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Development of Tracking System for Motorcycle

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Abstract

This paper discusses the development of a tracking system by utilizing the Internet of Things (IoT) and Global Positioning System (GPS) technologies to assist motorcycle users to locate their vehicles. The system comprises a tracker device and a cloud-based database. The tracker device obtained location information of latitude and longitude and transmitted the information to the Firebase real-time database. The tracker device comprises a NodeMCU ESP8266 and a GPS module. Based on the experiments conducted, the tracking system is able to locate the device with an accuracy of ±50 meters. The tracking system also had a long battery life, capable of withstanding 90 hours of use.

1. Introduction

Motorcycles are one of the most popular forms of transportation in Malaysia. As Nuradzimmah (2023) reports, the number of registered vehicles in 2023 is approximately 36.3 million, with motorcycles taking the second highest place. In addition to its popularity as a means of transportation, motorcycles are also reported for most cases of vehicle theft. In 2018, a total of 7,400 cases were reported and motorcycles accounted for 54% of stolen vehicles compared to private cars and commercial vehicles (Anthony, 2021). To track the vehicle availability and location, a tracking system is a must for every vehicle to assist the owners to locate their vehicle.

Nowadays, with advancement in technology, the tracking system is a common method of pursuing anything, regardless things, peoples or animals. For instance, Nurul & Noorhayati (2023) developed a GPS-based tracking system to track the missing luggage. Whilst Dawood et al. (2021) and Nur Fatini et al. (2021) developed the GPS-based tracking system to locate school children and the blood donor, respectively, Ramish et al. (2021) use of global positioning system (GPS) and Internet of Things (IoT) technologies on monitoring and tracking of farm animals. These present works demonstrate vital use of tracking systems in the present world, due to their expediency in tracking, monitoring for various applications (Maduka & Ibrahim, 2023).

For transportation, a vehicle tracking systems (VTS) is a solution that tracks location of a vehicle and transmits the information to a central data-collection system. Mohd Hakimi & Mohd Fiqri (2021) and Vikas et al. (2023) developed their GPS-based vehicle tracking system that uses GSM module to transferred the location information of their car to the mobile device. Likewise, this work proposes a tracking system for motorcycle user by utilizing GPS and IoT technologies to assist the user locate their motorcycle and store the information in the cloud-based database. Further discussion of this paper focuses on the development of tracker device and is organized as follows. In the next section, materials and methods used to develop the system are explained. Section 3 discusses findings of the system including its functionality and accuracy test. Lastly, conclude the work.

2. Materials and Method

The GPS-based motorcycle tracking system is consisted of a tracker device and a cloud-based database as illustrated in Fig. 1. The tracker device is functioned as GPS tracker and it is composed of a Neo-6M GPS module and NodeMCU ESP3266 board. The Neo-6M GPS module is used to obtained GPS data such as latitude and longitude of the location. The use of NodeMCU ESP8266 is to transfer the GPS data from the tracker device to the cloud-based database. Both tracker device and database communicate wirelessly via Wi-Fi.

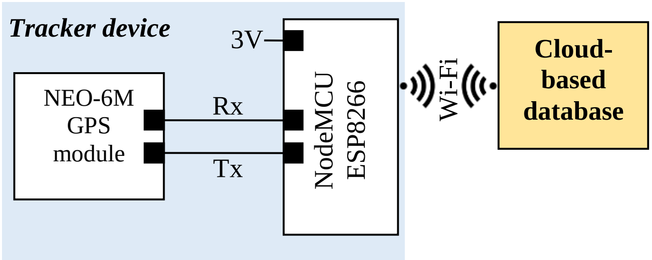


Fig. 1 *Overall block diagram of the GPS-based tracking system*

The development of tracking system is divided into two (2) main parts; configuration of cloud-based database and development of the GPS-based tracker device.

2.1 Configuration of cloud-based database

In this work, Firebase real-time database is used to store the GPS data consisted of latitude and longitude of motorcycle. In order to configure the database to be used by the system, the Firebase real-time database needs to be configured due to the essential information such as the Web API key, database URL, and secret key, are required in the program onto the NodeMCU ESP8266. These configurations allow the tracker device connect and keep an open bidirectional connection via WebSocket. Furthermore, when the tracker device pushes data to the database will cause it to be triggered, delivering and updated to all connected devices [5]. Fig. 2 shows the interface of the database.

Fig. 2 *Interface of Firebase real-time database*

2.2 Development of GPS-based Tracker Device

In this work, the tracker device is a battery-powered device; consisted of a NEO-6M GPS module with an antenna and a NodeMCU ESP8266 board. The GPS module is connected to the NodeMCU board to allow the GPS module stream the GPS data to the NodeMCU. The connection between the GPS module and NodeMCU is shown in Fig. 3 and Table 1. The GPS module used in this work is able to track up to 22 satellites due to the NEO-6M chip and the antenna attached to the module via the U.FL connector. Other key features are listed in Table 2 (Microcontroller lab, n.d.).

