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Application System Development of Accident Prevention and Safety Assistance using IoT Application

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ABSTRACT

The number of road accidents in Malaysia shows a steady increment from 2010 to 2019, reported by the Ministry of Transport Malaysia. This project aims to develop a system to prevent an accident by detecting aggressive driving. If an accident occurred, this system would send an alert for an immediate response, which is crucial to reduce the fatality rate. An accelerometer is utilized to detect aggressive driving and accident events. The method to detect aggressive driving is by determining an abrupt change in acceleration. For accident detection, the vehicle tilt angle and acceleration are monitored. An ESP32 SIM800L microcontroller processes the inputs and alert a web-based cloud service and a set phone number by Short Message Service (SMS). The microcontroller is used due to the embedded Global System for Mobile Communications (GSM) and other wireless communication modules. The small form factor gives an advantage in terms of mounting location flexibility. The alert contains the type of event, time, and location. This report contains the development of the proposed system, which includes the simulation for the system circuit and motion simulation. Accident detection, falls, SMS alerts and online alerts are consistently successful, while aggressive driving detection is inconsistent. Live tracking does not directly work during these detections. In conclusion, this project successfully detects accidents and sends alerts via SMS and internet using a Subscriber Identity Module (SIM) card.

1. Introduction

Road accidents in Malaysia increased by 8.8% from 2016 to 2019, with the fatality rate decreased by 13.7 %, as reported by the Ministry of Transport Malaysia. Although the fatality rate decreased significantly, the road accident trend steadily increased from 2010 [1]. The inclination means the prevention of road accidents must be taken more seriously. Therefore, accident prevention and safety assistance are essential to solving the inclining trend of road accidents. Immediate medical

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assistance for a vehicle accident depends on any person available in situ to alert authorities. This problem becomes significant if an accident happened in a low-traffic area. Some system has been developed to address this issue. Most of them do not utilize a standalone internet connection.

For example, the system uses a Bluetooth connection to a mobile phone to connect to the internet [2]. Another design uses Short Message Service (SMS) to alert the designated receiver [3]. This method will limit the function in terms of Internet of Things (IoT) implementation.

Additionally, the developed systems do not have an accident prevention method. Reduction of harsh driving is one of the critical factors to minimalize road accidents as it is the main factor contributing to a vehicle's roadworthiness [4]. Harsh driving can significantly reduce the longevity of vehicle parts due to increased load.

Tires are the most impacted parts by harsh driving. Tire performance is one of the most important factors for safety as it connects a vehicle to the road surface. Excessive tire wear can further increase accident chances as it reduces mechanical grip, mainly if used on a wet road.

Kattukkaran *et al.,* [2] developed Intelligent Accident Detection and Alert System for Emergency Medical Assistance. The system can alert the set medical assist provider after an accident is detected. The system detects accidents using an accelerometer to determine the vehicle's tilt angle and a heartbeat sensor to detect the driver's heart rate abnormality. The system uses an MSP430 microcontroller to decide if the alert will be sent from both sensors based on the accident's seriousness. Then, the system sends the information to a connected mobile phone through Bluetooth. Finally, the mobile phone will send a text message to the set phone numbers. However, the issue with the required phone connection may introduce negligence in this system by not connecting the mobile phone to the system before use.

Patil *et al.,* [3] developed Accident Identification & Alerting System. When the vehicle is in motion, the system's accelerometer sensor continuously analyses the vehicle's acceleration and axis. An ATmega328P microcontroller detects an accident if the acceleration value changes abruptly or exceeds the vehicle's tilt angle. A buzzer has been installed to indicate the detection of an accident. A GPS module identify the location of the vehicle to the medical facility. The system will send the emergency text message to the user-selected phone numbers through a connected GSM module in the system. Finally, an alert message is sent to registered phones with the position and timing of the accident. The acceleration parameter shows an advantage over project by Kattukkaran *et al.,* [2] in the accident detection algorithm with an additional vehicle's acceleration value. A web-based data center needs to be utilized to make the system IoT-based.

Kalyani *et al.,* [5] developed Accident Detection and Alert System. The system could send a text message alert if an accident occurred. A vibration sensor is used to detect accidents in terms of vibration. The sensor continuously senses the vibration of the vehicle. This data is fed to an Arduino Uno microcontroller. If the vibration exceeds a set value, which determines an accident, an alert text message will be sent using a connected GSM module to a set phone number. The alert message contains the location of the accident, which is tracked by a GPS module. The utilization of a vibration sensor limits the type of accident detected. The limitation is due to the vibration sensor is a scalar sensor. It also has output limitations because it either outputs low or high. The digital output further limits the use case for this system [6-12].

D. Shanthi and Kumar [6] developed an Accelerometer-based Transportation System. The system utilizes an accelerometer to determine the severity of an accident. The accident severity is separated into four levels: No Accident, Mild Accident, Medium Accident, and Severe Accident which are 0 to 4g, 4 to 20g, 20 to 40g, and more than 40g, respectively. The system will send an alert if an accident is a medium severity and above. The system utilizes an 89C51 microcontroller to process the sensor data and send an alert if an accident happened. When it detects an accident, the microcontroller activates a connected GSM module where a phone number has been set up to send a text message alert. This system further details the acceleration parameter used in project by Patil *et al.,* [3] to four different accident levels.

Fedorov *et al.,* [7] proposed Automatic Vehicle Accident Alert System. This system utilizes a combination of an accelerometer and a force sensor. The accelerometer acts as the primary sensor, while the force sensor acts as a secondary sensor if the primary sensor fails. A GPS module determines the vehicle's location. An Arduino Uno microcontroller was used in the system to determine the accident occurrence [13,14]. An alert would be sent through a Bluetooth-connected mobile phone to Amazon Web Services (AWS) if an accident happened. If a mobile phone is not connected, the system uses a secondary GSM module to send SMS alerts.

Table 1 shows the summary from the review of related works. Based on the gap of the related works and other sub-topics, this project will utilize an accelerometer to detect a vehicle's tilt angle and acceleration for accident detection. The alert will be sent through a standalone GSM module to the Thing speak IoT platform and SMS. This project also detects and alerts aggressive driving to reduce the accident risk [15,16].

