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A Development of Motorcycle Anti-Theft Equipment and Tracking System using Internet of Things

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Abstract*: This research aims to develop a motorcycle anti-theft equipment and tracking system using Internet of Things. The proposed system consists of five components. First, Hardware components are Arduino UNO R3, SIM800L module, GPS module and inclination sensor. The controlling software for Arduino and other hardware components is developed in C. Second, the system architecture is the overall system operations. Third, the design and construction of electronic circuit board connected with sensors. Forth, the motorcycle stealing analysis process analyzed data from the inclination sensor and the present geographical location of the motorcycle. If the motorcycle stealing is found, the proposed system notifies the motorcycle owner via Line application. Last, the data communication between hardware components and Firebase is utilized for obtaining the present geographical location of the motorcycle. The experimental results show that the proposed system can send message notification to the motorcycle owner via Line application. The performance of the proposed system is excellent with the average score of 92.83%. The developed Line application, which is user-friendly, simple and efficient, was installed on Android smartphones.

***Keywords*: Motorcycle Tracking, GPS, Google Map, Internet of Things**

I. INTRODUCTION

A Motorcycle is classified as a movable property that is used for traveling and parked in various places. If the motorcycles are expensive or popular brand, the motorcycle owners could be afraid of losing them. Although the motorcycles' owners lock their motorcycles using the best equipment and modern devices, the motorcycles can be easily stolen within a few minutes. The motorcycle theft is a growing issue in Thai society when people use motorcycles to travel and park them away from the visiting locations. The number of stolen cars and motorcycles are as much as ten thousand per year. The vehicle theft suppression center of Royal Thai police [1] reported the highest number of stolen vehicles in Thailand was 11,966 motorcycle thefts followed by 4,874 car thefts in 2021. According to the statistics, the police only recovered 10% of the stolen vehicles. The places where motorcycle thefts are most frequently happened were in national housing Rom Klao parking lot, national housing authority Klong Chan parking lot and Sanam Luang 2 parking lot, respectively. The vehicles were often got stolen between 00.01 am to 06.00 am. When the vehicles are lost, the recovery of the lost vehicles are time-consuming process, and the number of recovered vehicles is more or less than 10%. The problem of lost vehicle is not only the vehicle theft problem, but also the forgetting of the parking location. Both problems are time-consuming.

There are two strategies to prevent motorcycle thefts nowadays. First, the steering lock, which equipped with the motorcycle, is used to immobilize the steering wheel. However, the theft can use a tool to hammer the keyhole or the motorcycle neck to destroy the steering lock, then steals the motorbike. Second, installing a disc brake lock which is a special type of lock and sound the alarm when the motorcycle is moved. But the theft can unlock the disc brake, remove the alarm, and then steal the motorcycle. The Thai government policy nowadays emphasizes the economic development to support the vision "Stability, Prosperity, and Sustainability" by means of changing the economic structure to the innovation economics. Technology and innovation development can change Thailand into Thailand 4.0 which technologies play a major role in the domestic industrial development and people's lives. In addition, the Thai government supports various projects that emphasize the implementation of technologies for developing the country, for examples, startups, smart farming, smart devices, robotics and mechatronics. Furthermore, the Internet of Things (IoTs) are continuously applied to wide application because IoT devices are cheap and easy to implement, for instances, automatic water timers, humidity and temperature controllers in mushroom greenhouses, and appliance switch controllers via smartphones.

According to the factors stated above, the author proposed a development of motorcycle anti-theft equipment and tracking system Using Internet of Things. The proposed system composed of the following components: an electronic board which control the operations of related devices, a GPS module which helps the motorcycle owner to check the motorcycle's geographical location, a SIM800L module which enables an internet linking for sending the geographical location to a cloud server and receiving orders from an application on a smartphone, a relay was equipped to control the power supply switch.

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Thus, the motorcycle owner can immediately stop the machine when the motorcycle is stolen, or the motorcycle is driven away from the current parking location. An inclination module cooperates with the current geographical location are used for analyzing if the motorcycle theft happened. If the motorcycle theft is detected, the proposed system sends a notification via Line application on smartphones. All the listed devices above were equipped on a motorcycle which can reduce the motorcycle owners' worry when they have to park their motorcycles away from them or park the motorcycle for a long period of time.

