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A Development of the Internet of Things based Intruder Detection and Security Alarm System

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Abstract*: Intruders usually break into houses with the intention of committing burglaries. This research proposed a development of an intrusion detection and security Alarm System using the Internet of Things. The methodology of the proposed system consists of five components. First, the hardware components are Raspberry Pi 3 Model B+, a camera for Raspberry Pi, motion sensors, relays and speakers, while the software system was developed by Python. Second, the architecture of the proposed system. Third, the design and construction of the electronic circuit connected with sensors. Fourth, the intruder image analysis for the alarm system using OpenCV and Deep Learning. The face detected by the camera was compared with homeowner's pictures. If the detected face was not the homeowner, the system alarms the user or the owner via the smartphone LINE Application. Last, the Anto, which is the free and easy Internet of Things platform, connect the devices and the smartphone application together via the internet. Hence, the users or homeowners can control the devices or take the picture from a distance using a smartphone. The experimental results show that the proposed system can detect the intruder and alarm the homeowner via LINE Application on the smartphone. The experimental results show that the proposed system can efficiently detect the intruder and alarm the homeowner via LINE Application on the smartphone. The performance of the proposed system is excellent with the average score of 97.40%. The developed application on the Android smartphone is user-friendly, simple and efficient as well.

***Index Terms*: Alarm System, Anto, Internet of Things, OpenCV, Raspberry Pi.**

I. INTRODUCTION

[1] has defined the word "asset" as tangible or intangible objects which can be owned and converted into money. Assets can be classified into three types: 1) Fixed Assets such as factories, machines, lands, equipment. 2) Financial assets such as money, bank notes, stocks, bond and 3) intangible assets such as trademarks, patents, copyrights, and goodwill. Each homeowner has various types of assets and usually protect their assets in their houses using home security system. The popular security system is using security camera, lighting around the house and burglar alarm system. However, this method has some drawbacks, i.e., the lighting all night raise the electricity bill while IP cameras in markets cannot distinguish between intruders and animals such as lizards or cockroaches walking pass the cameras. In addition, the false alarms can be triggered by the moving objects that caused by the wind blows including the homeowner movement as well. Hence, the number of the notification message of the camera application is exaggerated.

On the other hand, Thai government have laid many policies in order to drive Thailand toward the Thai government vision "Stability, Prosperity, and Sustainability." Since technologies and innovations play a major role in improving the quality of life of people and domestic industry, the Thai government aims to improve Thailand's economy by changing the present economic structure into the value-based structure so called "Thailand 4.0." Thai government also has always been supporting projects that emphasize on utilizing technologies for developing the country. For example, startup, smart farming, smart devices, robotics, and mechatronics. Recently, Internet of Things (IoT) has been applied to numerous applications because it is low cost and easy to develop. Some good examples of IoT applications are automatic timer watering system, temperature and moisture controlling for mushroom farm, or turning appliances on-off by smartphones [2]. From the problems stated above; the authors have developed the Internet of Things based intruder detection and security alarm system (IDSS). The system composed of electronic circuit, camera module and motion detection sensor. Image analysis was applied to intruder detection system. If the system detects the intruders, the system automatically turns on lighting around the house and send signal or notification sound including captured image to homeowner via LINE Application. Hence, intruders could be scared and unsuccessfully break into the house or stop their stealing. The homeowner will not lose valuable properties and can control the proposed system, for instance, turn on or off the lighting, turn on or off the siren sound and control the camera to take a picture via the smartphone.

II. LITERATURE REVIEW

[3] explained that IoT composed of two important words which are "Internet" and "Things". The "Internet" is the very large computer network that connect and communication between computers, whereas "Things" are objects or devices, which composed of electronic circuits, e.g., air conditioner, electric fan, television, and etc,

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that can be connected with human using the internet. The advantages of IoT are efficiency, accuracy, database, and real-time processing.

