Vehicle Accident Detection System using Internet of Things (VADS – IoT)

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***Abstract*— This paper aims to improve the response time of the emergency response department to be informed on vehicle accidents in Malaysia. The primary impact of this work was to reduce the waiting period for accident victims to receive medical assistance and be rescued from a catastrophic vehicle accident. The conceptual idea of achieving this was by accommodating sensors and a microcontroller in a vehicle to compute the displacement of the vehicle. The system was developed using a vibration sensor to determine the collision impact of an accident and a gyro sensor to determine the x-y displacement of the vehicle. When an accident occurs, the instantaneous coordinates of the vehicle will be captured using a GPS module and transmitted to the emergency response department via a GSM module. The coordinates are visualized on a registered mobile phone at the emergency response department and mirrored to a desktop's Pushbullet application. With that, necessary emergency response units can be deployed to the accident location. The outcome of this project utilizes a gyro sensor to monitor angles between 45° – 315° and a vibration sensor at collision impact frequency of more than or equal to 90 Hz. The prototype can be a viable system to be incorporated by vehicle manufacturers in Malaysia to improve the safety features of a vehicle and ensure a better reliability of vehicle accident detection and reporting system.**

Keywords*— *Vehicle Accident Detection System, GSM, GPS, IoT, Pushbullet, Gyro sensor, Vibration sensor, VADS

I. Introduction

The amount of road accidents in Malaysia have been increasing at an alarming rate. In 2018, the Ministry of Transport (MoT) Malaysia reported a total of 548,-598 road accidents; where 6,-284 of them were casualties that resulted in death [1]. The life and death status of a victim is decided by the response time of the emergency response department (ERD) which varies depending on the speed the accident information is received by the ERD [2]. The importance of having a faster response time when an accident has occurred is crucial to accident victims. Extensive analysis has shown that by decreasing the accident response time by a minute, it would help increase the chances of saving an individual of up to 6% [3]. Characteristically, the response time of an accident is associated with the location and severity of an accident coupled with the congestion caused around the location of accident. During minimal traffic congestion, the occurrence of an accident would increase the response time for the ERD to be notified about the accident, sometimes up to 24 hours [2].

The proposed Vehicle Accident Detection System using Internet of Things (VADS – IoT) was introduced and developed to reduce the time taken for an accident to be reported to the ERD. The incorporation of IoT extends the network connectivity between different systems with minimal human intervention [4]. The communication between the on board sensors and Global System for Mobile Communications (GSM) module available in the vehicle's central processing box (CPB) forecast significant improvements of accident data transmitted towards the ERD, thus ensuring the system is reliable, efficient and effective [5]. The VADS was equipped with a gyro sensor for measuring displacement angles of a vehicle and a vibration sensor to measure the instantaneous collision impact frequency during an accident. The data collected from these sensors are then fed into an Arduino Mega microcontroller for comparison if an accident needs to be reported. In the event of a 'major' accident, the Arduino Mega microcontroller signals the Global Positioning System (GPS) module to extract the instantaneous coordinates of the vehicle and feeds it into the GSM module. The GSM module which already has an active subscriber identification module (SIM) card sends the instantaneous coordinates of the vehicle in a string format of a Google Maps link towards a registered mobile phone number at the ERD. Pushbullet application at the ERD mirrors the received coordinates from the mobile phone to a desktop. During a 'minor' accident in which there are no casualties reported, a terminating button can be used to terminate the data transmission towards the ERD. The application of using a terminating button in different VADS are discussed in several research papers as it helps in reducing valuable time in unnecessary accident reporting and serves the ideal purpose of an efficient vehicle accident reporting system (VARS) [6]–[10].

