Implementation of Intrusion Detection System for Smart Home

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Abstract. This paper introduces an implementation of intrusion detection system for smart home, which helps people to be aware of their home condition via notification from the proposed system. If someone tries to break into their homes, the system detects motion and capture picture of intruder. The objectives for this study are to implement a Smart Home Intrusion Detection System (IDS), to develop tool that can monitor and capture picture of intruder automatically and to reduce false alarm produced from the proposed system. The proposed system utilizes the Raspberry Pi technology, PIR Sensor and Raspberry Pi camera. The finding obtained from this study is that the false alarm is reduced and considered to be an effective system for Smart Home.

1. Introduction
For the past few years, we were often informed by social media about crime happening especially at home and it is increasing day by day. Most of this crime happened due to absence of the owner of the house. Sometimes, there were people in the house but they do not notice their home was broken in by the intruder as they were in their room or sleeping. Besides, with only elderly people in the house also does not prevent home to be safe from robbery. Thus, home security has been a major issue nowadays for people as safety and security of any living place is one of the most primary concerns. Everybody wants to take proper measures to prevent intrusion. But, how can we make living better and safe nowadays?

Today, lifestyle of every person is changing with advancement of Internet technology [1]. Internet of Things (IoTs) can be described as connecting everyday objects like smart phones, Internet televisions, sensors [2] and actuators to the Internet where the devices are intelligently linked together to enable new forms of communication amongst people and themselves [3]. One of the example use of IoTs is smart home as to counter problem arise in the home due to risk of burglary and robbery and the busy lifestyle [4]. Smart home is a home equipped with special facilities to enable owner of the house to control or program an array of automated [5] home electronic devices to assists in their busy lifestyle [6]. With this advancement of technology, the safety and security of people and their belongings can be improved.
Therefore this paper proposed an implementation of intrusion detection system for smart home, which helps people to be aware of their home condition via notification from the proposed system. This relieves their concerned over their home safety. The proposed system utilizes the Raspberry Pi technology. If someone tries to break into their homes, the system detects motion and capture picture of intruder. Then the system notifies the owner of the home by sending the notification through WhatsApp application because nowadays the use of WhatsApp application for communication is very popular, easy to access and effective.

The busy lifestyle of people nowadays is leading to the necessity of keeping surveillance over their homes for safety measure. But, how can they manage to keep surveillance over their home while actually busy with their work? This surely affects their productivity as worker, while having insecurities of their home and belongings. Thus, this paper focuses on the development of intrusion detection system for smart home by using Raspberry Pi technology. The system is able to monitor if some intruder detected in the area and allows a camera to take picture after motion is sensed. After that, notification is then sent to the owner regarding to the situation, subsequently for the owner to take further action.

2. Methodology
The Home security has been a major issue nowadays for people as safety and security of any living place is one of the most primary concerns. Everybody wants to take proper measures to prevent intrusion. Implementation of intrusion detection system for Smart Home is being proposed to be one of the best proper measures on preventing the intrusion. Thus, how can we implement a simple yet efficient intrusion detection system for Smart Home that helps to secure home?

Firstly, an environment for the proposed system needs be set up. The Raspberry Pi 3 Model B, PIR Sensor and a Raspberry Pi Camera are considered in this study. The Raspberry Pi is integrated with PIR Sensor and the Raspberry Pi camera module. The proposed system monitors the environment area. If there is no intrusion, the proposed system simply continues to monitor the environment. For the proposed system to detect movement of any intrusion, PIR Sensor is used that assists with the function. In case their intrusion detects, the proposed system captures the image of intruder by using Raspberry Pi Camera module, which integrated with the PIR Sensor and the Raspberry Pi. Thus, the overall flowchart for proposed system is illustrated in Figure 1.

![Flowchart of the proposed system](image-url)
2.1. *Raspberry Pi Microcontroller*

A Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation. The Raspberry Pi comes in two models, which are model A and model B. Main different between model A and model B is USB port. Model A board will consume less power and does not include an Ethernet port. But, the model B board includes an Ethernet port. Thus, the latest version of Raspberry Pi product is used in the development of proposed system, which is Raspberry Pi 3 Model B as illustrated in Figure 2.

