UNIVERSITY OF NAIROBI

DEPARTMENT OF ELECTRICAL AND INFORMATION ENGINEERING

RASPBERRY PI BASED SECURITY SYSTEM

PRJ INDEX 156

BY:

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Mr. Ondeng' Oscar

DEDICATION

To you who always believed in me - Mum.

ACKNOWLEDGEMENTS

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ABSTRACT

As an essential constituent of many associations' security and safety precedence, video surveillance has established its importance and benefits numerous times by providing immediate supervising of possessions, people, environment and property. This project deals with the design approach of an Embedded Real-Time Surveillance System Based Raspberry Pi SBC for intruder detection that reinforces surveillance technology to provide essential security to our life and associated control and alert operations.

The proposed security solution hinges on our novel integration of cameras and motion detectors into web application. Raspberry Pi operates and controls motion detectors and video cameras for remote sensing and surveillance, streams live video and records it for future playback. This research is focused on developing a surveillance system that detects strangers and to response speedily by capturing and relaying images to owner based wireless module.

This Raspberry Pi based Smart Surveillance System presents the idea of monitoring a particular place in a remote area. The proposed solution offers a cost effective ubiquitous surveillance solution, efficient and easy to implement.

This project will also present the idea of motion detection and tracking using image processing. This type of technology is of great importance when it comes to surveillance and security. Live video streams will therefore be used to show how objects can be detected then tracked. The detection and tracking process will be based on pixel threshold.

Keywords: *Embedded System, Raspberry PI, Surveillance System, Motion Detection, tracking, video processing*

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ABBREVIATIONS

CCTV……………………..Closed Circuit Television
DVR………………………Digital Video Recorder
IP Camera…………………Internet Protocol Camera
VPN……………………….Virtual Private Network
LCD……………………….Liquid Crystal Display
SBC………………………..Single Board Computer
RPI…………………………Raspberry Pi
TCP/IP…………………….Transmission Control Protocol/Internet Protocol
GSM………………………Global System for Mobile Communication
PIR………………………..Passive Infrared Sensor
P2P………………………...Point to Point
VCR………………………Video Cassette Recorder
HDMI……………………..High Definition Multimedia Interface
GPIO………………………General Purpose Input/Output
DAC……………………….Digital to Analog Converter
SSH……………………….Secure Shell
SMTP……………………..Simple Mail Transfer Protocol
MIME…………………….Multipurpose Internet Mail Extension

CHAPTER ONE

1.1 General Background

The demands on video surveillance systems are rapidly increasing in the present day. One of the first things people will want to know about their surveillance system is whether or not they have the ability to connect to it over the internet for remote viewing. In the past, security systems had to be monitored by a guard who was locked away in a room all day watching the monitors to make sure that nothing would happen. The other option was to come back and review the footage but damage could have happened. Therefore, researchers and scientists had to come up with ways of overcoming that and thus improving security at large.

Commercial spaces, universities, hospitals, casinos and warehouses require video capturing systems that have the ability to alert and record beside live video streaming of the intruder. The advancements in video surveillance technology have made it possible to view your remote security camera from any internet-enabled PC or smartphone from anywhere in the word. This encompasses the use of CCTV (DVRs) systems and IP cameras. This technology is awesome but its cost of implementation has proven to be an impediment especially for a small home application.

Therefore, new innovative technology revolves around affordability of a product in terms of its cost and ease of implementation. The Raspberry Pi crosses both criteria in that it is a cheap, effective computer which can be interfaced with other modules to realize systems with immense functionality. A lot can be done on it ranging from motor speed control, automatic lighting, VPN server, security system etc. [1] [2]. The latter is of great interest in this project.

The Raspberry Pi microcomputer is capable of implementing a cost effective security system for various applications. This new arising technology related to security provides a comfortable and safe environment for small homes. The various objectives of the system are to detect an intruder, take an image of the intruder and also convey an alert message to the facility owner. In doing so it thus allows for remote monitoring of homes from anywhere in the world.

The system to be designed cannot wholly replace the role of CCTV and IP surveillance cameras especially in large commercial set ups but will make it easy for low income home owners to monitor their homes at a very affordable price. In addition to the fact that the Raspberry Pi board is cheap, the camera to be used in this case is relatively cheap compared to the others. The whole security system circuitry is simple and easy to implement.

Image processing is a term which indicates the processing on image or video frame which is taken as an input and the result set of processing is may be a set of related parameters of an image. The purpose of image processing is visualization which is to observe the objects that are not visible. Analysis of human motion is one of the most recent and popular research topics in digital image processing. In which the movement of human is the important part of human detection and motion analysis, the aim is to detect the motions of human from the background image in a video sequence. It also includes detection and tracking [2]. The process of object tracking is segmenting a region of interest from a video frames and keeping track of its motion and position.

1.2 Problem Statement

The need to develop a cost effective surveillance system through innovative technology immensely influenced the development of this project. This project will design and implement a security system based on Raspberry Pi microcomputer. The system should be able to detect motion (intruder), activate a camera to take frames of video after motion is sensed and then send an alert to the facility owner through electronic mail plus an image attachment.

The cost of installation of any security system depends on several factors. First, the type of camera being used is of great consideration. A typical digital camera e.g. CCTV and IP camera with an LCD costs about US $ 450 [25] (different brands can differ on prices) while the Raspberry Pi SBC together with its camera module is estimated at US$ 80[25].

Another aspect of this project is to present an idea of monitoring and tracking of an intruder through the use of a camera. Any object passing through the field of view of camera will be detected then tracked in case the object attempts to move any body part.

1.3 Objectives

1.3.1 Overall Object

The main aim of this project is to design and develop a security system that includes features such as motion detection, image processing and emailing or SMS to facility owner. The system is to be based on Raspberry Pi SBC.

The specific objectives are:

- To study and describe how the Raspberry Pi can be interfaced with a motion detector and Pi camera.
- To study how a Raspberry Pi can be programmed so as to be able to send an email to a prescribed mailhub.
- To develop and build a prototype of the surveillance system based on the Raspberry Pi SBC.
- To design and implement a motion detecting and tracking system for real time video analysis.

1.4 Scope of the project

This project is focused on developing a surveillance system that detects motion and to respond speedily by capturing an image and relaying it to an administrator device through the internet platform. The system will require Raspberry Pi module, motion detection sensor, camera and internet connection. It will come up with an implementation of a surveillance system which presents the idea of monitoring a particular place in remote areas. The system can be monitored by the user form anywhere in the world.

However, this project will not attempt to design the motion detection device, camera or the Raspberry PI. It will therefore use these systems together with a suitable program script to accomplish a real time surveillance system as desired.

1.5 Justification

The security system to be designed in this project can be used extensively to monitor facilities by owners. The owner shall be able to monitor their property from wherever they are in the world. It will not replace the use of CCTV and camera surveillance systems but reduce the cost of implementation of a basic security system. This thus will enable small home owners to secure their facility at a cheaper cost.

CHAPTER TWO

2.1 Related Works on security Systems

In the present day, researchers and developers have come up with a wide range of surveillance systems that are used for remote monitoring, alerting as well as controlling tasks through affordable and easy to implement hardware systems. Some have so far been realized while others still remain a proposition.

An embedded home surveillance system which assesses the implementation of a cost effective alerting system based on small motion detection was presented by Padmashree A. Shake and Sumedha S. Borde. They worked on implementing cheap in price, low power consumption; well utilize resources and efficient surveillance system using a set of various sensors. Their system helps to monitor the household activities in real time from anywhere and based on microcontroller which is considered nowadays as a limited resource and an open source solution compared to SBC[3].

D. Jeevanand worked on designing of a networked video capture system using Raspberry Pi. The proposed system works on capturing video and distributing with networked systems besides alerting the administration person via SMS alarm as required by the client. Their system was designed to work in a real-time situations and based on Raspberry Pi SBC. Contrasting to other embedded systems their real-time application offers client video monitor with the help of alerting module and SBC platform[4].

Sneha Singhd and his team described IP Camera Video Surveillance system using Raspberry Pi technology. The Researchers aimed at developing a system which captures real time images and displays them in the browser using TCP/IP. The algorithm for face detection is being implemented on Raspberry Pi, which enables live video streaming along with detection of human faces. The research did not include any of surveillance reactions[5].

Mahima F. Chauhan and Gharge Anuradha offered to design and develop a real time video surveillance system based on embedded web server Raspberry PI B+ Board. Their system has low cost, good openness and portability and is easy to maintain and upgrade. Thus this application system provides better security solutions. This system can be used to effect security in banking halls, industry, environment and in military arts[6].

Jadhav G. J evaluates in 2014 the use of various sensors, wireless module, microcontroller unit and finger print module to formulate and implement a cost effective surveillance system. He and his team adopted an ARM core as a basis processor of the system. PIR sensor is used to detect motion in the vision area, while vibrating sensor is used to sense any vibration events such as sound of breaking. The intruder detection technique is proposed by using the PIR sensor that detect motion and trigger a system of alerting and sending short message service through GSM module for a specified phone number. Their work can be featured by adopting numerous diverse kinds of demanding database and thus it will be more secure and difficult to hack[7].

In 2014, Sanjana Prasad and his colleagues worked on developing a mobile smart surveillance system based on SBC of Raspberry Pi and motion detector sensor PIR. Their development boosts the practice of portable technology to offer vital safety to our daily life and home security and even control uses. The objective of their research is to develop a mobile smart phone home security system based on information capturing module combined with transmitting module based on 3G technology fused with web applications. The SBC will control the PIR sensor events and operates the video cameras for video streaming and recording tasks. Their system has the capability to count number of objects in the scene[8].

Uday Kumar worked on implementation of a low cost wireless remote surveillance system using Raspberry Pi. Conventional wireless CCTV cameras are widely used in surveillance systems at a low cost. He and his team implemented a low cost and secure surveillance system using a camera with Raspberry Pi and the images acquired have to be transferred to the drop box using a 3G internet dongle. This was successfully implemented using Raspberry Pi and 3G dongle[9].

2.2 Evolution of Security

With the invention of electricity, the art of home protection was greatly improved. In 1853, the first patent on electro-magnetic alarms meant that businesses and wealthy residents could secure valuables. Magnetic contacts were installed on the windows and doors that, when tripped, would send a signal through the electromagnetic wiring and sound an alarm. These groundbreaking security systems were effective in deterring break-ins from occurring[10].

According to Cisco Expo, major strides have been made with regards to surveillance systems. After the alarm system, analog video camera with Video Cassette Recorder evolved. It had poor imaging and no remote access. To overcome the drawbacks of this system, digital video recorders evolved. They gave good quality pictures and enable for transmission of video signals through data networks and thus allowed for remote monitoring[11].

Network Video Recorder then emerged. They have the advantages of the DVRs but have other merits over DVRs. They give more storage options and network connection. The most superior version is the type that uses Cisco Video Surveillance Platform. They give secure remote access and control from anywhere, fail-safe redundant storage, easy integration with other systems and enterprise class storage and support[11].

2.3 Security System Definition

Security literally means a way or method by which something is secured through a system of interworking components and devices. On the other hand, **security systems** are networks of integrated electronic devices working together with a central control panel to protect against burglars and other potential intruders[12]. Security systems work on the simple concept of securing entry points into a home with sensors that communicate with a control panel or command center installed in a convenient location. The sensors are typically placed in entrances as well as easily accessible windows. A typical home security system has the following components: A control panel, which is the primary controller of a security system, door and window sensors, motion sensors, wired or wireless security cameras, high-decibel siren or alarm and window stickers [11].