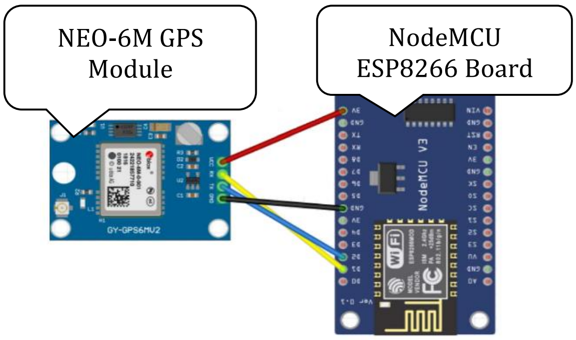


Fig. 3 *Physical connections in the tracker device*

Table 1 *Connection between GPS module and NodeMCU*

Pin of GPS module	Pin of NodeMCU
VCC	3.3V
TX	D2
RX	D1
GND	GND

Table 2 *Other key features of NEO-6M GPS module*

- Able to track five locations per second with an accuracy of 2.5 meters.
- Low supply current (approximately 45mA)
- Equipped with Power Saving Mode (PSM) which causes very less power consumption by turning the module ON/OFF according to the need.

The NodeMCU board, other than read GPS data from the GPS module; needs to establish Internet connection to access the database in the Firebase platform prior to store the data in the database. Hence, in this work, a portable Wi-Fi is used. The network credential that contains SSID and password of the Wi-Fi are needed and configured into the NodeMCU via Arduino IDE as shown in Fig. 4. Similarly, with the database, the Firebase database URL and secret key are configured into the NodeMCU. In order to connect the NodeMCU with the Wi-Fi, the *ESP8266WiFi.h* library is added in the sketch.

```
#include <FirebaseESP8266.h>
#include <ESP8266WiFi.h>
#include <SoftwareSerial.h>
#include <TinyGPS++.h>


#define FIREBASE_HOST "[redacted]firebasedatabase.app"
#define FIREBASE_AUTH "[redacted]K3Ho "
#define WIFI_SSID "[redacted]"
#define WIFI_PASSWORD "[redacted]"


const int RXPin = 4, TXPin = 5;
SoftwareSerial neo6m(RXPin, TXPin);
TinyGPSPlus gps;
```

Fig. 4 *Configuring communication between the tracker device, WiFi and database via Arduino IDE*

The GPS module of the tracker device communicates to the NodeMCU via serial communication at 9600 bps. The communication between two devices is allowable by included the *SoftwareSerial.h* library in the sketch. The TX and RX pins of the GPS module passed the GPS data as a parameter to the SoftwareSerial instance called *neo6m* in the National Marine Electronic Association (NMEA) format. The NMEA message is then parsed to obtain the readable format by added the TinyGPS++ library in the sketch.

```
smartdelay_gps(1000);

if(gps.location.isValid())
{
  float latitude = gps.location.lat();
  float longitude = gps.location.lng();


  if(Firebase.setFloat(firebaseData, "/GPS/f_latitude", latitude))
    {print_ok();}
  else
    {print_fail();}

  if(Firebase.setFloat(firebaseData, "/GPS/f_longitude", longitude))
    {print_ok();}
  else
    {print_fail();}

}
else
{
  Serial.println("No valid GPS data found.");
}
```

Fig. 5 *Determine the validity of the GPS data*

Fig. 5 shows the code snippet on how the system works. Once the WiFi connection is established, the availability of GPS data to the NodeMCU is checked by calling the *smartdelay_gps()* function. Whenever the data is available, the function reads and encodes the data using *read()* and *encode()* function, respectively, within one millisecond before it fetch next reading. Fig. 6 shows the code in the *smartdelay_gps()* function.

```
static void smartdelay_gps(unsigned long ms)
{
  unsigned long start = millis();
  do
  {
    while (neo6m.available())
      gps.encode(neo6m.read());
  } while (millis() - start < ms);
}
```

Fig. 6 *Determine the availability of* GPS data

Then, the system checks the validity of location information. When the latitude and longitude are valid, the values are extracted to the latitude and longitude variables, respectively. Otherwise, an error message *"No valid GPS data found"* is displayed. The extracted data is then transferred and stored to the Firebase real-time database. In order to allow data transferred between NodeMCU and Firebase platform, the library named *FirebaseESP8266.h* is added in the sketch.