Table 1
Related works summary

Solution	Main Sensor	Accident Detection	Alert Method	Aggressive Driving Detection
Kattukkaran *et al.,* [2]	Accelerometer	Tilt Angle	SMS (Mobile Phone)	No
Patil *et al.,* [3]	Accelerometer	Acceleration	SMS (Integrated)	No
Puneetha *et al.,* [5]	Vibration	Vibration	SMS (Integrated)	No
D. Shanthi and Kumar [6]	Accelerometer	Acceleration (Severity)	SMS (Integrated)	No
Fedorov *et al.,* [7]	Accelerometer	Acceleration	Internet (Mobile Phone)	No
This Project	Accelerometer	Tilt Angle, Acceleration	Internet (Standalone), SMS	Acceleration

2. System Overview

Figure 1 shows the system block diagram which contains the elements of the system. If an event processed by the microcontroller occurred, the system would send the type and the location of the event to the output elements. The output elements are an LCD screen, a GPRS module, and the Thingspeak cloud service.

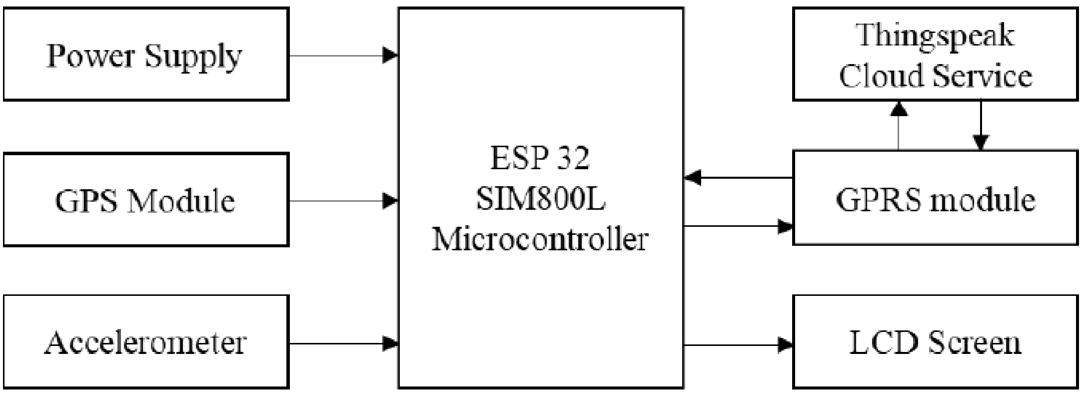

Fig. 1. Block diagram of the system

2.1 System Flowchart

Figure 2 shows the system flowchart, excluding the accident and aggressive driving detection, split into connector D. The system starts when the input power is turned on. Next, the accelerometer readings and the location are constantly monitored by the system. The system sends the live location to the web-based cloud service. If there is currently no internet connection, the live location updates are skipped until the system reconnects to the internet while the queued data waits for the connection. The accident event is determined to occur when the high acceleration value or tilt angle is exceeded. If low acceleration value and minimum time exceeded, the system determined aggressive driving occurred. The events data are sent to the cloud-based service.

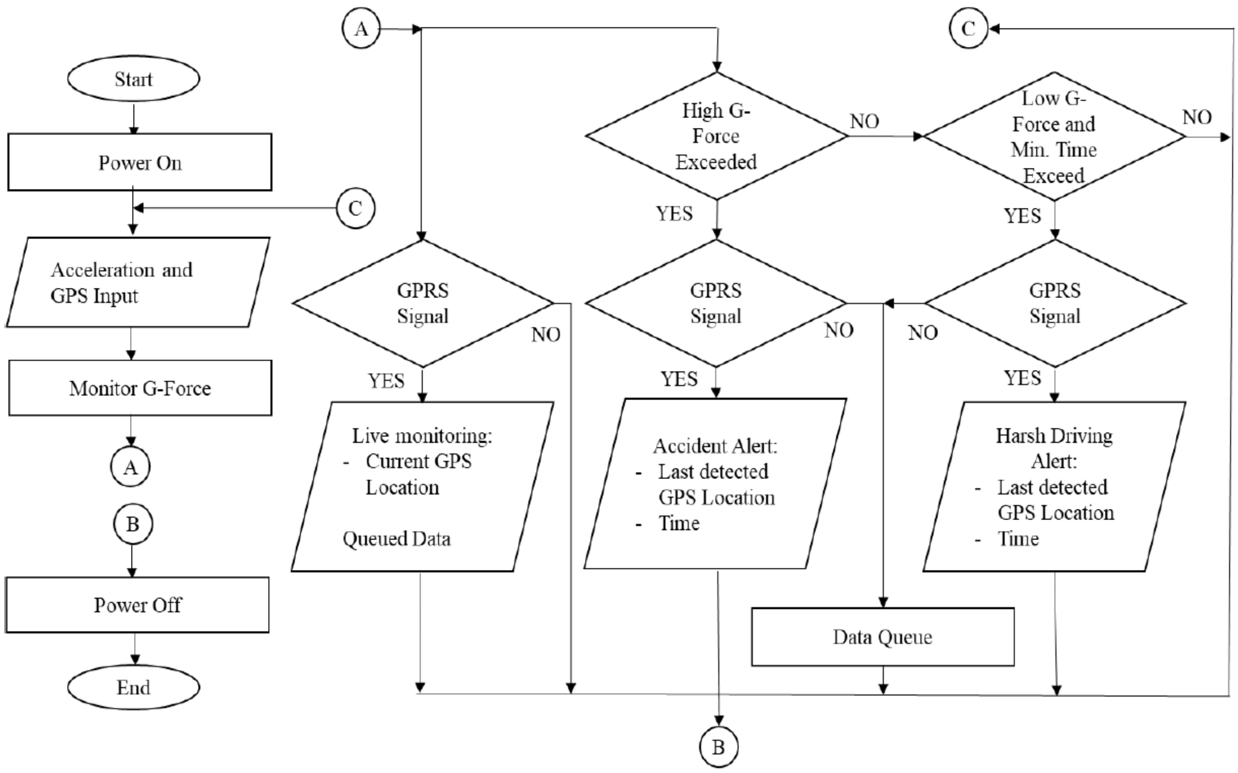

Fig. 2. System flowchart

2.2 Circuit Simulation

This simulation utilizes potentiometers to simulate tilt reading using Proteus software. An accident is determined when the vehicle is tilted more than 45° relative to the direction of gravitational acceleration. The detection is in the X and Z-axis. The simulation circuit setup consists of an Arduino Uno, a 20*4 LCD, two potentiometers for X and Z-axis, as shown in Figure 3. The potentiometers are used to simulate accelerometer input while the LCD will show the results.