Moreover, Raspberry Pi provides features like media center, retro gaming machine, robot controller [7], stop motion camera, time lapse camera, FM radio station, smart TV and many more. By using this technology also help in providing system such as build a motion capture security system which combines the motion software with uvccapture, a tool for capturing the footage from webcam. A basic home automation system [8], which detailing on controlling [9] the work of home appliances [10,11] becomes one of example product that used Raspberry Pi technology. The specification for Raspberry Pi 3 Model B is shown in Table 1.

![Figure 2: Raspberry Pi 3 Model B](image)

| Type of Hardware         | Description                                      |
|--------------------------|--------------------------------------------------|
| System on Chip (SoC)     | BCM2837                                          |
| CPU                      | Quad Cortex A53 @ 1.2 GHz                        |
| Instruction set          | ARMv8-A                                          |
| RAM                      | 1GB SDRAM                                        |
| Storage slot             | Yes, for a microSD                               |
| Ethernet                 | 10/100                                          |
| Wireless                 | 802.11n / Bluetooth 4.0 [12]                    |
| GPU                      | Video Output: HDMI / Composite Audio Output: HDMI / Headphone GPU: 400MHz VideoCore IV |
| USB Port                 | 4                                                |
| GPIO                     | 40                                               |
2.2. PIR Sensor Module

The PIR sensor is used to detect any movement from it designated range. The module is a small, inexpensive, low-power, easy to use and don't wear out module, as illustrated in Figure 3. PIR sensors are incredible, they are flat control and minimal effort, have a wide lens range, and are simple to interface with.

![Figure 3: PIR Sensor](image)

When the sensor is idle, both slots can detect the same amount of IR, the ambient amount radiated from the room or walls or outdoors. Moreover, when warm bodies like a human or animal passes by, it first intercepts one half of the PIR sensor, which will cause a positive differential change between the two halves. Then, when the warm body leaves the sensing area, the reverse happens, where the sensor generates a negative differential change. So, these change pulses are what is detected by the PIR sensor. The specification of the PIR sensor module is shown in Table 2.

| Specification     | Description                                                                 |
|-------------------|-----------------------------------------------------------------------------|
| Size              | Rectangular                                                                 |
| Output            | - Digital pulse high (3V) when triggered (motion detected) digital low when idle (no motion detected). |
|                   | - Pulse lengths are determined by resistors and capacitors on the PCB and differ from sensor to sensor. |
| Sensitivity Range | up to 20 feet (6 meters) 110° x 70° detection range                          |
| Power supply      | 5V-12V input voltage for most modules (they have a 3.3V regulator), but 5V is ideal in case the regulator has different specifications. |
2.3. *Raspberry Pi Camera Original Version*

The Raspberry Pi camera module connects to Raspberry Pi by way of a short ribbon cable. The camera is connected to the BCM2835 processor on the Pi via the CSI bus, a higher bandwidth link which carries pixel data from the camera back to the processor. This bus travels along the ribbon cable that attaches the camera board to the Pi. The sensor itself has a native resolution of 5 megapixels and has a fixed focus lens onboard. The camera also capable of 2592 x 1944-pixel static images for still image, and supports 1080p30, 720p60 and 640x480p60/90 video. The original camera module is supported in the latest version of Raspbian, Raspberry Pi's preferred operating system. Figure 4 illustrates the 5MP camera board for Raspberry Pi.

![Figure 4: Original Camera Module Raspberry Pi](image)

Raspberry Pi Camera module has two versions, which are the original camera module and camera module version 2. For this study, the original Raspberry Pi Camera Module is used. The specification of Raspberry Pi Camera module for the original version is shown in Table 3.

| Specification            | Description                        |
|--------------------------|------------------------------------|
| Size                     | Around 25 x 24 x 9 mm              |
| Weight                   | 3 g                                |
| Still Resolution         | 5 Megapixels                       |
| Video Modes              | 1080p30, 720p60 and 640x480p60/90  |
| Linux Integration        | V4L2 driver available              |
| Sensor                   | OmniVision OV5647                  |
| Sensor Resolution        | 2592 x 1944 pixels                 |
| Sensor Image Area        | 3.76 x 2.74 mm                     |
| Pixel Size               | 1.4 m x 1.4 m                      |
| Optical Size             | 1/4                                |
| Full-frame SLR lens equivalent | 35 mm                 |
| S/N Ratio                | 36 dB                              |
2.4. System Architecture and Design
The Raspberry Pi is integrated with those modules; PIR Sensor and Camera module to be a complete detection system. Figure 5 and Figure 6 show an overview on how the proposed system is implemented and the high-level design is established.

