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Development of a Smart Motion Detection Device for Home and Office Security Applications

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Abstract: The aim of this paper is to develop, implement and test an effective and practical working solution to a smart motion detector for LPWAN technologies using appropriate software and hardware platform. The smart motion detection system consists of a Raspberry Pi, an LCD display, PIR sensors, and wires. The hardware design collaborates with Python programming by being installed on a Raspberry Pi, and it is a key function to detect who is entering a room. The proposed smart motion detector will be able to detect whether a person is leaving or entering a room by analyzing signals from multiple motion sensors. The research carried out a comparative analysis of LoRA, SigFox, NB-IOT Low Power Wide Area Network technologies which include the principle of operation, characteristics, hardware, and make recommendation for the most suitable technology. The remote status update function implementation was done where the system sends the motion events to the cloud over a wireless interface using MQTT protocol. The evaluation which was based on extensive simulation demonstrated the detection of each sensor.
Keywords: Smart motion detector, Raspberry pi, Python coding, PIR sensors, LPWAN technologies

I. INTRODUCTION

In recent years, the occurrence of insecurity in residential and commercial buildings has skyrocketed [15]. Detecting when a person leaves [1] or enters a room is critical for creating a safe living environment for people and their belongings. There are numerous [2] motion detection options, each of which is influenced by environmental factors, performance requirements, and technology availability [2]. Recently, embedded system implementation has played a significant role in security management and surveillance security system using Raspberry Pi [4]. Wireless embedded system plays an important role, and it is an advancement of embedded system that is used to transfer data to a location or hub, where it is stored for future needs. Researchers developed a real-time target tracking system based on a Python programming algorithm and a theft detection system using a PIR sensor between 2018 and 2020 [5] [6]. However, in 2017 and 2020, raspberry pi smart home automation with unique door motoring system was used for elderly people and smart classroom for image processing for student safety [7][8]. A smart motion detection device for home and office security applications is a critical technology in the fight against insecurity in homes and offices. This device, which can be installed in hundreds of homes and offices, can send motion events to the cloud. The smart motion detection is programmable (python), and the raspberry hardware is modified in terms of software via VMware.

Low-power WAN (LPWAN) is a wireless wide area network technology that interconnects low-bandwidth, battery-powered devices with low bit rates over long ranges [3]. LPWAN technology has created a new wave of decentralized applications. This new wave of decentralization has many uses. One such application is using this networking technology to allow users to share a single server with multiple devices. This new wave of decentralization has created new opportunities for the spread of Internet applications. The main idea of LPWAN is always bigger, better, faster when it comes to cellular connectivity, basically every device or technology tries to optimize the download speed and therefore contains very complex modules that provide the connectivity. Various technologies such as multi-carrier are presented. and they are moving towards 5G mobile broadband (Magic Magic) which is used to stream high quality video and offers infinite bandwidth. In the other side, there is a large demand of IOT.

Based on the research and understanding for the smart motion detector the categorization of low power wide area network is divided into Proprietary technology and cellular technology[14]. In terms of technical and professional, it called as non-3GPP (proprietary technology) and 3GPP (cellular technology). In clients or common person point of view it is called as Unlicensed spectrum (non-3GPP) and Licensed spectrum (3GPP). Proprietary technology consists of Lora, Sigfox and Weightless. On other side, Cellular technology consists of LTE and NB-IOT.

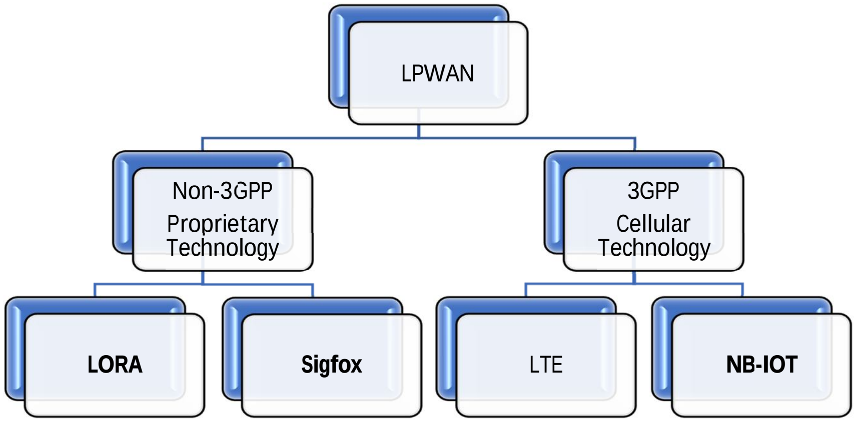


Fig-1: LPWAN Classification

Proprietary technologies are not standardized by 3GPP but they either have an open specification available. But at the end Proprietary technologies (Lora, Sigfox) did not have any infrastructure. So new infrastructure is built up, especially to optimized for low power, low data devices. One big thing that is different from cellular technology is all these approaches need to rely on shared media. So opposed to cellular technology where operators are buying license for a lot of money. Therefore, Sigfox and Lora cannot use the license spectrum and they need to rely on unlicensed spectrum, which is shared between other technologies like WIFI and Pushed to talk (walkie talkie). When it comes to cellular technology it uses telecommunication infrastructure, which is rolled out everywhere. Secondly, cellular side it is as very closed ecosystem like maximum of two or three operators per country.

This research will go through experimental methods like connecting the GPIO pins of raspberry pi processor to Raspbian OS and different types of sensors like motion, light is used connect the hardware to obtain the result of the smart motion detection using python programming.

II. COMPARATIVE ANALYSIS OF LORA, SIGFOX and NB-IOT

This section discusses all three LPWAN technologies and compares them in the non-3GPP and 3-GPP categories. In order to find the most suitable technology for the smart motion detector using raspberry Pi, a comparison between LoRa and Sigfox from proprietary technology will be established, and the best of non-3GPP category will be compared with NB-IOT, which is a cellular technology.

A. LoRa Technology

LoRa technology is the DNA of the IOT, connects sensors with the cloud and enables real-time communication of information and analyses to improve efficiency and productivity. Several older wireless systems use FSK modulation as the physical layer because it is an efficient modulation to achieve low power consumption, although the communication range has been increased significantly[2]. SimTech, LoRa Innovation has more than 600 popular use cases for smart and smart cities, focused homes and buildings, smart agriculture, smart supply chain, smart marketing, and coordination.

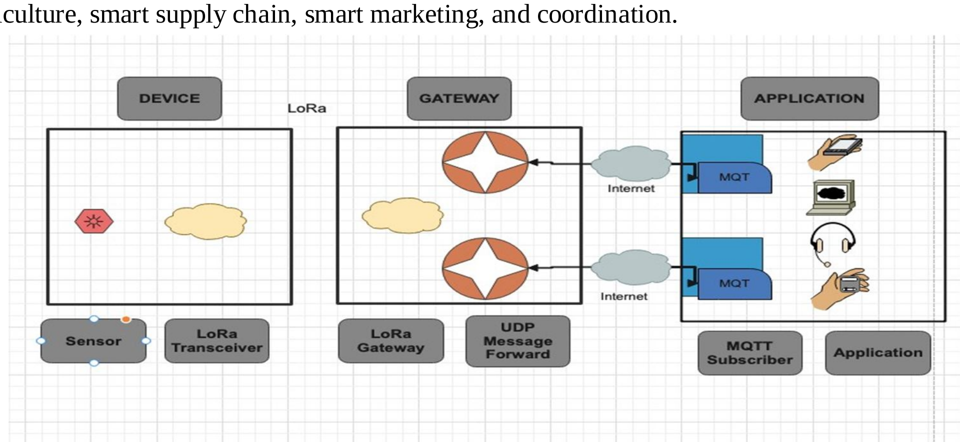


Fig-2: Architecture of LoRa Technology

Several LoRa nodes connected to the LoRa gateway, which channel the data from the nodes to a network server and from then on, the data is moved to a variety of applications servers(cite). Therefore, Connection between device and gateway are in the form of star topology or network and the nodes cannot talk to each other directly [2]. Figure 2 shows the LoRa network architecture, which can consist of numerous elements like LoRaWAN devices, LoRa gateway bridge, LoRa server, LoRa geoserver, LoRa application server LoRaWAN devices are IoT devices (sensor, air quality, temperature, humidity, location, etc.) send the information to the LoRa network via the LoRa gateways. The LoRa Gateway Bridge is responsible for communication together with the gateway. Converts the packet forwarder UDP convention to messages over MQTT. LoRa Server is aware of the organization of the status of the array or network.