II. THEORY AND RELATED WORK

This section presents the concepts, theories and related work as follows:

A. Internet of Things

Patel et al. [2] stated that Internet of Things is a type of network which connects the internet-based things on stipulated protocols. For example, information exchange and communications, electronic devices controlling, monitoring, tracing, real-time data collecting and processing. Communications can be classified into three types: 1) human to human 2) human to machines/things and 3) machines/things to machines/things. All these communication types are based on internet. Khunboa [3] presented those technologies are important for developing the country to Thailand 4.0. IoTs is one of the important factors for supporting the domestic industrial sector. The communications between human, machines and data within the industry can increase the speed and accuracy of the decision-making. Furthermore, IoTs can be applied to various applications to develop numerous new innovations and services, for examples, patient motion sensors used in hospitals which can detect movement and falls of the patients and then send notifications to nurses or doctors for help, motion sensors in houses detect the movement of the habitants and control the appliances switches within the houses. The predicted number of connected devices into the IoTs infrastructure is increasing into many billion devices.

B. Global Positioning System

Mahisanon [4] explained that Global Positioning System (GPS) is the system that provides information about locations on earth using (X, Y, Z) coordinates, velocity, and time. The fundamental is GPS satellites send signals to GPS receivers e.g., mobiles, cars, ships, around the earth. The distance from at least three GPS satellites to a GPS receiver is calculated. If the exact locations of GPS satellites are known, then the location on earth can be indicated. Nowadays, GPS is applied to various fields, for instances, cargo transportation, robotics, drones, and self-driving cars. This research used a GPS module GY-NEO6MV2 for Arduino "Fig. 1" to read a present geographical location of the motorcycle. This module can receive the GPS signal, communicate with many types of microcontrollers, i.e., I2C, SPI and UART. It is suitable for tracking as well.

Fig. 1.A GPS module GY-NEO6MV2 for Arduino.

C. Literature Review or Related Work

In present time, researchers proposed the ideas, the employment of Internet of Things and Global Positioning System to tracking pets, motorcycles, motorcycle falls, or the elderly falls as follows:

Nantaharn et al. [5] presented a smart pet collar application. This research aimed to study and developed an application for tracking pets. The proposed application is comparable to an assistant that can locate the pet position and help reduce the lost pet. In addition, this proposed application showed the basic health information using the pet's pulses and temperature analysis. The analysis of the user satisfaction survey shows that the application design facilitates users by user-friendly interface, easy to learn, the beauty of user interface is not good enough, but overall satisfaction is in the good range. This research idea can be adapted to motorcycle tracking in cases of motorcycle theft or forgetting the parking position.

O-Chaka et al. [6] developed FollowGPS: motorcycle tracking system focused on 1) construction a prototype device for preventing the motorcycle theft using an application on an Android smartphone cooperated with Global Positioning System and Internet of Things and 2) Reduction of the motorcycle lost. The experimental results show that the proposed system tracks motorcycles that moved away from the parked location and decreases the chance of losing motorcycles. The user satisfaction survey shows that the overall satisfaction score to Follow GPS is in the high range. The utilization of the proposed system increases the user confidence for the system installation and reduce the risk of the motorcycle theft. However, this research has only motorcycle tracking via Android smartphones. It cannot analyze if the motorcycle theft happens. Therefore, the authors adapt the idea of the Follow GPS by implementing the additional motorcycle theft analysis using an inclination sensor and current geographical coordinates of the motorcycle.

Kiatchalermkhun et al. [7] developed a motorcycle fall detection system for helping the injured person from the motorcycle fall accident.

The proposed system used motorbike incline degree detection which obtained from the linear acceleration and angular velocity sensor GY-521 module. The GY-521 module, installed at the motorbike, measures the incline degree of the motorcycle from the linear acceleration and angular velocity or the speed of the fall, then sends the incline degree to be processed. If the process result is the motorcycle fall, the module GA6-SIM900 sends a short message notification to the target smartphone along with the latitude and longitude of the injured person which are read from the module NEO-6M. The smartphone user can immediately see the real accident location in Google map. Thus, the authors adopted the module GY-521 and a GPS module for positioning of the motorcycle in the analysis process of the motorcycle theft.

Wuttisit [8] developed a fall detection device for elderly and data classification movement activity using weighted K-Nearest Neighbor algorithm on a IoT-based portable embedded system. The developed device and system can help the healthcare professionals to track the elderly who are at the risked of falling and predict the probability of falling using Weight K-Nearest Neighbor. Furthermore, the movement activities of the elderly and fall detection are reported via an IoT cloud service provider's website and send notification to healthcare professionals. The experimental results from testing the fall detection device and tracking the movement activities of the elderly showed that the device can detect the fall and predicted the occurrence of the fall. The fall detection performance showed the accuracy of 85.80% and the accuracy of 92.48% The proposed system predicted the likelihood of falling due to the movement activities as the people who are at risk of falling with an average sensitivity of 90.91% and people without the risk of falling with a specific average of 98.98%. This research is adapted for the motorcycle theft analysis process by using inclination sensor which can indicate the characteristics of the motorbike stealing behavior.