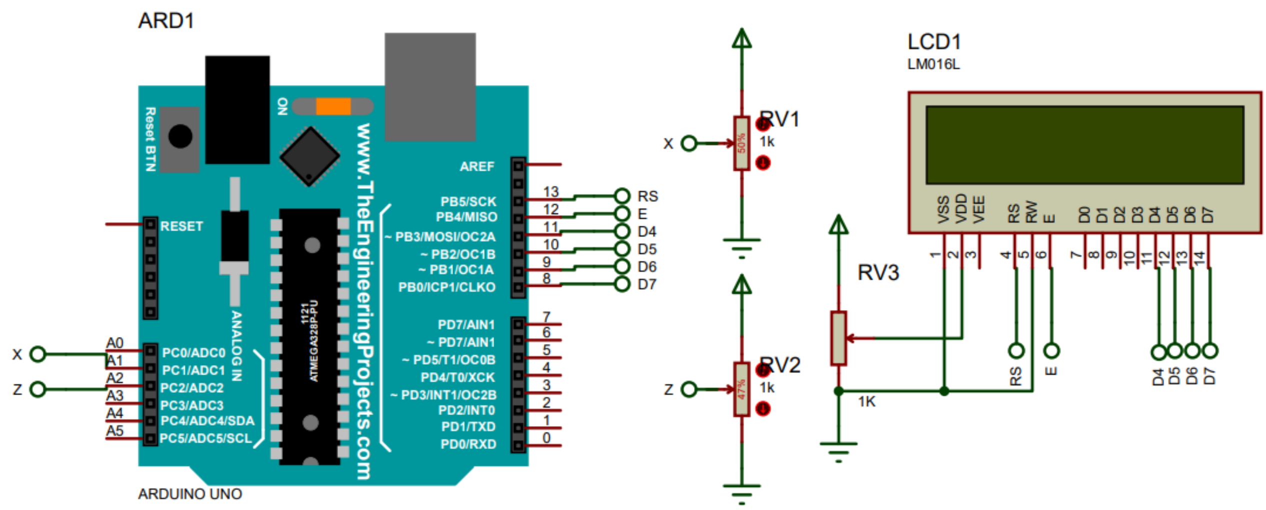

Fig. 3. Circuit diagram

From Table 2, the simulation successfully determined an accident when the tilt angle reached 45° and more in either direction.

Table 2
Circuit simulation result

Input X Potentiometer, (%)	Input Z Potentiometer, (%)	X-axis Tilt Angle, (°)	Z-axis Tilt Angle, (°)	Condition
0	0	-90.000	-90.000	Accident
100	0	89.820	-90.000	Accident
0	100	-90.000	89.820	Accident
50	50	0.000	0.000	Normal
50	0	0.006	-90.000	Accident
0	50	-90.000	0.006	Accident
30	30	-36.040	-36.040	Normal
30	80	-36.040	53.964	Accident
60	30	17.930	-36.040	Normal
25	40	45.000	-17.930	Accident

2.3 Accident Simulation

An RC car has been designed in Solidworks software to simulate an accident. The design is based on Wltoys 124019 RC car with a 1/12 scale, as shown in Figure 4. The simulation setup example of moving car, stationary car, solid body contact is shown in Figure 5. The parameter set for the simulation is shown in Table 3.

Fig. 4. Wltoys 124019 RC car dimensions

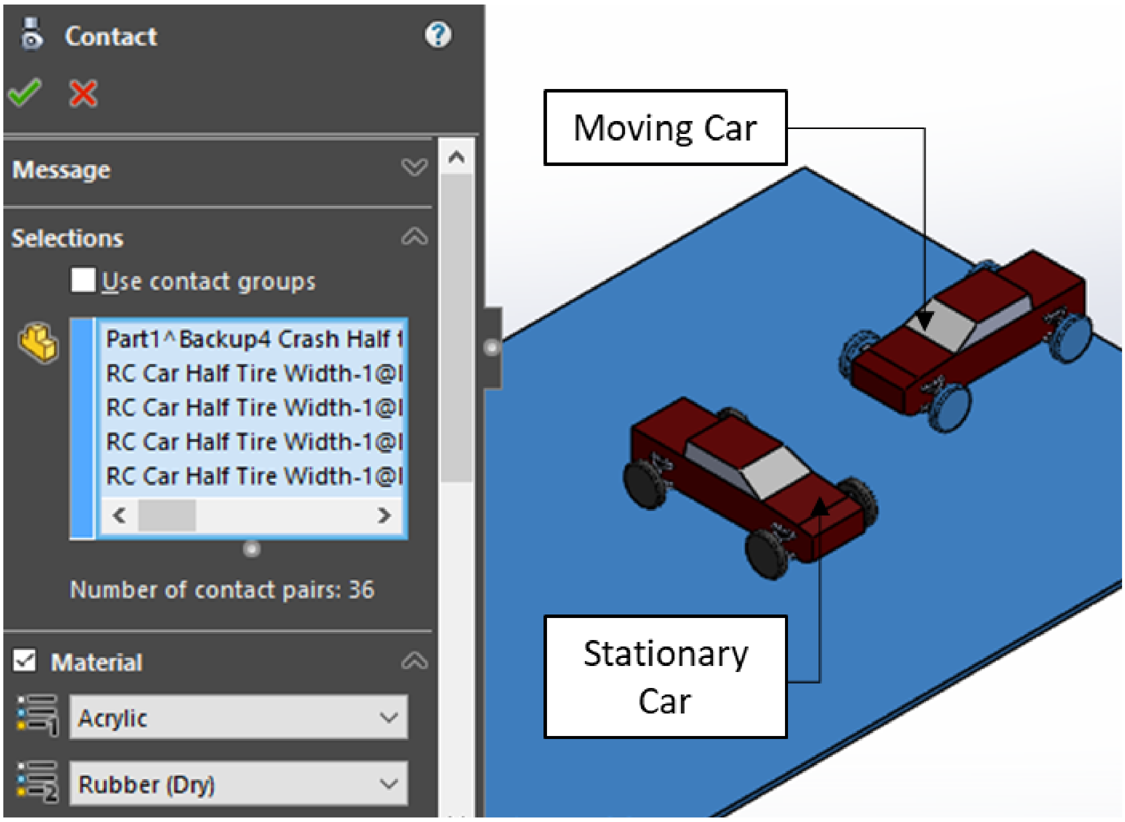

Fig. 5. Accident simulation setup

Table 3
Simulation parameter setup

Parameter	Value or Option
Solid Body Contact	Car to track and moving car to stationary car with material
Car Mass	1.5kg
Gravity	9806.65mm/s2
Moving car velocity	5km/h
Result acquisition	Linear velocity and linear acceleration

Figure 6 and Figure 7 show the motion simulation of the RC car accident. The simulation started with the car move at 5 km/h or 1.3889 m/s. For velocity, the first impact recorded at 0.14 seconds with velocity reduced to 0.914 m/s, while the second impact recorded at 0.22 seconds with velocity reduced to 0.631 m/s. For acceleration, the first impact peaked at 0.14 seconds with -28.799 m/s2 acceleration or -2.94 g (gravitational acceleration), while the second impact peaked at 0.22 seconds with -67.074 m/s2 acceleration or -6.84 g.