B. Sigfox Technology

Sigfox technology is an end-to-end network and uber of IOT, which sends small data packets from sensor to the network and cloud to connect the sensor to the digital world. Sigfox consumes less power and is effective over long distances compared to connection protocols like Bluetooth and WIFI, which work better at close range and use more power [2]. the company itself owns all its technology from backend data and cloud server to the end point software. the end point is the market.

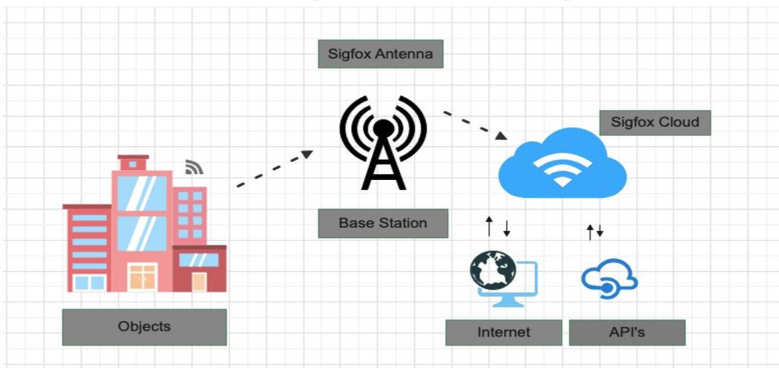


Fig-3: Architecture of Sigfox Technology

Figure-3 consists of three important elements they are objects, base station, Sigfox cloud. objects are also generally called as devices, which includes sensor. this object sends their data to a base station. base station is local additional local Sigfox antenna that receive message from emitting devices and forward them to Sigfox cloud [2]. Sigfox cloud is a central hub where all the information is stored, and data processing takes place.

C. NB-IOT Technology

It is narrow band IoT,standard based and based on existing cellular network infrastructure. Normally, cellular network hello's signal to transfer large volumes of data at high speed with low latency over very large distance [2]. The trade of the cellular devices consumes lot of power, and they are relatively expensive.

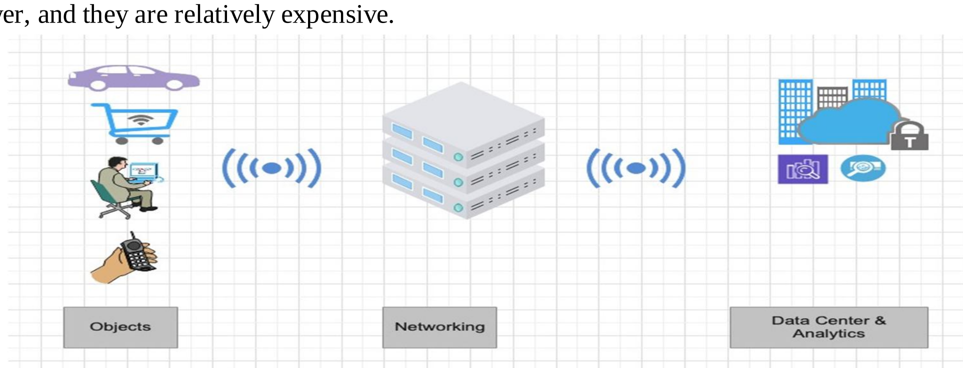


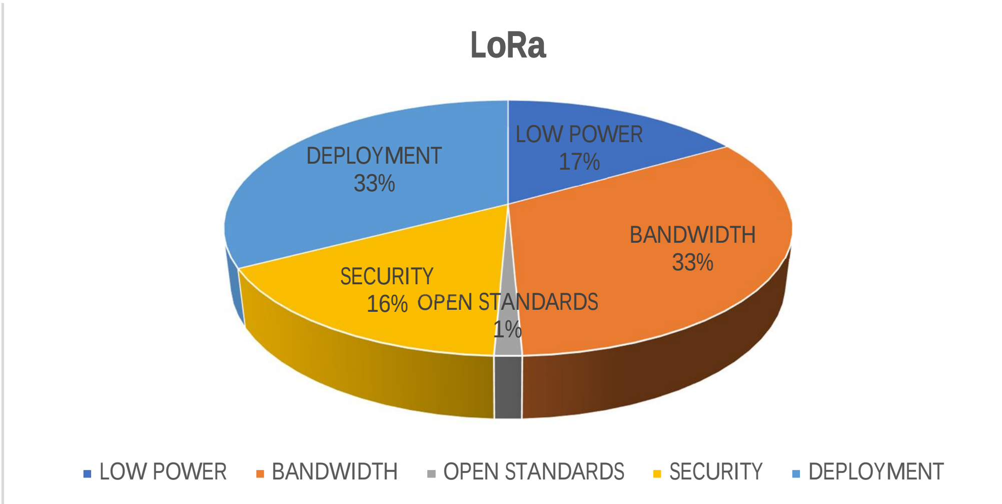
Fig-4: Architecture of NB-IOT

NB-IOT does not require gateways like LoRa and Sigfox and the sensors of sensors of NBIOT can directly communicate with primary servers and NB-IOT enables cost effective nodes that can on batteries for maximum 10 years.

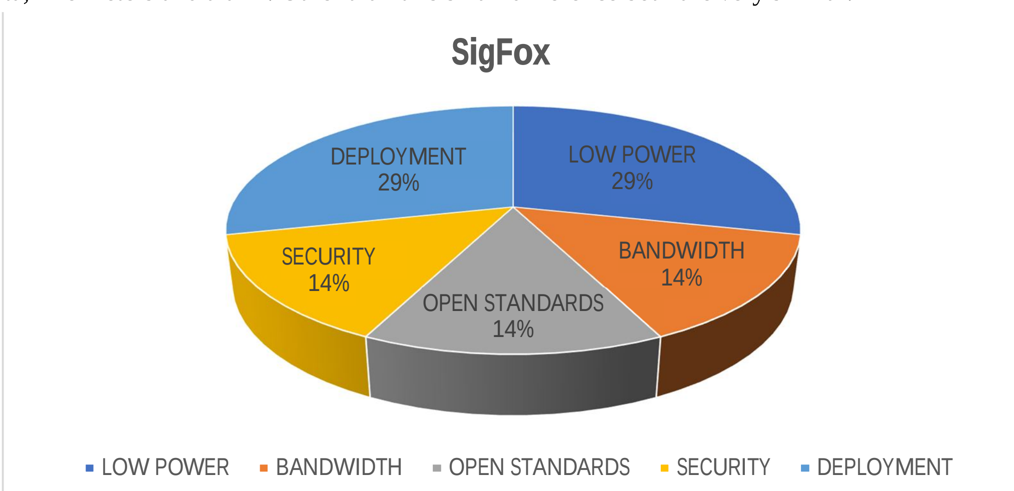
D. LoRa vs Sigfox

Both technologies as its own transceiver, physical protocol, firmware, gateways, and network up to the application. before starting the discussion on use cases in practical scenario the information is not totally fair because it depends on people decision. according to recent survey Sigfox is not used by most people because the network is not available everywhere[12]. However, LoRa is the option for most people because the user itself can set up and manage their own network. That aside, LoRa and Sigfox are equal when it is implement in practical scenario with few limitations.

LoRa is likely the best choice because the data transmission nodes are bidirectional, and it connects in symmetric link structure. For instance, if the user needs to give a command or control functions to system it is easily accessible by the user itself. Maybe this is the one of major reason why lora is used most among people.



In contrast, with Sigfox also have bidirectional transmission nodes. Even, controls and command function are accessible. But the major drawback is the network density would need to higher due to the asymmetric link[12]. Therefore, it is better for applications that transmit small data, like meters and alarm. Other than this small difference both are very similar.



The goal of the report and the project is not about which network is best. It's all about LPWAN technology. When it comes to IOT connectivity. So, considering LPWAN technology for smart motion detector application, which can give the performance to the user needs. The report conclude that symphony Link is a wireless system installed in Lora technology [13]. with which IoT devices can connect safely and easily and should overcome the limitations of a LORAWAN system(cite). Symphony Link is specifically designed for Low Power Wide Area Network (LPWAN) applications that are easily scalable and operate with world-class reliability(cite).