Kumari et al. [9] presented a motorbike security system using Internet of Things. The proposed security system composed of a GPS module for collecting the present geographical coordinates of the motorbike and a vibration sensor for sending SMS notification to the user. The experimental results showed that the proposed system had efficient performance and increased the security for the motorbike. The authors adapted this security system idea to the motorcycle theft analysis process.

Tashfia et al. [10] proposed a system that monitors a motorcycle as well as its rider's condition using IoT devices and an expert system to diagnose if the rider wears a helmet or is drunk. The smart helmet has an alcohol detection sensor and sends the notification to the rider about the engine condition and the likelihood of danger by using the information about the engine temperature, motorcycle speed, engine, the distance from the neighboring vehicles (left, right, front, and back sides), and current geographical coordinates. In the case of an accident, the proposed system sends an SMS, including Global Positioning System location to the authorized contacts. The experimental results showed that the proposed motorcycle security system help riders to avoid the fatal accidents on roads and can drive safely. This research can be applied to the motorcycle tracking in the case of motorcycle theft or forgetting the parking location.

According to the literature review and related work above, the authors designed and developed a motorcycle anti-theft equipment and tracking system using Internet of Things. The detailed descriptions of the proposed system are described in the following section.

III. METHODOLOGY

The authors divided the proposed motorcycle anti-theft equipment and tracking system using Internet of Things into five components. First, hardware and software components. Second, the system architecture. Third, the design and installation of the electronic board and sensors. Forth, the motorcycle theft analysis process. Last, the data communication between devices and Firebase. The details are described as the follows.

A. Hardware and Software Components

The authors utilize the hardware and software components in this research for alarming when the system detects the invader around the house. The details are as follows:

1. Arduino UNO R3 is the popular standard board. The size is suitable for the beginning phase of study. There are variety of shields for applications. This research used the Arduino UNO R3 for controlling the operations of the motorcycle anti-theft and tracking device.
2. SIM800L module worked with micro sim. This module only sends and receives SMS and the mobile number in contacts and cannot use for conversation. It also enables the internet connection. There are libraries for this module that facilitate the coding process. The proposed system utilized the SIM800L module for internet connection and SMS reception. SMS is the command for turning the engine power supply of the motorcycle on or off.
3. Inclination sensor GY-521 module composed of accelerometers and gyroscope which can operate in concurrently. This module is utilized for checking the moving direction and checking the changing directions of x, y, and z axes. The proposed system used GY-521 and geographical coordinates of the motorcycle for motorcycle theft analysis process.
4. GY-NEO6MV2 GPS module for Arduino is a module that receives the GPS signal to read the current location of the motorcycle. It can communicate with microcontroller via I2C, SPI and UART. In addition, this GPS module is suitable for tracking application as well.
5. Relay is an electronically switch that controls the opening or closed circuit of the power supply of the motorcycle.

In addition, the authors developed an application on Android smartphones for the motorcycle owners. The owners can control the operation of the proposed system by themselves e.g., controlling the power supply to turn on or off, tracking the motorcycle from the real-time geographical location. The experimental results showed in the experiment section.

B. The System Architecture

The system architecture is designed using Internet of things shows in "Fig. 2". There are two operations as follows:

1. Anti-theft operation has three steps

1.1 A user or motorcycle owner controls the power supply switch via a smartphone. The proposed device receives the SMS and process it to send the command to turn on or off the power supply. If the power supply is turned off, the theft cannot drive the motorcycle.

1.2 The proposed equipment analyzes the information from inclination sensor and real-time geographical location of the motorcycle if the motorcycle theft happens. If the motorcycle is moved from the previous inclination and the geographical location is changed, the equipment notifies via Line application on the motorcycle owner's smartphone.

1.3 The proposed device sends real-time geographical coordinates to Firebase which is the IoT Real-Time Database.

2. Motorcycle tracking operates as follows

2.1 A user or motorcycle owner can track the motorcycle via smartphones.

2.2 Google map shows the real-time geographical location of the motorcycle by retrieving the current motorcycle position from Firebase database.

