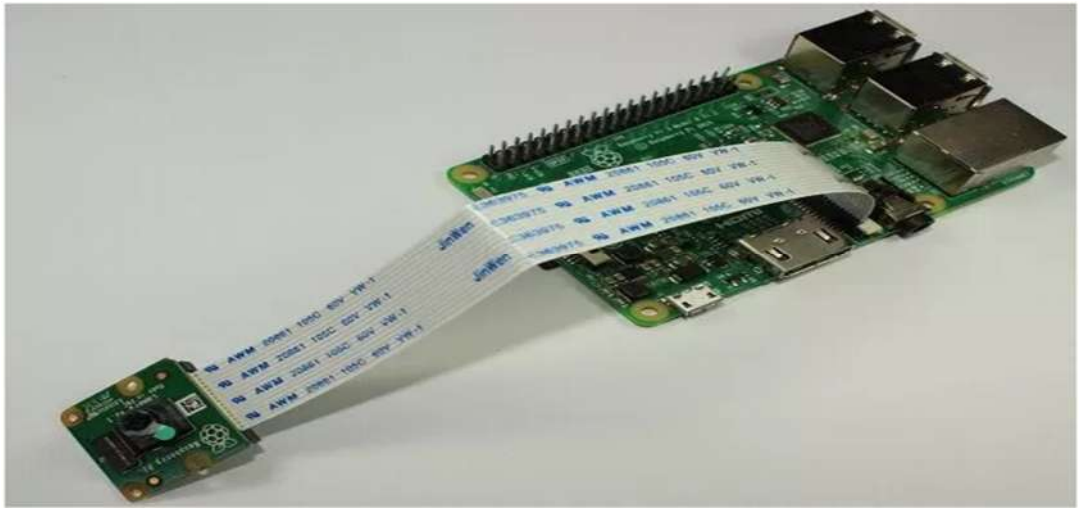

Figure 12: Pi camera module connected to a raspberry pi board (random nerd tutorials, n.d.)

DETECTION AND RECORDING USING CAMERA

Table 1: Different threshold level of the camera

Frame threshold	0	5	10	15	20
Motion detection	NO	YES	YES	YES	YES
CAPTURE	NO	NO	YES	YES	YES
RECORD	NO	NO	YES	YES	YES

The frame threshold determines how well the system will perform and how fast it will record and capture images of an object intruding the area. At 5% threshold, the camera could only view the area and moving objects, but could not take any record of movements, i.e. it neither took pictures nor recorded video (Table 1), however, it viewed the surrounding. At the 10% threshold, the camera viewed and captured the movements in the covered area. The records for both video and images were saved but at a minimal rate. At this 10% threshold, the rate of motion detection is low. Sometimes, the object had left the covered area without been captured by the camera. In this scenario, the record saved did not aid security much and or intrusion alert as the actual image of the object that intruded were not captured. Notwithstanding, it was still an indication that there was an intrusion.

At the 15% threshold, the performance was better. The camera could view and take a record of detected motions. This threshold did not capture the image of the moving object at the exact time of detection but the camera started recording as soon as it sensed motion. The capture was effected slightly negatively because of the time being used by the system in processing the motion detected while the video was being recorded as soon as the object was detected.

At the 20% threshold, the performance was fair, better than the 10% threshold but with no much difference compared to the case of the 15% threshold.

RESULTS OBTAINED

For a 5% to 20% threshold, the camera was configured to use still image and records for 10 seconds. Thereafter, the images were to be sent to the property owner via email. The system was configured also to send an SMS alert that will enable the property owner to act fast to prevent an intruder from carting away valuables. The SMS alert was sent via the bulk SMS service, which is cheaper compared to implementing a GSM module. As such, the user (the property owner) was able to receive both emails (which included the video and pictures taken) and the SMS alert about the detection of the intruder. The copies of the pictures and videos were also stored on the Raspberry Pi. Figure 12 shows the web interface and the Raspberry Pi camera module recording.