![Figure 5: System Architecture for Proposed System](image1)

![Figure 6: High-Level Design](image2)

3. Analyses and Results
3.1. Environment Setup
Here, we considered three scenarios that we have setup for the proposed system testing. The different between scenarios is the number of PIR Sensor used and the positioning of PIR Sensor and several testing is done in each scenario in order to get accurate results. Scenario I states the position of PIR Sensor in the house model on the right side. Meanwhile, for Scenario II states the position of PIR Sensor in the left side in the house model. Scenario III is having two PIR sensors in the house model. The main purpose of having these three scenarios is to observe the effectiveness of proposed system by reducing the false alarm.
3.1.1. Scenario I. The first environment setup for testing is shown in Figure 7. In this environment setup, we used only a PIR Sensor integrated with Raspberry Pi Camera using Raspberry Pi technology. The position for PIR sensor is on the right side of the house model. There would be testing for this scenario as to get the accurate result, where the test object is placed in the house model and observation for testing to be done. The PIR sensor must be able to sense movement of object and the image must be captured successfully.

![Figure 7: Scenario I House Model Setup](image)

**3.1.1.1 Testing Scenario I**
The purpose of testing for Scenario I is to get the accurate result, where the test object is placed in the house model and observation for testing to be done. The result of Scenario I is then compared with the result of Scenario II and Scenario III.

In Scenario I, the testing is done as follows:
1. Testing is done from door part of house model.
2. Testing is done on various directions as to get accurate result.
3. PIR Sensor must sense the movement of test object.
4. Raspberry Pi Camera must be able to capture image of test object.

**3.1.1.2 Result Testing Scenario I**
The result of every testing for Scenario I is shown in Table 4.

| Test Object Task       | Test Number | Detection from PIR Sensor | Image Captured by Raspberry Pi Camera |
|------------------------|-------------|----------------------------|--------------------------------------|
| Stay still             | 1           | Y                          | Y                                    |
|                        | 2           | Y                          | Y                                    |
| Move toward PIR Sensor | 1           | Y                          | Y                                    |
|                        | 2           | Y                          | Y                                    |
| Move vertically to opposite side | 1       | Y                          | Y                                    |
|                        | 2           | Y                          | Y                                    |
| Move toward Window     | 1           | Y                          | Y                                    |
|                        | 2           | Y                          | Y                                    |
3.1.1.3  **Analysis Testing Scenario I (Justification)**

We can see that the PIR sensor can detect the movement from the door. The PIR Sensor detects presence of test object and the system manages to capture image of test object when the test object is in all movement available in testing. This is because the test object is in the area that the Raspberry Pi camera covered. So, the process of detection and capturing image successfully tested.

![Result Image Captured Scenario I](image_url)

**Figure 8: Result Image Captured Scenario I**

3.1.2  **Scenario II.** The second environment setup for testing is shown in Figure 9. Same goes for this environment setup, we used only a PIR Sensor integrated with Raspberry Pi Camera using Raspberry Pi technology. The position for PIR sensor is on the left side of the house model. There would be testing for this scenario as to get the accurate result, where the test object is placed in the house model and observation for testing to be done. The PIR sensor must be able to sense movement of object and the image must be captured successfully.

![Scenario II House Model Setup](image_url)

**Figure 9: Scenario II House Model Setup**

3.1.2.1  **Testing Scenario II**

The result of Scenario II is then compared with the result of Scenario I and Scenario III. The purpose of testing for Scenario II is to get the accurate result, where the test object is placed in the house model and observation for testing to be done.
In Scenario II, the testing is done as follow:
1. Testing is done from window part of house model.
2. Testing is done on various directions as to get accurate result.
3. PIR Sensor must sense the movement of test object.
4. Raspberry Pi Camera must be able to capture image of test object.