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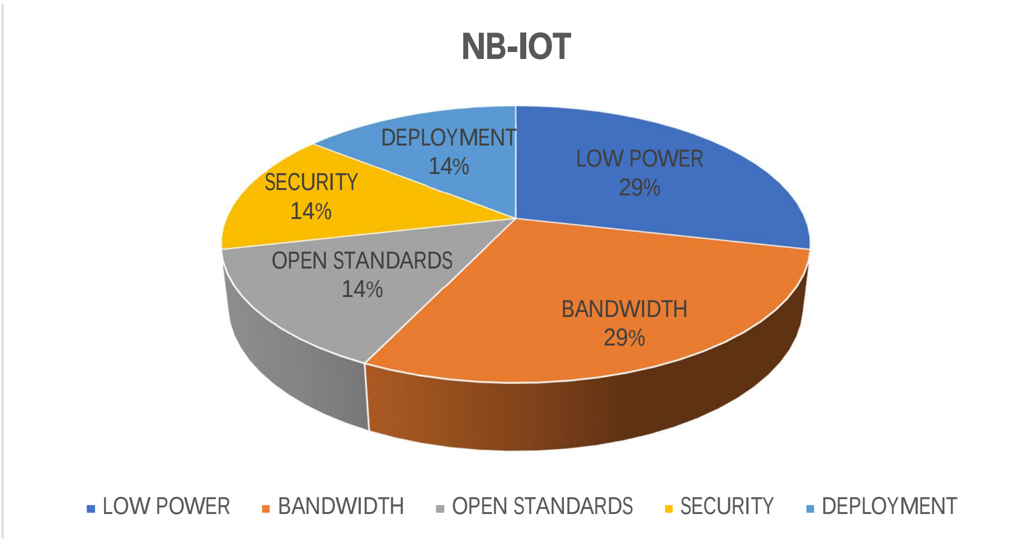
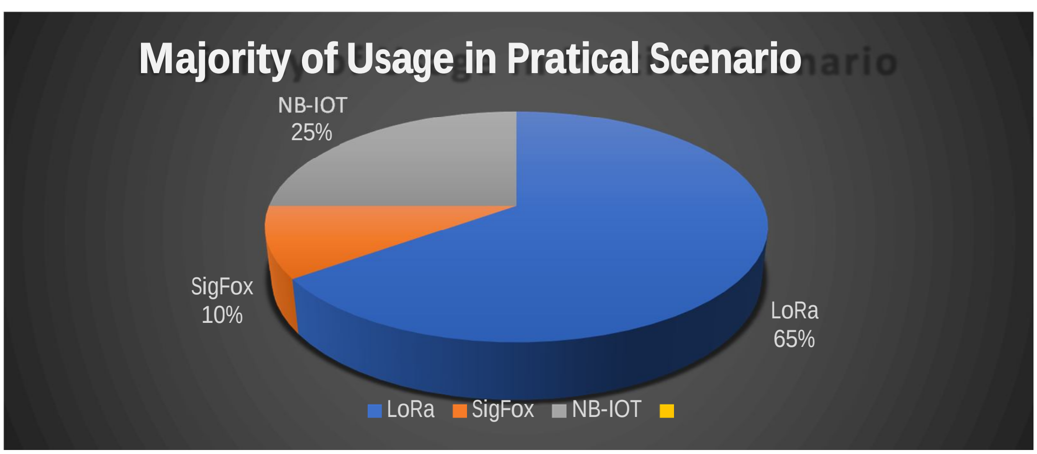
E. LoRa vs NB-IOT

1) LoRaWAN uses less power compared to NB-IOT, making it a more practical solution for projects that require higher update rates.
2) LoRaWAN consumes less power and offers longer battery life compared to NB-IOT (more than 15 years compared to more than 10 years).
3) When it comes to bandwidth and cover, things begin to overlap
4) The maximum power of data for NB-IOT is 60 kbps, a highest touch than LoRa.
5) NB-IOT is more secured, when compare LoRa due to 256-bit 3GPP encryption.



The biggest difference between the two is their profitability. LoRaWAN solutions can achieve lower operating costs compared to NB-IOT, both through unlicensed frequency usage and lower power consumption (which in turn extends battery life and reduces service costs). In the case of application, both technologies are used equally in the respective areas where NB-IOT scores somewhat high due to security and is not profitable.



In general, LoRa is cheaper than NB-IOT. Even the market price is high. this report analyse that both are crucial to getting the IoT industry grow. In summary, it can be said that costs are important in all use cases. For example, most farmers who adapt to IoT innovations because they are profitable and improve smart farming. As a result, compared to NB-IOT solutions, the LoRa system is primarily used by humans, and it is suitable for Raspberry Pi smart motion detectors, inexpensive, and the network can be privately owned.

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III. EXPERIMENTAL SET UP

After deciding and concluding which LPWAN technology is suitable for the smart motion detector, this stage explained the device's implementation using a block diagram and a flow chart.

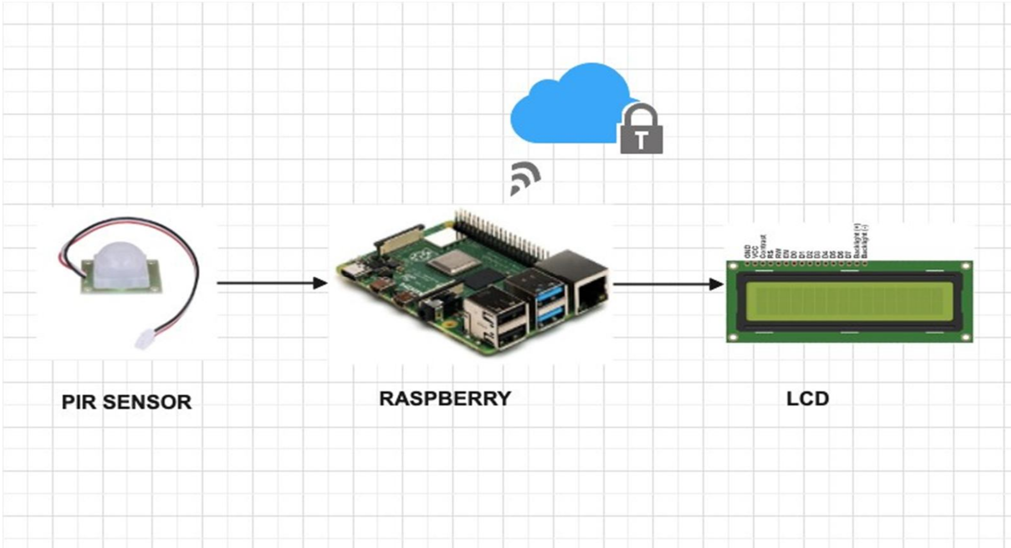

Fig-4: Block diagram for smart motion detector

The above diagram depicts how various inputs to the system, communicate with each other and send the values to the cloud through raspberry pi. The diagram consists of the following component where it is clearly elaborate the PIR sensors is interfaced with raspberry and LCD, and additionally if want LED can connect from the output port pins of raspberry for indication. Later, the data will store in the cloud platform using python coding. The most important phase is to analyse by listing the requirement and required system specification. In our case, the requirements are raspberry pi, LCD, PIR and programming skill with modified VMware, which is already discussed in the report. Secondly, designing place a major role with working flow chart based on the block diagram.

The first stage is to install Raspbian OS in the desktop. After installing, set the password for security before developing application.