In present, IoT is applied to many applications for connecting everything to the internet. Hence, human can control devices via the internet, for example, turning on or off lighting in the houses from long distance or via smart phones, monitoring the surveillance cameras, modern agricultural management, industrial machine controlling from long distance, improved the efficiencies of telecommunication and logistics, home security system including home perimeter, object detection sensor, and etc. In addition, Researchers have proposed concepts, IoT applications and security system developments as follows:

[4] presented that applying IoT to agriculture could increase the efficiency and losses due to pests or plant disease. They proposed the modern technology consisted of the wireless internet connection, soil sensor, humidity sensor, temperature sensor and leaf wetness sensors. Those sensors were combined with IoT based expert system in order to deliver cotton farming recommendation for Pakistani farmers. The experimental results show that 65 out of 100 Pakistani experts and farmers satisfied with the proposed system. This result is consistent with [5] who presented that IoT application could increase the efficiency of Lingzhi mushroom farming at Maejo University, Thailand. They proposed IoT based smart farming, which composed of IoT and a humidity sensor that measured and monitored the humidity of the Lingzhi mushroom farm. The obtained humidity data were processed using the NETPIE platform in order to automatically control the sprinkler and fog pump operation. The proposed smart farm also notified the farmers of the sprinkler and fog pump functional status and time stamp via LINE Application.

[6] proposed a real-time detection, tracking and counting people who were passing by a stationary camera. The proposed system using Pi camera module installed on Raspberry Pi board and a speaker for playing sound while counting. Kalman filtering and MATLAB Simulink was utilized for image processing. The experiments performed on the comparison between the real number of people and the counted number of people by the proposed system. The results show that the system can correctly count the number of people by 91.67 percent. This research brings the idea of applying the algorithm to detect people and analyze whether the detected people are intruders or not.

[7] showed that using low cost hardware such as Raspberry Pi and Pi camera module for showing real-time images. Voila Jones, the face detection algorithm, was developed and image processing by Python and Open CV library. The experimental results found that Voila Jones algorithm could correctly count the number of human faces even though there are robot or animal faces in the images. However, the limitation of Voila Jones algorithm is that it can only produce the good results when the testing human face images are in the full front-facing direction.

[8] proposed a microcontroller-based home security system which consisted of three protection level as 1) The homeowner' fingerprint scanner for entering the house. 2) Using the motion detection sensor for identifying intruders who trying to break into the house. 3) Using smoke detection sensor for fire detection in the house. All data from those three sensors were sent to the homeowner via smartphone in cases of reporting home security status or intrusion warning or fire alarm. While [9] designed a home security model using IoT with Arduino Uno for processing data from the motion sensor and sent the post processing data to a Web Server. The users or homeowners can monitor home security status by login to the website via web browsers. However, this research lacks notification or alarm controlling function for preventing intruders.

Therefore, from the literature reviewed above, the authors designed and developed the Internet of Things based intruder detection and security alarm system. The details description of the proposed system is described in the next section.

III. METHODOLOGY

This research was divided into five parts: 1) hardware and software components. 2) the system architecture, 3) design and installation electronic circuit with sensor, 4) image processing for intruder warning, and 5) data communication in the internet using Anto. The details are as follows.

A. Hardware and Software components

The hardware and software components of the proposed IDSS are

1. Raspberry Pi 3 Model B+ is the small, low cost board with many types of connection port such as USB, HDMI, LAN, and Camera. It can be applied to various applications such as multimedia, image processing or education. This research used it to control the alarm whenever IDSS detects intruders.

2. Pi camera module is the image acquisition module. The image processing was implemented using Python and OpenCV library in order to detect any intruders.

3. PIR motion sensor detects infrared waves that radiate from human body or moving animals. The sensor can cover the distance of 3 to 7 meters and operate every 300 milliseconds. Therefore, this motion sensors are commonly utilized in security systems, especially intruder detection system.

4. Relay is the switch that controls the lighting operation.

5. Active Buzzer is the alarming device in this study which sound the alarm if any intruders are detected.

In addition, the authors developed an Android smartphone application which allows the homeowner to manually control IDSS, for example, turning on or off lighting system, turning on or off the alarm and photographing.

B. IDSS Architecture

The IDSS pushes notification and sound the alarm if the intruders are detected. IDSS architecture is shown in Fig. 1 operates with two modes.

