Implementation of Home Security Motion Detector using Raspberry Pi and PIR Sensor

Amir Hifzan Azhar[1], Mohd Fairuz Iskandar Othman[1], Nazrulazhar Bahaman[1], Mohd Zaki Mas'ud[1] and Zurina Sa'aya[1]
[1]Fakulti Teknologi Maklumat dan Komunikasi (FTMK), Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
Email: b031810264@student.utem.edu.my

Abstract—Home Security Motion Detector is a system to monitor the movements of intruders in the home area. However, the existing CCTV system lacks a motion detection mechanism and is expensive. Therefore, a low-cost system is implemented using Raspberry Pi Zero, a PIR Sensor, a Pi Camera, push notification features, and Android applications. The Android application is integrated with the proposed system to allow users to monitor their homes from remote sites. The system may also be controlled with a few basic commands, which the user may enter into the Telegram application. The PIR sensor allows night vision motion detection and records the video for future reference. Findings show that even though the home security motion detector system is a low-cost system but it produces a high-quality output in a fast duration of detection, which the alert notifies the user's smartphone. In a conclusion, the proposed system shows that the system is able to send notifications even though the camera is blocked by a barrier. The motion sensor detects the presence of movement based on infra-red light in a range of 14 meters. The significance of the proposed system produces a convenient and secure environment for the neighbourhood from burglars and intruders.

Index Terms— Motion detector, PIR Sensor, Home security, Telegram, Raspberry Pi, Alert system

I. Introduction

Security is one of the most critical issues in today's world, whether for homes or businesses. The increased number of workers in the labour force reduces the amount of time people spend at home, making home security insecure. In addition to break-ins, the proliferation of internet retail has resulted in an increase in porch piracy in recent years. This study addresses home protection issues by offering a motion detector system that makes use of a Raspberry Pi, a Pi camera, and PIR Motion Detection Sensors [2].

The Raspberry Pi [3] is a miniature device (roughly the size of a credit card) that can be plugged into a computer monitor or other display and operated using a keyboard and mouse. It runs the Raspbian OS [4] operating system which can be a very useful system for running programmes written in programming languages such as Scratch and Python. Consequently, this study's aim is to develop a Home Security Motion Detector using Raspberry Pi and PIR sensor to send push notification to the user. This study helps user with alert system which notify the user using android application such as Telegram that is connected to the Raspberry Pi.

II. Previous Work

This study was designed to address a number of issues of [5], [6] and [7] respectively. In one method, a web camera [7] is installed in a home where motion is detected and information is sent to the user's phone via GSM module.

The article [8] offers the concept of using a smart phone to monitor a specific location in a remote region. This system captures data using a Raspberry Pi board and a camera, then delivers it via a 3G dongle to a smart phone over the internet.

The notion of controlling appliances via android phones is described in the paper [9]. The user sends the instructions via the Wi-Fi network from a faraway location. The relay circuit is enabled and the appliances are controlled by the Raspberry Pi device.

Author [10] suggested a home monitoring and security system using an Arduino Uno microprocessor and a PIR sensor, as well as temperature and humidity sensors. The method aims to use changes in motion and temperature in a monitored room to enhance intrusion detection accuracy by minimising false detections based on line of sight, which may be cut by any entity, not just an intruder. If the temperature rises over a certain level and motion is detected, an SMS message is delivered through GSM to the owner's phone.

This author [11] proposed a surveillance-enabled automated security system. To identify the presence of an intruder and capture his/her image, a PIR sensor and a camera were attached. The owner is notified using GSM technology's Short Message Service (SMS). An Atmega644p microcontroller was at the core of the system, receiving and processing data from the PIR sensor and deciding whether or not to send an SMS notification message with the recorded image.

Using a Raspberry Pi and the NodeMCU IoT/Wi-Fi module, Sruthy and George [12] presented a Wi-Fi enabled home security and surveillance system that merged sensor warnings with video surveillance. The major features of this system are intrusion and fire detection. Data may be retrieved from nearly anywhere or uploaded to a cloud storage for future monitoring because the system is entirely reliant on Wi-Fi connectivity. The NodeMCU module is linked to a PIR sensor node and a fire sensor node to detect human presence and fire, respectively. A signal is sent to the Raspberry Pi if a detection is made, and the built-in webcam is turned on to capture the occurrence. The viewer may see a live video of the scenario from a distance by connecting to the Raspberry Pi's IP address. The system offers two methods for sending alarm notifications: SMS (through a GSM module) and email. The GSM module informs the police in the event of an incursion and the fire department in the event of a fire.