II. Research Review

A vibration and gyro sensor are effective components used in VADS because of their behavioral properties. Research works done in [11] indicated that a vibration sensor was sensitive to small vibrations which helped in indicating collision impacts when a vehicle was abruptly stopped by an external object. The adaptation of a gyro sensor in [11] measured the displacement of the vehicle in the x-y displacement axis to determine the angular acceleration and tilt angle of the vehicle when it was thrown off the road. Similarly, authors in [2] proposed the similar VADS which was equipped with a vibration and gyro sensor. In this research project, the authors used the vibration sensor to detect the number of vibrations recorded in 5 seconds to determine the severity of an accident. The findings indicated that less than 10 vibrations recorded in 5 seconds was associated with a minor accident while more than 10 vibrations recorded in 5 seconds was associated with a major accident. The angular displacement of the vehicle was measured by monitoring the instantaneous change of angular displacement reading in 5 seconds using a gyro sensor. A sudden change of the gyro's angular displacement in less than 5 seconds was accredited to the vehicle rolling of the road while an angular displacement of more than 5 seconds was accredited to the vehicle being thrown off a cliff. The similarities of both these research papers were that the computation of data was done by an Arduino microcontroller.

Using an ARM7 32 – bit microprocessor, a VADS was designed using vibration, gyro, piezoelectric and accelerometer sensors. This development was consistent with the research conducted by authors from [6], [9], [12], [13]. Authors from [9], [12], [13] utilized an accelerometer to measure the angular displacement of the vehicle and fed that data into an ARM 32 – bit microprocessor. The information was displayed on a Liquid Crystal Display (LCD) to monitor the accidents reported. The advantage of using this VADS was the ARM7 32 – bit microprocessor was a reliable data computation processor as it could handle clustered information being fed at once into the microprocessor. The research findings obtained in [6] illustrated that the ARM7 32 – bit microprocessor was used to compute logical inputs and outputs from a vibration sensor and GPS and GSM modules. The networking of data was done by an electrically erasable programmable read – only memory (EEPROM) which acted as the storage server for associating phone numbers of the closest ERDs and emergency contacts information of the victim. The advantage of using an EEPROM in comparison with data computation done on the ARM 7 microprocessor was that information can still be accessible even when the ARM7 microprocessor was turned off.

The adaptation of using a mobile phone for data transmission towards the ERD was essential since it had its own GSM broadcasting service available on it. In research done by authors from [14], the information of an accident was stored on a flash chip. The information from the flash chip was transmitted to a mobile phone which communicated directly with the ERD using GSM technology. The significance of using a flash chip was to ensure the accident information was received by the ERD even when the rest of the control system was damaged in an accident. Identically, findings of similar work were seen in [15] where the author stressed about the utilization of a mobile phone to transmit accident information to the ERD. In this research findings, the GPS system on a mobile phone was used to detect the location, speed and displacement of a vehicle. An accident triggers the mobile phone to transmit the vehicle's instantaneous coordinates to the ERD via cellular network.

In addition to designing a VADS which was able to handle clustered amount of information while still communicating effectively with the ERD, a Raspberry Pi module was used instead. This idea was supported by research findings obtained in [4] where the author utilized a vibration sensor which had its vibration collision frequencies pre – programmed into a Raspberry Pi module. A GPS module was interconnected with the Raspberry Pi module and emergency contacts of an individual was registered in the Raspberry Pi module. Similarly, authors in [16] utilized a Raspberry Pi module to transmit accident information towards the ERD while an Arduino microcontroller was used for data computation of the piezoelectric sensor readings. The advantages of utilizing a Raspberry Pi module instead of an Arduino microcontroller includes in having 40 times of clocking speed, 12 800 times of processing random access memories (RAMs) and advanced internet connectivity [17].

III. Research Method

A. Block Diagram of VADS – IoT

The overall design of the VADS – IoT is shown in Fig. 1. The power for the Arduino Mega microcontroller was obtained from a vehicle's cigarette lighter receptacle (CLR). A vibration and gyro sensor measured the vehicle's collision impact frequency and x-y displacement of the vehicle, respectively. The communication peripherals were a GPS and GSM module to capture instantaneous coordinates of the vehicle and transmit it towards the ERD, respectively. A terminating button was used to terminate the data transmission. All these electronic components were placed inside a CPB along with its cooling system. A cooling fin was mounted on the top of the current and voltage regulator of the Arduino Mega microcontroller to evenly dissipate heat produced by the microcontroller during operation.