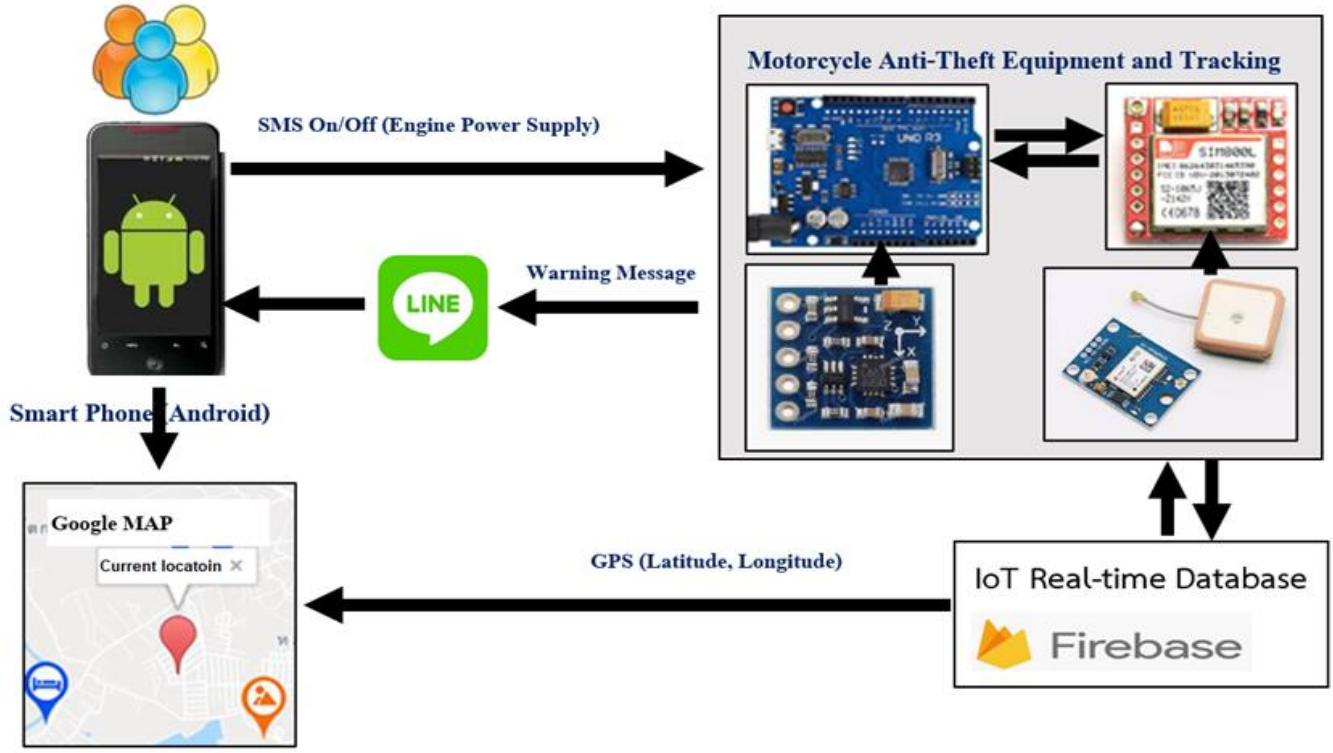

Fig. 2.System Architecture.

C. Design and Installation of the Electronic Board and Sensors

Fritzing is the application program that the authors used in the design of the connection between the electronic board and sensors for a motorcycle anti-theft equipment and tracking system using IoTs. "Fig. 3" shows our design and "Fig. 4" shows the installation of the proposed device on a motorcycle.

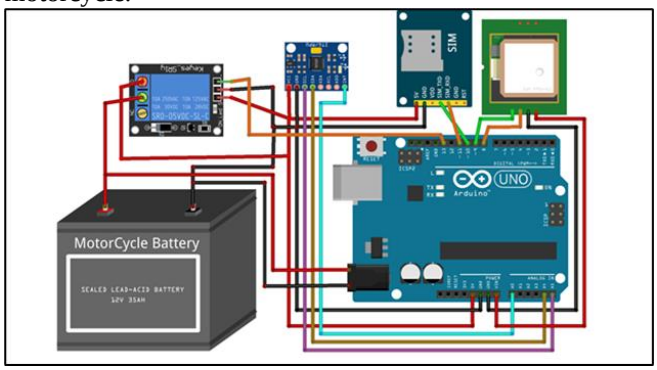

Fig. 3.The design of the connection between the electronic board and sensors for a motorcycle anti-theft equipment and tracking system using IoTs.

The details description of the design from "Fig. 3" are as follows.

1. A SIM800L module is connected to Arduino UNO R3 board in order to enable the internet connection for sending and receiving SMS from application. The SIM800L Rx pin is connected to port 11 of the Arduino, Tx pin is connected to port 10. The power supply of SIM800 is connected to 5V power supply of Arduino, and GND is connected to GND.

2. A GPS module is connected to the Arduino UNO R3 board for reading the current geographical location and sending it to the Firebase IoT Realtime Database. The Rx pin of the GPS module is connected to port 9 of the Arduino. The Tx pin of the GPS module is connected to port 8 of the Arduino. The power supply of the GPS module is connected to port 3.3 V of the Arduino and GND is connected to GND.