1) Automatic mode workflow described as follows:

1.1 If IDSS detects intruders in the house, IDSS pushes notification and the photograph to the homeowner's smartphone via LINE Application, sound the siren and turn on the lights around the house (only at night).
1.2 If IDSS cannot detect any moving objects, the system does not push notification and not sound the alarm.
2) Manual mode by using Anto for data communication via the internet. The workflow of manual mode is as follows:
2.1 Users can manually turn on or off lighting system or alarms (siren sound) using smartphones.
2.2 Users can manually take photographs.

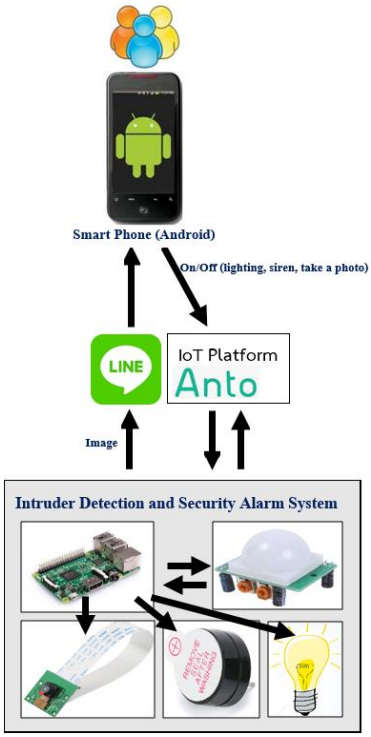

Fig. 1 IDSS Architecture

C. The design and installation of electronic circuit with sensor

In this research, the authors used Fritzing, which is Open Source software for designing the virtual electronic circuit or board, to design the virtual Raspberry Pi 3 Model B+ board that connected with PIR motion sensor, speaker, and relay to control lighting operation as shown in Fig. 2. Installation of the sensor and equipment on Raspberry Pi 3 Model B+ board within the experimental house shown in Fig. 3 and 4, respectively. The lighting equipment and the motion sensor was installed in separate boxes in order to be easily moved and arranged in suitable positions.

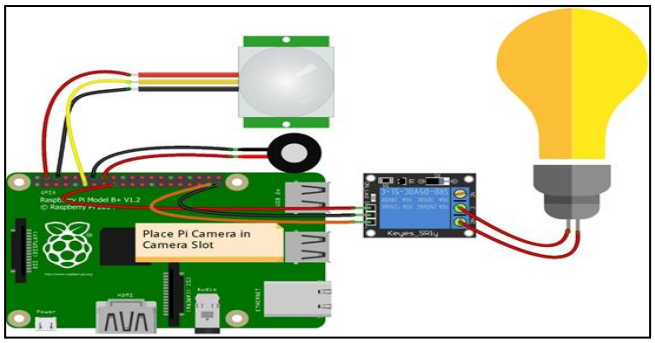

Fig. 2 The model of the workflow of Raspberry Pi 3 Model B+ board

Fig. 3 The installation of sensor and equipment with Raspberry Pi Model B+ board beside of the house

Fig. 4 The installation of sensor and equipment with Raspberry Pi Model B+ board in front of the house

D. Image Processing for Intruder Detection and alarming

Python programming language, OpenCV library and deep learning is employed for the development of IDSS as shown in Fig. 5. The image processing details are as follows.

1. Loading homeowner's image.
2. If the moving objects are detected, IDSS performs image processing in order to classify the types of objects within the tested image. The authors deployed learning data from [10] that utilized Deep Learning and OpenCV for classify the types of detected objects, for example, chair, human, desk, bird, dogs, and cats.
3. IDSS brings objects that were classified as human from step 2 to perform face detection using Haar Cascades.
4. The faces from step 3 are recognized as a homeowner or not the homeowner. If the faces are recognized as intruders, the alarm is activated (turn on the lights at night and sound the siren) and push notification to LINE Application on homeowner's smartphone.

In case of the homeowner's face is detected among the other's faces, IDSS does not alarm and not push the notification. Because IDSS interprets that the homeowner allows those detected people to enter the house.