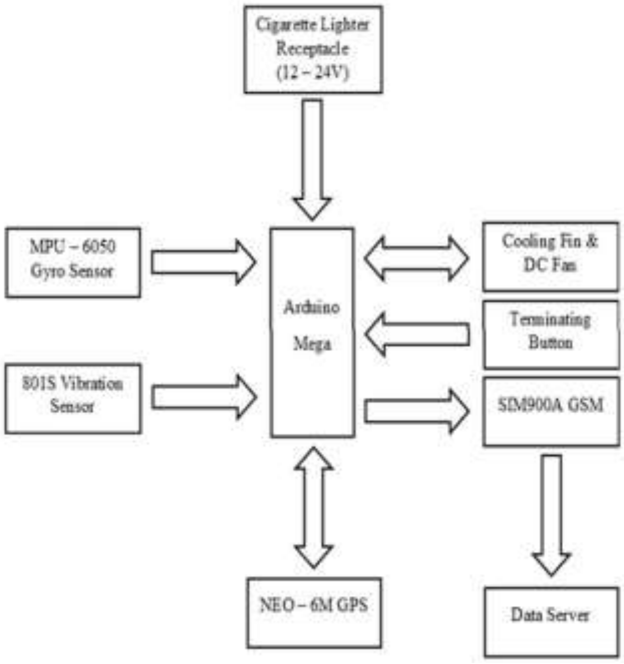

Fig 1. Block diagram of the VADS – IoT

B. Design of Experiment

The problem – solving seven stages flowchart is depicted in Fig. 2. The process begins with the gyro and vibration sensor monitoring for upcoming accidents. When an accident occurs, the GPS module extracts the instantaneous coordinates of the vehicle and transmits it towards the GSM module. The Arduino Mega microcontroller enables the GSM module to communicate with a registered mobile phone number at the ERD. Within a minute, the ERD will be notified about the accident and necessary ERUs can be deployed. The feedback mechanism was a terminating button to proceed or terminate the data transmission towards the ERD. Pressing the terminating button within 15 seconds of an accident will terminate the data transmission towards the ERD. 'Bottle – neck' crowding of a VARS results in unnecessary wastage of time and causes the ERD to react in a confused manner. The application of the VADS designed was to reduce 'bottle – neck' crowding and clustered amount of information being transmitted towards the ERD. The overall idea of having a delay of 10 – 30 seconds before the accident information was transmitted towards the ERD can be supported by justifications made by various authors in [2], [18]. The circuit diagram of the VADS is illustrated in Fig. 3.