2.4 Current Security Technologies

2.4.1 Arduino Based Home Security System

This security system project deals with the design and development of a theft control system for home, which is being used to prevent/control any theft attempt. The developed system makes use of an embedded system comprising of an open hardware microcontroller(Arduino) and a modem based on Global System for Mobile communication (GSM) technology[13].

The designed and developed system can be installed in the home. An interfacing intrusion-detector unit is also connected to the microcontroller-based security system. The system thus incorporates a passive infrared sensor (PIR) for motion detection. In case of an intrusion attempt, a warning message is being transmitted by the system (as an sms) to the owner's mobile phone, or to any pre-configured mobile phone number for further processing.

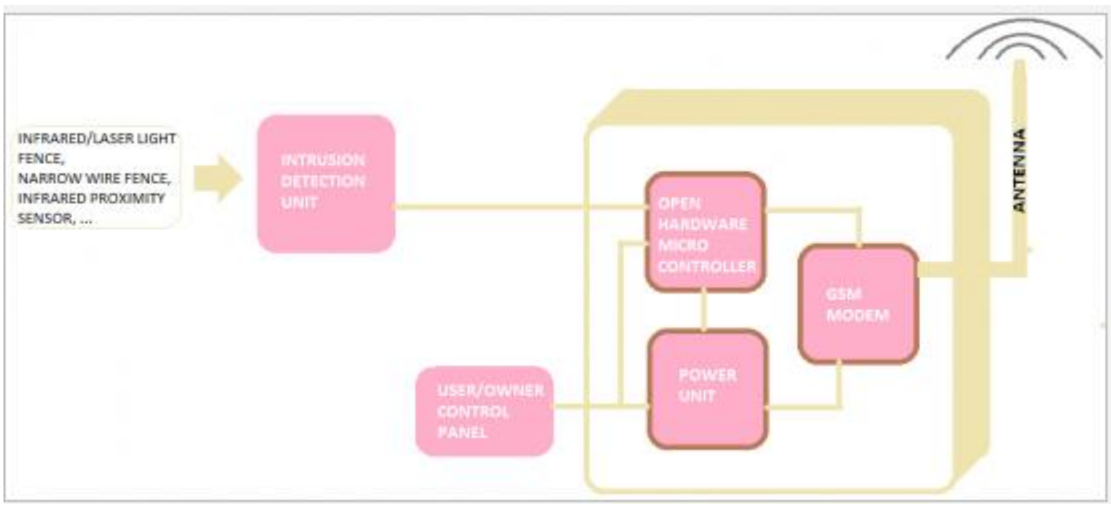

Figure 1: Arduino based home security system block diagram[13]

The security system comprises of an Arduino Uno microcontroller, a standard SIM900A based GSM/GPRS modem and PIR sensor. The whole system can be powered from any 12VDC/2A power supply unit/battery.

2.4.1.1 How it works

Its working principle can be analyzed from the block diagram of fig 1.1. When input power is applied to the system, the system goes into standby mode. However, when the terminals of connector joining PIR with the Arduino microcontroller are short circuited, the preprogrammed warning message is automatically transmitted to the concerned mobile number. This system however does not transmit the image of the intruder. It only conveys a notification message.

2.4.2 Closed-circuit television (CCTV) Security System

Video surveillance is the use of video cameras to transmit a signal to a specific place, on a limited set of monitors. It differs from broadcast television in that the signal is not openly transmitted, though it may employ point to point (P2P), point to multipoint, or mesh wireless links.[14] In the U.S. the first commercial closed-circuit television system became available in 1949, called Vericon[15].

2.4.2.1 Operation of a CCTV Security System

The simplest system is a camera connected directly to a monitor by a coaxial cable with the power for the camera being provided from the monitor[16]. The outdoor or indoor camera take several images per second and thus cannot be differentiated by human eye. The images are then transferred via a coaxial cable or optic fibre to a computer placed in a secure location. This computers are monitored by security personnel and responds to any improper behaviors'[17]. These systems have been incorporated with alarm systems so as to send out an alert in case of a security bridge.

Two types of CCTV storage exist; VCR and DVR. The DVR system is more superior as it can be able to transmit digitized video signals over the data networks and thus can allow for remote control and monitoring of the system.

2.4.3 Remote Surveillance IP System

IP surveillance is a digitized and networked version of closed-circuit television (CCTV). In an IP surveillance system, an IP camera records video footage and the resulting content is distributed over an IP (Internet protocol) network[18]. Adding networking capability to digital CCTV provides additional benefits, including:

- Improved ability for remote viewing and control. Anyone on the network can potentially see video from any camera connected to the network.
- IP storage makes it possible to store data in any geographic location.
- Greater ease of distribution. An image of a crime suspect, for example, can be immediately distributed to officials.
- The ability to connect to email and other communications systems so that alerts can be sent automatically.

2.4.4 Raspberry Pi Based Surveillance System

A raspberry pi can be used to implement a security system with motion detection, image processing and alert mechanism. The alert ought to contain a time lapse photo or video and transmitted over the internet. This thus will enable the users to monitor the homes from anywhere in the world.

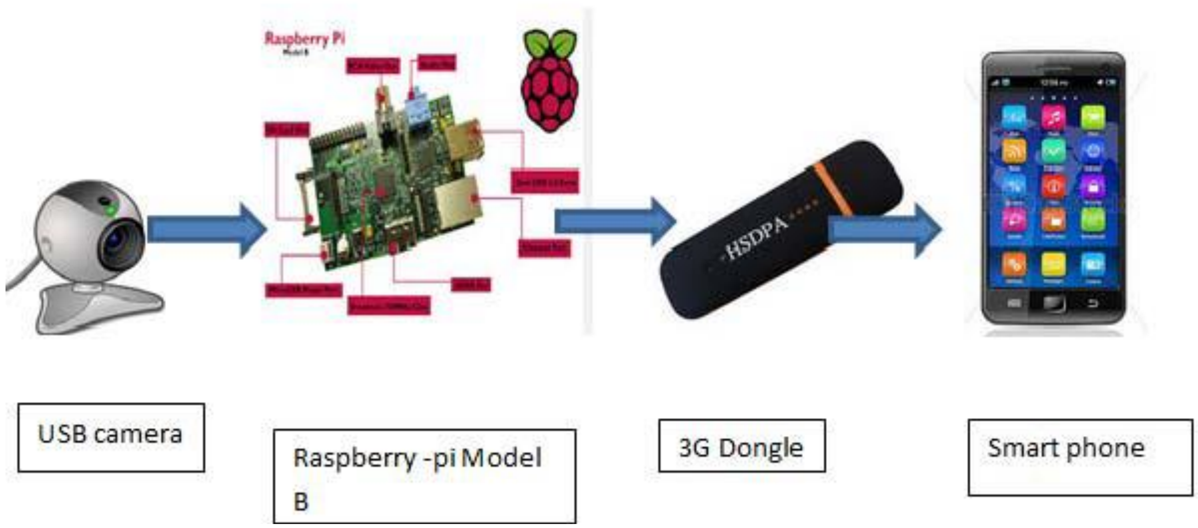

Figure 2: Raspberry Pi based Security System [19]

As shown in the figure above, the whole architecture of the system is composed of five modules namely:

- Raspberry Pi SBC model
- Pi camera/USB Camera
- PIR sensor
- WiFi Dongle
- Monitor/laptop

The role of each module shall be discussed in detail later in this chapter.

2.4.4.1 Why Raspberry Pi based Security Systems for Homes?

Several criteria have been used to select a security system required to safeguard a facility. The chief among all these has been the cost of implementation of such a system. The Raspberry Pi is also a very versatile device whose functionality is not limited. It can be extended from being merely a security device to temperature control device, automatic lighting and proxy server. The following reasons explain the need to have your home security system based on Raspberry Pi:

- An IP Camera system has the ability to distribute alarm messages over the internet as well as the Raspberry Pi based security system. However, the cost of an IP Camera makes it not easily affordable to small home owners.(insert cost plus citation) Thus they can be deployed in large industrial set ups, defence forces, police departments etc.
- Arduino microcontroller based security system can be relatively cheaper to implement as compared to Raspberry Pi based system but its memory capacity renders it more ineffective especially when trying to interface with other modules e.g. camera, monitors, motion sensors, mouse and keyboard. Raspberry Pi has an extendable SD card storage and can be expanded to suit the needs of an individual. Moreover, Arduino

microcontroller requires a GSM modem to enable it transfer information through the internet. The Raspberry Pi has a port to connect it to the internet.

- A CCTV surveillance system is expensive to purchase and install compared to the system in question. It requires a DVR system to connect it to the data networks through TNP/IP. A DVR on its own is very expensive. Hence such a system may not be afforded by low income home owners.

2.5 Image Processing

Image Processing is a technique to enhance raw images received from cameras/sensors placed on satellites, space probes and aircrafts or pictures taken in normal day-to-day life for various applications[20]. Most importantly, this technology is used in surveillance.
There are two methods available in Image Processing:

2.5.1 Image Processing Techniques

2.5.1.1 Image Blurring

Gaussian blur (also known as Gaussian smoothing) is the result of blurring an image by a Gaussian Function. It is a widely used to reduce noise and detail[20]. The visual effect of this blurring technique is a smooth blur resembling that of viewing the image through a translucent screen, distinctly different from the bokeh effect produced by an out-of-focus lens or the shadow of an object under usual illumination[19]. Gaussian smoothing is also used as a pre-processing stage in computer vision algorithms in order to enhance image structures at different scales[21]. The equation of a Gaussian function in one dimension is:

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}} \qquad \text{……………………………………………………………………. (1)}$$

2.5.1.2 Grayscalling

Grayscale is a range of shades of gray without apparent color[22]. The darkest possible shade is black, which is the total absence of transmitted or reflected light. The lightest possible shade is white, the total transmission or reflection of light at all visible wavelengths [22]. Intermediate shades of gray are represented by equal brightness levels of the three primary colors (red, green and blue) for transmitted light, or equal amounts of the three primary pigments (cyan, magenta and yellow) for reflected light[23].

In the case of transmitted light (for example, the image on a computer display), the brightness levels of the red (R), green (G) and blue (B) components are each represented as a number from decimal 0 to 255, or binary 00000000 to 11111111. For every pixel in a red-green-blue (RGB) grayscale image, R = G = B. The lightness of the gray is directly proportional to the number representing the brightness levels of the primary colors. Black is represented by R = G = B = 0 or R = G = B = 00000000, and white is represented by R = G = B = 255 or R = G = B = 11111111. Because there are 8 bits in the binary representation of the gray level, this imaging method is called 8-bit grayscale[20].

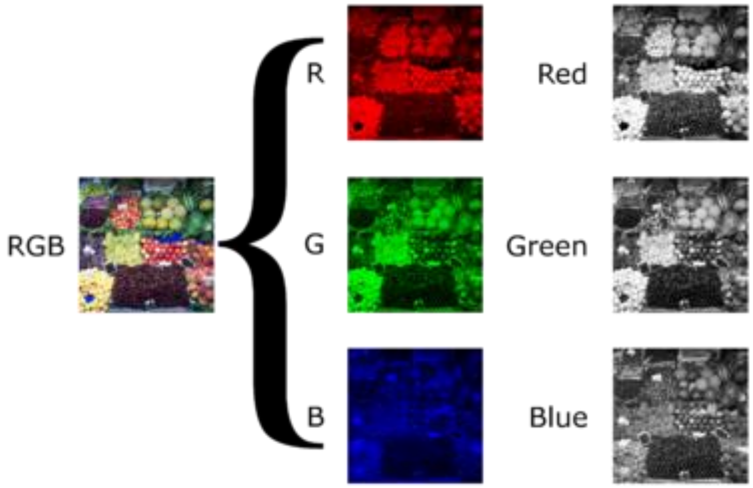

Figure 3: Original and gray images [19]

2.5.1.3 Thresholding

Figure 4: Thresholding [19]

Thresholding is a process of converting a grayscale input image to a bi-level image by using an optimal threshold[22]. The purpose of thresholding is to extract those pixels from some image which represent an *object* (either text or other line image data such as graphs, maps). Though the information is binary the pixels represent a range of intensities. Thus the objective of binarization is to mark pixels that belong to true foreground regions with a single intensity and background regions with different intensities.