III. Methodology And System Design

This study uses Rapid Development methodologies. RAD is a style of agile software development that emphasises quick product launches and iterations. RAD also prioritises applications and customer reviews over rigid preparation and

specification documentation. There are some of the key benefits and advantages of RAD which are code reuse is encouraged, which means less manual writing, less space for error, and faster testing times, better risk control so stakeholders discuss and fix code bugs as implementation activities continue, increased adaptability and versatility so developers can make changes easily during the development process and iterative development that reduces development time and speeds up execution.

A. Methodology

The RAD [13] approach is a software design technique that was created to combat the rigidity of other traditional software development models–models in which it is difficult to make modifications after the initial development has been completed. At every stage of the development process, the RAD approach is designed to be adaptable to changes and to accept new inputs, such as features and functionalities.

According to author [13] there are 5 stages in RAD. The first stage is define and finalize project requirements. During this stage, stakeholders meet to identify and finalise project specifications such as project priorities, objectives, schedules, and budget.

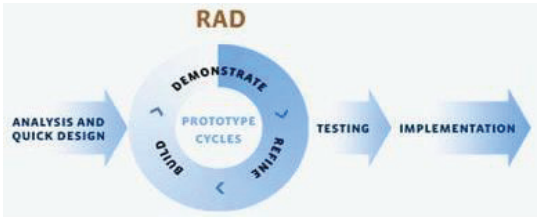

Fig. 1. RAD Methodology [13]

When the project's specifications have been specifically identified and scoped out, the management approval was requested. In this stage, the problem statement were found and then the objectives to come out with the solution. The requirement for this study is finalize for examples all the component needed such as the Raspberry Pi Zero, the Pi Camera and the PIR Sensor was bought.

The second stage is begin building prototypes. As soon as the scoping for the project is finish, the development can begin. The designers and engineers can work together to build and refine operating designs before the finished product is complete. In this stage, the prototype was built based on the client and improves the prototype time by time.

The third stage is gather user feedback. Prototypes and beta systems are transformed into working models in this process. Users' input is then gathered by developers in order to modify and refine designs to produce the next possible product. In this stage, all the feedback from the client is collected after let the client to have a look at the prototype. Then all the feedback is used to improvise the prototype.

The fourth stage is testing. This stage allows me to validate my software product and ensure that all of the moving pieces perform in accordance with client standards. Continue to incorporate customer input as the code is checked and retested to ensure proper operation.

The last stage is present the system. This is the last stage before the finished product is released to the public. It entails data transfer as well as user training.

B. System Design

a) Requirement Analysis

The process of identifying user expectations for new or altered software is known as requirement analysis, sometimes known as requirement engineering. In software engineering, it is also known as requirements gathering or requirements capture.

The PIR sensor and Pi Camera have been attached to the Raspberry Pi in order for the hardware device to begin receiving input. The instruction is programmed in the Raspbian [4] operating system and sent via Botfather [1]. The Botfather [1] then send the input to the Raspberry Pi, and if motion is detected, the sensor will capture it. The Botfather [1] also deliver input to Raspberry Pi if the user input command via telegram. After the motion detected or the user input the command, the Raspberry Pi sent the output to the user via Telegram.

Fig. 2 shows the design of the connection of the PIR sensor to Raspberry Pi Zero. The VCC pin of the sensor is connected to 5V pin. The OUTPUT pin of the sensor is connected to any numbered GPIO pin on the Raspberry Pi and the GND is connected to ground pin on the Raspberry Pi.

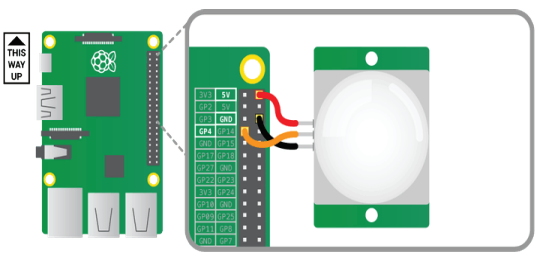

Fig. 2. Raspberry Pi GPIO to Sensor Pin Design.

b) Hardware

- Raspberry Pi Zero

For this study to success, there are several hardware and software that are needed. The Raspberry Pi Foundation introduced the Raspberry Pi Zero, the smallest and most affordable member of the Raspberry Pi family to date, measuring 65 mm 30 mm and costing US$5. The Zero is similar to the Model A+ in that it lacks camera and LCD connectors, but it is smaller and consumes less power.