3. A GY-521 module is connected to Arduino UNO R3 board for measuring the incline degree of the motorcycle.

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The connections between the GY-521 module and the Arduino are the SCL pin of the GY-521 and port A5 of the Arduino, SDA pin and port A4, INT pin and port A0, power supply pin and 5V, and GND pin and GND.

4. A relay module is connected to Arduino UNO R3 board for turning the power supply of the motorcycle on or off. Port 13 of the relay module is connected to port 5V of the power adapter module. GND pin of the relay module is connected to GND of the power adapter module.

Fig. 4.The installation of the proposed device on a motorcycle (under seat).

D. Motorcycle Theft Analysis Process

The data from the inclination sensor and the current geographical coordinate of the motorcycle is used to analyze if the motorcycle is stolen. If the motorcycle is moved until it tilts, rapid changes in acceleration, and changes location as if it is stolen. The proposed instrument sends notification via Line application on the motorcycle owner smartphone. The authors collected the inclination data from the proposed devices that installed under the motorcycle seat. A Honda Wave motorcycle was equipped with the proposed device was used as a prototype. The data prototype shows in "Table. I".

Table- I: Inclination data (angular) and acceleration (linear) of the motorcycle.

angle X	angle Y	angle Z	angle GX	angle GY	angle GZ
79	77	6	86	89	89

"Table. I" demonstrates that when the device is placed, the angle X, Y and Z are 79, 77 and 6, respectively. The acceleration GX, GY and GZ of the parked motorcycle are 86, 89 and 89, respectively. All the data are analyzed along with the present geographical location of the motorcycle as showed in "Fig. 5".

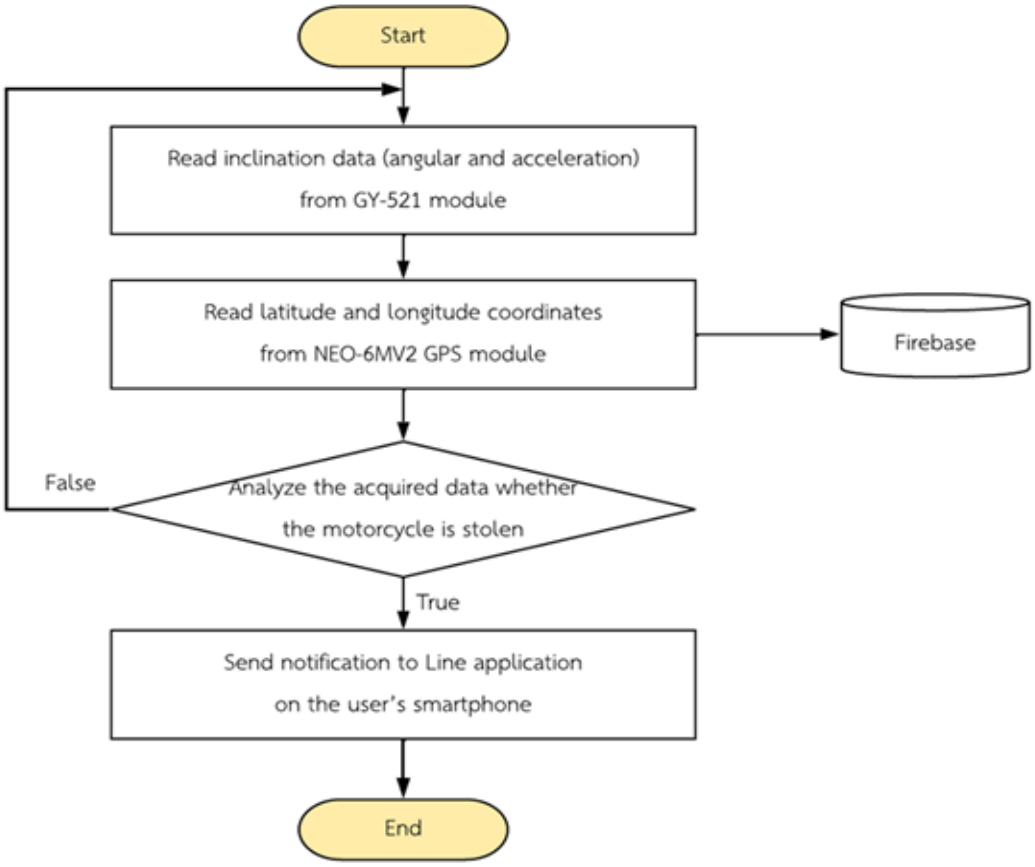

Fig. 5.A flowchart of the motorcycle anti-theft equipment and tracking system using IoTs.