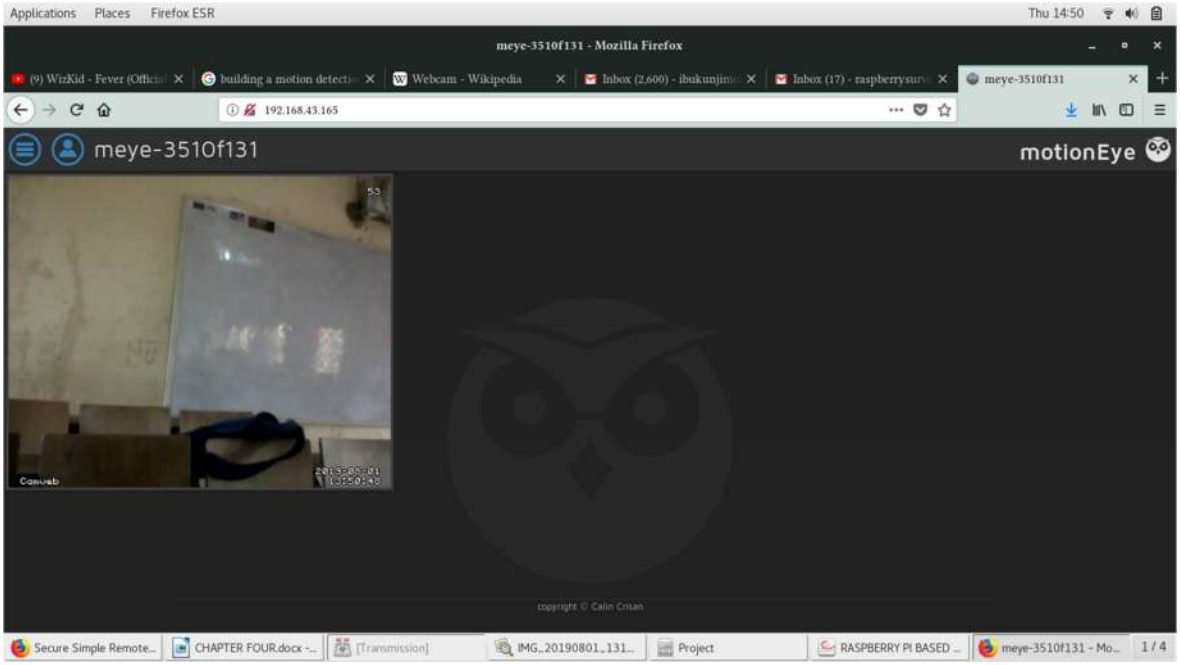

Figure 12: The web interface and the Pi camera module recording

In Figure 12, the screenshot of the web interface of the MotionEyeOS depicted the defined area for surveillance and the bag as the object that was been protected. Since no motion detected, the camera did not capture it. The system is configured to automatically scan the defined (covered) area.

Figure 13 shows the image gotten from the Pi system indicating the capturing of an intruder. The system detected motion and captured the whole area at the same time, recording all activities for 10 seconds.

Figure 13: Image got from the pi system showing the capturing of an intruder.

EMAIL NOTIFICATION

After detecting motion, as the system was programmed to notify the property owner via email, precisely G-Mail (Figure 15). The email was sent to the property owner (Figure 15 – 17).

Figure15: Email sending over the Internet.