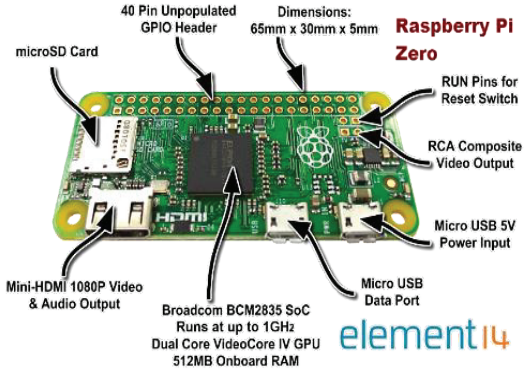

Fig. 3. Raspberry Pi Zero [14]

- PIR Sensor

A PIR sensor can detect variations in the quantity of infrared radiation impinging on it, which varies based on the temperature and surface properties of the objects in front of it. When an item, such as a person, passes in front of a backdrop, such as a wall, the temperature in the sensor's field of vision rises from ambient temperature to body temperature and then back again.

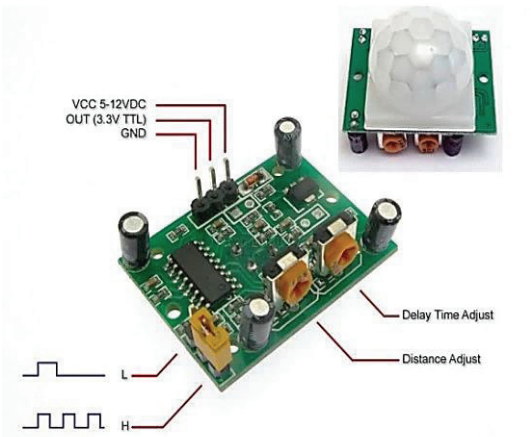

Fig. 4. PIR Sensor [15]

- Pi Camera

This 5-megapixel sensor with OV5647 camera module can capture 1080p video and still photographs and connects to your Raspberry Pi directly. This is the newest version of the Raspbian [4] operating system that is plug-and-play compatible, making it ideal for time-lapse photography, video recording, motion detection, and security applications. The board itself is small, measuring around 25mm x 23mm x 9mm and weighing little over 3g, making it ideal for mobile or other applications where size and weight are critical.

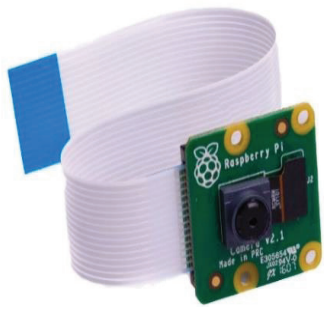

Fig. 5. Pi Camera [16]

- Female Jumper Wires

Jumper wires are short wire conduits that may be used to connect components on breadboards or anywhere else. This product's female and female heads, which include plastic heads, can enable a simpler connection without the need for soldering.

Fig. 6. Female Jumper Wires [17]

- Laptop

This study requires the use of a laptop to program the hardware and create the project report. The project requires a minimum of 4GB of RAM to run. In this study, VNC is used to connect to the Raspbian OS [4] in order to construct the Home Security Motion Detector System.

- Android Smartphone

An android phone is needed for this study in order to use the Telegram application so that the Raspberry Pi can send the push notification to it.

c) Software

- Raspbian OS

Raspberry Pi OS has been specifically designed for the Raspberry Pi range of small single-board computers powered by ARM CPUs. Except for the Pico microcontroller, it operates on all Raspberry Pi models. Raspberry Pi OS's desktop environment is a modified LXDE with the Openbox stacking window manager and a unique look.

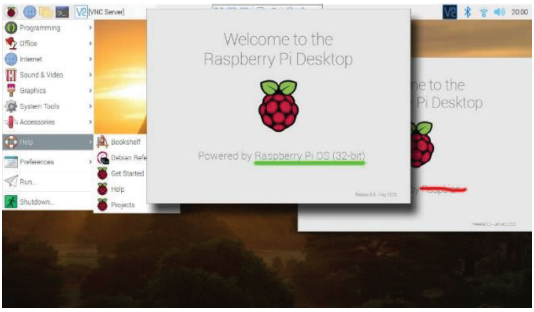

Fig. 7. Raspbian OS [18]

- Telegram

Telegram is a cross-platform, cloud-based instant messaging (IM) programme that is available for free. End-to-end encrypted video calling, VoIP, file sharing, and a variety of other capabilities are also available. It was released for iOS on August 14, 2013, and for Android in October 2013.