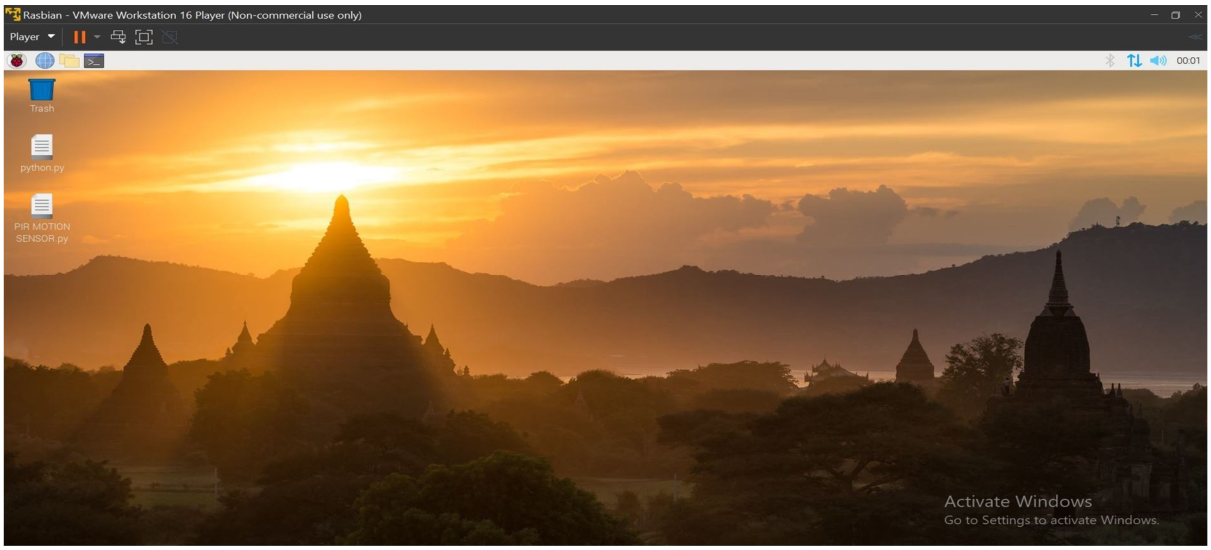

Fig-5: Raspbian OS

After opening the Raspbian OS > open terminal, which is in top left corner. Where it is used to code the Raspbian like updating, installing any software, setting GPIO pins, camera connection enable even we can write the program using raspberry code.

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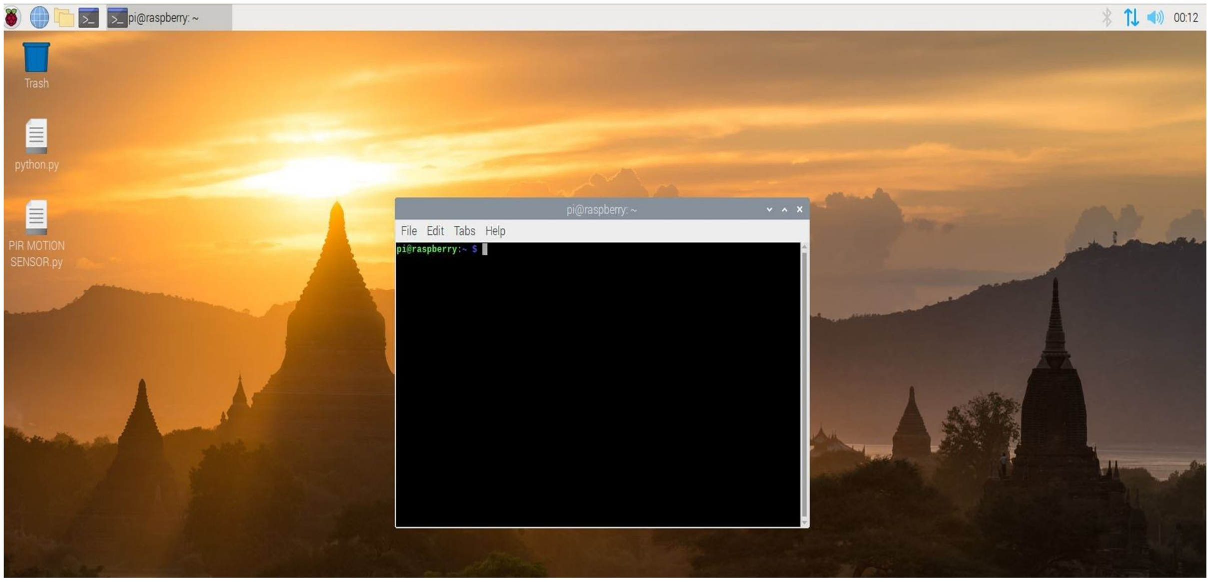

Fig-6: Raspberry Terminal

Following that opening terminal, the basic command for software installation to run like installing the python and raspberry tools.