From "Fig. 5" shows the flowchart of the motorcycle anti-theft equipment and tracking system using IoTs begins with

1. Inclination (angular and acceleration) data reading from GY-521 module
2. The present geographical coordinates are read from a NEO-6MV2 GPS module and collect the data in the Firebase database.
3. Analysis process of the motorcycle theft
   3.1 Read the power status
   3.2 If the angular inclination changes more than 20 (to the left or right position/positive or negative values), and the power status is 0, and the change of the present motorcycle location is more than 3 m, then the motorcycle is stolen.
   3.3 if the power status is 0 and the change of the change of the present motorcycle location is more than 3 m, then the motorcycle is stolen.
4. If the result from step 3 is the motorcycle theft happens, the proposed system sends notification message to Line application on the user's smartphone. The user can see the real-time location of the motorcycle on Google map on the smartphone. The flowchart of the operation of the application on the user's smartphone "Fig. 6".

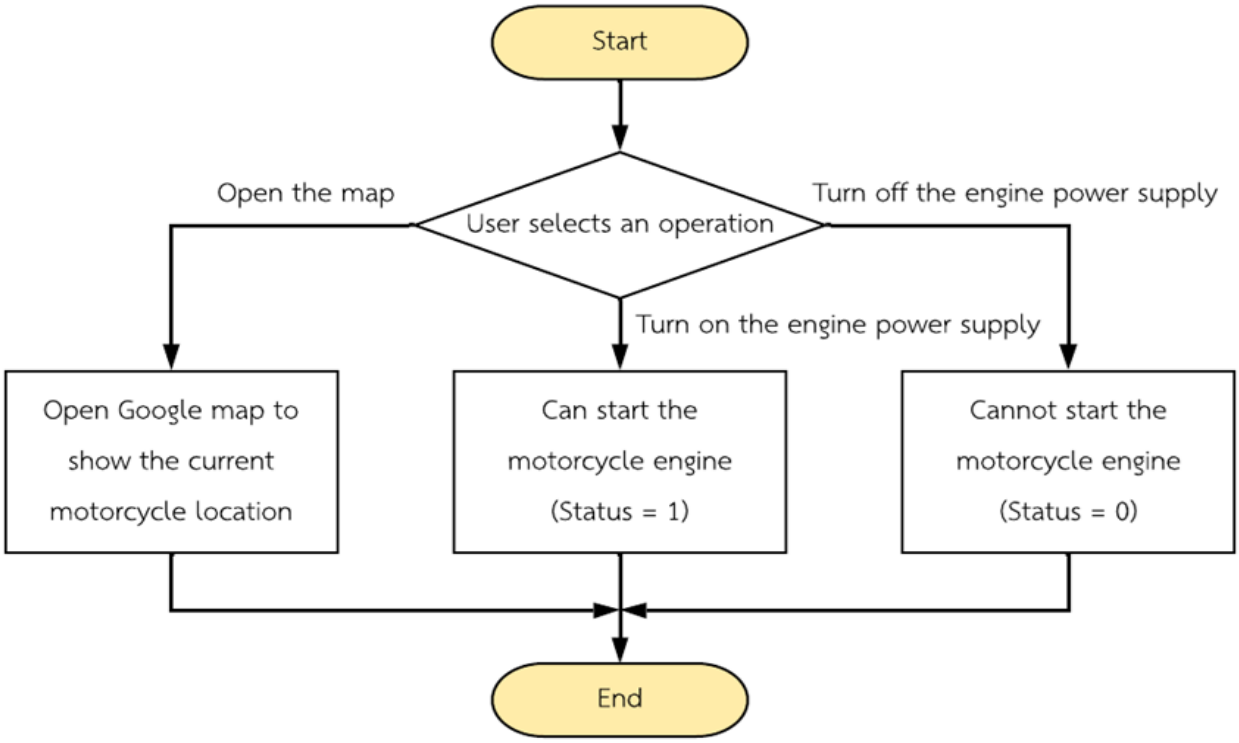

Fig. 6.The flowchart of the operation of the application on the user's smartphone.

The flowchart of the use of the application on the user's smartphone in "Fig. 6" shows that the user can choose one of three commands i.e.,

1. Opening the map in the case of the user needs to see the real-time location of the motorcycle.
2. Turning on the power supply in the case of the user needs to drive the motorcycle.
3. Turning off the power supply in the case of the user arrives the target and stop the motorcycle engine. The theft then cannot steal the motorcycle because the engine will not be started.