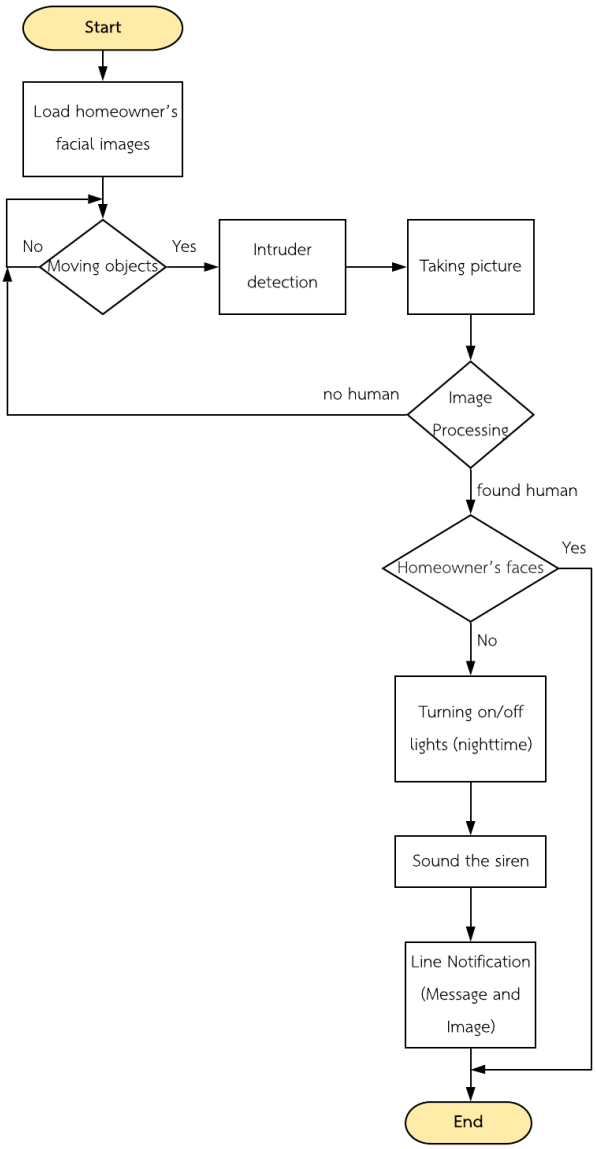

Fig. 5 The workflow of image analysis for intruder notification

E. Data communication in the Internet Using Anto

Anto is an IoT Platform which is the communication medium and make IoT based innovations easier. For example, users can control microcontroller boards through the internet using smartphones or control system operations through web site, including communications through HTTP, HTTPS, MQTT, MQTTS, and Web socket. Users can employ Anto free of charge and do not need to have their own servers or rent servers. Nowadays, Anto supports various families of board, for instance, ESP8266, ESP32 and Raspberry Pi. The authors used Anto for data communication between the electronic board and the smartphone. Data of the IDSS are the switches status of the lighting (LED1), photographing (PHOTO) and siren (SOUND) as shown in Fig. 6. If a user send command through a smartphone, those status data are sent to the microcontroller in order to control the equipment operations as needed.

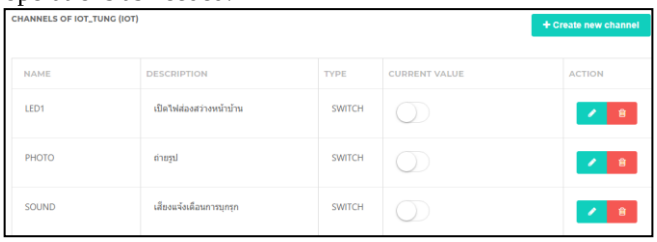

Fig. 6 The screen of the data communication using Anto

IV. EXPERIMENTS AND RESULTS

The authors conducted the experiments on IDSS during daytime and nighttime within Deprom2 village, Muang District, Nakhon Sawan Province, Thailand. Four homeowner's faces were the test objects as shown in Fig. 7.