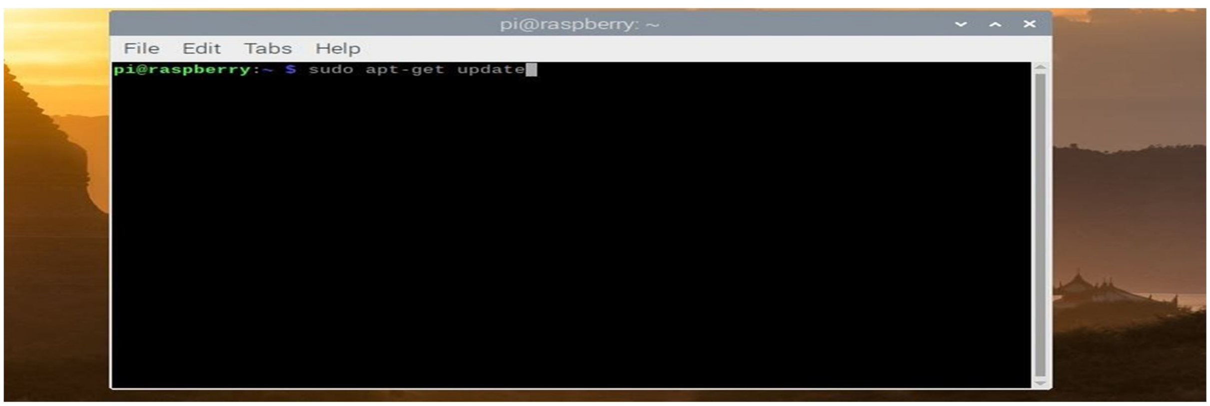

Fig-6: sudo apt-get update for tools

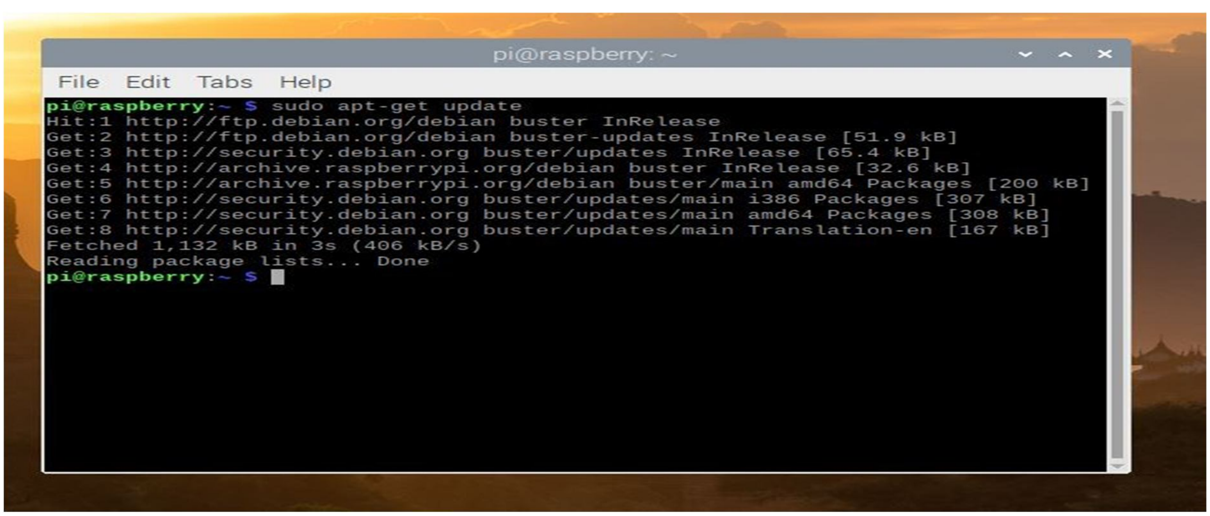

Fig-7: sudo apt-get update for tools

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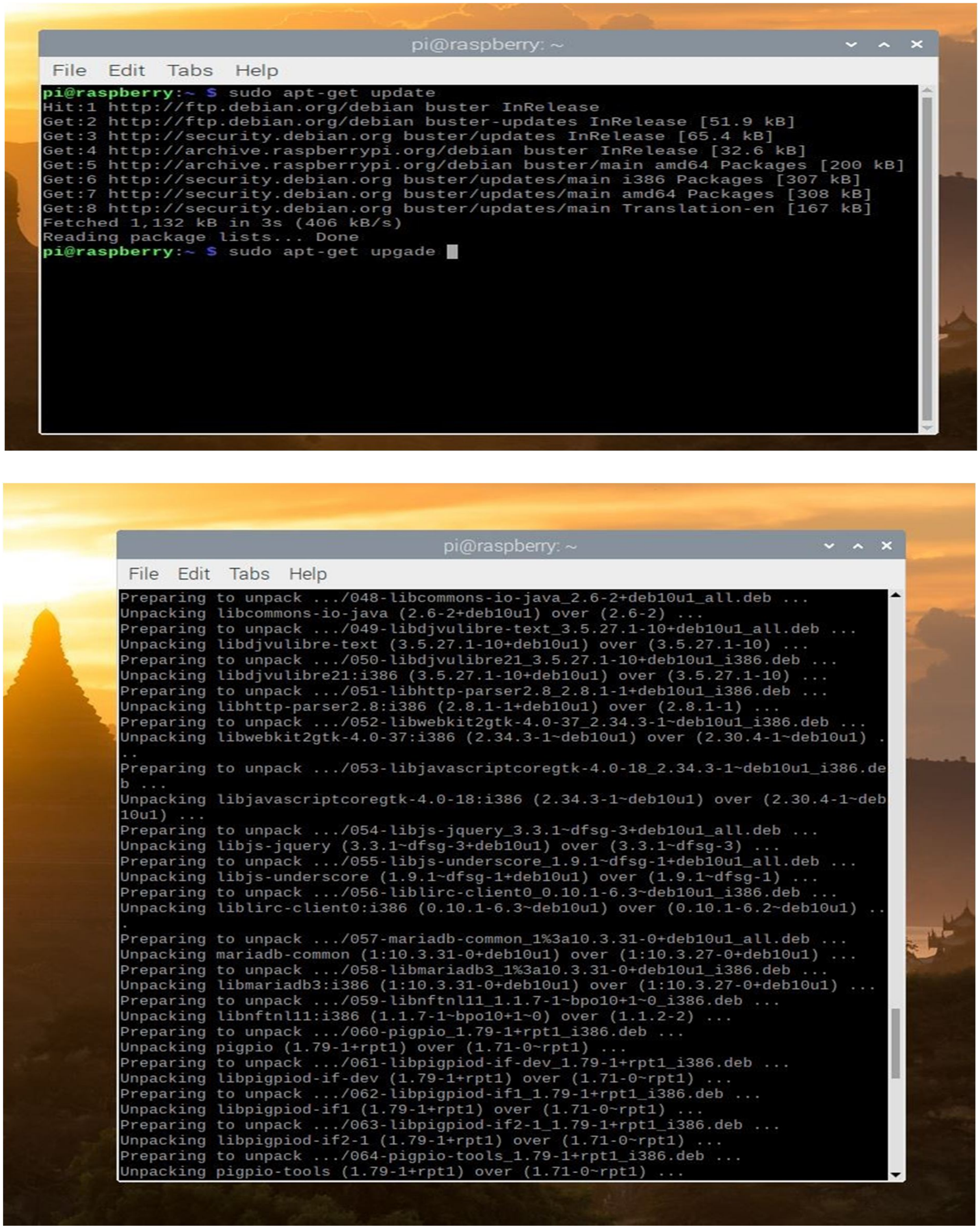

Fig-8: sudo apt-get upgrade for tools

After the fundamental work and command that update the Raspbian program. Utilizing Nano command or python computer program we will begin programming the code for our smart motion detector by configuring the raspberry pi GPIO pins with the built python code. Regularly, most of the version of raspberry have 40 pins and precisely 26 pins are the GPIO pins and remaining pins are control and ground pins blended with two EEPROM pins.

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The source code of our application is to distinguish the human, which is plan as it were for indoor exercises. So the code we intend to write will expand through the use of a stream chart, which is shown below, and it will discuss almost all programming techniques in the context of human development.

Flow Chart

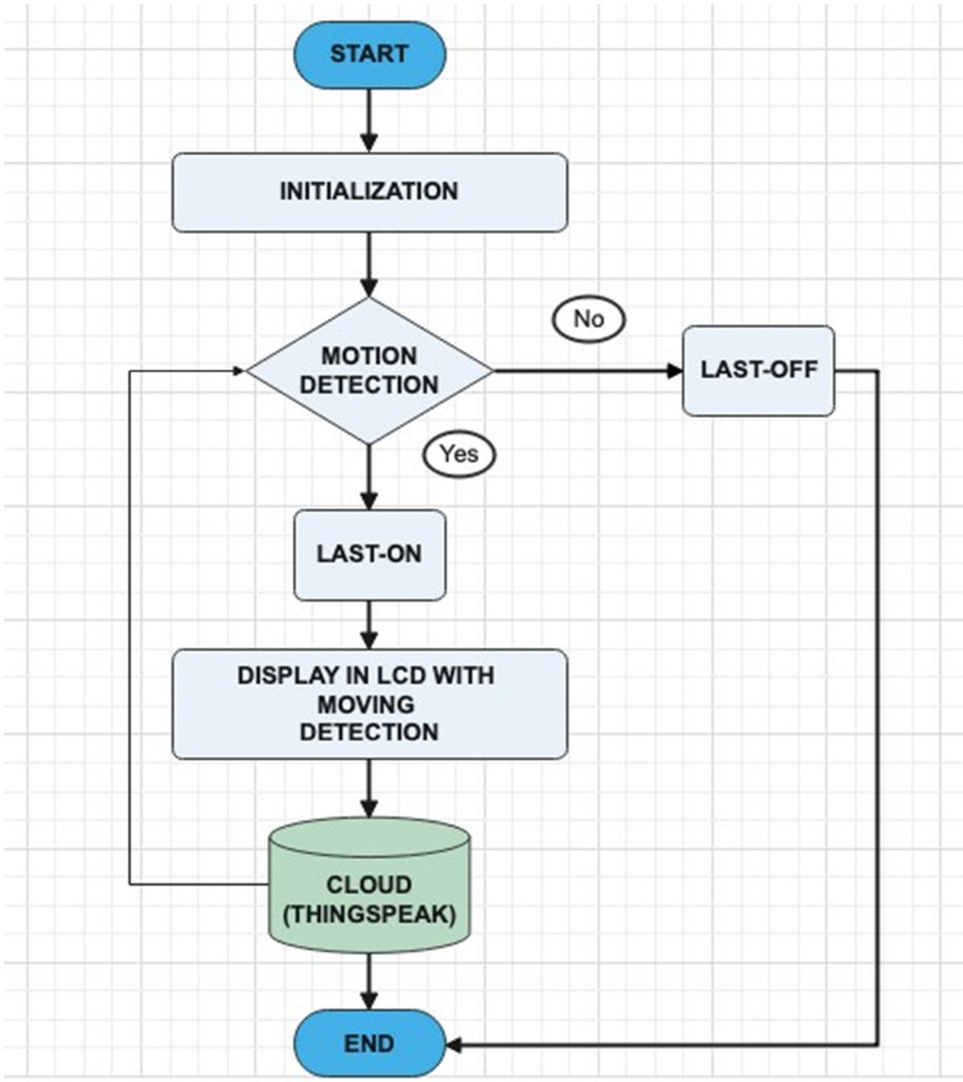

Fig-9: Flow chart of the source code

The above graphical representation describes the steps of the application with the sequential order presenting the flow of our coding algorithms. Many research project and application like this developed for detecting based on the simple presence detection using array PIR sensors. In addition to the presence of simple people, however, the production of the PIR sensors depends on several other aspects, including the removal of the body movement of the PIR sensor, the direction and the movement speed and the presence of multiple persons.

IV. METHODOLOGIES AND IMPLEMENTATION

In this section we display the strategy to distinguish human developments in a room in eight headings. They are north, south, west, east with a 4 array PIR sensor and discuss the possible implementation of northwest, southwest, southeast, northeast, etc within the same array of 4 PIR sensors. Ordinarily, the PIR sensor could be a dual detection sensor in which we are able put a Fresnel lens rather than a single lens to extend the location precision [16]. The four adjusted directions in dual detection are north-south, west-east, north-west-south-east, and north-eastsouth-west.