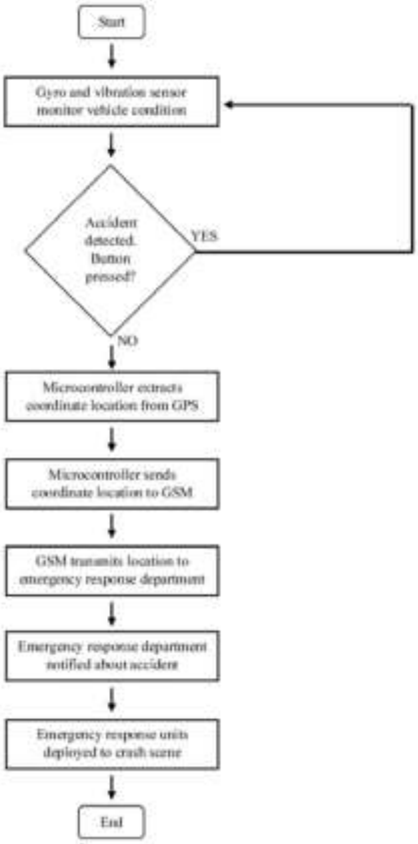

Fig 2. Flowchart of the VADS – IoT

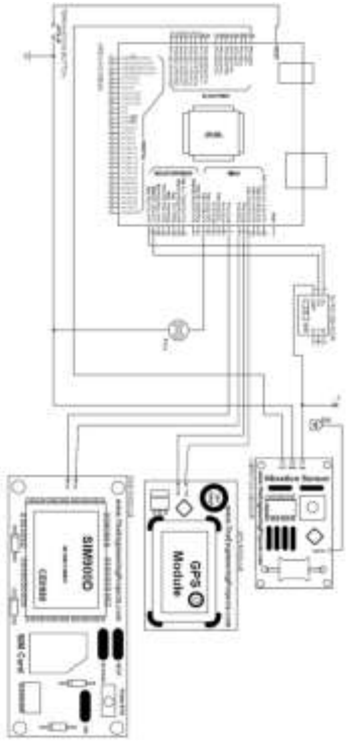

Fig 3. Circuit diagram of VADS – IoT

C. Structure Design of the CPB

The CPB was fabricated to be water – resistant, fire retardant and shockproof to ensure a long – life span for its consumers. A 10” x 4” polyvinyl chloride (PVC) junction electrical box was used to accommodate all the electronic components. Particularly, the CPB was tested of its ability to resist water entering its interior by immersing it in water of depth 8” for 10 minutes. The results indicated that the CPB was IP56, protected from dust and high – pressure water jets. Fig. 4(a) illustrates the CPB tested for its water – resistant properties while Fig. 4(b) shows the interior surfacing of the CPB remained dry after the water – resistant test.

Fire retardant properties was included in the overall fabrication of the VADS by adding insulating materials inside the interior of the CPB. The objective was to lengthen the destruction time of the CPB during a major accident. The solution was to equip the interior of the CPB with a high – density polyethylene (HDPE) board and an 8 mm shock absorbent sponge. The HDPE board had a tensile strength of 15.66 MPa and a melting point between 110 – 140 °C [19]–[21]. Characteristically, a sponge/foam was used to absorb unintentional shocks from the surrounding, thus the 8 mm shock absorbent sponge was layered on the interior surface of the HDPE board.

The CPB was designed to be placed in a vehicle where it had a minimal chance of being destroyed when an accident occurs. Based on similar studies conducted in [22], [23], vehicle accidents in Malaysia are associated with frontal and rear – end crashes. This was because there was substantial amount of 'crush space' at which a vehicle channels its momentum to when an accident occurs. A higher level of safety features only meant there were more 'crush space' which a vehicle can transfer its momentum during an accident [22]. Due to this fact, the CPB was best suited to be placed underneath the vehicle's rear middle seat. This prohibited the CPB from being an obvious target of destruction during accidents.

Fig 4. a) Water – resistant test of CPB; b) Interior overlook after water – resistant test

D. Design of Cooling System in CPB

The VADS had many active electronic components in the CPB and all these electronic components were fitted into a confined space inside the CPB, causing them to produce a substantial amount of heat. A temperature test was conducted using an infrared thermometer to determine the amount of heat produced by each of these components which is illustrated in Fig. 5. Table 1 exemplifies the measured temperature values of four electronic components after an hour of operation. The vibration sensor was less than 20 °C, therefore it was not considered to be a primary heat producer in Fig4.

An author in [24] described that the causes of overheating a semiconductor material was due to the physical dimension of its devices. Electronic components are extremely sensitive to spikes of temperatures. The tendency for them to fail are extremely likely when they are exposed to high temperatures for a long period of time. This would result in those electronic components to produce false readings/data which could possibly lead to the failure of a device to produce reliable results. In this case without proper dissipation of heat, the VADS would produce inaccurate accident information which would lead to an unreliable VARS. Hence, cooling systems were incorporated in the VADS.