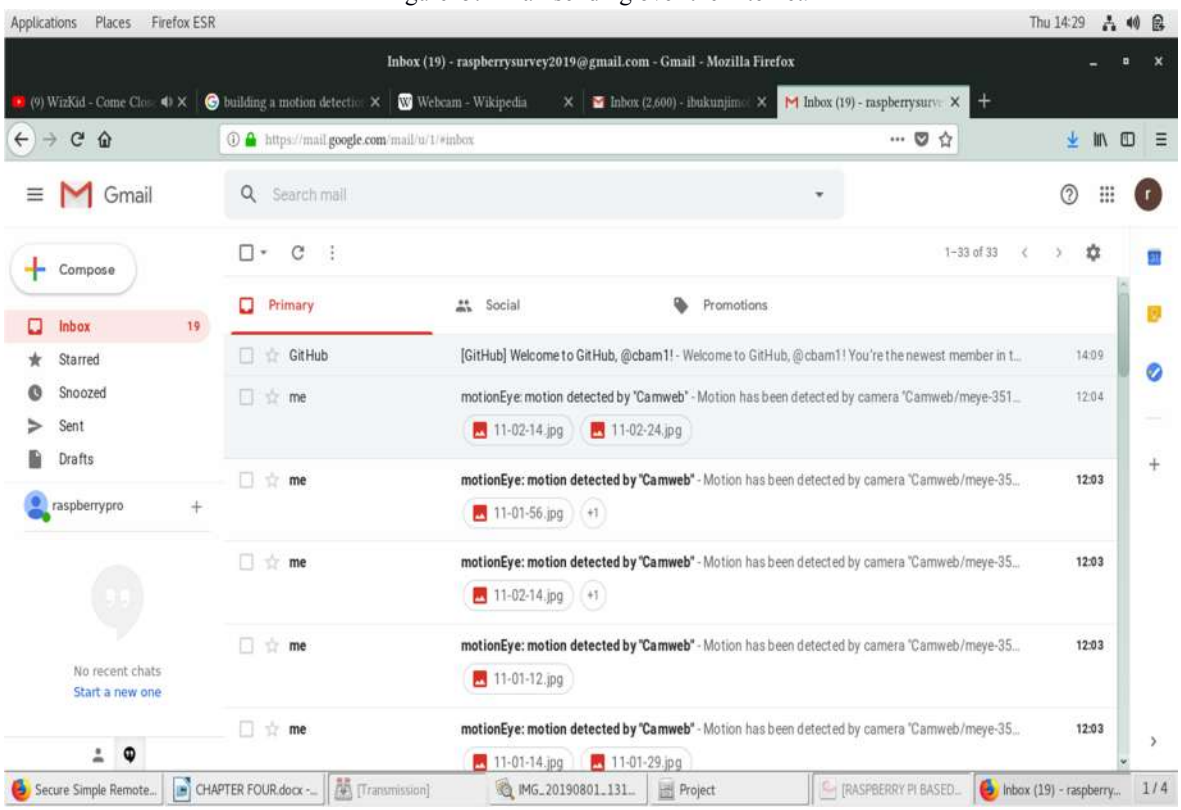

Figure16: An image captured by the camera (Image of an intruder).