The sensor associated to the raspberry is best utilized or set on the ceiling within the living-room. Based on this thought we will make four sensors utilizing Python purport commands with NumPy, SciPy and Import-Raspberry-LCD.

```
#!/usr/bin/python3 from json import load import numpy as np import time
from libex import MyCircuit from libex import configuration circuit = MyCircuit(configuration)
@circuit.run
def main():
from Adafruit_CharLCD import Adafruit_CharLCD from gpiozero import Buzzer, LED, PWMLED, Button, Distance Sensor, MotionSensor.
from lirc import init, nextcode from py_irsend.irsend import send_once from time import sleep
lcd = Adafruit_CharLCD (2, 3, 4, 5, 6, 7,16,2)
led1 = LED(21) led2 = LED(22)
motion_sensor1 = MotionSensor (20) motion_sensor2 = MotionSensor (23) motion_sensor3 = MotionSensor (24) motion_sensor4 = MotionSensor (25)
```

after the source code of over program, We made four development sensors with interfacing GPIO pins (20,23,24and 25) and LCD relates to 2,3,4,5,6,7,16,2 pins utilizing thonny python IDE. Each sensor distinguishes for instance, direction up for first sensor, direction left for second sensor, direction right for third sensor and direction down for fourth sensor.

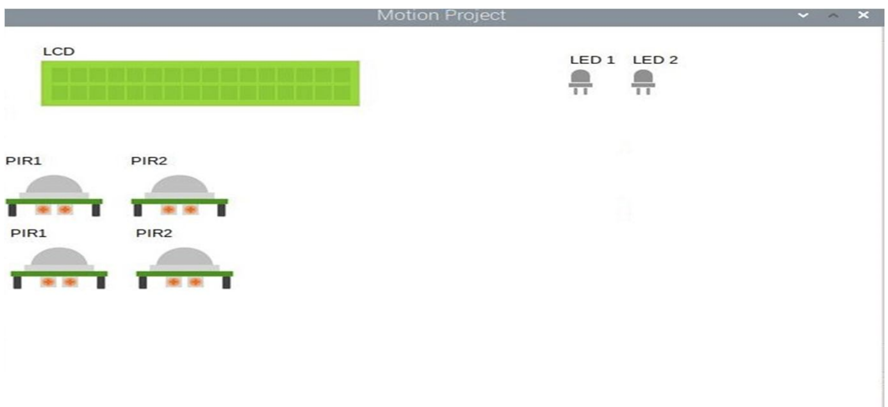

Fig-10: Sensors and LED with LCD of the code

```
last on = np. array ([0,0,0,0]) last off = np. array ([0,0,0,0])
```

The above-stated coding lines indicates if the movement detected it states last on, if not last off and it is also indicating to LED. The Fig-10, first row sensors consist of up and right denoting sensors PIR-1 and PIR-2, following that, second row sensors consist of left and down representing sensors PIR-1 and PIR-2.

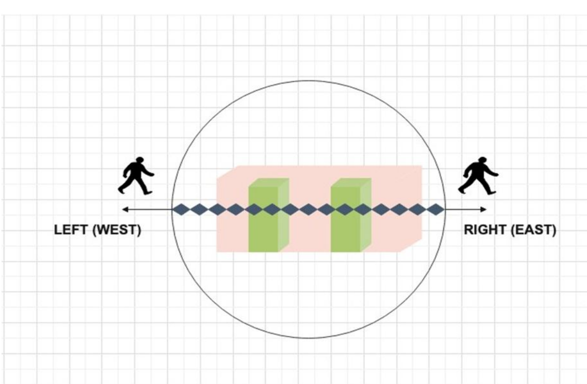

Fig-11: Left and Right.

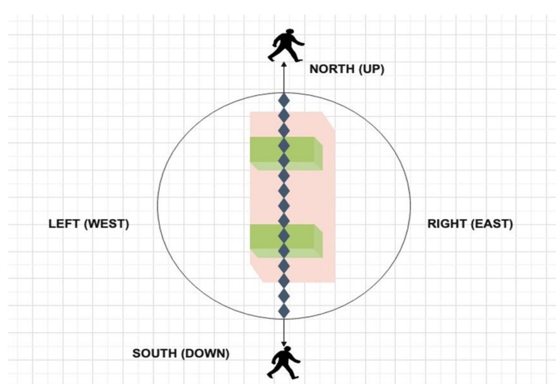

Fig-12: Up and Down

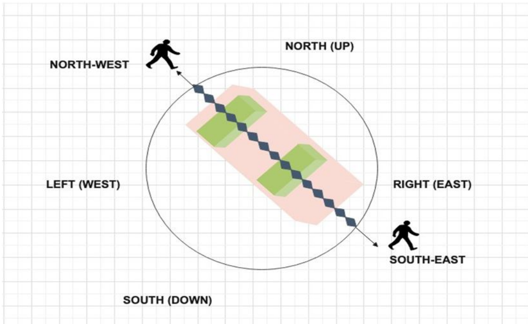

Fig-13: North-West and South-East

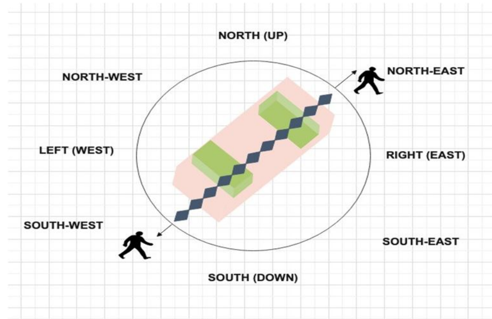

Fig-14: South-West and North-East

Fig-11 represents both directions left and right, which consist of two sensors. Following that, Fig-12 shows direction up and down also consist of two sensors[10]. Based on the understanding just imagine the four sensor is consider as a laptop arrow key and using while loop concept if the motion is detected the condition will be true. If not, it considers as no movements in the room.

This report only shows the working code output of concept and discuss the result of fig-11 and fig-12. However, fig-13 and fig-14 can be implemented in practical set-up through hardware installation and in-depth coding to build and develop axis level source code using raspberry pi or any micro-controller[16]. whose both vertical and horizontal field of views are 45 degrees with calculation by finding length and breadth of the room.

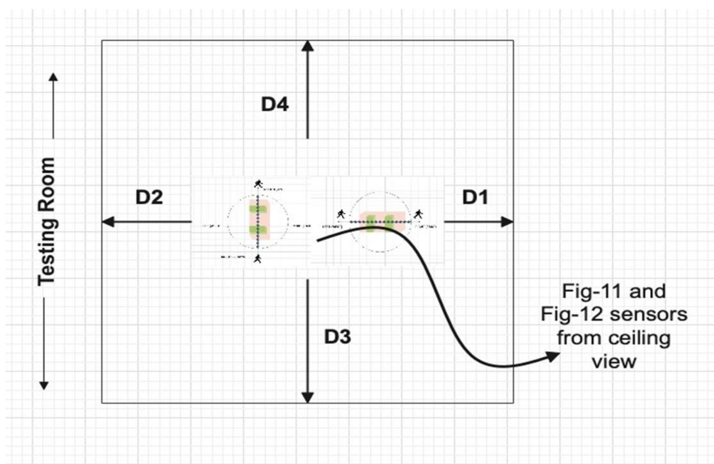

Fig-15: Implementation of developed sensor in room

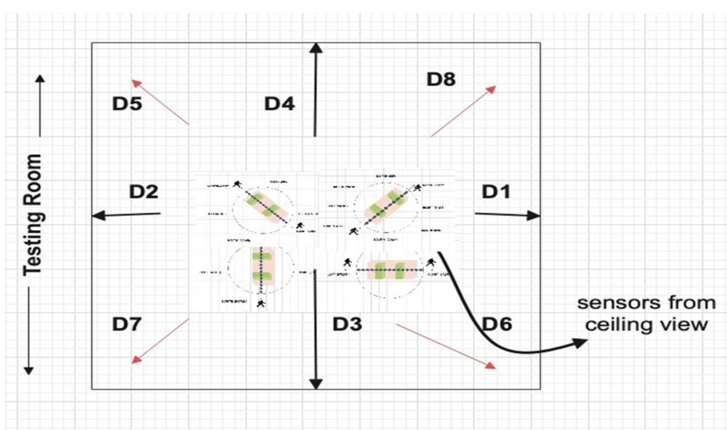

Fig-16: The top view of sensors and their tracking with all directions

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Fig-15 shows the ideology, how the developed smart motion sensors work in a room, where D1 denotes direction right, D2 denotes direction left, D3 denotes down and D4 denotes up.