2.5.2 Object Detection and Tracking

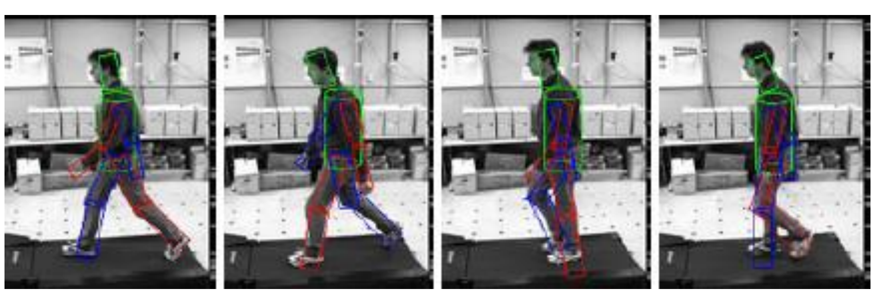

Figure 5: Detecting moving object [23].

The above can be achieved through the implementation of the algorithm below:

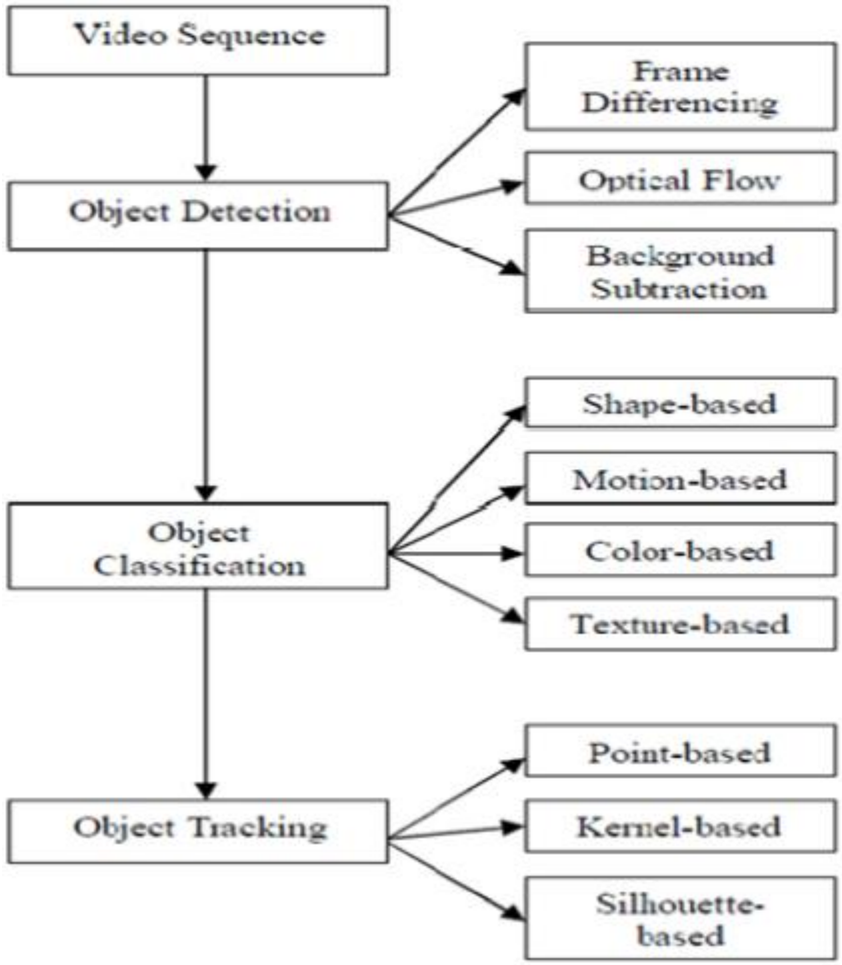

Figure 6: Video analysis [24].

2.5.3 Methods of Detection and Tracking

2.5.3.1 Background Subtraction Method

A very widely used method which is simple to implement by just subtracting the current frame from previous frame and obtaining threshold value of difference between given pixel value and obtained pixel value [24]. If threshold value is greater than the given the pixel it is considered as foreground. This method is not as appropriate as it is highly inaccurate and gives false rate detection.

2.5.3.2 Real Time Background Subtraction and Shadow Detection Technique Theory

It describes two type of distortion namely brightness distortion and chromaticity distortion based on RGB values of pixels in given image. This method is accurate up to some extends as it also detect the shadow part of object [23].

2.5.3.3 Template Matching

Template Matching is probably the best method for some specific environment. It's the most accurate although sometimes there is lack of originality in object detected. Object can be detected for one specific video using a template cropped from the video. However, there is no guaranteed accuracy because all that is known is the best match for each frame; no scanning is done on the percentage template matches the frame. It only works if the object is always in the video, otherwise it will create a false detection [23].

2.5.3.4 Shape Based

Shape based method is used to detect objects in real-world images. The shape features are more striking as compared to local features like SIFT because most object categories are better described by their shape then texture, such as cows, horses and cups and also for wiry objects like bikes, chair or ladders, local features contain large amount of background noise. Thus shape features are often used as a replacement to local features [23].

2.5.3.5 Optical Flow Method

Sequences of ordered images allow the estimation of motion as either instantaneous image velocities or discrete image displacements. The optical flow methods try to calculate the motion between two image frames which are taken at times *t* and $t + \Delta t$ at every voxel position. These methods are called differential since they are based on local Taylor series approximations of the image signal; that is, they use partial derivatives with respect to the spatial and temporal coordinates [23].

For a 2D+*t* dimensional case (3D or *n*-D cases are similar) a voxel at location (x, y, t) with intensity $I(x, y, t)$ will have moved byΔx, and Δt between the two image frames, and the following *brightness constancy constraint* can be given[23]:

$$I(x,y,t) = I(x + \Delta x, y + \Delta y, t + \Delta t) \quad \text{..........} \quad (2)$$

From these equations it follows that [23]:

$$\frac{\partial I}{\partial x}\Delta x + \frac{\partial I}{\partial y}\Delta y + \frac{\partial I}{\partial t}\Delta t = 0 \quad \text{..........} \quad (3)$$

or

$$\frac{\partial I}{\partial x}\frac{\Delta x}{\Delta t}+\frac{\partial I}{\partial y}\frac{\Delta y}{\Delta t}+\frac{\partial I}{\partial t}\frac{\Delta t}{\Delta t}=0 \quad \text{……………………………………………… (4)}$$

This results in

$$\frac{\partial I}{\partial x}V_x+\frac{\partial I}{\partial y}V_y+\frac{\partial I}{\partial t}=0 \quad \text{……………………………………………….. (5)}$$

Thus:

$$I_xV_x+I_yV_y=-I_t \quad \text{…………………………………………………….. (6)}$$

or

$$\nabla I^T\cdot\vec{V}=-I_t \quad \text{………………………………………………………… (6)}$$

2.6 The Raspberry Pi

The Raspberry Pi is a Linux based microcomputer based on ARM architecture[24]. It was built mainly to aid in developing open source game. The device is estimated to cost about $35 [30] depending on the model.

2.6.1 The Raspberry Pi Models

This part describes the models of Raspberry Pi available. This report will not attempt to provide full specifications but an overview in order to help in making a decision as to which device it is required to accomplish the objectives in question. Currently, five Raspberry Pi models do exist. They are: Model B+, Model A+, Model B, Model A and the Compute Module (currently only available as part of the Compute Module development kit). All these models use the same SoC (System on Chip - combined CPU & GPU), the BCM2835, but other hardware features differ[25].

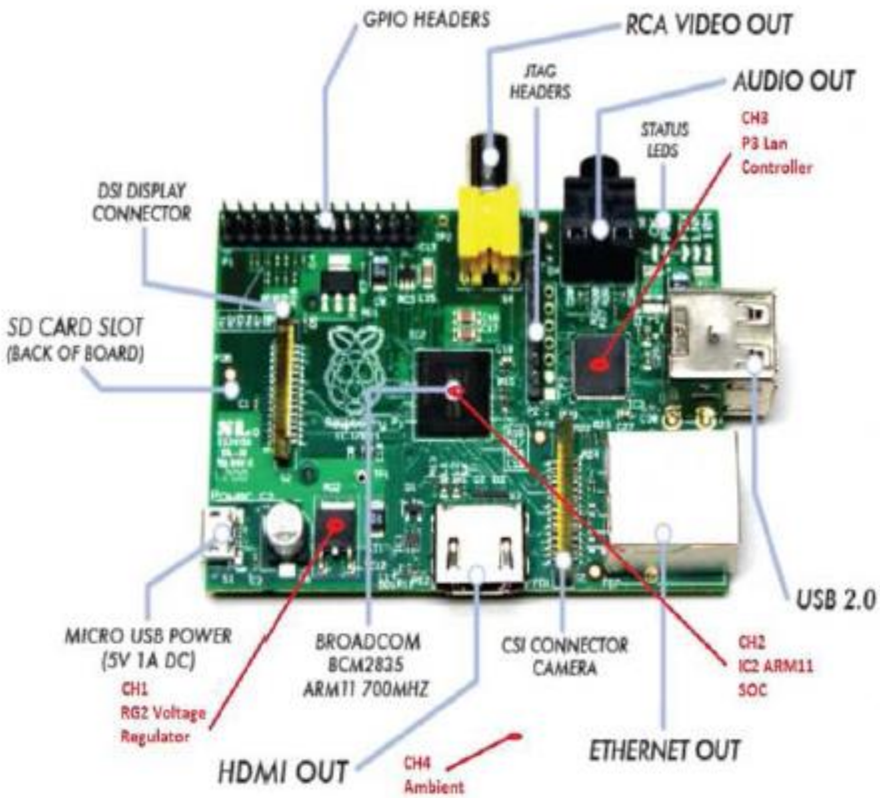

Figure 7: The Raspberry Pi [25].

a) Model B+/B

First release was made in July 2014. This Model is an upgrade of the Model B. It has the following characteristics: 4 USB ports, 40 pins on the GPIO header , Improved power circuitry which allows higher powered USB devices to be attached and now hot-plugged. The full size composite video connector of Model B has been removed and the functionality moved to the 3.5mm audio/video jack and the full size SD card slot of Model B has also been replaced with a much more robust microSD slot[25]. The following details some of the improvements over the Model B:

- Current monitors on the USB ports mean the B+ now supports hot-plugging
- Current limiter on the 5V for HDMI means HDMI cable-powered VGA converters work in all cases.
- 14 more GPIO pins
- EEPROM readout support for the new HAT expansion boards
- Higher drive capacity for analog audio out, from a separate regulator, which means a better audio DAC quality
- No more back powering problems, due to the USB current limiters which also inhibit back flow, together with the "ideal power diode"
- Composite output moved to 3.5mm jack

- Connectors now moved to two sides of the board rather than the four of the original device
- Ethernet LEDs moved to the Ethernet connector
- 4 squarely-positioned mounting holes for more rigid attachment to cases.

b) Model A/A+

This is the basic device, with a single USB port and 256MB of SDRAM. Onboard ports include: Full size SD card, HDMI output port, Composite video output, One USB port, 26 pin expansion header exposing GPIO, 3.5mm audio jack, Camera interface port (CSI-2), LCD display interface port (DSI) and One microUSB power connector for powering the device[25].