Based on the temperature findings obtained, only the current and voltage regulator of the Arduino Mega microcontroller had enormous amount of heat produced; almost equivalent to 40 °C. As a solution, a 0.6" x 0.5" aluminium cooling fin was mounted above the current and voltage regular of the Arduino Mega microcontroller. Thermal heatsink compound was applied on the current and voltage regulator before the aluminium cooling fin was mounted above it by means of silicone sealant. Fig. 6(a) shows the thermal heatsink compound on the current and voltage regulator while Fig. 6(b) shows the aluminium cooling fin mounted above it. The reason of using an aluminium cooling fin was justified by authors in [25] indicating that passive cooling method of dissipating heat like aluminiums had a thermal conductivity of 237 W/m-K at 300 K (26.85 °C) and 240 W/m-K at 350 K (76.85 °C). Based on these findings, an aluminium cooling fin was used to dissipate the heat from the current and voltage regulator of the Arduino Mega microcontroller. In lieu of the heat produced by other electronic components in the CPB, a 12 DV fan was mounted at the interior base of the CPB to introduce forced convection.

Fig 5. Temperature measurement test using infrared thermometer

TABLE I. Temperature Measurement Results Of Electronic Components

Components	Temperature, °C
Current and voltage regulators	39.6
GSM module	31.8
GPS module	31.5
Gyro sensor	28.4

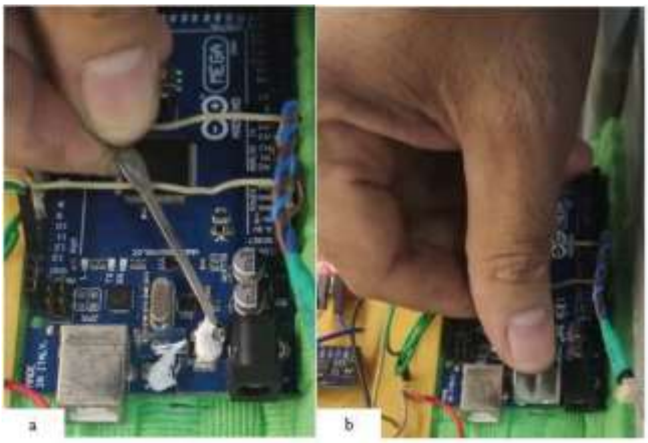

Fig 6. a) Thermal heatsink compound layered on current and voltage regulator; b) Aluminium cooling fin mounted above the current and voltage regulator

E. Power Supply for the VADS

In ensuring the VADS had a stable power supply, it required 1 A of current at voltages between 6 – 12 V [26]. The conventional CLRs found in vehicles are rated at 12 V/1 A, sufficient to power the entire VADS. Therefore, the VADS was powered from the vehicle's CLR using a male cigarette lighter socket (CLS) with the other end having a 5.1 mm x 2.1 mm DC barrel jack connector. The Arduino Mega microcontroller was connected to the DC barrel jack connector while the CLS was interconnected with the CLR in the vehicle with a protective fuse of 1 A. The significant of employing a fuse was to avoid an overcurrent flow from the CLR towards the Arduino Mega microcontroller [27]. Fig. 7 shows the connections made with the entire circuit enclosed in the CPB.

Fig 7. Power supply from CLR to VADS

IV. Results And Discussion

A. Temperature Characteristics of the Aluminium Cooling Fin and CPB

The final temperature testing was done inside the CPB and on the aluminium cooling fin. A clamp multimeter was interconnected to a thermocouple thermometer which was inserted in the power adapter hole made in the CPB. The aluminum cooling fin's temperature and the average CPB inner's temperature was measured for 12 hours, with readings taken every 2 hours. The graph in Fig. 8 exemplifies the variation of temperature readings taken on the aluminium cooling fin while graph in Fig. 9 exemplifies the average CPB inner's temperature.

In Fig. 8, the current and voltage regulator of the Arduino Mega microcontroller had a lower measured temperature once the aluminium cooling fin was mounted above it. This helped the dissipation of heat to be rapid, causing less surface area of heat to be accumulated at one point. The error of data deviation was determined to be small, indicating that the changes of temperature every 2 hours were small. In view of the graph in Fig. 9, it is seen that after the 8th hour, the temperature started to remain constant at around 35 °C. This indicated that the inner environment of the CPB was dissipating heat evenly via forced air convection of the DC fan.