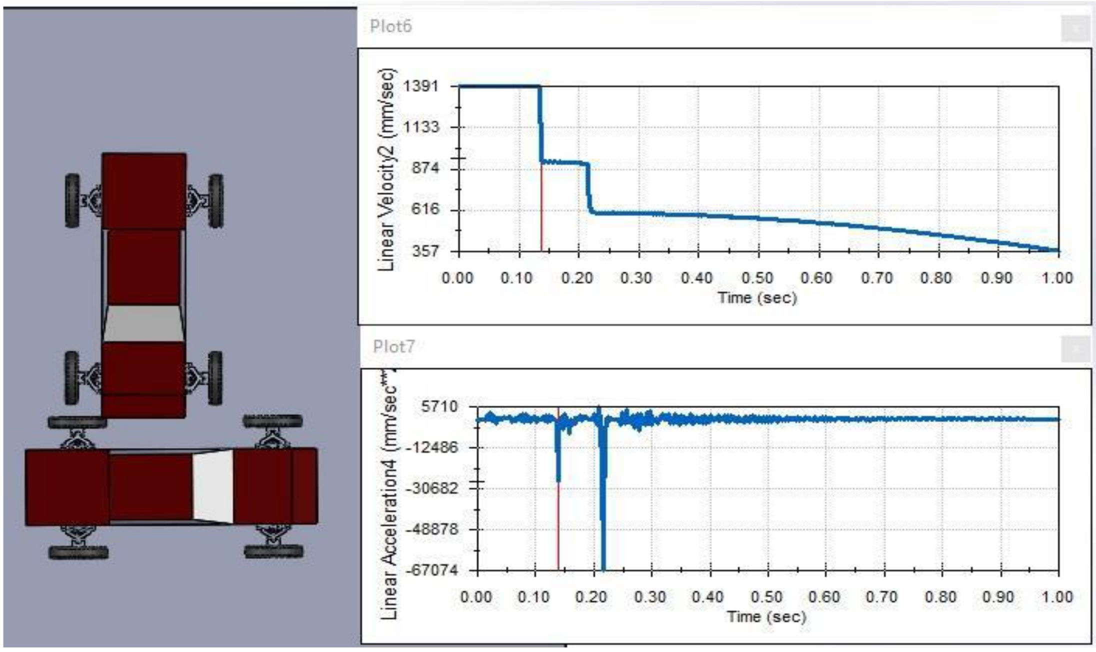

Fig. 6. First impact of RC car accident simulation

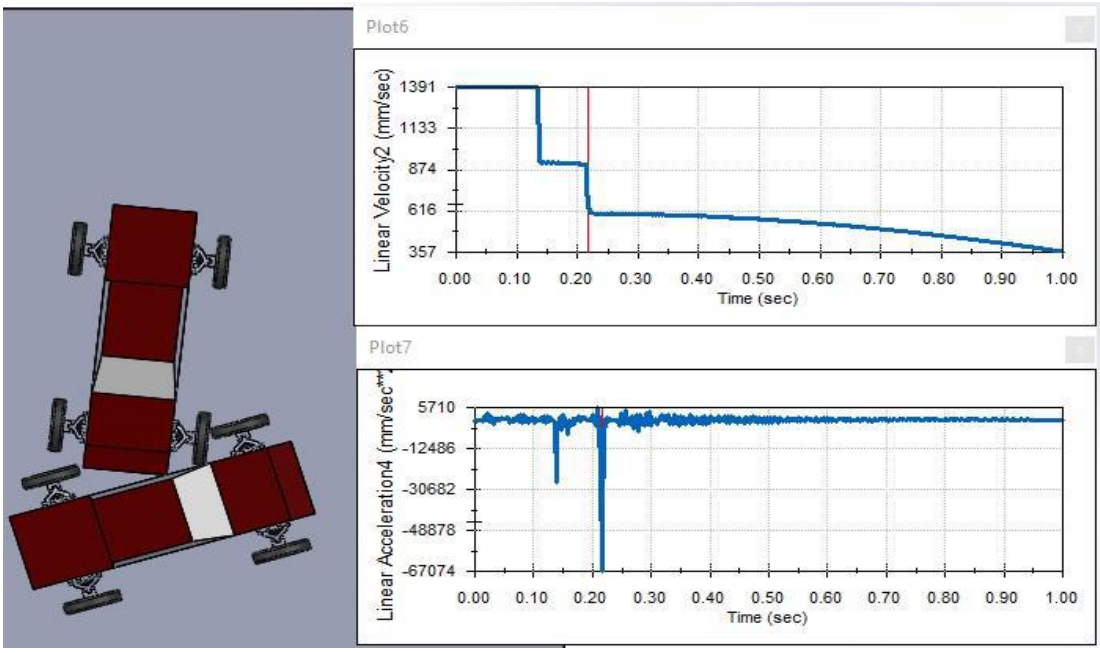

Fig. 7. Second impact of RC car accident simulation

2.4 Prototype Hardware Development

The developed prototype is shown in the Figure 8. Power supply module is not used since the microcontroller supports direct connection of 3.7 V lithium battery. Push button is added to cancel SMS transmission within pre-set time. Figure 9 shows the mounted prototype module. It is mounted on a sturdy PVC foam platform. The platform attached to the RC car using four nylon cable ties.