- The Botfather

Botfather [1] is a universal automation framework that was created by a group of European students. Botfather [1] was first established to compete with other computer science students in the creation of bots for casual gaming. It has now been expanded to enable for the automation of Android, Browser, and Desktop apps. Table 1 shows the requirements needed.

TABLE I
REQUIREMENT TABLE

Hardware	Software
Raspberry Pi Zero	Raspbian OS
PIR Sensor	Telegram
Pi Camera	The Botfather
Jumper Wires	
Laptop	
Android Smartphone	

The architecture that would be utilised to construct a system is described in high-level design (HLD). The architectural diagram depicts a comprehensive system, indicating the primary components that would be produced for the product as well as their interactions.

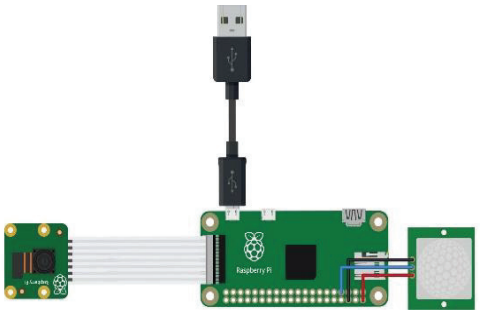

Fig. 8. Circuit Diagram [19]

Fig. 8 shows the circuit diagram of the system. The Raspberry Pi zero is used as a microcontroller to control the PIR sensor and also to control the pi camera. The Raspberry Pi can be booted up when connected to the micro USB cable. The PIR sensor is attached to the Raspberry Pi zero using 3 female-to-female jumper wires which are VCC to pin 2(5V), OUT to pin 16(GPIO 23) and GND to pin 6(ground) while the pi camera is connected using ribbon cable.

Fig. 9 shows the High-Level Design Diagram for this study. There are two ways that the diagram shows. The first one is with the black arrows and the other one is with the orange arrow. The black arrow show the path on how the system works. When the PIR sensor detect the motion, the Pi Camera records a 30 second video and send the video to the Raspberry Pi to convert it into MP4 then the video send to the Telegram via Botfather [1] which is the users' phone. The orange path show how the user interact with the system. The user can insert command that shown in Fig. 11 then the command sends to the raspberry pi. After that Raspberry Pi reacts based to the user command. Then when user execute the command, it follows back the black arrow start from the PI Camera.

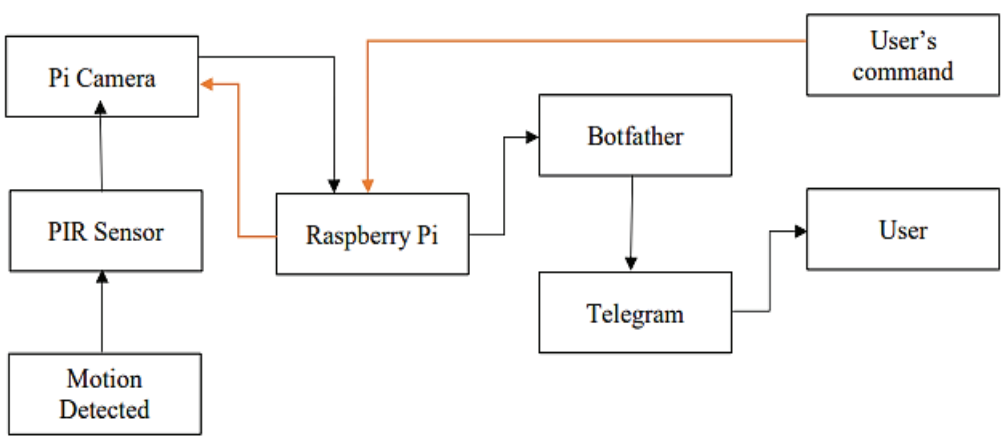

Fig. 9. High-Level Design Diagram.