3.1.2.2 Result Testing Scenario II
The result testing for Scenario II is shown in Table 5.

Table 5: Result Testing Scenario II

| Test Object Task            | Test Number | Detection from PIR Sensor | Image Captured by Raspberry Pi Camera |
|-----------------------------|-------------|---------------------------|---------------------------------------|
| Stay still                  | 1           | Y                         | N                                     |
|                             | 2           | Y                         | N                                     |
| Move toward PIR Sensor      | 1           | Y                         | Y                                     |
|                             | 2           | Y                         | Y                                     |
| Move vertically to opposite side | 1   | Y                         | Y                                     |
|                             | 2           | Y                         | Y                                     |
| Move toward Door            | 1           | Y                         | Y                                     |
|                             | 2           | Y                         | Y                                     |

3.1.2.3 Analysis Testing Scenario II (Justification)
We can see that the PIR sensor can detect the movement from the window. The PIR Sensor detects presence of the test when the test object is in all movement available in testing. Unfortunately, when the test object stayed still in at the window direction, the image of test object is not being captured even though the PIR sensor detects the presence of test object. This is because the test objects that doing task stayed still and not being in the area that the Raspberry Pi camera covered.

Figure 10: Result Image Captured Scenario II

3.1.3 Scenario III. The third environment setup for testing is shown in Figure 11. In this environment setup, we used two PIR Sensor integrated with Raspberry Pi Camera using Raspberry Pi technology. In the testing, both PIR sensors must be able to sense the test object, but prior to have some time for both PIR sensors to sense the test object. Thus, the images of test objects are captured successfully.
3.1.3.1 Testing Scenario III
The result of Scenario III is then compared with the result of Scenario I and Scenario II. The purpose of testing for Scenario III is to get the accurate result, where the test object is placed in the house model and observation for testing to be done. The result of Scenario III is then compared with the result of Scenario I and Scenario II.

In Scenario III, the testing is done as follow:
1. Testing is done from both part of house model. (door and window)
2. Testing is done on various directions as to get accurate result.
3. PIR Sensor must sense the movement of test object.
4. Raspberry Pi Camera must be able to capture image of test object.

3.1.3.2 Result Testing Scenario III
Both the PIR Sensors must be functioning successfully. The result testing for Scenario III is shown in the Table 6.
### Table 6: Result Testing Scenario III

| Direction | Test Object Task | Test Number | Detection from | Image Captured by Raspberry Pi Camera |
|-----------|------------------|-------------|----------------|---------------------------------------|
| Door      | Stay still       | 1           | Y              | N                                     |
|           |                  | 2           | Y              | N                                     |
|           | Move toward PIR Sensor | 1     | Y              | N                                     |
|           |                  | 2           | Y              | N                                     |
|           | Move vertically to opposite side | 1     | Y              | Y                                     |
|           |                  | 2           | Y              | Y                                     |
| Window    | Stay still       | 1           | Y              | N                                     |
|           |                  | 2           | Y              | N                                     |
|           | Move toward PIR Sensor | 1     | Y              | N                                     |
|           |                  | 2           | Y              | N                                     |
|           | Move vertically to opposite side | 1     | Y              | Y                                     |
|           |                  | 2           | Y              | N                                     |

### 3.1.3.3 Analysis Testing Scenario III (Justification)

We can see that in every direction have different results of testing. In Scenario III, there are two types of testing, where the compilation of testing is done from door and window part. In both testing, we can see that the image captured by the Raspberry Pi is much lower. This is because as to have the Raspberry Pi camera to success capture image of test object, the test object must be sensed by both PIR sensors. But, we can see that some testing that resulting on the both PIR Sensors sensed and Raspberry Pi camera captured the image successfully. Thus, the false alarm for the proposed system can be reduced by implementing this scenario.

![Figure 12: Result Image Captured Scenario III](image)
4. Conclusion and perspectives
As to improve human lifestyle nowadays, a system had been proposed to provide simple yet efficient intrusion detection for Smart Home. The purpose of having this system is to help in securing home as busy lifestyle of human nowadays is leading to the necessity of keeping surveillance over their homes for safety measures. The proposed system utilizes the Raspberry Pi technology. This paper proposed the use of the hardware modules, which are Raspberry Pi 3 Model B, PIR Sensor and Raspberry Pi camera. The proposed system is able to monitor and detect if some intruder in the area and allow a camera to take picture of the intruder. Moreover, the false alarm can be reduced in the proposed system as to have an effective intrusion detection system. The proposed system is developed based on the objectives of the study, which are to implement Smart Home Intrusion Detection System, to develop tool that can monitor and capture picture of intruder automatically and to reduce false alarm from the proposed system.

The recommendation that can be done in future work is to implement a module for notification process for the proposed system. This will help to give a better improvement for the proposed system in implementing a good Smart Home.

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