E. Data Communication Between Devices and Firebase

Budsabong et al. [11] explained that Firebase is the Google's real-time database that can be applied to a variety of applications that require instant responses. IoTs applications are suitable for using Firebase because Firebase works fast and has efficient internet connection. Firebase Realtime Database is NoSQL Cloud Database that collects the data in JSON format, automatically syncs real-time data with every connected device, and can work off-line (the data is stored in the local storage until the application goes online, then the stored data will be automatically synced). In addition, the Security Rules allows users to define the data access (Read, Write). Firebase is designed as API and Cloud storage for Real-Time Application developers supporting many platforms including iOS, Android, and web application. API helps the developers to store and sync data. In this research, the authors use Firebase Realtime database for storing the real-time geographical coordinate of the motorcycle as shown in "Fig. 7". The real-time data is stored as JSON format as follows.

```
{ "MotoC" : {
"MotoC_1" : {
"lat " : "15.672459",      the latitude of the motorcycle
"lng" : "100.088653",      the latitude of the motorcycle
"status" : "0"             Status 0 = normal, 1 = abnormal
"time" : "2021-1-22 19:47:20"  }}}  date and time
```

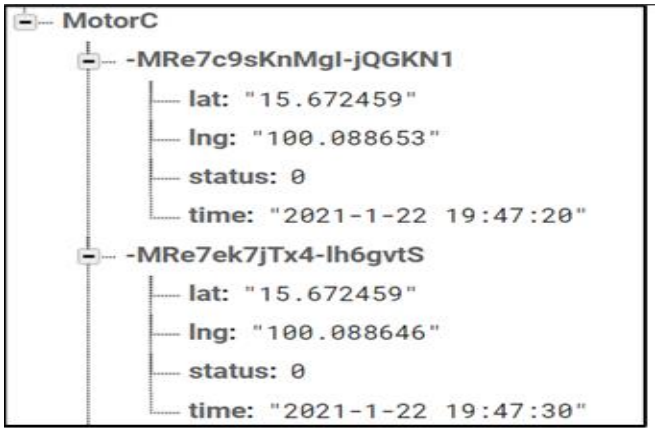

Fig. 7.Storing the data in the Firebase Realtime Database.

IV. THE EXPERIMENTS AND RESULTS

The authors tested the proposed motorcycle anti-theft equipment and tracking System using Internet of Things. The experimental results are showed in three parts. First, the results from testing the operation of the motorcycle anti-theft equipment. Second, the results from controlling the motorcycle anti-theft equipment via smartphones. Third, the performance of the proposed system. The details are as follows.

A. The Results from Testing the Operation of The Motorcycle Anti-Theft Equipment

When the equipment detects that the motorcycle is stolen, it sends notification messages to Line application of the owner as shown in "Fig. 8".

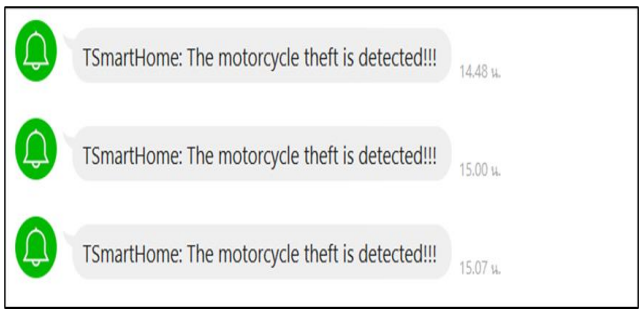

Fig. 8.Notification messages if the motorcycle theft is detected.

B. The Results from Controlling the Motorcycle Anti-Theft Equipment and Tracking System using Internet of Things via Smartphones

The proposed system operation is not only automatic, but it also allows the user or the motorcycle owner to control the engine power supply via Android smartphone. There are three modes for the user to choose how to control the engine power supply. 1) "Turn on" means the motorcycle engine can be started. 2) "Turn off" means the motorcycle engine cannot be started. 3) "Follow" means real-time tracking the geographical location of the motorcycle. The screenshot of the application on a smartphone is shown in "Fig. 9".