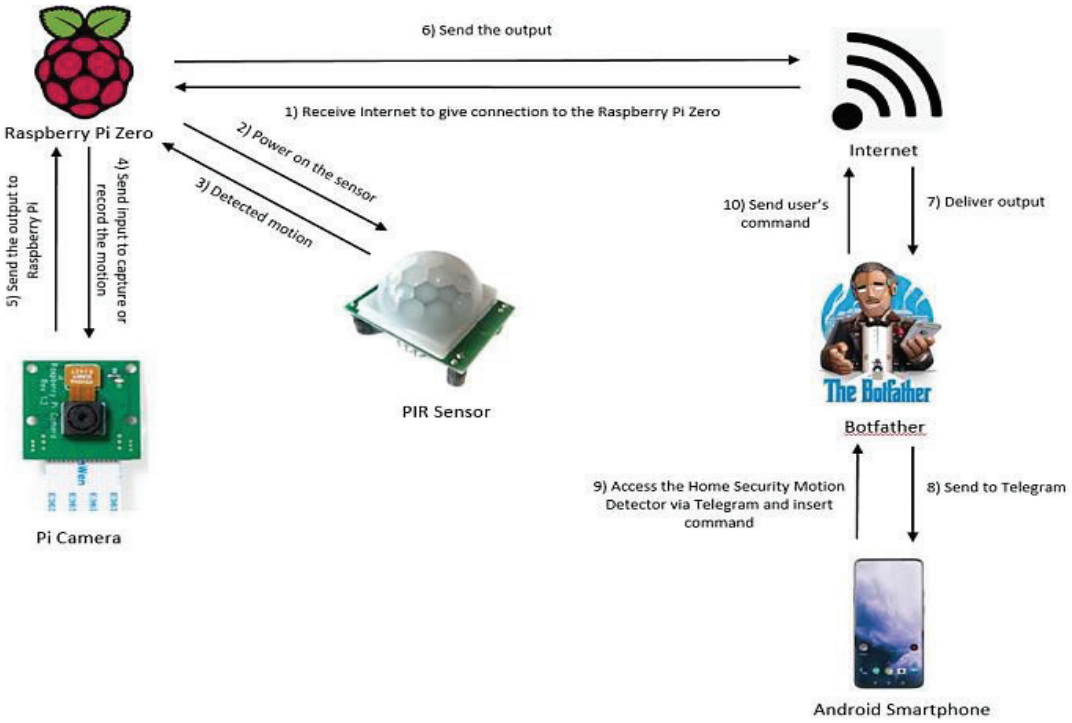

Fig. 10. System Architecture.

Fig. 10 shows the system architecture for this study. The design is conceptualized of how the system works. The Raspbian operating system [4] is used to construct the motion detecting system. Because the system is controlled by Botfather [1], the Telegram app on the user's smartphone serves as the system's interface. The system can be run after the Raspberry Pi is boot up and receive the internet. Once the Pi Camera and the PIR sensor is running, the PIR sensor can detect any motion and the Pi Camera can record or capture. Any motion that is detected by the PIR sensor records by the Pi Camera and the recording of 30 seconds video delivers to Raspberry Pi for the conversion process to MP4. Then Raspberry Pi uses internet to send the output to Botfather [1] which the user gets the notification via Telegram in their smartphone.

C. Implementation

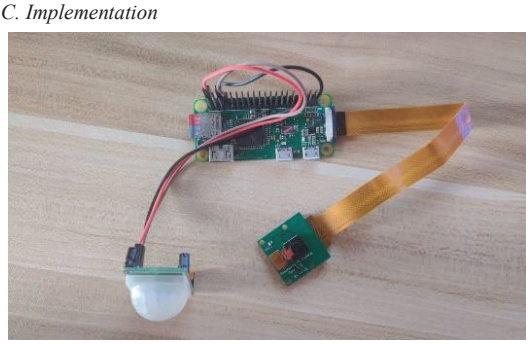

Fig. 11. Actual Product Development.

Fig. 11 shows the actual product that has been assemble. So after all the component has been fully assemble, the Raspbian OS [4] was installed and connected to the laptop virtually using VNC Viewer. This study uses Telegram as an interface and to control the system. User can interact with the system using the Botfather [1] within the Telegram itself. This interface provides the user with a fundamental understanding of how the system's flow operates. Telegram application need to be install either in android phone or computer so that the motion detection system can be control. The Raspberry Pi is connected to the telegram via bot which is using a bot token that need to be create first in order to get the token ID. After that, the token ID is put in the python code in the Raspberry Pi. Fig. 12 shows that the Raspberry Pi is successfully connected to the telegram. Then, to check whether the system is running or not, just send /status command to show the status of the home security system. Fig. 10 show the interface and the flow design of the project.