2.6.2 Programming the Raspberry Pi

To enable communication with the outside world, the Raspberry Pi has to be programmed with a suitable programming language. These languages include Java, FOTRAN, Pascal, Python, C, C++ etc.[26]. Each language has its own syntax and semantics. RPI can be programmed using any of these languages but for purposes of this project, Python will be of great importance to study. It is provided by default through and thus optimum operation of the Pi can be achieved.

2.6.3 Raspberry Pi Operating Systems

An operating system makes Raspberry Pi run. Since Raspberry Pi is a credit sized computer that is based on Linux, optimum performance of RPI can be achieved if it is therefore operated in this environment. Raspbian provides more than a pure OS: it comes with over 35,000 packages, pre-compiled software bundled in a nice format for easy installation on RPI[25]. Important to note is that the Raspberry Pi does not operate in a Windows environment. To get access to Pi from windows we require Putty Software. Putty is an SSH and TelNet client.

2.6.4 The Pi Camera Module

The Camera Board on the Raspberry Pi is a small printed circuit board with a camera on it. The PCB is connected to a ribbon cable which connects to the Pi itself on its own port. The ribbon can be extendable. The camera on the board is very small (*5MP camera*)[25]. As for now it is the only Camera made specifically for the Pi therefore these specifications cannot be updated. Since it uses 250mA, externally powering the Pi should be sufficient enough for the camera[27].Specific configuration settings are required to initialize the camera plus a Python script to enable it take pictures.

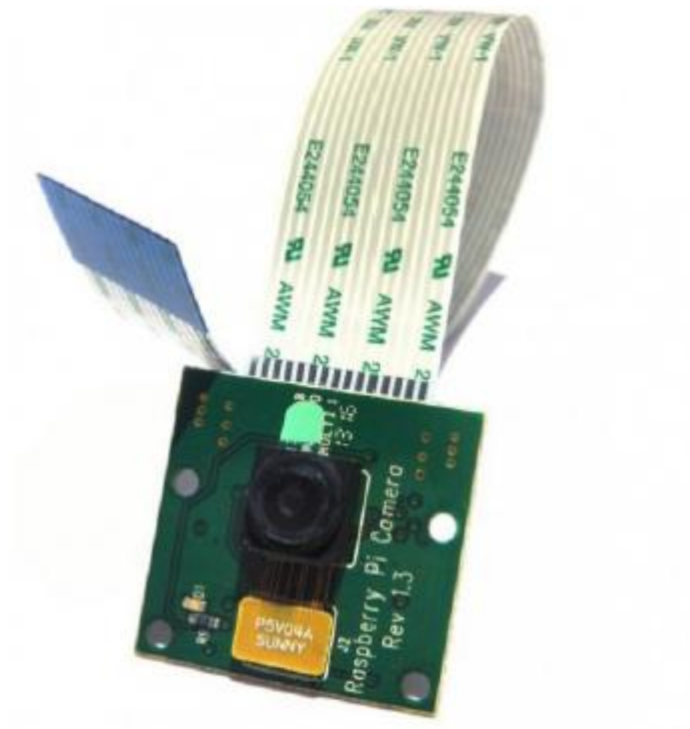

Figure 8: Pi Camera module[25].

2.7 Passive Infrared Sensor

2.7.1 Principle of operation of a PIR Sensor

An individual PIR sensor detects changes in the amount of infrared radiation impinging upon it, which varies depending on the temperature and surface characteristics of the objects in front of the sensor [28]. When an object, such as a human, passes in front of the background, such as a wall, the temperature at that point in the sensor's field of view will rise from room temperature to body temperature, and then back again[28].

The sensor converts the resulting change in the incoming infrared radiation into a change in the output voltage, and this triggers the detection. Objects of similar temperature but different surface characteristics may also have a different infrared emission pattern, and thus moving them with respect to the background may trigger the detector as well[28].

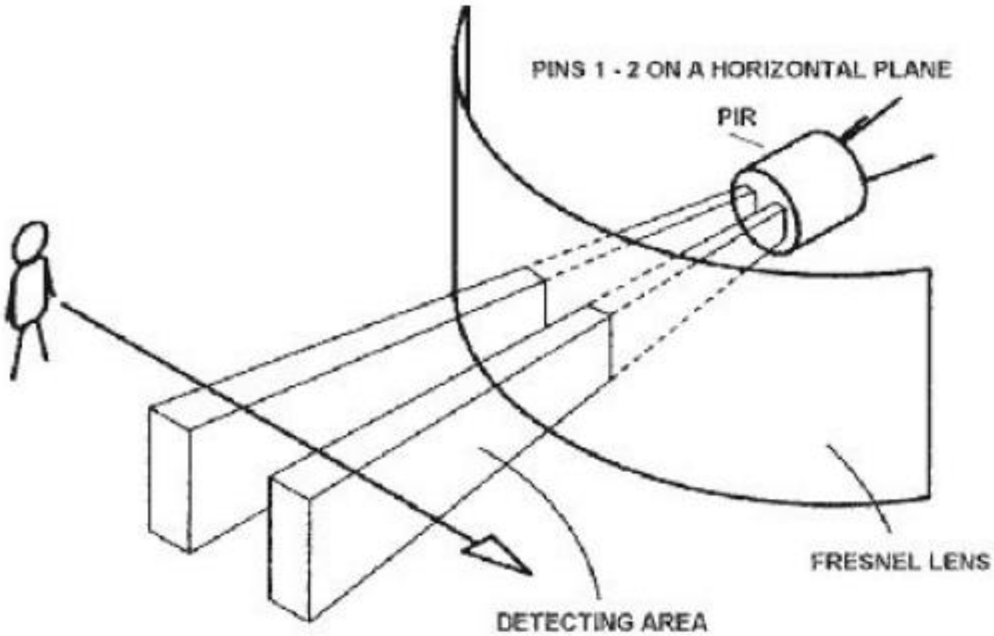

Figure 9: Operation of a PIR sensor[29].

2.7.2 Reading PIR Sensors

Connecting PIR sensors to a microcontroller is really simple. The PIR acts as a digital output so all you need to do is listen for the pin to flip high (detected) or low (not detected). It is likely that you'll want retriggering, so be sure to put the jumper in the H position! [30] Power the PIR with 5V and connect ground to ground. Then connect the output to a digital pin i.e. the GPIO pin of the RPI device. A C/Python code can then be used to read a channel from the PIR sensor[29].

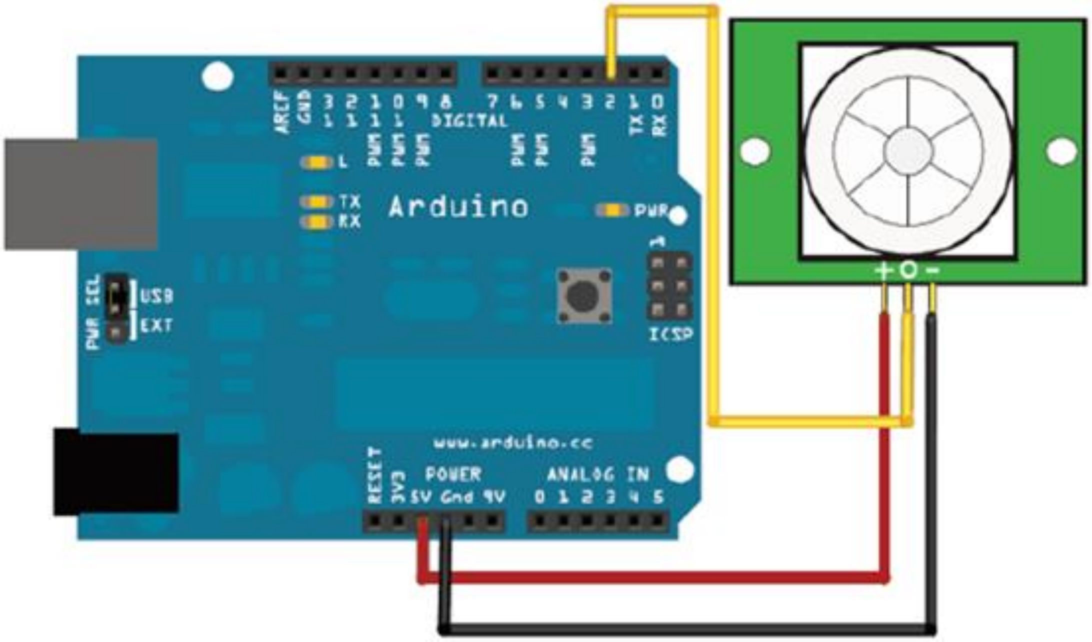

Figure 10: Controlling the PIR sensor from an Arduino Microcontroller [30].

2.7.3 Changing the sensitivity of the PIR sensor

There are two 'timeouts' associated with the PIR sensor[31]:

- The “Tx” timeout: how long the LED is lit after it detects movement - this is easy to adjust on Adafruit PIR's because there's a potentiometer.
- The “Ti” timeout which is how long the LED is guaranteed to be off when there is no movement. This one is not *easily* changed but if you're handy with a soldering iron it is within reason.

2.7.3.1 “Tx” timeout consideration

On Adafruit PIR sensors, there's a little trim potentiometer labeled **TIME.** This is a 1 MΩ adjustable resistor which is added to a 10K series resistor[30]. And **C6** is 0.01uF so;

Tx = 24576 x (10K + R_time) x 0.01u ………………………………………………………….. (7)

If the R_time potentiometer is turned all the way down counter-clockwise (to 0 ohms) then[30];

Tx = 24576 x (10K) x 0.01uF = 2.5 second…………..……………………………………….. (8)

If the R_time potentiometer is turned all the way up clockwise to 1 MΩ then[30];

Tx = 24576 x (1010K) x 0.01uF = 250 seconds ……………………………………………... (9)

2.7.4 Example Applications of the PIR sensor

- Remote camera trigger
- A home-made security system using PIR sensors (which is built into a Start Trek panel!) PIR sensor + Arduino + Servo = automatic cat door!
- Motion detection in home surveillance/security systems [28].

2.8 Email Notification

In order to allow for email notifications to send, the OS needs a program that allows for emails to be sent[31]. Simple Mail Transfer Protocol (SMTP) is a program that allows a system to deliver an email from a local computer to a mailhost. It does not receive mail but can send out mail. SMTP is ideal for situations where alerts are needed to be sent, therefore it is useful when sending notifications.

A python script can be used to achieve this. It may just send a notification without image or can be modified to send an attachment along with the alarm message[17]. For SMTP to support transmission of an attached file, Multipurpose Internet Mail Extension (MIME) is required.

CHAPTER THREE

3.1 Resources

For an embedded real-time surveillance system to be utilized for effective monitoring and alerting, the system has to have at least three functions. These functions are: detection, image processing and alert mechanism. This Raspberry Pi based security system is thus composed of mainly two parts. These are: design hardware and design software

3.2 Design Hardware (System Modules Set Up and Configuration).

The entire system modules consist of seven parts components namely:

- Raspberry Pi Model B+ controller,
- PIR motion sensor,
- RJ45 Ethernet connector,
- Pi camera module
- MicroSD card
- LED and 220 Ohms resistor
- USB powered cable.