Fig. 7 The homeowner's faces used in the experiments

Two experimental results are 1) The result from IDSS when the intruder is detected 2) The result of the controlling of the notification on a smartphone and 3) The experimental results of IDSS operation in case of an intruder broke into the house. The details are as follows.

A. The result from IDSS when the intruder is detected

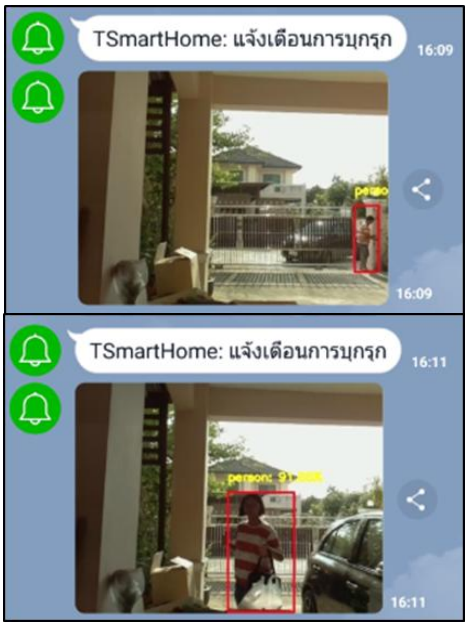

Fig. 8 The Notification and the intruder's image that IDSS detected during the daytime

Figure 8 shown the experiments for the intruder detection mechanism were conducted during the daytime and the nighttime (Fig. 9). The results show that IDSS can detect moving objects, analyze the captured image, identify if any human is in the image, and he is the homeowner or not. Then, IDSS sends the data and captured image to the homeowner by LINE Application.

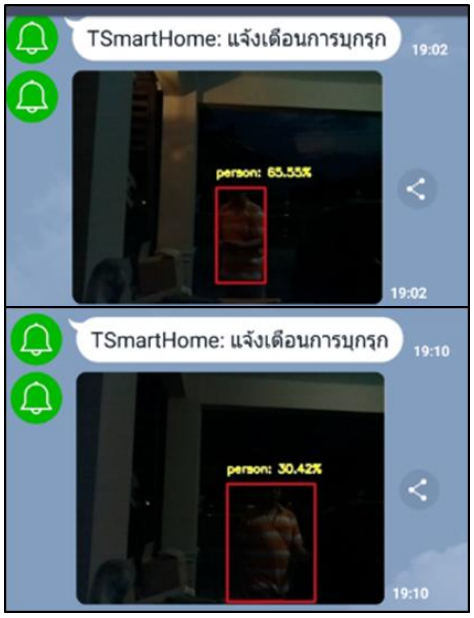

Fig. 9 The Notification and the intruder's image that IDSS detected during the nighttime

B. The result of the controlling of the notification on a smartphone

The proposed IDSS can operate in automatic mode, the user or the homeowner can manually control the operation of IDSS using an Android smartphone. Manual mode consists of the lighting control (turn on or off the light switch), alarm control (turn on or off the siren sound) and photographing. The display of manual mode on the smartphone shown in Fig. 10 and the results from manual mode shown in Fig. 11.