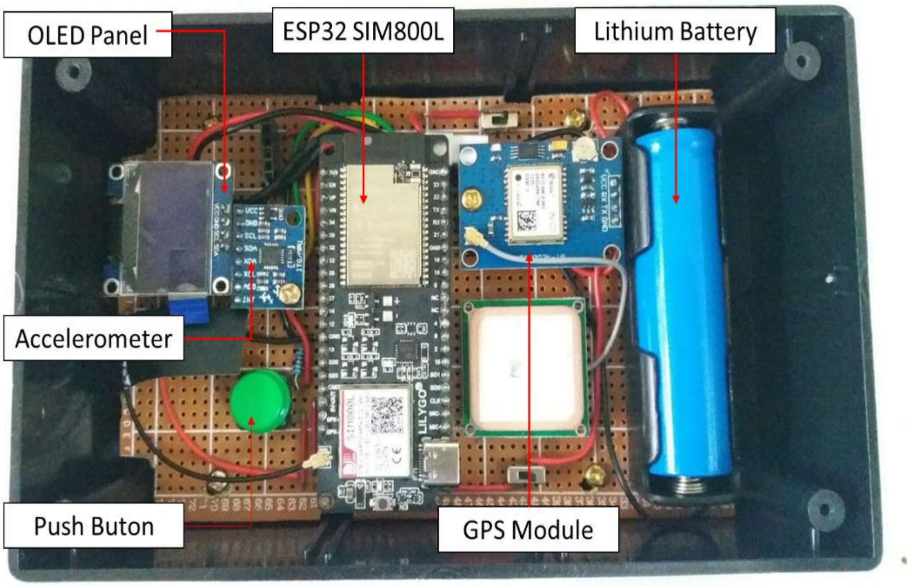

Fig. 8. Hardware developed prototype module

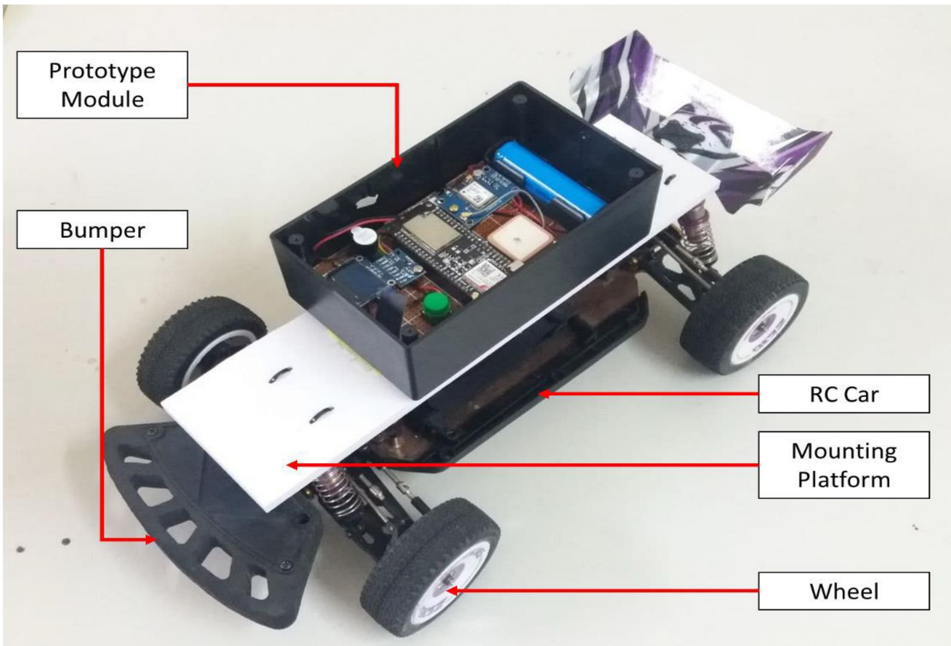

Fig. 9. Mounted Prototype Module

2.5 IoT Platform Setup

Blynk has been selected due to the microcontroller consistently crashes using Thing speak with SIM internet. The dashboard of the page is set up to show the location of the module, accident, aggressive, and fall alerts.

2.6 Live Tracking Setup

The live tracking functions is tested with driving the RC car through the drawn line as shown in the Figure 10. The tracked locations are the result of this test.

Fig. 10. Live tracking setup

2.7 Tilt Detection Test Setup

The RC car is tilted manually while the mounted module connected with serial monitor until the car flipped. The angles that determined the point of flipping are the output of this test. Then, the car is placed normally and moved manually to front, left and right.

2.8 Accident Detection Test Setup

The RC car is driven until it hit the obstacle as shown in Figure 11. It tested multiple times with increasing throttle until mild accident and severe accident are detected. The output of this test is accident severity, RC car speed and acceleration magnitude.

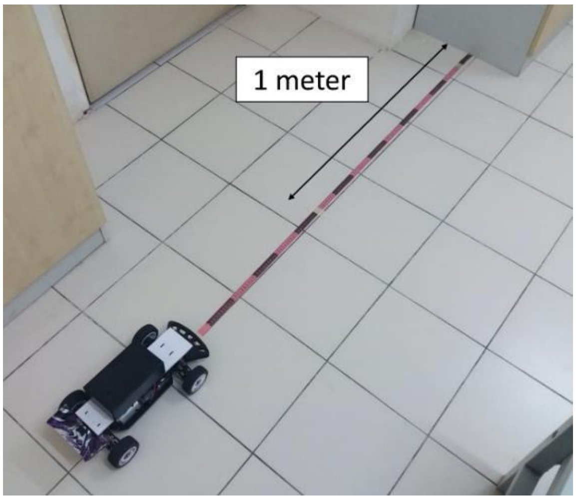

Fig. 11. Accident test setup

2.9 Aggressive Driving Detection Test Setup

The RC car is driven multiple times with various throttle input and scale, as shown in Figure 12 until aggressive driving detected. The successful detections are the output of this test.

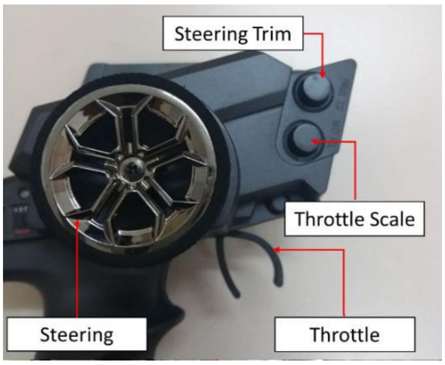

Fig. 12. Radio transmitter

2.10 Fall Detection Test Setup

Fall detection timer is set to 10 microseconds for the stability of the module. Then, the RC car is dropped with increasing height until fall is detected. The setup is shown in Figure 13 below.

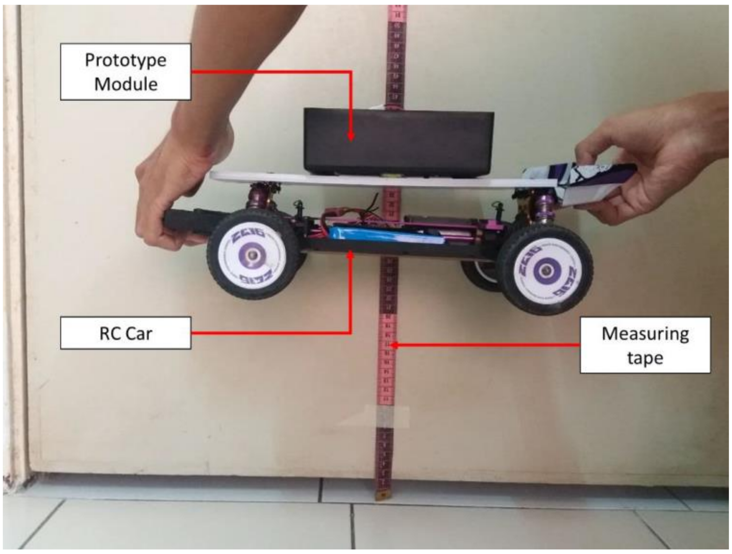

Fig. 13. Fall test setup

2.11 Combined Programming Code Test Setup

The RC car is driven multiple times to test all the functions of the module with a combined programming code. This test is conducted to confirm the functionality of the module.