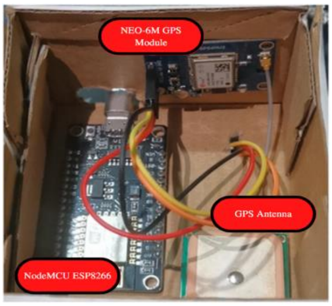
2.3 Experimental setup

In this paper, the testing is conducted to test the functionality of the tracker device and the accuracy of the location. The functionality test of the device is performed by observing the information on the serial monitor and the Firebase real-time database. Whilst the accuracy test is performed to verify the correctness of the obtained coordinates by the tracker device.

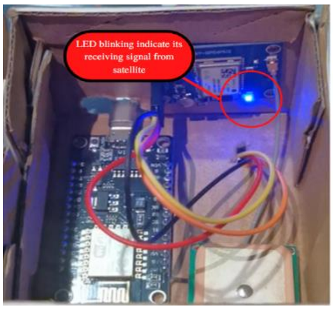
In order to perform the mentioned test, the tracker device is mounted on the motorcycle which shall move from one location to another based on the chosen reference locations. obtained the coordinates on the Firebase real-time database, the motorcycle stays at the reference location and author holds the mobile phone to observe the coordinate stored in the database. For each reference locations, the coordinates stored in the database are then entered to the Google Maps in decimal degrees (DD) format [Google Maps, n.d.] for verification of information.

3. Results and Discussion

Fig. 7 shows the prototype of the tracker device that is powered *ON* using a power bank. With dimension of 10.0 x 10.5 x 6.5 centimeters, the arrangement of components inside the tracker device and status of GPS module can also be observed. On the GPS module, there is an LED namely position fix LED. This LED indicates through its blinking effect whether the module is searching for satellites or has already found them. In Fig. 7(b) shows the LED is ON indicates that it is communicating with a nearby satellite. Whereas, Fig, 7(a) shows the LED is OFF indicates the module still searching for the satellite. Once the device able to communicate with the satellite, then the functionality and accuracy test can be performed and the findings are discussed in the next subsection.



(a) GPS module searching for the satellite



(b) GPS module found the satellite

Fig. 7 *Prototype of the tracker device*

3.1 Functionality test

The functionality of the tracker device can be justified by analysing the serial monitor of the Arduino IDE after the code is uploaded to the NodeMCU. The serial monitors display information about connectivity status of Wi-Fi, Firebase, and GPS. Fig. 8 shows the serial monitor of the Arduino IDE for the tracker device. The serial monitor shows the IP Address of the Wi-Fi and the status of the Firebase connection. The latitude data will be stored at path /GPS/f_latitude while longitude data will be stored at /GPS/f_longitude in the Firebase real-time database. After the GPS module is connected to the satellite and NodeMCU is connected to Wi-Fi, it will send the latitude and longitude of the device to the database.

```
................
Connected with IP: 192.168.68.127

Connecting Firebase.....
Firebase OK.
------------------------------------
OK
PATH: /GPS/f_latitude
TYPE: float
ETag: bGGndB8P/vY4d4BOYvmPz6oVsbQ=
------------------------------------

------------------------------------
OK
PATH: /GPS/f_longitude
TYPE: double
ETag: Qba+3yGS9ZjxA5/pfngLQZbobV4=
------------------------------------
```

Fig. 8 *Connectivity of Wi-Fi, Firebase and GPS on Serial Monitor*

Fig. 9 shows an example of findings for functionality test which the latitude and longitude are sent to Firebase database. The findings show that the tracker device able to connect to the portable WiFi, obtained the GPS data and transferred the data to the database of the Firebase platform.

Fig. 9 *Example of latitude and longitude sent to Firebase*

3.2 Accuracy Test

The accuracy test is conducted by comparing the GPS data obtained by the tracker device and the Google Map. In this test, four locations around Parit Raja area which are Taman Robena, Sekolah Menengah Kebangsaan Tun Dr Ismail (SMKTDI), Jalan Kristal 6 and Jalan Kristal 7, are chosen as reference locations. Table 2 summarises the findings of the test.

The findings show that the device able to provide GPS data as same as in the Google Map. The difference is only on the format of GPS data. In Firebase real-time database, the GPS data is stored in decimal degrees (DD) format. Whilst the Google Maps able to display in two formats; the decimal degrees (DD) and degrees, minutes, and seconds (DMS) (Google Maps, n.d.). In addition, based on observation during the accuracy testing, the device able to track the location accurately within approximately 50-meter radius.