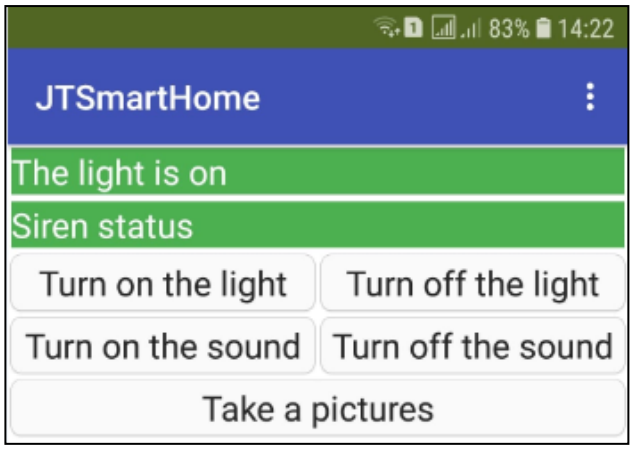

Fig. 10 The display of manual mode on the smartphone

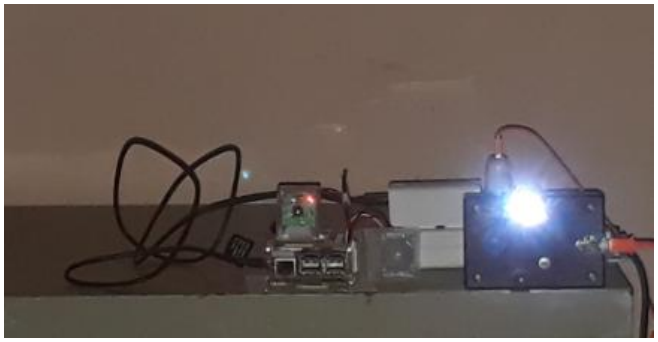

Fig. 11 The Results Of Manual Lighting Control Using Smartphone

C. The experimental results of IDSS operation in case of an intruder broke into the house.

The experiment on the IDSS operations in case of an intruder broke into the house performed by three functions: 1) the intruder detection. 2) Notification if the intruder were detected and 3) Lighting control, siren sounding and photographing. The experiments were conducted for 30 days. The results shown in Table I.

TABLE I: THE EXPERIMENTAL RESULTS OF THE IDSS IN CASE OF AN INTRUDER BROKE INTO THE HOUSE

Functions	Operating Results	
	Active (%)	Inactive (%)
1. The intruder detection		
1.1 Motion detection testing	92	8
1.2 Homeowner's image analysis	82	18
2. Notification		
2.1 Push notification through LINE Application	100	-
2.2 2.2 Sending captured photographs to LINE Application	100	-
3. Lighting control, siren sounding and photographing		
3.1 Manually turn on or off the lighting system	100	-
3.2 Automatically turn on or off the lighting system	100	-
3.3 Manually turn on or off the siren	100	-
3.4 Automatically turn on or off the siren	100	-
3.5 Manually photograph	100	-
3.6 Automatically photograph	100	-
Average	**97.40**	**2.60**

Table I shows that IDSS's average score is 97.40% which is in the excellent criteria. Both manual and automatic functions of IDSS, i.e., the notification through Line application, lighting control, siren sounding, and photographing can fully function without errors. The motion detection was unable to detect some moving objects because if the intruder passed the sensor when it was in the delay for the next detection. The homeowner's image analysis produced the wrong results because the face in the tested image was unclear or the image was from a far distance.

V. CONCLUSIONS AND FURTHER WORK

In this research, the authors proposed the Internet of Things based intruder detection and security alarm system, so called IDSS. The hardware components are electronic circuit board, Raspberry Pi 3 Model B+ to control IDSS operation. Anto, an IoT Platform are utilized in data communication via the internet. If IDSS found any intruder, IDSS pushes the message notification and captured image to users by LINE Application and trigs the alarm. IDSS could stop the intruders from breaking into the house and leverage homeowner's anxiety since the homeowner received the notification. The surveillance camera on the markets does not have the intruder detection mechanism as the same as IDSS. In addition, the homeowner can manually control the operation of IDSS via the smartphone, for example, he can manually turn on or off lighting or taking pictures. The experimental results show that the proposed system can efficiently detect the intruder and alarm the homeowner via LINE Application on the smartphone. The performance of the proposed system is excellent with the average score of 97.40%. The developed application on the Android smartphone is user-friendly, simple and efficient as well.

However, in case of intruders were detected during the nighttime, the captured intruder' image is too dark and could not clearly show the intruder's face. Hence, the captured intruder's image cannot be used as evidence for the police's investigation. Thus, the lighter bulbs should be installed around and in the house. On the other hand, if the homeowner passes the camera but does not face the camera in the front, IDSS could identify the detected human as the intruder and trig the alarm and notify the homeowner. In future work, the authors will install the infrared camera which produces clear picture during the nighttime. In addition, the machine learning will be trained to recognize the homeowner's characteristics such as clothes and body figure, in order to improve the efficiency of IDSS.

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