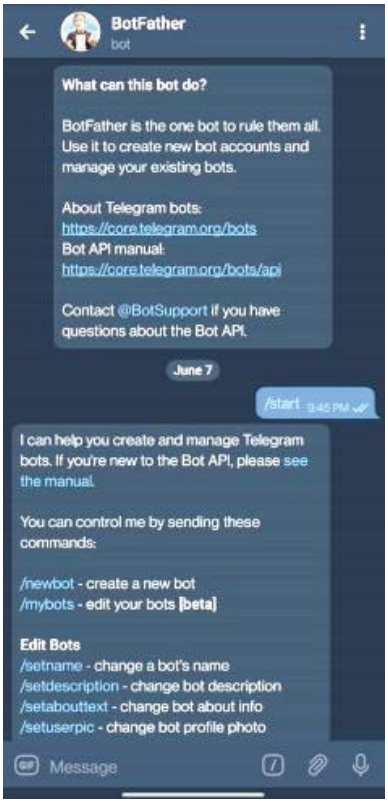

Fig. 12. User Interface.

Once the sensor detect any motion or movement, it takes 30 second video and send to the Botfather [1] which is to the user's smartphone. The user also can insert some command that is shown in the Fig. 13. This can be very useful as the user can instantly open the Telegram application and go to the Botfather [1] chat and can start to control the system. When the user insert the /start command, the bot executes and if it detect any motion, it takes 30 seconds video to the user. When the user insert the /video command, the bot sends the recording of the current situation for about 30 second. When the user insert the /photo, the bot sends the image of the current situation to the user. When the user insert the /status command, the bot sends the status of the system whether it is running or not. When the user insert the /help command, the bot shows all the command that the user can use to control the bot. When the user insert the /stop command, the bot stops detecting any motion. Fig. 12 – 19 show how the system works whether based on the motion detection or user command.

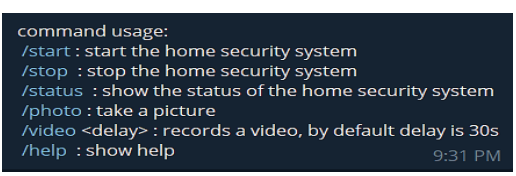

Fig. 13. Command Usage.

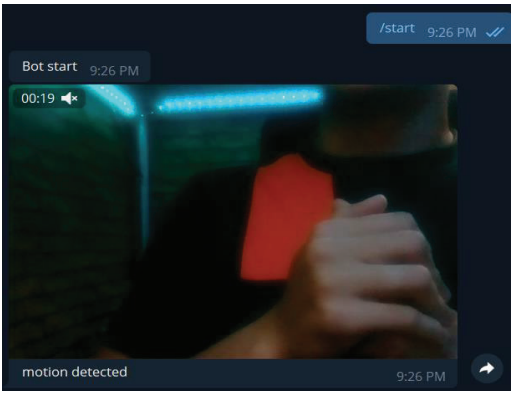

Fig. 14. Start Command.

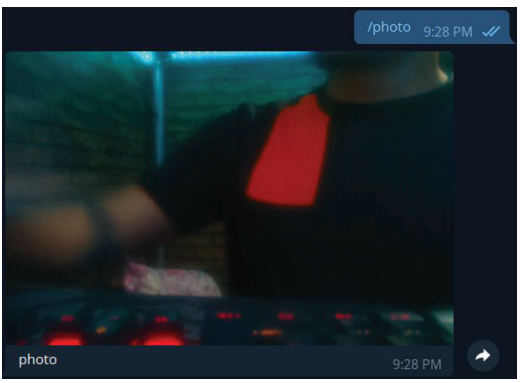

Fig. 15. Photo Command.

Fig. 16. Stop Command.

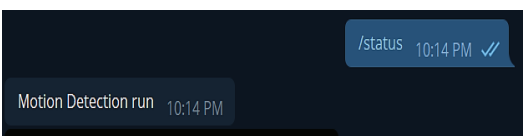

Fig. 17. Status Command.

Fig. 18. Video Command.