3. Results and Discussion

The results include live tracking, tilt detection, accident detection, aggressive driving detection, fall detection, and the combined programming code of the module.

3.1 IoT Platform Result

The Blynk dashboard is successfully set up as shown as Figure 14.

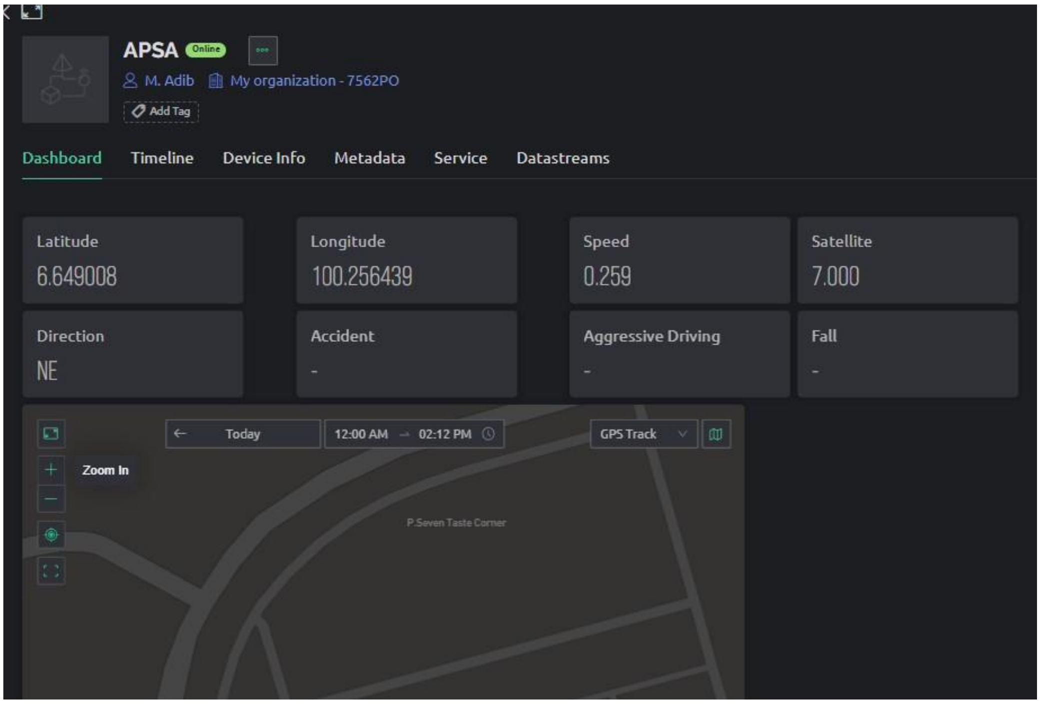

Fig. 14. Blynk dashboard

3.2 Live Tracking Result

The module is successfully tracked. The tracking result in Figure 15. shows that the GPS tracking is not accurate compared to the planned the path of the RC car with 100 meters radius of accuracy.

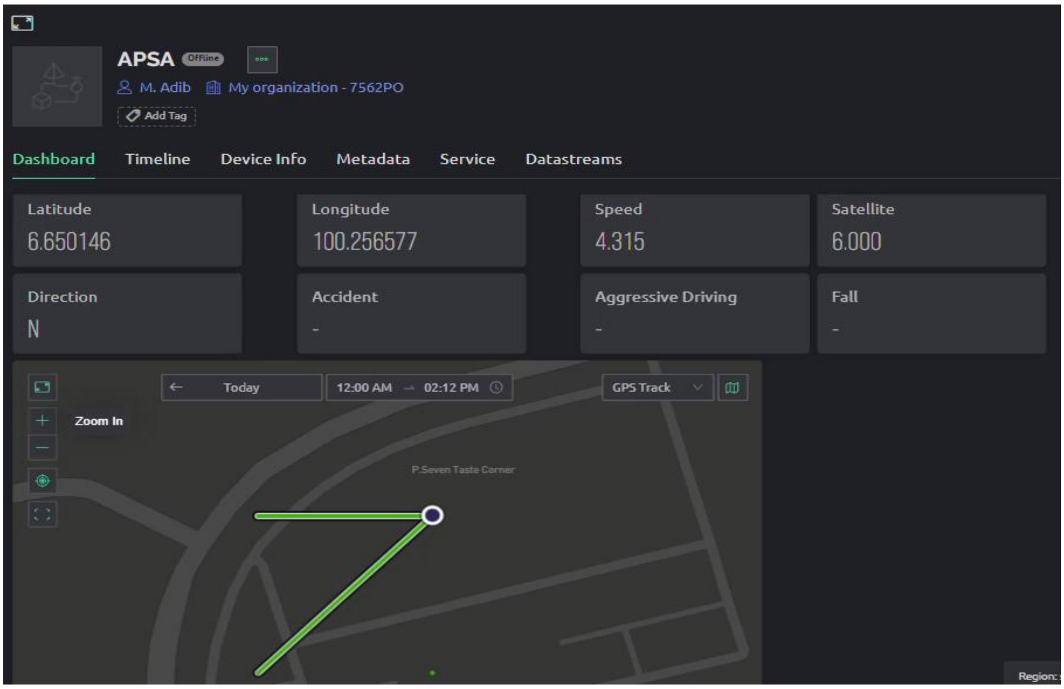

Fig. 15. Live tracking result

3.3 Tilt Detection Result

The right tilt test result in Figure 16 shows the car flipped at angle X = -60° and the left tilt shows the car flipped at angle X = 60° as shown in Figure 17. However, when the module is moved as shown in Figure 18, the reading of angle also changed. This proved tilt angle detection using only accelerometer is not achievable for this project. For that reason, tilt angle detection is discarded.