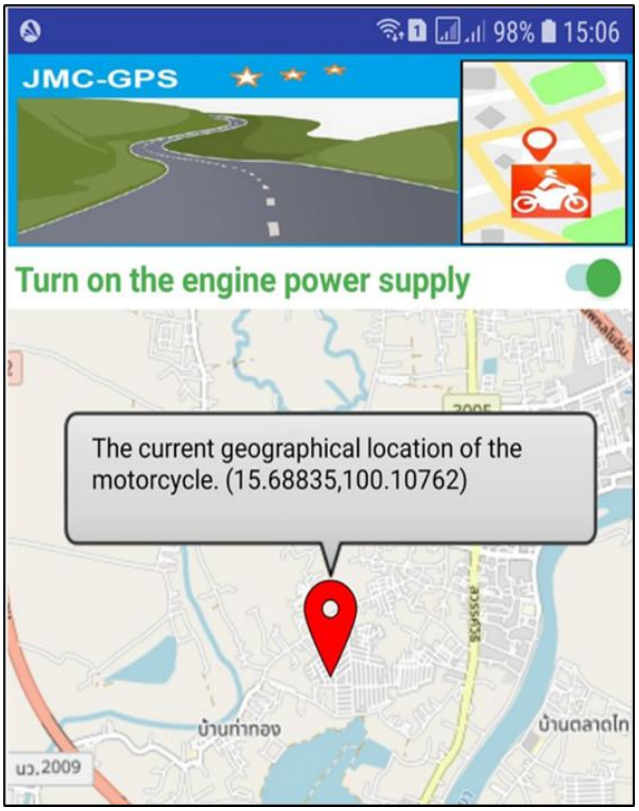

Fig. 9.The screenshot of the application on a smartphone.

C. The Performance of the Motorcycle Anti-Theft Equipment and Tracking System Using IoTs

The authors tested the motorcycle anti-theft equipment and tracking system using IoTs on two issues: The operation of the motorcycle anti-theft equipment and tracking system, and the engine power supply controlling by 100 times each. The results shown in "Table. II".

Table- II: The experimental results on the performance of the motorcycle anti-theft equipment and tracking system using IoTs.

Testing Issues	No. of Successes	No. of Failures
1. The motorcycle anti-theft and tracking system		
1.1 The motorcycle theft analysis by using inclination sensor data and the current geographical location.	85%	15%
1.2 Showing the real-time geographical location on Google map.	100%	-
1.3 Storing the geographical coordinate of the motorcycle.	87%	13%
1.4 The motorcycle theft notification via Line application.	85%	15%
2 The engine power supply controlled by smartphone		
2.1 Turning on the engine power supply (the motorcycle can be started)	100%	-
2.2 Turning off the engine power supply (the motorcycle cannot be started)	100%	-
Average	**92.83%**	**7.17%**

The results from "Table. II" show that the performance of the motorcycle anti-theft equipment and tracking system using IoTs is in the excellent criteria which the average score is 92.83%. The real-time geographical location of the motorcycle can be displayed on Google map. The controlling of the engine power supply (the motorcycle can or cannot be started) was done without any failure. The motorcycle theft analysis process that used the inclination sensor data and the current geographical location showed some failures. Because of the motorcycle was moved to a short distance and the new location was not much different from the original location. Therefore, the analysis did not detect motorcycle theft and did not send notification via Line application. Some real-time geographical coordinates of the motorcycle were unsuccessfully stored in the database if the internet connection was lost while the motorcycle was moving.

V.CONCLUSIONS

This research is the development of the motorcycle anti-theft equipment and tracking system using IoTs. The proposed system is useful for communities or interests who would like to apply various technologies to the motorcycle security system management. The motorcycle anti-theft equipment and tracking system using IoTs composed of three parts:

1. The motorcycle theft analysis and sending notification via Line application on the motorcycle owner's smartphone developed by C for Arduino. Internet of Things was applied to the proposed system. The hardware components are Arduino UNO R3 board to control the related devices operations, inclination sensor, SIM800L module, and GPS module. The Firebase Realtime Database stored the real-time geographical location via the internet. If the proposed system analyzes the data and the detect the motorcycle theft, then the notification message is sent to the Line application of the motorcycle owner. The experimental results show that the proposed system can successfully notify the motorcycle owner and meets the objective of the research.

2. The motorcycle tracking and the engine power supply controlling using Android smartphone can successfully operate. If the motorcycle is stolen, the motorcycle owner tracks the motorcycle via Android smartphone's application which showed the real-time location of the motorcycle on Google map. The motorcycle owner can also stop the motorcycle engine by turning off the engine power supply via this application.

3. The author performed the performance tests on the motorcycle anti-theft equipment and tracking system using IoTs for 100 times. The results show that the proposed system is in the excellent performance by the average score of 92.83%. The application is user-friendly, efficient, and not complexed.

In future work, the authors will install the environment sensors that are useful to the rider's health. For example, air quality sensor, PM 2.5 particle sensor, carbon dioxide sensor, and carbon monoxide sensor. The data from these additional sensors will be displayed on the smartphone's application or a website. Therefore, the riders can protect themselves by wearing suitable masks. In addition, the sensor that can detect if a rider does not wear a helmet will be installed in the future system. If the helmet is not detected, then the rider cannot start the motorcycle engine. All these improvements are for the safety of the motorcycle rider.

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Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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