Subsequently, Fig-16 represents the ideology of all direction. where D5 denotes direction of north-west, D6 denotes direction of south-east, D7 denotes direction of south-west and D8 denotes direction of north-east.

```
while True:
    if motion_sensor1.motion_detected:
        led1.on()
        lcd.clear()
        lcd.message("Detected Up!")        else:
        led1.off()

     if motion_sensor2.motion_detected:
        lcd.clear()
        lcd.message("Detected Left!")
        led2.on()        else:
        led2.off()

     if motion_sensor3.motion_detected:            led1.on()
        lcd.clear()
        lcd.message("Detected Right!")        else:
        led1.off()

     if motion_sensor4.motion_detected:            led2.on()            lcd.clear()
        lcd.message("Detected Down!")        else:            led2.off()
      sleep (1)
```

The above coding lines states while loop statement, which is basic concept for any coder. If there is movement in the room it is consider as motion detected and condition true. If it is not, it is considered as false. Therefore, each sensor is connected to LED and LCD.

V. EXPERIMENTAL RESULTS

The proposed IoT-based smart motion detector consisting of raspberry, sensor, LCD, LED, and Python code using a modified software called VMware, the goal of the application developed in this report is to detect 100 of these motion detectors in the area to implement Greater London. Based on the developed application, this report shows the result of the project, which can be converted into a practical scenario.

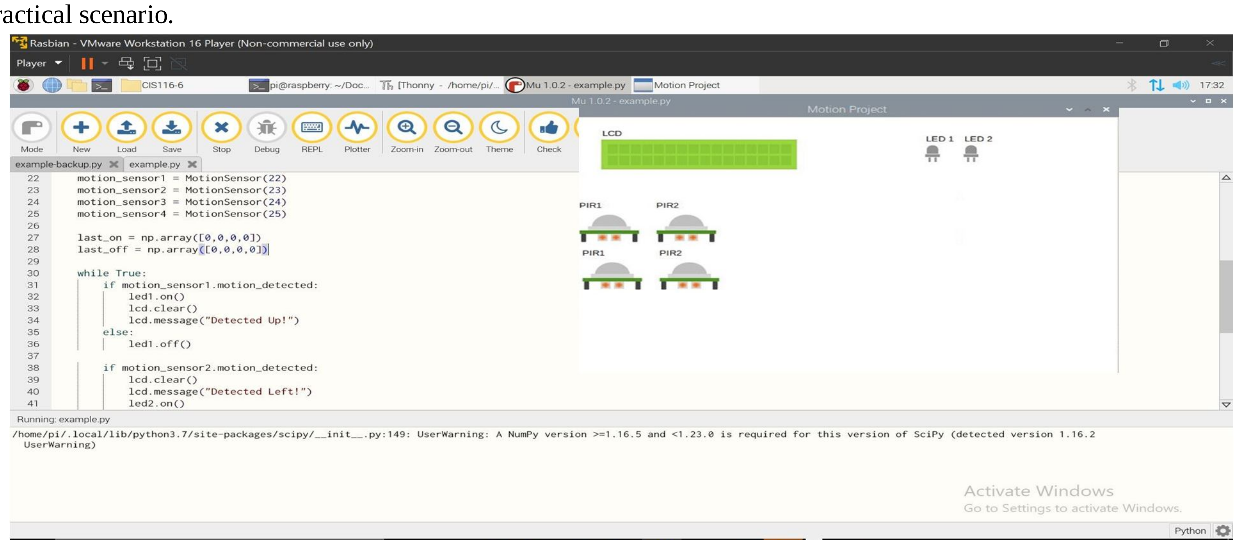

Fig-17: Testing the code

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Fig-17 represents the code I developed, and it is running without any error, the challenges I faced while developing the code is connecting the motion sensor to the GPIO pins. After I used nano command in the raspberry terminal and install SciPy software the code running properly without any error.

The goal of the code is to detect the direction of north, south, east, and west. Therefore, the source code I developed denotes each direction to each sensor, which clearly shown in Fig-10. Basically, pi is the main system of our application. Here configuring the code with raspberry GPIO pins is a big task. Which I faced challenging while implementing in VMware.

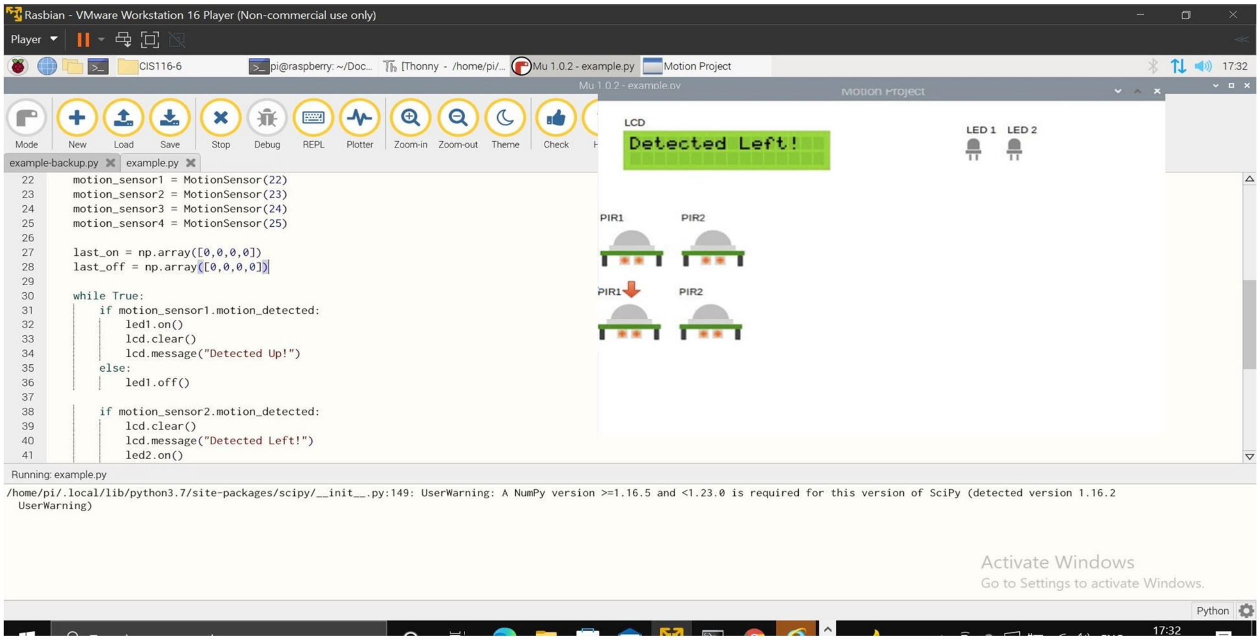

Fig-18: Detecting left

While placing the cursor to second row first sensor, the code we develop detected the direction of left, which is denoted as west for understanding the concept.