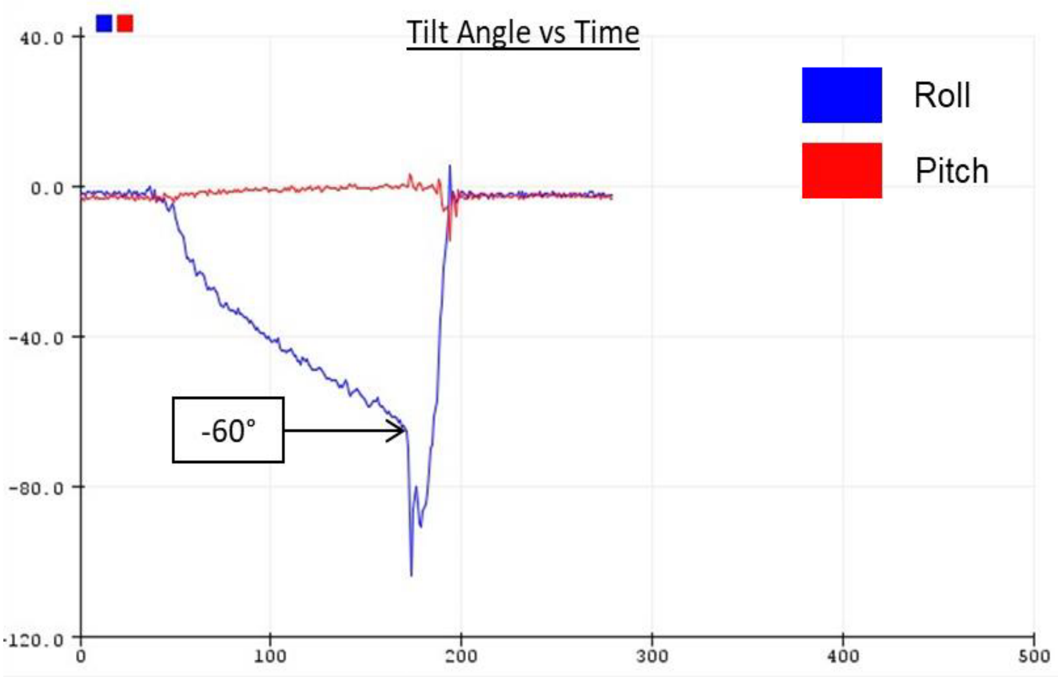

Fig. 16. Right tilt test

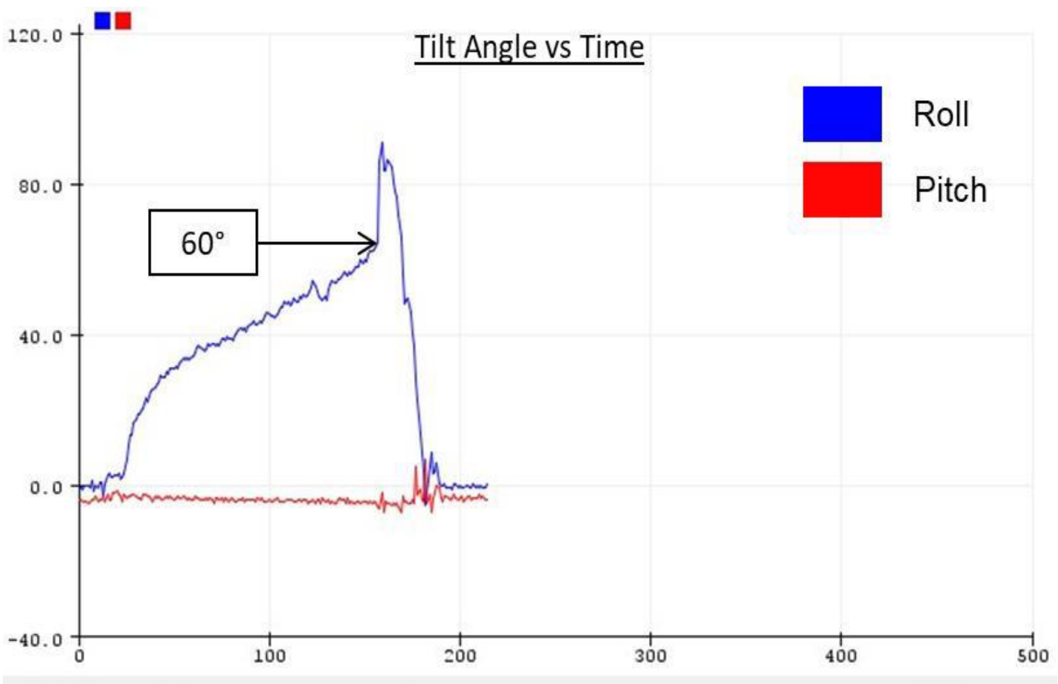

Fig. 17. Left tilt test

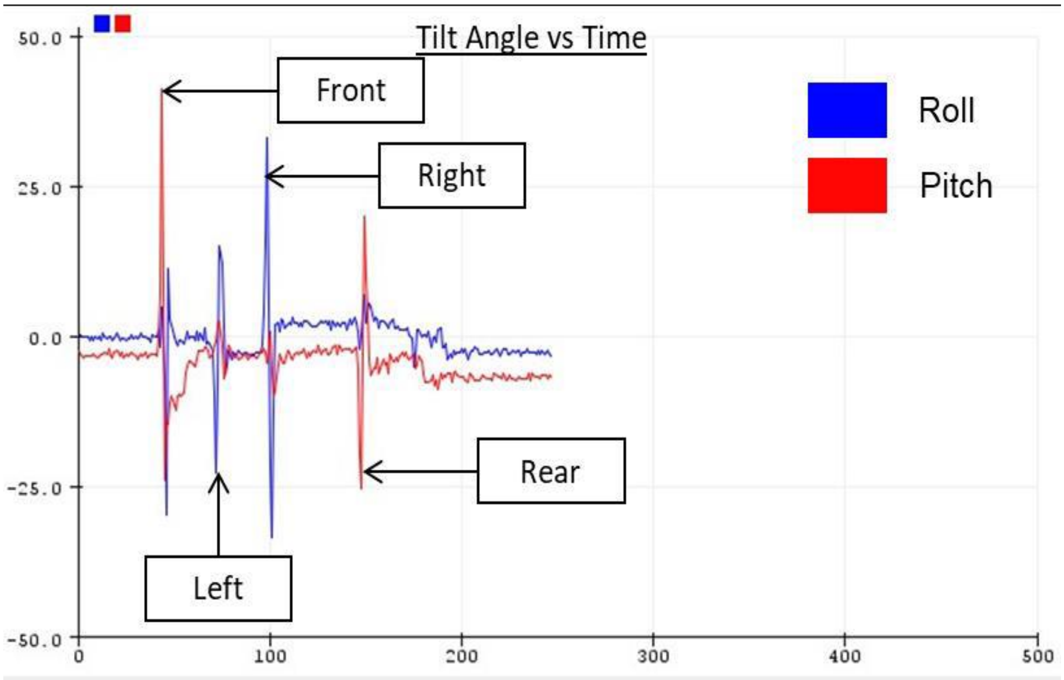

Fig. 18. RC car manually moved in tilt test

3.4 Accident Detection Result

The speed of the car acquired through recording of videos. The time at which the car is at 1 meter from the obstacle and when the car hit the obstacle is recorded as shown in Figure 19 and Figure 20. Table 4 shows the result of the accident test. The accident successfully detected with two severities since the obtained accelerometer determined fault at detecting more than 4g.