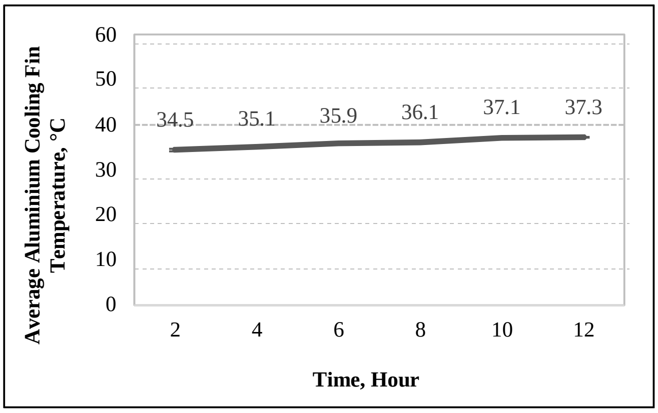

Fig 8. Average aluminium cooling fin temperature over a span of 12 hours

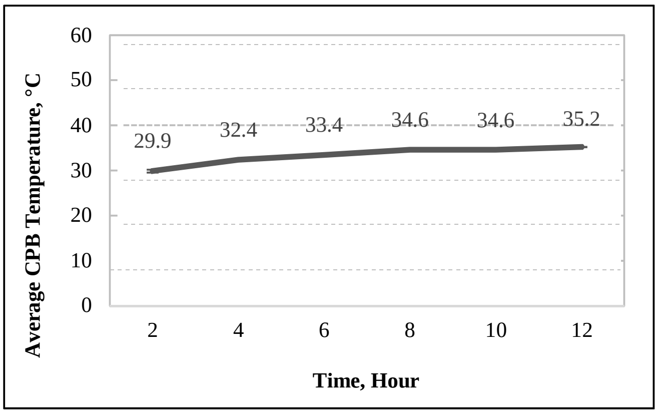

Fig 9. Average CPB temperature over a span of 12 hours

B. VADS – IoT System Responses to An Accident Environment

Fig. 10 shows the outcome of the designed VADS – IoT. A Maxis carrier SIM card was placed inside the GSM module for data transmission of instantaneous accident coordinates. Silicone sealant was used to fill any gaps/holes once the DC barrel connector was fitted through the CPB.

Fig 10. Final VADS - IoT prototype

The simulation of accident was done at a construction area which had uneven, bumpy and untarred roads. An accident was simulated by driving fast and braking at a sharp turn radius which resulted in the VADS to detect an 'accident', thus providing the instantaneous coordinates of the vehicle. In 20 seconds, those coordinates were visualized on a registered mobile phone. Fig. 11 shows the pseudocode of the accident information on the Arduino IDE serial monitor. When the visualized information was mirrored to the desktop using the Pushbullet application, the string formatted Google Maps coordinates was clicked and the Google Maps link web page was displayed which showed the location of the extracted coordinates. Fig. 12 shows those coordinates on the desktop's Pushbullet application while Fig. 13 illustrated those coordinates on the Google Maps web page.

The minimum conditions for the VADS to extract the accident coordinates was determined by two components; gyro and vibration sensor. The gyro sensor had angles between 45° - 315° while the vibration sensor had threshold collision impact frequency of more than or equal to 90 Hz. The 'AND' between these two pseudocodes caused the VADS to detect an occurrence of an accident. Upon completion of the testing, the prototype was fully functioning with satisfying all the defined objectives. The VADS – IoT was ensured to have fulfilled the requirement of being a time saving VARS.