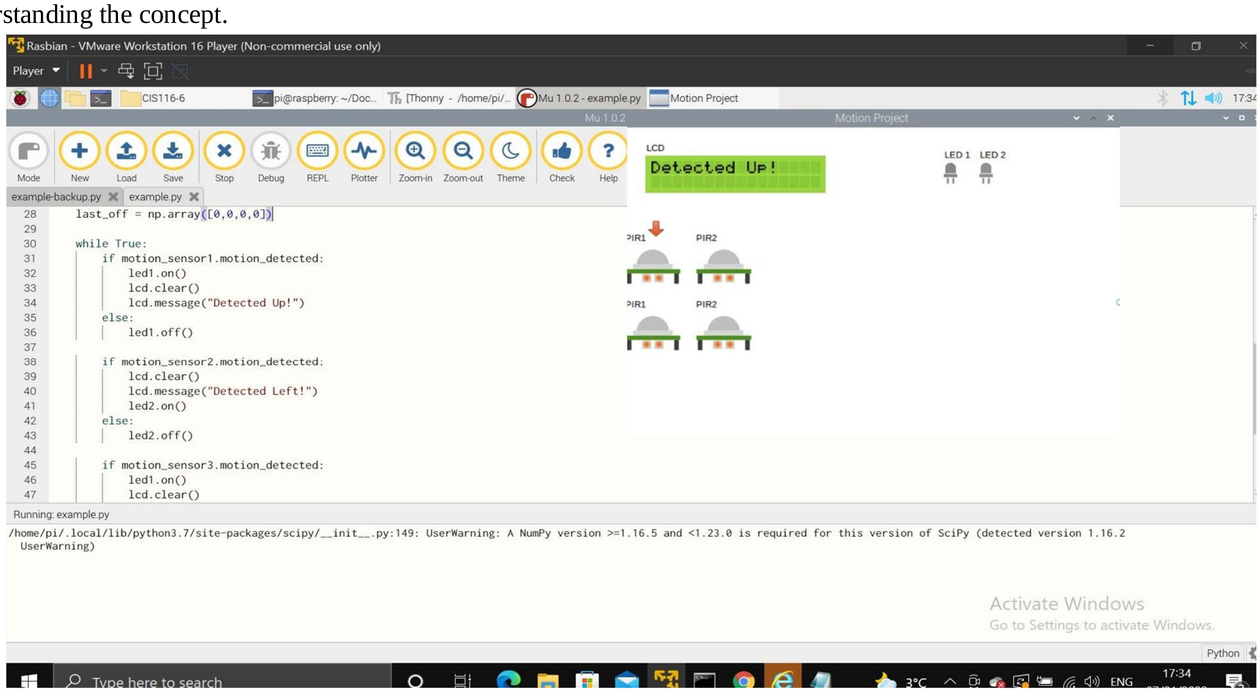

Fig-19: Detecting up

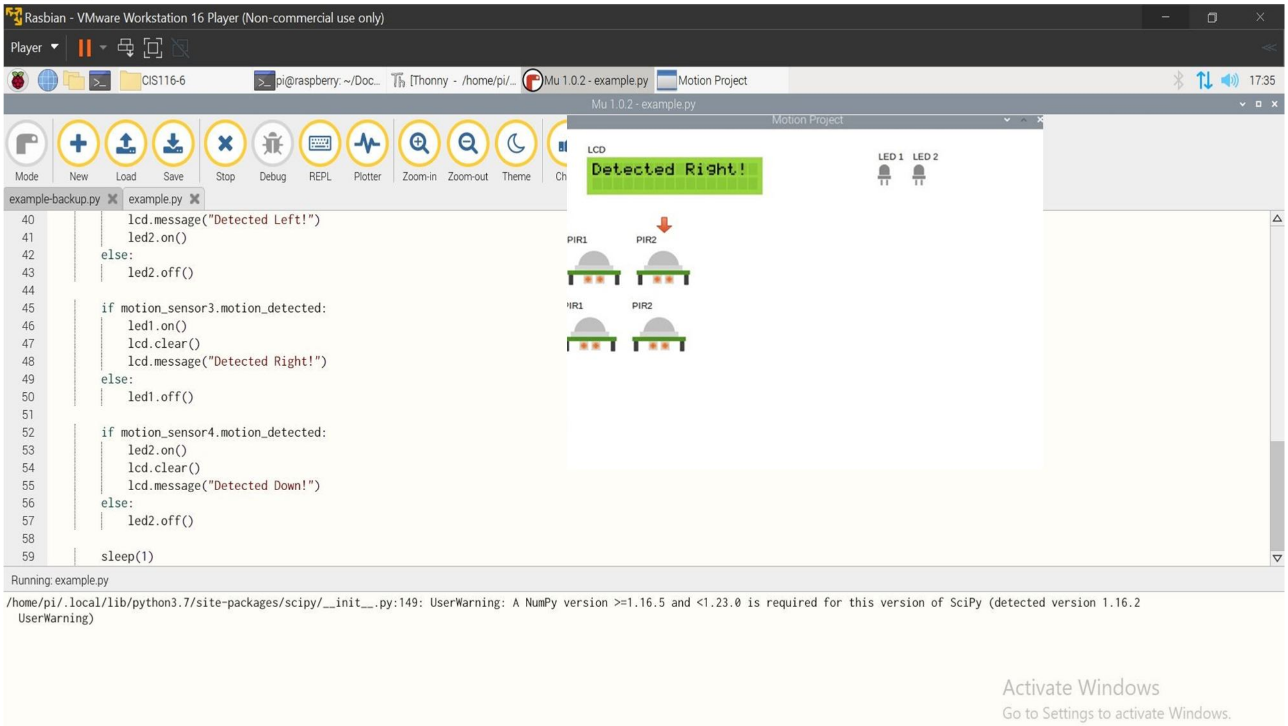

Fig-20: Detecting right

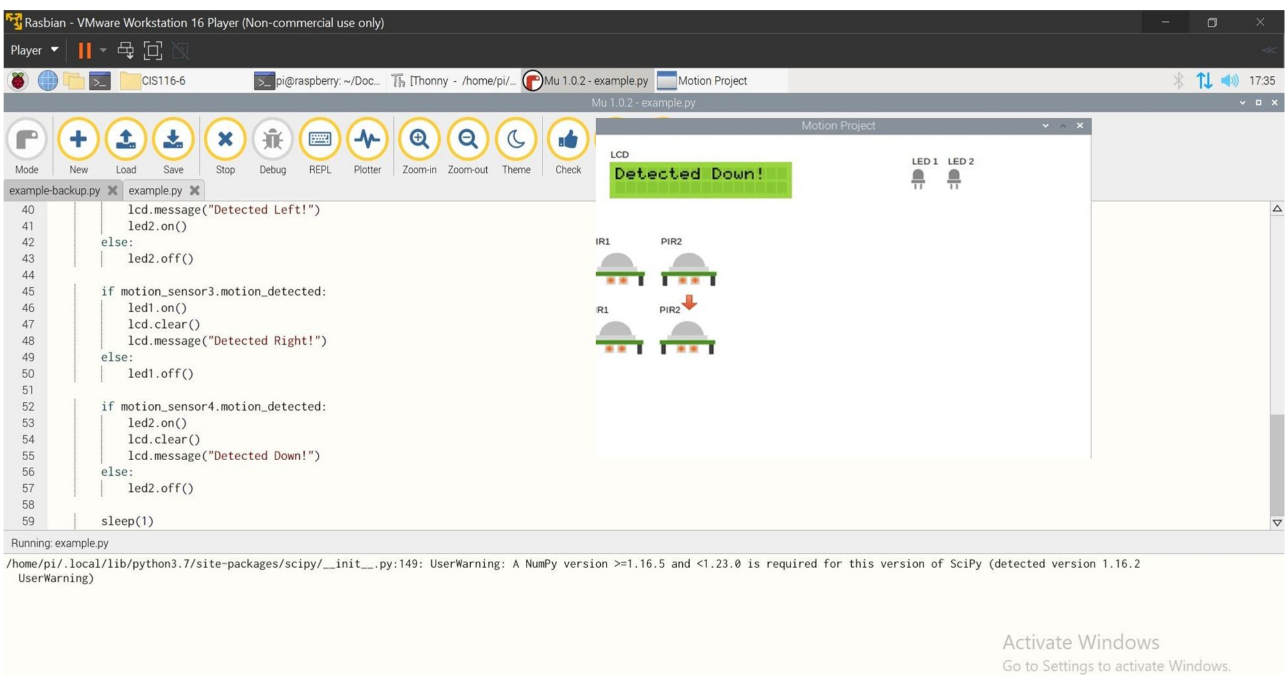

Fig-21: Detecting down

Following that, Fig-19, Fig-20, and Fig-21 represents the detection, while keeping the mouse to each sensor, which We indicated with red arrow in the whole screenshot. For our experiment we only consider four PIR sensors, raspberry, and the python coding, which detects only left, right, up, and down. When it comes to accuracy of our application is only 85 percent success rate in terms sensing the movement because PIR sensors can detect human being with maximum of 10 meters range and biggest drawback is if the temperature of the room is over 37 degrees. The sensors automatically turn off. Therefore, the result discussed the testing with successful coding, which runs the raspberry and detect the person movement in the room with the help of PIR sensor.

VI. CONCLUSION

The present work develops the smart motion detector based on IoT in order to precisely detect the direction of movement. The work provides the simulation with raspberry, PIR sensors and Python code. In addition, this application provides security for the home and office. The aim of this work is partially achieved if only four directions are recognized, and the work highlights and analyses the problems encountered while running the application. We have also found that the use of machine learning algorithms will advance the smart motion detector in the future.

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