3.3 Battery Life of the System

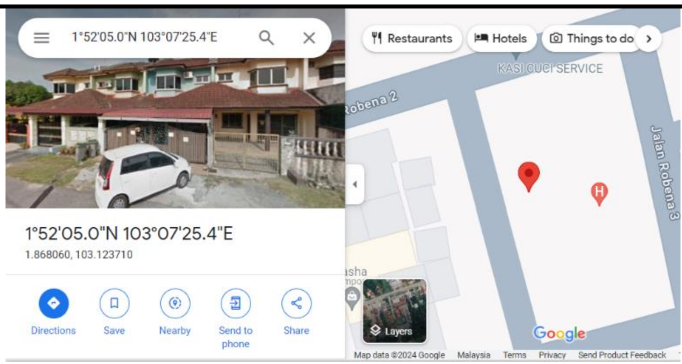
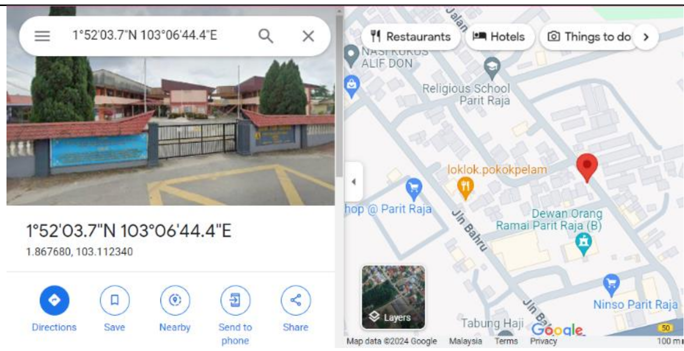
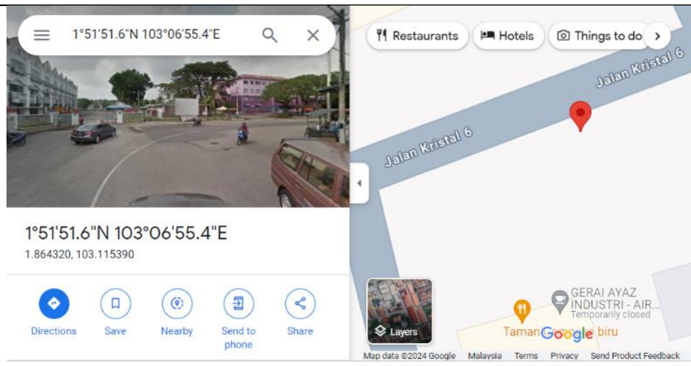
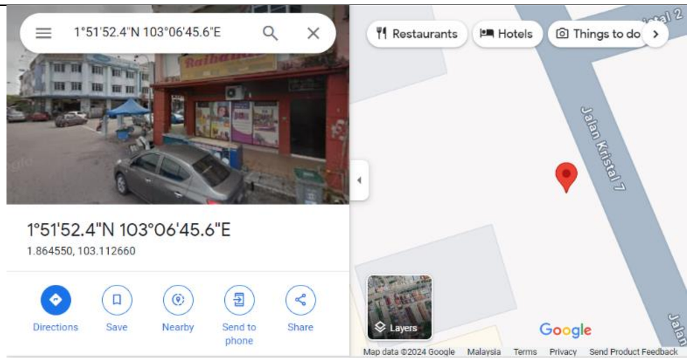
The battery life of the system is calculated based on battery capacity over power consumption in hours unit. Since the system uses 9900mAh and 110mA as a power source for the device and power consumption, respectively, therefore the system's battery life is 90 hours of use. However, based on observation, the battery life is shortened to approximately 40 hours; might be due to the device actively search for Wi-Fi connectivity.

4. Conclusion

In conclusion, the tracking system for motorcycle is successfully developed by utilizing GPS and IoT technologies. The system is able to obtain the location information of latitude and longitude prior to store in the cloud-based database. The findings show that the tracker device is fully-operation to provide location information. The device also able to communicate with the database in Firebase platform to store the accurate location information in real-time.

As future work, the mobile application is suggested to develop and integrate with the existing system to provide a real-world location to the users with a seamless experience and interpretation of monitoring data. It also suggested to reduce the dimension of the tracker device to fit in the motorcycle.

Table 3 *Comparison of location information in Firebase real-time database and Google Maps*

Reference location	Coordinate of reference location on the Firebase real-time database	Coordinate of reference location on Google Maps
Taman Robena	GPS f_latitude: 1.86806 f_longitude: 103.12371	
Sekolah Menengah Kebangsaan Tun Dr Ismail (SMKTDI)	GPS f_latitude: 1.86768 f_longitude: 103.11234	
Jalan Kristal 6	GPS f_latitude: 1.86432 f_longitude: 103.11539	
Jalan Kristal 7	GPS f_latitude: 1.86455 f_longitude: 103.11266	

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Muhamad Rizuwan Aizat Che Othman;* ***data collection:*** *Muhamad Rizuwan Aizat Che Othman;* ***analysis and interpretation of results:*** *Muhamad Rizuwan Aizat Che Othman;* ***draft manuscript preparation:*** *Muhamad Rizuwan Aizat Che Othman, Zarina Tukiran. All authors reviewed the results and approved the final version of the manuscript.*

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