3.2.1 Raspberry Pi Model B+

This is the model that was chosen to implement the project. It has merits over other models in that it has increased number of USB ports and large number of GPIO pins. Moreover, this piece of hardware was available at the department.(refer to section two for diagram)

3.2.1.1 Booting Up the Pi Model

Raspbian 'Wheezy' image was written into the 4GB Micro SD card. This was the operating system chosen to run on the Pi because the OS has been optimized and ported to the Raspberry Pi ARM architecture. This OS has very good integration with the hardware and comes pre-loaded with a GUI and development tools.

After slotting in the Micro SD card and connecting RJ45 Ethernet cable to the Pi and the personal computer with Putty software (Putty is an SSH client used to remotely access and control the Pi from computer running on Windows platform) the system was powered. Putty was then started and the default static IP address of the Pi was typed into the host name field. While doing this, windows pc was set to manual IP configuration. This was to allow it communicate with the Raspberry Pi.

3.2.1.2 Setting Up internet connection on the Pi

Internet was necessary in so that the Pi can communicate over network protocols and thus allow for installation of necessary Python packages. The architecture below was used to achieve that.

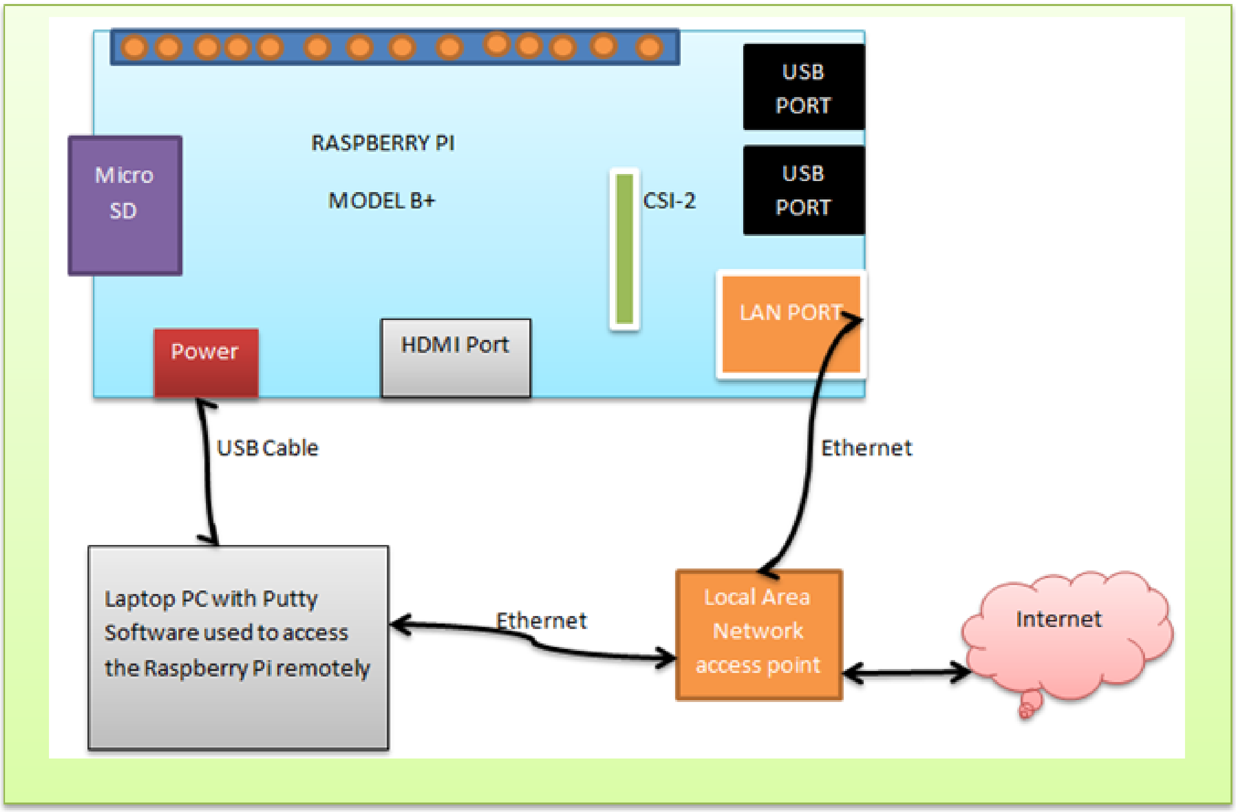

Figure 11: internet set up architecture

Since the broadcast router uses Dynamic Host Configuration Protocol (DHCP) to dish out IP addresses to devices connected to it, it was necessary to change the IP address of the Pi from static to dynamic. This was done by editing the network interfaces file using the command;

```
sudo nano  /etc/network/interfaces
```

3.2.1.3 Enabling the Pi Camera

This is the camera made specifically for the Raspberry Pi. It was hooked to the raspberry pi through CSI-2 electrical port which is an extremely fast port. To configure and enable the camera, the following commands were executed at the CLI of the raspberry pi:

```
sudo apt_get update
```

```
sudo apt_get upgrade
```

```
sudo raspi-config
```

After these configuration settings, the system was rebooted. This was done to ensure that the camera was allocated enough space in memory. The camera takes 5MP image and has a resolution of 1080 by 890. And to ensure that the camera was well configured and functional, the following command was executed.

```
sudo raspistill –o image.png
```

This by default this command takes a three second image and save it in a file called image.png.

Figure 12: Raspberry Pi camera module

3.2.3 Setting Up the Passive Infrared Sensor

This is formed the prime motion sensor. It was used to control the entire system. The device used here was HC501SR passive infrared sensor. The detection range is 7 meters by 140(degrees) coning angles. It has a delay time of 16 seconds but adjustable. The ambient temperature is 253K-323K. It was powered directly from the Pi through the 5V dc supply pin. Its output was connected as the input to the programmable GPIO pin.

3.2.4 Automatic Light Simulation

An LED was used to simulate an automatic light control. This was designed to be controlled through the action of a PIR sensor. This device was connected to the GPIO pin through a 220Ω resistor.

3.3 Hardware Architecture

The entire system modules were interfaced together as shown below.

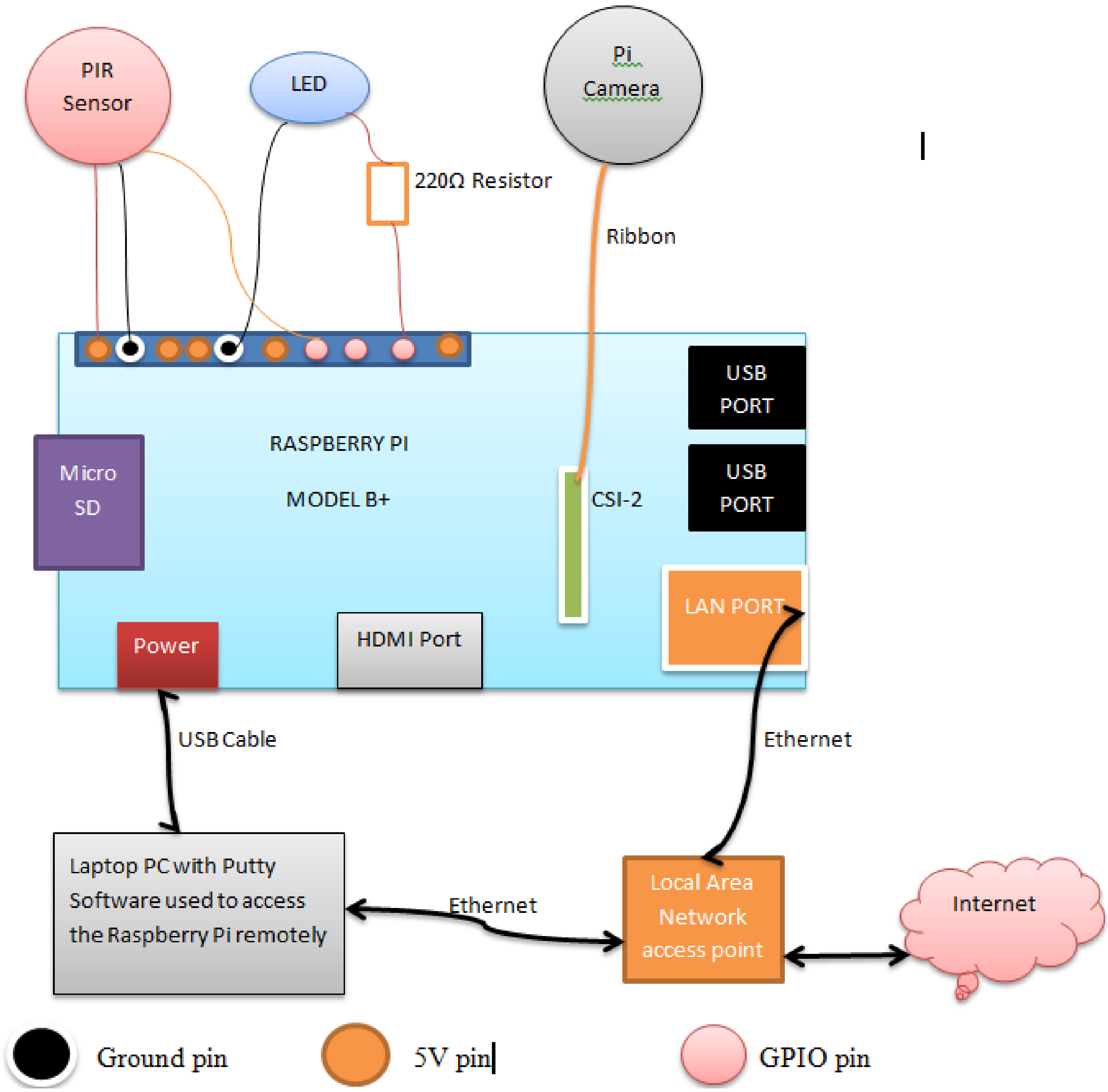

Figure 13: Hardware Architecture of the Security Systems Based on Raspberry Pi.

3.4 Design Software

3.4.1 The flowchart of the Raspberry Pi Based Security system

This following flowchart was used to design and thus document the security systems project. It illustrates the series of events starting from intrusion event up to the point when it sends out an alert. This algorithm was implemented using a Python script. Figure 3.4 below presents the basic flowchart of the entire system.