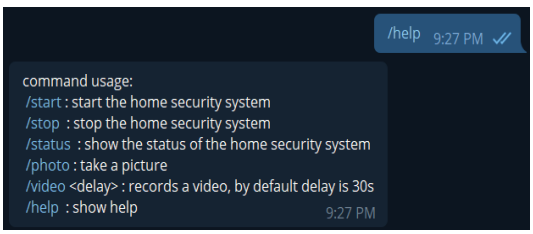

Fig. 19. Help Command.

D. Testing Results

In this phase, several testing were conducted. The first testing were conducted using a PIR sensor and a Pi camera. This testing is made to see the functionality of the system itself. The Telegram program is used to receive messages and transmit commands, making the system user-friendly and efficient. In each testing, 10 tests were performed and the number of passing results were recorded. Table 2 shows the result of the first testing. In second testing, the sensitivity of the sensor were tested and the range of the detection also were tested and the results is shown in Table 3. The last testing is to test the functionality of the system. Table 4 shows the results of the testing.

TABLE II
FUNCTIONALITY RESULTS

Test	Condition	Accuracy Of PIR Sensor (%)	Comment
1	2pm (Good lighting)	95	PIR sensor and Pi Camera works perfectly.
2	5pm (Enough lighting)	90	PIR sensor and Pi Camera works fine.
3	7pm (Good lighting due to outdoor lamp)	80	PIR sensor and Pi Camera works fine.
4	11pm (Good lighting due to outdoor lamp)	80	PIR sensor and Pi Camera works fine.
5	1am (Good lighting due to outdoor lamp)	80	PIR sensor and Pi Camera works fine.
6	6am (Outdoor lamp turn off automatically)	60	PIR sensor works fine but Pi Camera suffer to record quality video.
7	Pi Camera is blocked	-	PIR sensor still detect any motion and the Pi Camera still record video.
8	PIR sensor is blocked	-	PIR sensor cannot detect any motion.
9	Both PIR sensor and Pi Camera is blocked	-	PIR sensor cannot detect any motion.
10	9am (Good lighting)	90	PIR sensor and Pi Camera works fine.

Based on the Table 2, we can see that the result from test 1 until test 6 were the best example on how the system works. The system works perfectly if it get very good lighting and mostly the Pi Camera is place where it has good lighting such as at the front door and porch. On test 6, the accuracy drop to 60% due to the severe lighting, the PIR sensor still works perfectly but the Pi Camera cannot record quality video because of the severe lighting. The video recorded by the Pi Camera unclear and a little bit noisy but it still send the video to the user as a push notification via Telegram. Test 7 until test 9 were done to test the limit of the system. Test 7 shows that the Pi Camera still record the video because the PIR sensor detect any motion but the video is black because it is blocked. Test 8 were done to see whether the PIR sensor still can run if it is blocked. The test shows that the PIR sensor cannot detect any motion if it is blocked. Test 9 shows that the PIR sensor cannot detect any motion then the Pi Camera not record any video until the PIR sensor is unblocked. Test 10 shows that the system back to running smoothly if the PIR sensor and the Pi Camera is not blocked. Each condition is tested 5 times for example Test 1 was made at condition 2 pm and have good lighting. So, 5 test were made within the same condition and equation below is used to calculate the accuracy of the PIR Sensor

$$\text{Test} = \frac{(\text{test1}) + (\text{test2}) + (\text{test3}) + (\text{test4}) + (\text{test5})}{500} \times 100$$

TABLE III
SENSITIVITY

Test	Range	Sensitivity	Comment
1	Up to 6 meters	Set to high	Any movement can be detected.
2	Up to 6 meters	Set to low	Need more movement to be detected.
3	Up to 3 meters	Set to high	Detect unnecessary movement.
4	Up to 3 meters	Set to low	Small movement can be detected easily.

Table 3 shows the range of the PIR Sensor when it set to certain sensitivity. The sensitivity of the PIR Sensor can be set either to the low or high sensitivity. In test 1, the sensitivity is set to high and the range of detection is up to 6 meters. Any movement can be detected easily but this can be a disadvantage as in test 3 which it detect unnecessary movement for example a pet walking from a far distance. This can also cause false positives in smaller spaces. In test 2 from Table 3, the sensitivity is set to low and any movement from distance up to 6 meters need more movement to be detected. First I did was walked approximate 7 meters away from the sensor and I had to make a big movement to get detection. But in test 4 which the sensitivity is set to low and the range is up to 3 meters, any movement can be detected easily. For this study, low sensitivity and range up to 3 meters that is suitable for the environment around the front door or place that the user want to put the camera. Any motion or movement up to 3 meters can be detected easily and unnecessary movement from far away should not be detected.