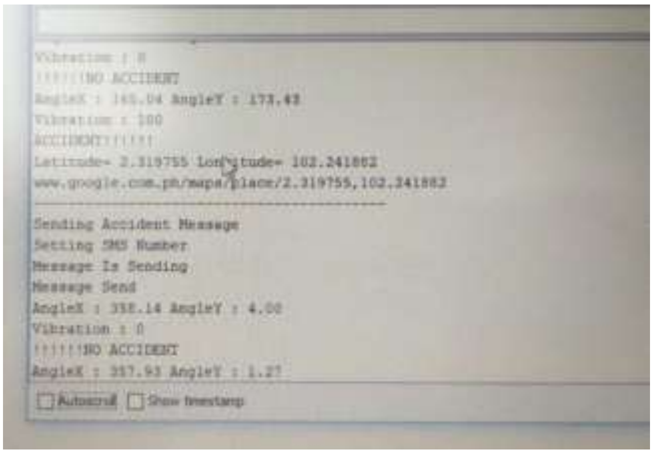

Fig 11. Instantaneous accident information on Arduino IDE

Fig 12. Pushbullet application on desktop

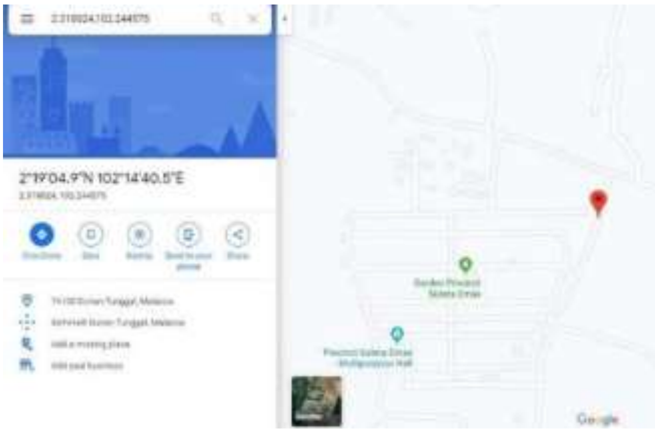

Fig 13. Extracted coordinates on Google Maps

C. Problems Faced in Development of VADS – IoT

A Digital Humidity and Temperature (DHT11) sensors was initially proposed to monitor the temperature changes in the CPB and to operate the DC fan accordingly. The problem identified was the temperature readings always interrupted the establishment of connection between the GPS module and Arduino Mega microcontroller. The solution to this was to remove the DHT11 sensor and to operate the fan independently.

Instead of conventional radial cooling, the initial VADS was designed to have water cooling system. The problem identified was the low efficiency of the water cooling system to disperse heat from the interior of the CPB since it will not be in direct contact with the electronic components. The designed was modified to equip an aluminium cooling fin to disperse heat only from the current and voltage regulator of the Arduino Mega microcontroller.

Another problem identified was that the GSM module did not function ideally since it was designed to obtain power from the printed circuit board (PCB) which had power connections route made directly from the Arduino Mega microcontroller. The copper route of the PCB did not provide adequate power to ensure the GSM module was stable to have a strong cellular connectivity. Overcoming this, the GSM module was directly connected to the Arduino Mega microcontroller to obtain independent power.

V. CONCLUSION

This work has developed a VADS – IoT to improve the response time of the ERD by answering the justified initial objectives. It was established that when the pseudocode of the vibration and gyro sensors were met, the VADS extracted the instantaneous coordinates of the vehicle and transmitted it towards the ERD. This design is viable in Malaysia as it can be equipped in upcoming vehicle manufacturing companies to help save more life with minimal amount of human intervention. The ERD would also be a great beneficial of responding to emergency accident situation more accurately and effectively without any wastage of additional time.

This work has opened several questions that needs further investigations and improvements. Future prospects include in transmitting the accident data directly towards a web server. This would abstain the use of a mobile phone at the ERD and further improve the speed of the accident data transmission. GPS and GSM modules can also be removed from the system. Instead, the VADS can be directly interconnected with the vehicle's GSM and GPS module, reducing the overall cost and simplifying the development of the system.

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