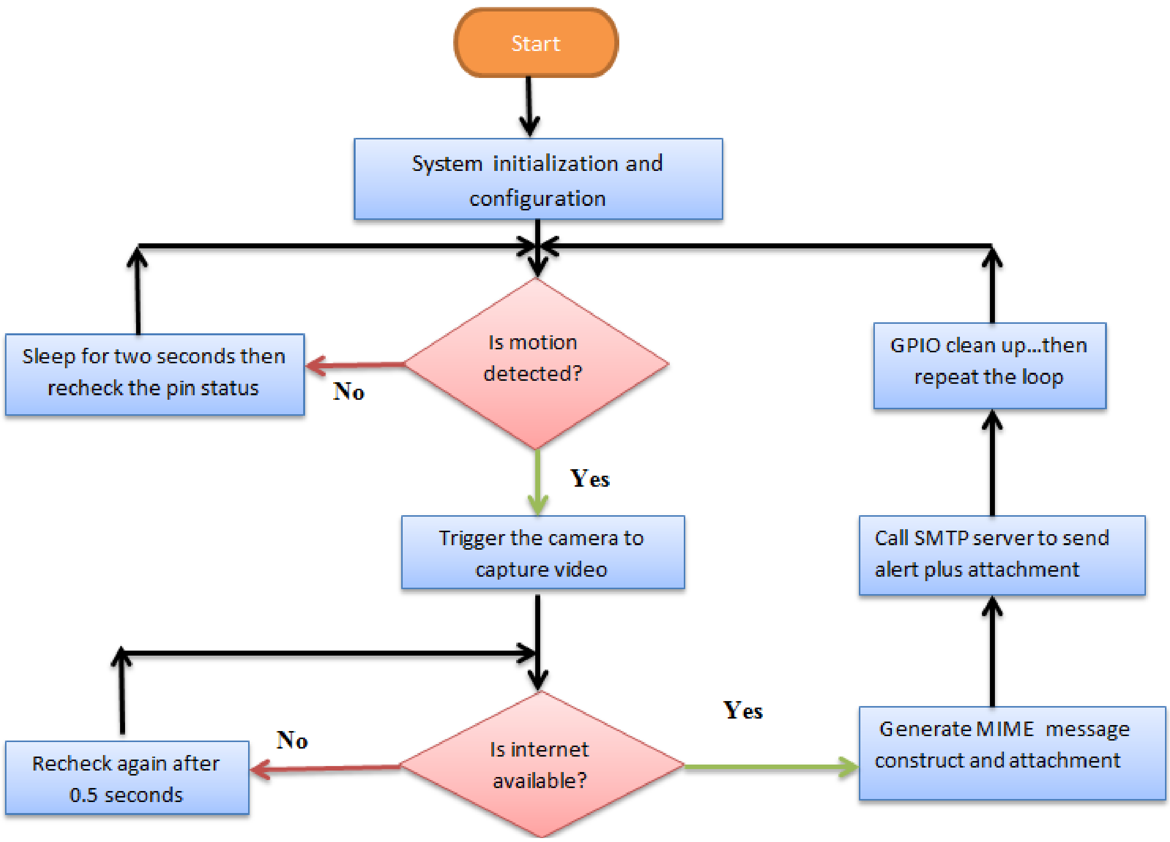

Figure 14: Flowchart implementation of the security system

3.4.1.1 System initialization and configuration

This involved the following tasks:

- ❖ Importing Python libraries and packages. These libraries are predefined and help in making the interfaced modules work properly.
- ❖ Pi Camera setting and configuration.
- ❖ GPIO settings and pin initialization: (the channel was set using the BCM channel numbering. Passive infrared pin channel was set to read mode while the led channel was set to drive/write mode.

a) Read a Channel

In order to read the value of any GPIO pin, simply type; GPIO.input(channel)

b) Drive a channel

In order to drive a channel of GPIO pin, type; GPIO.output(channel, status)

This sequence of events can be elaborated well using the block diagram below.

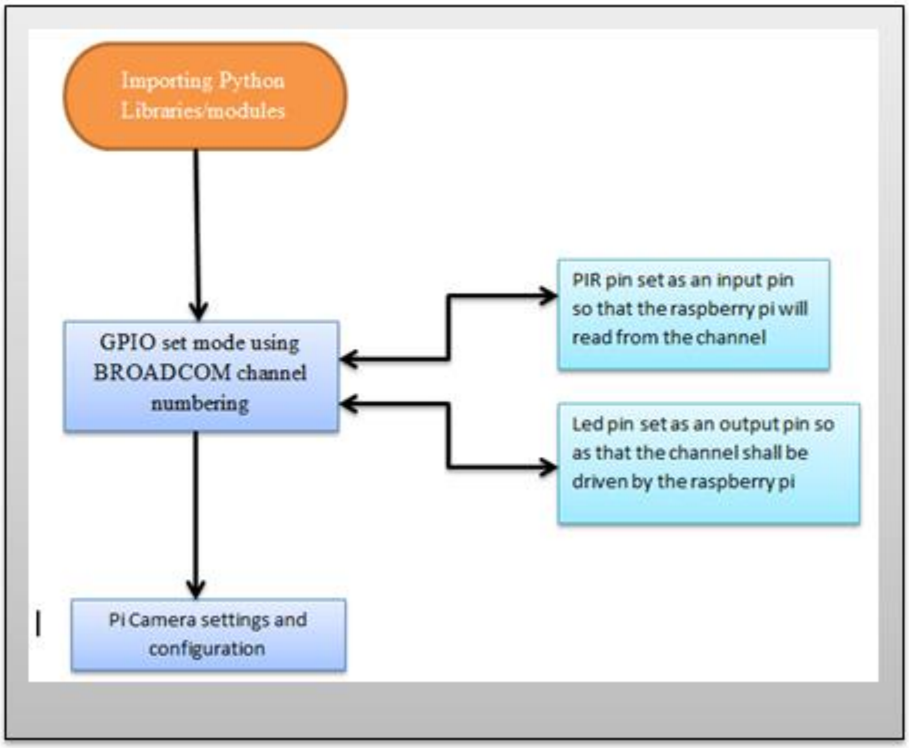

Figure 15: System Initialization and configuration

3.4.1.2 Generating and sending e-mail

After configuring the system to send an alert to the predefined subscriber, it was then necessary to generate and send the mail. Multipurpose Internet Mail Extension (MIME) package was then called and used to generate the attachment. MIME supports characters other than ASCII, non – text attachments (audio, video and application programs) etc. It thus extends the format of an email. Simple Mail Transfer Protocol (SMTP) program was then used to deliver the email from the Raspberry Pi to the configured mailhub. This can be summarized using the blocks below.

3.4.1.3 Pseudocode

i. Upon restart of the system, send out email with boot IP assigned to a mailhost.
ii. Check the status of the GPIO pin. If the pin is LOW, GPIO output pin 13 should remain LOW and the system is idle. Else if the pin suddenly goes HIGH. Interpret this as an interrupt event.
iii. While the value of the input GPIO pin is HIGH (interrupt event), set pin 13 to be HIGH. This instance blinks the LED. Call the function that starts the Pi Camera.
iv. Camera takes a 10 seconds video and save it in a file.
v. The system checks whether the internet is enabled on the Raspberry Pi.
vi. If internet, send email to a prescribed mailhost. If no internet, wait for 5 seconds then check again.

Reset the PIR sensor pin to LOW and recheck again the status after 2 seconds. This should return the program to the main loop.

3.4.1.4 Developing the Full Code Listing.

To be able to develop the Python script that executes the algorithm defined in the flowchart, the following were done at the CLI of the Raspberry Pi:

- The Pi was started and a directory was created using *mkdir* command
- Inside the directory, a file was created using the *touch* command and made executable using *sudo chmod +x (filename).*
- The *nano* command was then used to open the editor and the full Python code was written there. The script was executed using the following command:

```
Sudo python filename.py
```

(Full code listing is appended as appendix (ii))

3.5 OpenCv – Python Video Processing

OpenCv is a very powerful tool used to analyze images and video files. The basic processing procedure to be followed is detailed in the flowchart below. Thresholding as a technique of image processing was chosen for the implementation of motion detection and tracking in video streams. The choice to script using OpenCv – Python was because Python on its own does not support video processing. There is so far no video processing library in Python. OpenCv thus provided the necessary platform to achieve image processing. The following flowchart was used for this implementation

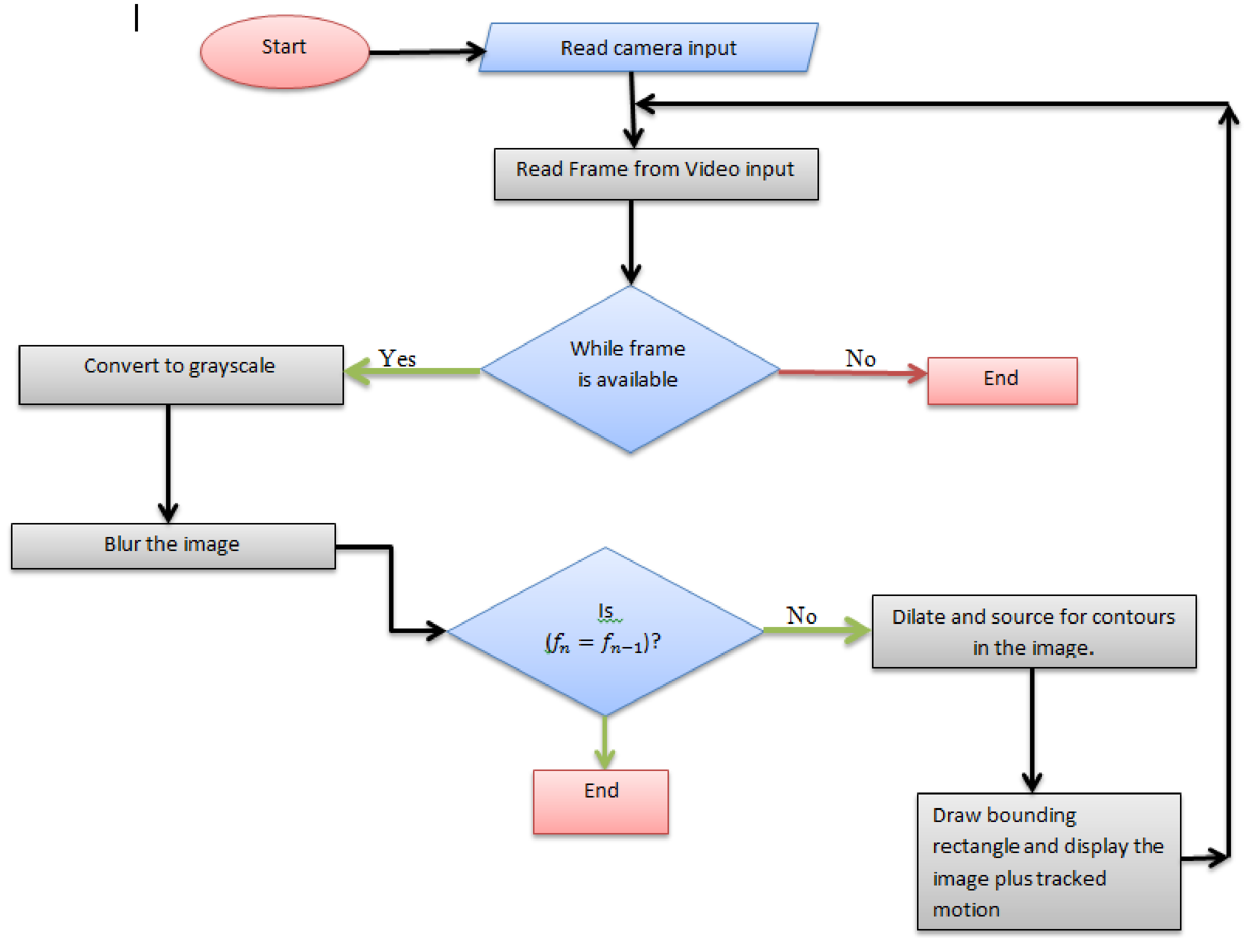

Figure 16: Flowchart of motion detection and tracking algorithm

3.5.1 Pseudocode

i. Start the camera and set to capture video stream
ii. Grab a frame from the video stream. If frame is grabbed, continue with the process. Else stop. Initialize the frame as the current frame
iii. Convert the captured frame to grayscale. Then do Gaussian blurring to remove noise in the gray image
iv. Capture another frame and repeat step two above.
v. Check for pixel threshold if enough to call motion detected
vi. Draw a rectangle around the region where motion was detected

(The code listing is provided in appendix (ii)**)**

CHAPTER FOUR

4.1 RESULTS

4.1.1 Detection Using a PIR Sensor

Tweaking the sensitivity of the PIR sensor among different levels, the following were the results:

Sensitivity = maximum

Table 1: Results for maximum sensitivity of the PIR sensor

Distance in meters	***LED ON/OFF***	***Alert send***	***Ref.***
15	OFF	NO	NONE
10	OFF	NO	NONE
8	OFF	NO	NONE
6	YES	YES	Fig. 4.4
5	YES	YES	Fig. 4.4
4	YES	YES	Fig. 4.4
3	YES	YES	Fig. 4.4

Sensitivity = medium

Table 2: Results for medium sensitivity of the PIR sensor

Distance in meters	***LED ON/OFF***	***Alert send***	***Ref.***
15	OFF	NO	NONE
10	OFF	NO	NONE
8	OFF	NO	NONE
6	OFF	NO	NONE
5	ON	NO	NONE
4	ON	YES	Fig. 4.4

3	ON	YES	Fig. 4.4

Sensitivity = Low

Table 3: Results for minimum sensitivity of the PIR sensor

Distance in meters	***LED ON/OFF***	***Alert send***	***Ref.***
15	OFF	NO	NONE
10	OFF	NO	NONE
8	OFF	NO	NONE
6	OFF	NO	NONE
5	OFF	NO	NONE
4	OFF	NO	NONE
3	ON	YES	Fig. 4.4

4.1.2 Detection and Tracking Using Camera

Table 4: Changing the threshold level of the camera

Pixel threshold	0	5	10	20	25	30	50	80	100
Motion detection	NO	YES	YES	YES	YES	YES	YES	YES	NO
Tracking	NO	YES	YES	YES	YES	YES	YES	YES	NO

4.1.2.1 Captions Showing detection and tracking using camera in real time video

Threshold level = 25

Figure 17: Motion detection and tracking in real-time video stream. Result when the object in the field of view of the camera was stationary.

Threshold level = 25 pixels

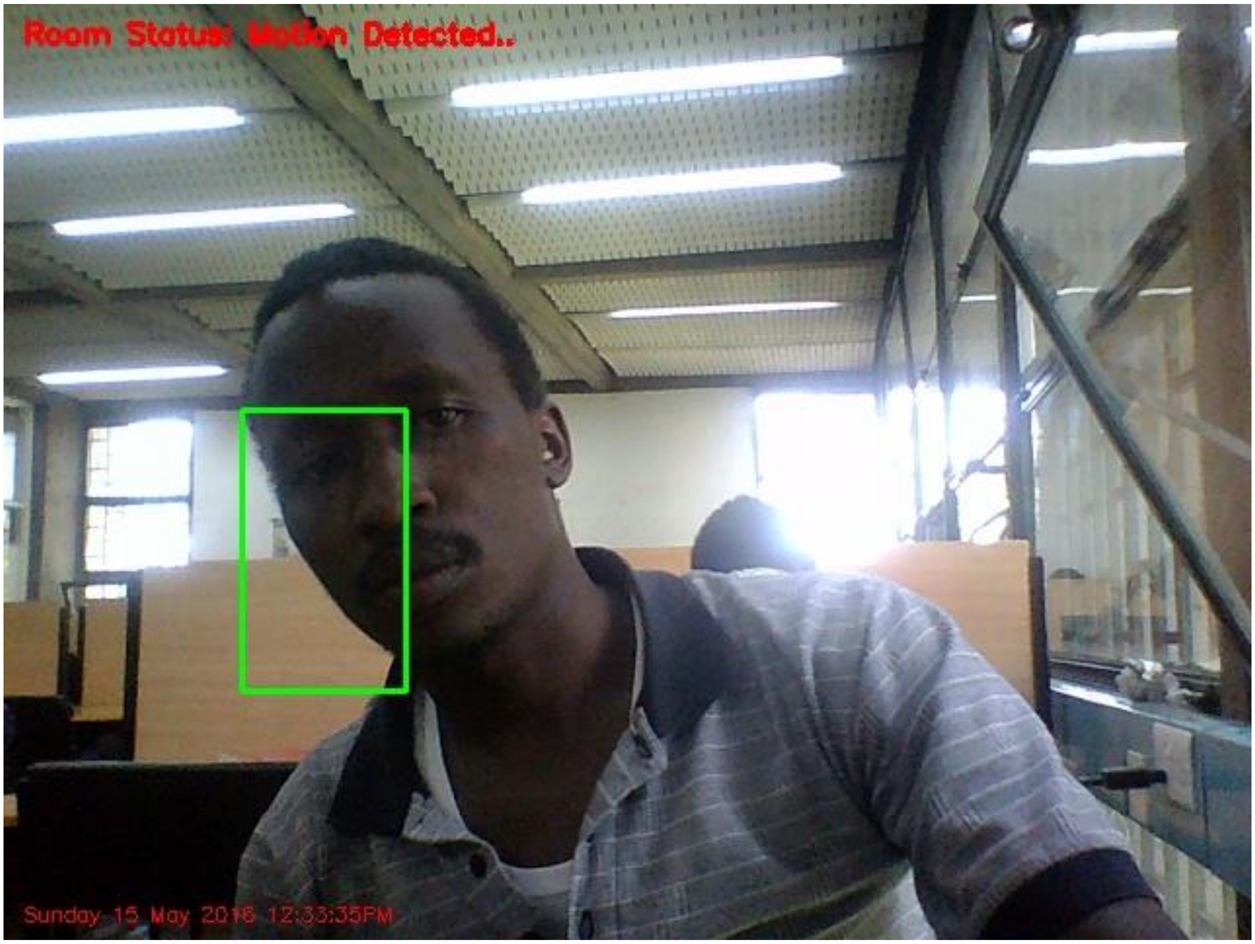

Figure 18: Result showing the tracking upon motion of an originally stationary object.

Threshold = 100 pixels

Figure 19: Result for detection and tracking at a threshold level of 100 pixels. This was obtained irrespective of motion of the object

4.2 ANALYSIS OF THE RESULTS

Executing the Python script in appendix (i) successfully yielded the results indicated in tables 1-3. It can be depicted that the range of detection of the PIR sensor varies at different sensitivity levels. The higher the sensitivity of the sensor the higher the range of detection

Referring again to the results in tables 1-3, it can be safely said that the PIR sensor formed the primary motion detector and hence the first line of defense. All the other modules solely depended on the PIR GPIO pin to go HIGH. In case this sensor fails, the whole security procedure as designed shall fail.

The send alerts from this part are provided in appendix section. They show the email send to a mailhost through SMTP protocol. The attached file is a 10 second video that shall be analyzed in order to explain the concept of image processing in real time video.

Running the Python-OpenCv code provided in appendix (ii) did not yield successful results in the RPI. This was because a large video file or otherwise live video streams require large processor speed. The RPI runs at 700MHz. This script was thus implemented differently on the laptop PC. The results in table 4 were obtained.

From those results in table 4, it can be deduced that varying the pixel threshold of the camera achieves the action of detection and tracking. However, detection occurs only within some limits. This can be shown by comparing the captions indicated in Figures 18 - 20. At a pixel threshold = 25, Motion detection and tracking was achieved, while at 100 pixels (Figure 20), no detection nor tracking was possible. In Figure 16, f_n and f_{n-1} represents the amount of pixels for the previous object and amount of pixels for the current object.

4.3 CONCLUSSION

The project designed and implemented a security system based on the Raspberry Pi. The aspects of the system are: motion detection using a PIR sensor, video capturing using a Pi Camera and sending out an alert through e-mail. It did not however achieved the option of image processing in the Raspberry Pi because of system constraints i.e. processor speed.

4.4 RECOMMENDATIONS

The following are recommended**:**

- Major improvements on the system processor speed are much needed in order to process large files e.g. video for effective motion detection and tracking.
- The designed security system can be used in homes to monitor the facility at any given time.
- The system requires to be remotely controlled. Hence, future explorations should focus much more on the same.

CHAPTER FIVE

5.1 REFERENCES

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5.2 APPENDICES

5.2.1 Appendix (i)

Pure Python code used to implement the RPI based security system. This is the code that was executed in the Pi .

```
#!/usr/bin/env python

#Import necessary Python packages
import RPi.GPIO as GPIO
import time
import picamera
import sys
import urllib
import smtplib
import picamera
import mimetypes
import email.mime.application
import subprocess
from email.mime.text import MIMEText

#Check for the type of connection either wlan or ethernet
def connect_type(word_list):
	if 'wlan0' in word_list or 'wlan1' in word_list:
		con_type = 'wifi'
	elif 'eth0' in word_list:
		con_type = 'Ethernet'
	else:
		con_type = 'current'
	return con_type

#gmail settings

toaddrs = 'sheshaisylvestre@yahoo.com'
username = 'singoee93@gmail.com'
fromaddrs = 'singoee93@gmail.com'
password = 'sylvestre'

#setting up server to use to send mail

smtpserver = smtplib.SMTP('smtp.gmail.com', 587)
smtpserver.ehlo()
```

```
smtpserver.starttls()
smtpserver.ehlo()
smtpserver.login(username, password)

arg='ip route list'
p=subprocess.Popen(arg,shell=True,stdout=subprocess.PIPE)
data=p.communicate()

ip_lines = data[0].splitlines()
split_lines_a = ip_lines[1].split()
split_lines_b = ip_lines[1].split()

ip_type_a = connect_type(split_lines_a)
ip_type_b = connect_type(split_lines_b)
ipaddr_a = split_lines_a[split_lines_a.index('src')+1]
ipaddr_b = split_lines_b[split_lines_b.index('src')+1]

my_ip_a = 'Your %s IP address is %s' % (ip_type_a, ipaddr_a)
my_ip_b = 'Your %s IP address is %s' % (ip_type_b, ipaddr_b)

msg1 = MIMEText(my_ip_a)
msg1['Subject'] = 'BOOT IP'
msg1['From'] = 'singoee93@gmail.com'

arg='ip route list'
p=subprocess.Popen(arg,shell=True,stdout=subprocess.PIPE)
data=p.communicate()

ip_lines = data[0].splitlines()
split_lines_a = ip_lines[1].split()
split_lines_b = ip_lines[1].split()

ip_type_a = connect_type(split_lines_a)
ip_type_b = connect_type(split_lines_b)
ipaddr_a = split_lines_a[split_lines_a.index('src')+1]
ipaddr_b = split_lines_b[split_lines_b.index('src')+1]

my_ip_a = 'Your %s IP address is %s' % (ip_type_a, ipaddr_a)
my_ip_b = 'Your %s IP address is %s' % (ip_type_b, ipaddr_b)

msg1 = MIMEText(my_ip_a)
msg1['Subject'] = 'BOOT IP'
msg1['From'] = 'singoee93@gmail.com'
msg1['To'] = 'toaddrs'

smtpserver.sendmail(fromaddrs, toaddrs, msg1.as_string())
```

```
smtpserver.quit()
time.sleep(10)

#GPIO Pin set up and initialization using board pin numbering
GPIO.setwarnings(False)
GPIO.setmode(GPIO.BOARD)
pir_pin = 11                        #Initialize the channel as input
GPIO.setup(11, GPIO.IN)                    #Read value from channel

led_pin = 13                        #initialize the channel as output
GPIO.setup(13, GPIO.OUT)                   #Drive the channel
GPIO.output(13, GPIO.LOW)

#A function to blink an LED(represent the automatic light system)
def led_light():
    valueX = GPIO.input(11)
    if valueX == True:
            time.sleep(2)
    elif valueX == False:
        GPIO.output(13, False)
        time.sleep(1)
# A function that captures video
def video_capture():

    with picamera.PiCamera() as camera:
        camera.resolution = (640, 480)
        camera.sharpness = 0
        camera.contrast = False
        camera.ISO = 0
        camera.saturation = 0
        camera.exposure_mode = 'auto'
        camera.exposure_compensation = 0
        camera.video_stabilization = False
        camera.crop = (0.0, 0.0, 1.0, 1.0)
        camera.hflip = True
        camera.vflip = True
        camera.brightness = 60

        # set filename and capture video to that file.

        filename = 'my_camera.h264'
        camera.start_preview()
        time.sleep(1)
        print 'Taking Video..Wait'
        camera.start_recording(filename)
        camera.wait_recording(10)
```

```
        camera.stop_recording()
        print 'Video taken..checking for internet connectivity.'



# Main program loop
try:
    while True:

        for i in range(0, 10000000):
            value1 = GPIO.input(11)
            if value1 == False:
                print 'system not alarmed...'
                time.sleep(5)
            elif value1 == True:
                print 'Motion Detected...alert start'
                led_light()
                video_capture()
                try:
                    stri = "https://www.google.co.in"
                    e = 'no connection'
                    data = urllib.urlopen(stri)
                    print("Connected")
                    print "Sending mail...."

                        #send gmail to prescribed mailhub

                    fromaddrs = 'singoee93@gmail.com'
                    password = '**********'
                    username = 'singoee93@gmail.com'
                    toaddrs = 'sheshaisylvestre@yahoo.com'



                    Subject = 'PIR Activated!!!'

                    body = email.mime.Text.MIMEText('PIR Sensor detected motion')
                    msg = email.mime.Multipart.MIMEMultipart()
                    msg['Subject'] = 'PIR Triggered!'
                    msg['fromaddrs'] = 'singoee93@gmail.com'
                    msg['toaddrs'] = 'sheshaisylvestre@yahoo.com'
                    msg.attach(body)
                   #send the attached file
                    filename = 'my_camera.h264'
                    fp = open(filename, 'rb')
                    att = email.mime.application.MIMEApplication(fp.read())
```

```
        fp.close()
        att.add_header('Content-Disposition','attachment',

        filename=filename)

        msg.attach(att)

        server = smtplib.SMTP('smtp.gmail.com', 587)
        server.ehlo()
        server.starttls()

        body = email.mime.Text.MIMEText('PIR Sensor detected motion')
        msg = email.mime.Multipart.MIMEMultipart()
        msg['Subject'] = 'PIR Triggered!'
        msg['fromaddrs'] = 'singoee93@gmail.com'
        msg['toaddrs'] = 'sheshaisylvestre@yahoo.com'
        msg.attach(body)

#send the attached file
        filename = 'my_camera.h264'
        fp = open(filename, 'rb')
        att = email.mime.application.MIMEApplication(fp.read())
        fp.close()
        att.add_header('Content-Disposition','attachment',

        filename=filename)
        msg.attach(att)

        server = smtplib.SMTP('smtp.gmail.com', 587)
        server.ehlo()
        server.starttls()
        server.ehlo()
        server.login(username, password)
        server.sendmail(fromaddrs, toaddrs, msg.as_string())
        server.quit()
        GPIO.output(13, False)

except e:
        print ("not connected")
        if True:
                print("Wait...")
                time.sleep(5)
                stri = "https://www.google.co.in"
                data = urllib.urlopen(stri)

        else:
```

```
                print "Sending mail ...."

#Exit upon keyboard press
except KeyboardInterrupt():
    GPIO.clenup()
    time.sleep(2)
    raise
```