TABLE IV
FUNCTIONALITY TESTING RESULT

No	Scenarios	Predicted Result	Actual Result	Pass/ Fail
1	Motion detector able to trigger the Pi camera to record image	Video of the person is recorded	Video of the person is recorded	Pass
2	Push notifications have no significant delay	User is notified in less than 40 seconds after motion triggered	User is notified in less than 40 seconds after motion triggered	Pass
3	Raspberry Pi is storing every single video recorded by the system	Yes	Yes	Pass
4	Raspberry Pi respond to every user command via Telegram	Yes	Yes	Pass
5	Motion detection and notifications are stopped on demand	Yes	Yes	Pass

Based on Table 4, Five test scenarios are run to validate the system's functionality. The actual test results are compared to the predicted result for each test. The test is regarded passed if the actual results are equal to or better than the predicted results. Table 4 shows that all five tests succeeded, indicating that the system's features are working as intended.

IV. DISCUSSION

The price comparison between this study and other aftermarket CCTV can be seen because this study was design with low cost budget and the amount that has been used to purchase all the products is RM67 only compare to the price of other CCTV which is RM100 and above.

The testing result shows that the system can still send push notification even though the Pi Camera is blocked. This is because the PIR sensor detect motion and Raspberry Pi sends input to Pi Camera to record a 30 second video and send the video to the Telegram and indirectly, the video is used as a push notification.

Basically, motion detection relies on light sensors to detect the presence of infrared light generated by a heated object or the lack of infrared light when an item blocks a beam emitted by another portion of the device. The infrared light emitted by a heated item is detected by a PIR sensor. It is made up of pyroelectric sensors that convert temperature changes into an electric signal. When infrared light strikes a crystal, an electrical charge is generated. As a result, a PIR sensor can detect the presence of humans within a detection range of around 14 meters.

Moreover, the internet connection for the Raspberry Pi need to be strong and fast enough so that the push notification can be get on time. For this study, portable hotspot is used for the internet connection of the Raspberry Pi. Therefore, there are some slight of delay for the push notification because the size of the recorded video roughly at range 1MB to 30MB in size which need a quite strong and fast internet to be able to send it to the Telegram at a rapid rate.

There may be some possible limitations in this study. The first is the connection of the internet to the Raspberry Pi. This project only used mobile data and it affects the speed for the Raspberry Pi to send push notification. Also, this project has a drawback in terms of how long the user gets notified once the motion is triggered. It is because the system needs to record 30 seconds video first then after that it sends the video as a push notification to the user. Moreover, the pi camera do not have the night vision mode that can record video at night or dark condition. So, when at night or dark condition, the pi camera records a blank video if the motion is triggered.

There is clearly future work to be done to overcome the limitations on this project. The first is strong internet connection such as using Wi-Fi improves the speed for the Raspberry Pi to send push notification. It helps the user to get notified in short period of time. The second is use text and video to be send as push notification. For example, if the motion is triggered, Raspberry Pi first send the text to the user to alert the user and followed by the video of the motion. This help the user to get notified even faster and can take action if needed. Lastly, adding night vision mode to the camera improves the quality of the video recorded especially at night and dark condition. It provides with much more details to the video since night vision has the ability to see in low-light condition.

V. CONCLUSION

Security of our homes and belongings has been a big issue in recent years. Even with the greatest security people on the job, there is a lot of theft and vandalism going on around us. Home Security Motion Detector Using Raspberry Pi and PIR Sensor *To Send Push Notification To The User* becomes a useful device for home residents, especially those who want to protect their home from intruders When the PIR sensor senses activity, it sends an alert to the user. The overall objectives for this project have been achieved in order to make this study different from the others. Every gesture or acceleration detected by the sensor is captured by the Pi Camera and sent to the user. Because of the usage of mobile technologies, this method is highly convenient. It's dependable and secure, with privacy on both sides. In the event of an emergency, necessary action can be

performed in a short amount of time. The user may defend oneself from intruders by placing the Home Security System in the proper location, such as their home, office, or server room. In a later version, the Android phone application is used to control the home security system, and the app has a number of useful and simple features that can be learned quickly after using it. In this study, the propose study and construct a low-power, low-cost, and inconspicuous home security system that aids in the detection of motion. The technology is incredibly low-maintenance and may be used in tomorrow's smart houses.

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