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Real-Time Drowsiness Detection System for Driver Monitoring

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Abstract. Nowadays, the rate of road accidents due to microsleep has been alarming. During microsleep, people might doze off without realizing it. For many decades, drowsiness detection system for vehicles was not among the major concerns though it turns out as one of imperative features that could have avoid microsleep and thus should be implemented in all vehicles in order to ensure safety of drivers and other vehicles on the road. To the best of our knowledge, enforcements on driving restriction during drowsiness state is yet to be implemented. The absence of such system in the current transportation systems expose drivers to great danger especially at night because accidents are highly likely to happen at night due to drowsy and fatigue drivers. Therefore, this project proposes a real-time drowsiness detection system for vehicles, featuring ignition lock to reduce accidents. An eye blink sensor is embedded in a wearable glasses and heart beat sensor is used to detect drowsiness level of drivers. The system also includes SMS notification system to relatives or friends with location details of the drowsy driver. This project is able to detect and react based on 3 levels of drowsiness by alerting the driver through buzzer. Ignition lock will be applied when high level of drowsiness is detected. Consequently, the vehicle will be slowed down and eventually stopped when dangerous level of drowsiness is detected as a safety precaution.

1. Introduction

Accidents involving vehicles on road are becoming unpreventable nowadays. World Health Organization (WHO) once had revealed that over 3400 people die on the world's road every day and billions of people are suffering non-fatal injuries and disabilities as a result of their injuries [1]. Traffic Safety Foundation study found that 37% of drivers have fallen asleep behind wheels. This might be due to drowsiness or mircosleep. Accidents could cause fatal injuries and increase mortality rates.

According to statistic of Indonesia National Police, from 2007 to 2010, 65% of accidents is due to human carelessness and human error. For instance, in 2011 during EID festival, a statistic reveals that most of the accidents in that country happened due to drowsiness of drivers (1018 cases) [2]. Studies also shows that most of the accidents around the world are due to drowsiness [3][8]. Drowsiness is commonly known as tiredness or sleepiness which leads to falling asleep at inappropriate times or situation. Drowsiness causes the driver to loss control on speed or become unaware of obstacles on road and this could end up in fatal accidents. Statistics show that fatal accidents happen every 52 seconds

around the world [4]. Driving after working hours might cause drivers to be drowsy and careless due to tired of working or driving for long time. Some important problems have been outlined as follows:

- **Inefficient drowsiness detection systems**
  Many drowsiness detection systems have been developed and implemented but some of the systems do not have an effective system to alert the drivers. Those systems do not alert the driver by triggering buzzer but just display warnings on LCD using different colour of LEDs that light up according to drowsiness levels. This causes the driver to be unaware of the dangerous situation. This still putting drivers at high risk of accidents.
- **Existing systems does not provide real-time drowsiness detection**
  Moreover, only few of the existing systems provide real time drowsiness detection. Real time in this system means that once drowsiness is detected, there should be an immediate action taken without delay to save the drowsy driver from getting into an accident. Systems with real-time is an important factor for designing drowsiness detection.
- **Lack of notification in current drowsiness detection mechanisms**
  Besides that, most of the previous proposed systems do not send notification (SMS, email, etc) with location details of the driver to the driver's next of kin. This notification is critically important to ensure the safety of the associated driver. If nobody comes to pick up the driver from the location where the car has been stopped, the driver might continue to drive in drowsy state which is fatal to the driver and also other vehicles around. By sending out notification to their relative or friends, the safety of the driver can be ensured.

2. Objectives

Based on the stated problems stated, this project has outlined the following objectives.

- To develop a system that can automatically detect and perform appropriate immediate reaction based on different level of drowsiness.
- To design a system that will automatically control the speed of vehicles when drowsiness is detected and apply ignition lock when highest level of drowsiness is detected.
- To develop a drowsiness detection system with SMS notification that includes the location of the vehicle by using GSM and GPS modules.

3. Related Work

The tremendous increase in road accidents around the world has led to serious investigation among researchers. Many different solutions have been proposed to improvise safety of drivers. However, most of existing drowsiness detection systems still suffer some drawbacks. Most of the systems can only detects drowsiness and gives out warnings to alert drivers while still allow them to ignore the warnings and continue driving in drowsy condition. In this case, road accidents can still happen and the menaces imposed by these drivers to other road users are still high.