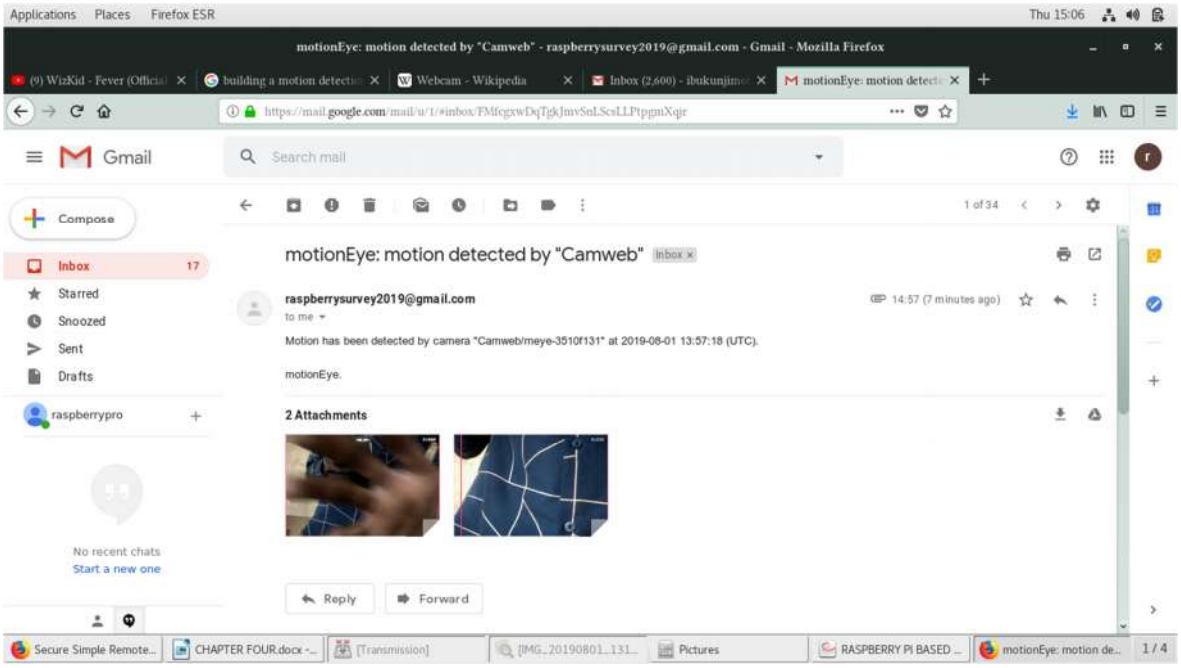

Figure17: Email notification.

SMS NOTIFICATION

The system was also configured to send a text message to the property owner's phone number as an intrusion detection alert via bulk SMS service provider's site (Figure 18).

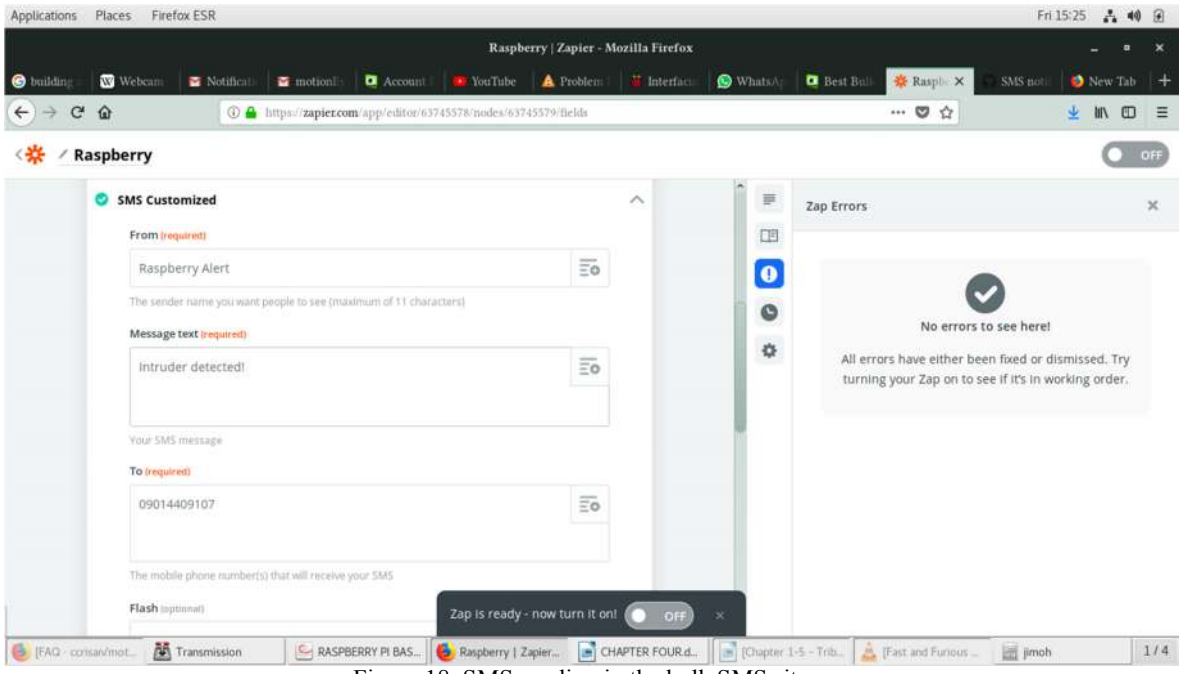

Figure 18: SMS sending in the bulk SMS site.