5.2.2 Appendix (ii)

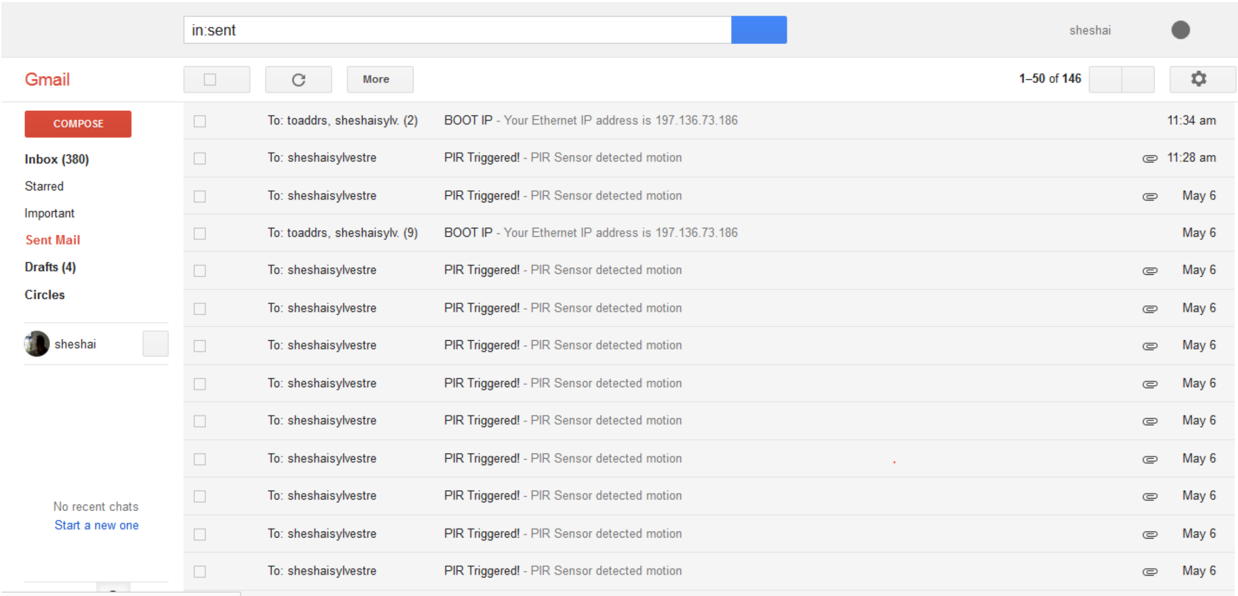
OpenCv – Python Code.

```
# import the necessary packages
import argparse
import datetime
import time
import cv2

# construct the argument parser and parse the arguments
ap = argparse.ArgumentParser()
ap.add_argument("-v", "--video", help="C:\Users\shadrack\Desktop\opencv")
ap.add_argument("-a", "--min-area", type=int, default=1000, help="minimum area size")
args = vars(ap.parse_args())

# if the video argument is None, then we are reading from webcam
if args.get("video", None) is None:
	camera = cv2.VideoCapture(0)
	time.sleep(1)

# otherwise, we are reading from a video file
else:
	camera = cv2.VideoCapture(args["video"])

# initialize the first frame in the video stream
currentFrame = None
S
# loop over the frames of the video
while True:
	# grab the current frame and initialize the occupied/unoccupied
	# text
	(grabbed, frame) = camera.read()
	text = "No Motion Detected...."

	# if the frame could not be grabbed, then we have reached the end
	# of the video
	if not grabbed:
		break

	#convert it to grayscale, and blur it

	gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
	gray = cv2.GaussianBlur(gray, (21, 21), 0)

	# if the first frame is None, initialize it
	if currentFrame is None:
```

```
            currentFrame = gray
            continue

        previousFrame = currentFrame
        currentFrame = gray
                # compute the absolute difference between the current frame and
        # first frame
        frameDelta = cv2.absdiff(previousFrame, gray)
        thresh = cv2.threshold(frameDelta, 100, 255, cv2.THRESH_BINARY)[1]

        # dilate the thresholded image to fill in holes, then find contours
        # on thresholded image
        thresh = cv2.dilate(thresh, None, iterations=2)
        (cnts, _) = cv2.findContours(thresh.copy(), cv2.RETR_EXTERNAL,
            cv2.CHAIN_APPROX_SIMPLE)

        # loop over the contours
        for c in cnts:
            # if the contour is too small, ignore it
            if cv2.contourArea(c) < args["min_area"]:
                continue
           # compute the bounding box for the contour, draw it on the frame,
            # and update the text
            (x, y, w, h) = cv2.boundingRect(c)
            cv2.rectangle(frame, (x, y), (x + w, y + h), (0, 255, 0), 2)
            text = "Motion Detected.."
                # draw the text and timestamp on the frame
        cv2.putText(frame, "Room Status: {}".format(text), (10, 20),
            cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 0, 255), 2)
        cv2.putText(frame, datetime.datetime.now().strftime("%A %d %B %Y
%I:%M:%S%p"),
            (10, frame.shape[0] - 10), cv2.FONT_HERSHEY_SIMPLEX, 0.35, (0, 0, 255),
1)

        # show the frame and record if the user presses a key
        cv2.imshow("Security Feed", frame)
        cv2.imwrite("security.jpg", frame)
        #cv2.imshow("Thresh", thresh)
        #cv2.imshow("Frame Delta", frameDelta)
        key = cv2.waitKey(1) & 0xFF
       # if the `q` key is pressed, break from the lop
        if key == ord("q"):
            break

# cleanup the camera and close any open windows
cv2.destroyAllWindows()
```

5.2.3 Appendix (iii)

Send mail



Received mail

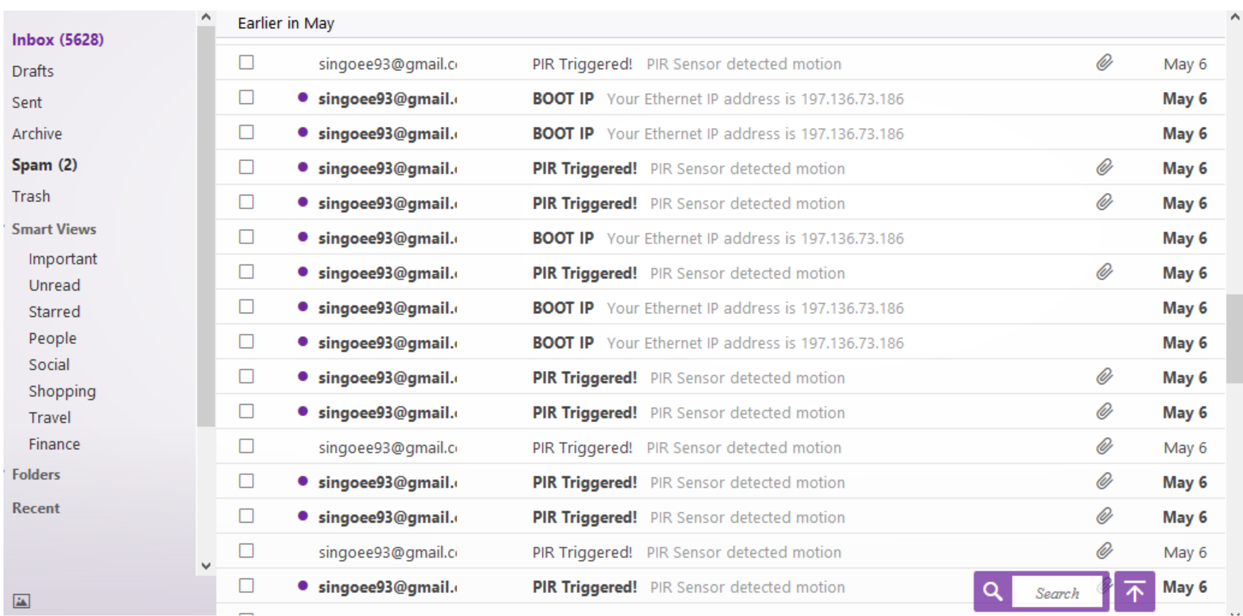


Fig 4.4: Result showing an email notification sent from gmail to yahoo mail