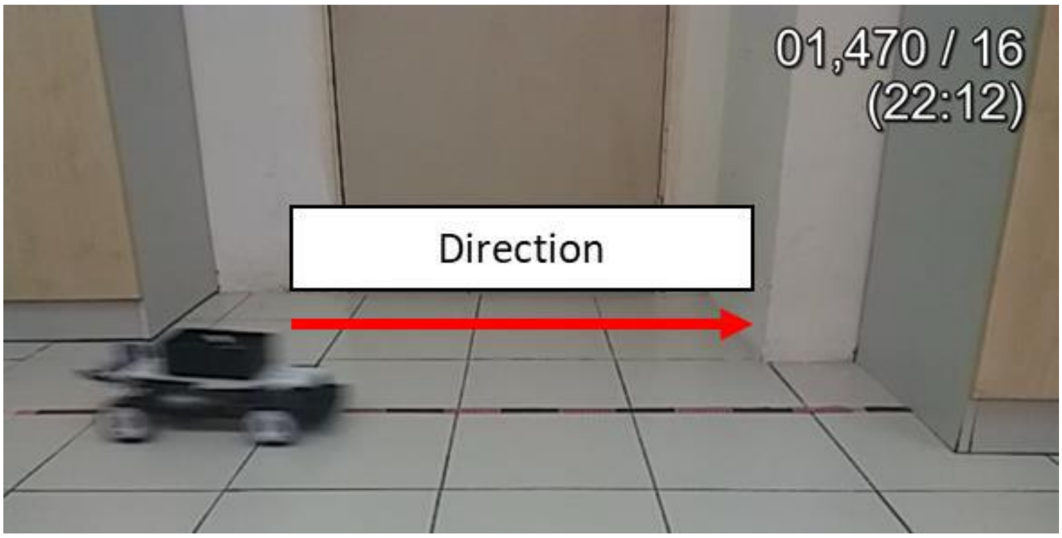

Fig. 19. Velocity acquisition start time

Fig. 20. Velocity acquisition end time

Table 4
Accident test result

Accident Severity	Time Start (ms)	Time End (ms)	Speed (m/s)	Acceleration (g)	Accident Severity
Mild Accident	14497	2054	1.80	2.36	Mild Accident
Severe Accident	772	1222	2.25	4.11	Severe Accident

3.5 Aggressive Test Result

The result shown in Table 5 proved the aggressive driving detection is not totally successful as it is inconsistent.

Table 5
Aggressive test result

Throttle Scale (%)	Throttle (%)	Detection
0	50	NO
0	100	NO
100	100	YES
100	100	NO
100	100	YES

3.6 Fall Detection Test Result

The result in Table 6 shows the fall detection is declared from 20 cm to 30 cm.

Table 6
Fall detection result

Height (cm)	Detection
5	NO
10	NO
15	NO
20	YES
25	YES

3.7 Combined Test Result

The results are obtained shown in Table 7 based on the sequence as follows: The live tracking failed while alert is functional while SMS alert is successful. Figure 21 shows the SMS alerts for the test, which are the first five alerts.

Table 7
Combined tests result

Test	Aggressive Driving Detection	Fall Detection	Accident Detection	SMS Alert	Blynk Alert
1	NO	YES	YES	YES	YES
2	YES	YES	YES	YES	YES
3	YES	YES	YES	YES	YES
4	YES	YES	YES	YES	YES
5	YES	YES	YES	YES	YES

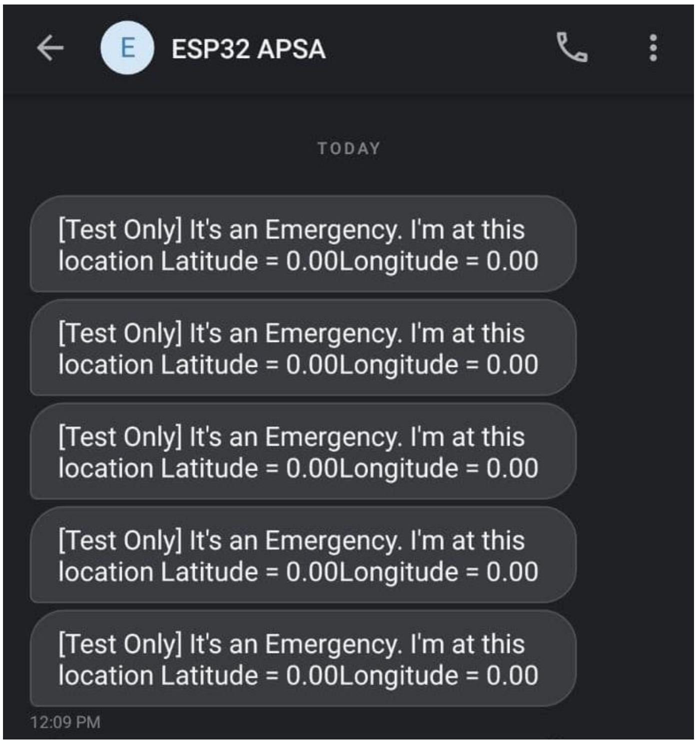

Fig. 21. SMS alerts

4. Conclusions

In this report, the development of this project has been presented. This report includes the background study and literature review to improve the developed system. Then, a proposed system was determined from the gap of the previous works. From the gap, the proposed system's block diagram, flowchart and components have been determined. Then, the circuit schematic, board layout, prototype model, and RC car model have been designed to be implemented for simulation.

The circuit simulated to determine an accident by monitoring the RC car's tilt angle. The results show that the system can detect an accident. When the monitored tilt angle reached 45° in the X-axis and the Z-axis, an accident event is determined. The accident motion also has been simulated. The results show that the accident has two significant impacts. The first impact recorded when the moving RC car hit the tire of the stationary RC car with -2.94 g of acceleration. When the second impact peaked, the simulation recorded -6.84 g of acceleration.

For hardware development, it is developed and tested. The parameters are obtained through testing. Accident and fall detection are consistently successful, as well as SMS alert. However, the result of aggressive driving and live tracking is not consistent with 75% success and failed respectively. The aggressive driving only functional without other detection programming coded. The issue still has not been solved. Finally, all the objectives of this project have been achieved, which are to design a circuit diagram and a prototype module of Accident Prevention and Safety Assistance, to develop the prototype module and monitor the communication system, and the last one is to test and analyze the performance of the developed system.

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