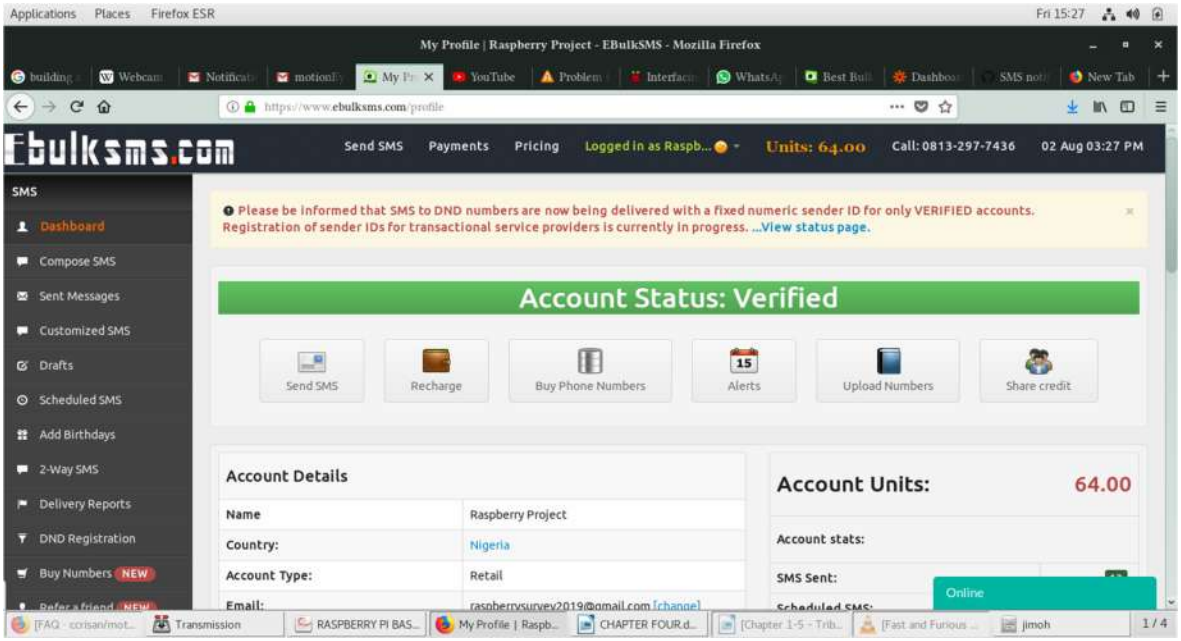

Figure 19: The bulk SMS website

Figure 20: The SMS received after the raspberry Pi sent the mail.

Figure 18 - 20 show how the email was being linked to a bulk messaging site. SMS was sent immediately an email was delivered. This helps notify the property owner about the intrusion immediately when he/she is not online.

The Raspberry Pi based surveillance system is not only a cost-effective system but also convenient and user-friendly. It provides the capability of collecting authentic and purposeful information. Moreover, the user, if so wish, can configure the system to have an online live stream of what is going on where the system is located. Thus, after getting a notification, the owner only needs to simply enter the IP address along with the stream port number on a web browser; and he/she then would be seeing what is happening in real-time. Technologically, Raspberry Pi is the surveillance system of the future not simply because of its portability but because of its capabilities.

CONCLUSION

This work is of excellent use for home protection as it is cheap and it has low energy consumption compared to traditional CCTV camera (Maksimović, 2014) (MONA, 2018) (Sharma, 2017). Incorporating this technique will positively contribute to the present security system. Unlike CCTV cameras, the Raspberry Pi is cheaper and gives high resolution and low power consumption features.

The security level is increased due to the usage of Raspberry Pi which sends the images to the user (the property owner) at low cost thereby being affordable by a majority. Raspberry Pi based surveillance system using innovative technology being a smart economic and efficient platform for implementing the home security system has a lot of advantages among which are that necessary action can be taken within a short time by the property's owner and or security agent. Furthermore, its maintenance is considerably cheap and very affordable. Though presently the option of high-quality image processing is not achieved in the Raspberry Pi because of system constraints which are processor speed, the Raspberry Pi and the related open source applications with its ever-growing community and development provide great hope for a better and easily affordable security system in the near future.

RECOMMENDATION FOR FUTURE WORK

The future work should take into consideration better image processing in the Raspberry Pi considering the processor speed.

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