Most of the existing works are focusing on both internal and external vehicles to prevent accidents due to drowsiness. Studies carried out on the internal unit of vehicle are mainly concern on drivers. This is because the main reason of 20 % of the crashes and 30 % of fatal crashes around the world is caused by drowsiness of drivers and lack of driver's concentration [5]. The system inside will alert the driver by giving some warnings when the driver is already drowsy. Figure 1 shows various techniques on drowsiness detection methods.

3.1 Physiological Approach

Physiological approach refers to the method of detecting drowsiness by using data collected through sensors fixed on driver's body such as wearable device [6]. According to Anilkumar et al., 2017 [7], drowsiness can be detected using camera which is placed at an angle where drivers's face can be clearly captured. Then the video input is converted into frames and analysed using frame difference algorithm.

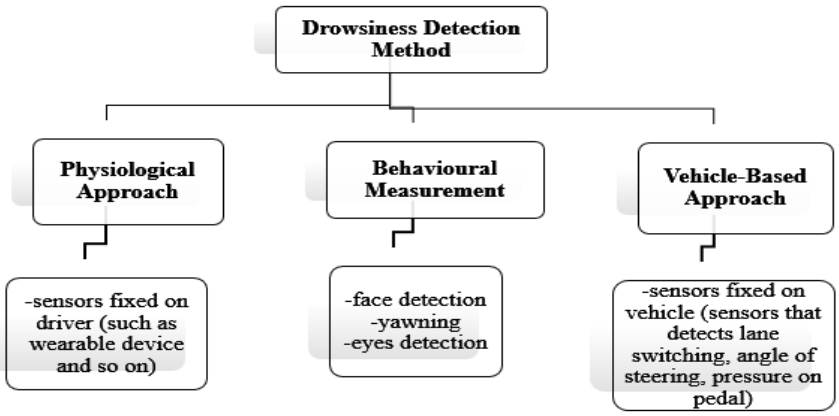

Figure 1. Various techniques to detect drowsiness (A. Lemkaddem et al., 2018)

Heart rate of driver is analyzed using ECG sensor for simulation purposes. Sample of ECG signal is taken to make comparison with normal heart rate (60 > rate < 100). Finally, the decision is made whether the driver is drowsy by matching both outputs from camera and heart beat rate. Driver is monitored continuously and warnings through audible speaker is given to prevent accidents if the driver seems to be drowsy. However, some limitation can be seen when generating audible warning is just not enough to ensure safety of driver.

Riztiane et al., 2017 [8] have proposed a system in which driver have to wear a wearable device to obtain the normal heart rate and the value is saved on the device. Once it is saved, the driver could turn on their front camera of mobile phone which will detect driver's face, mainly the eyes. Then, the state of eyes, whether it is opened or closed will be detected and the heart rate of driver is also monitored for making comparison between current heart rate while driving and the heart rate. Both the data will be combined to determine drowsiness state of driver. As the drowsiness value is indicated, three levels of alarm warnings such as normal, drowsy or sleepy will be determined. Moreover, if the eye blinking duration of driver exceeds the pre-defined condition and if drowsiness is also detected through heart beat rate, then the warning alarm will be triggered to alert the driver. However, driver needs to restrict his or her activities to a minimum movement so that the device can produce measurement accurately.

Another physiological approach is proposed by Gobhinath et al., 2017 [9] which includes a few sensors such as eye blink sensor, heart-beat sensor and body temperature sensor. In this project, eye blink rate, heart beat rate and body temperature of driver are monitored by using sensors separately and the measured values are sent to microcontroller and compared with the reference values which were recoded previously. If the values do not match the reference value, warning will be displayed on LCD. The car engine is controlled by microcontroller. If the sensors detect no output, the engine will be locked or stopped by microcontroller. Similar like [9], Leng et al., 2015 [10] also proposed a system which is mainly based on biomedical and motion sensors. This project exposes wristband consists of a few sensors such as *Photoplethysmogram* sensor and galvanic sensor. All the data collected will be sent to driver's smart phone through Bluetooth. Those data are analyzed with the motion sensor which are built-in accelerometer and gyroscope sensors. Sensors data including heart rate, pulse rate variability, respiratory rate, stress level and adjustment counter aid to detect drowsiness of driver. If drowsiness level reach 5 which indicate 80% drowsiness, a vibration of smart watch (wristband) will be triggered.

3.2 Behavioral Measurement

Behavioral measurement refers to the changes in reactions of driver's face which usually could be detected through yawning, monitoring state of eyes and mouth. Manu, 2017 [11] focused on face detection and skin segmentation method which only considers chromatic components. In this method,

eyes of driver are tracked and the position of eyes is detected by Viola Jones and Sobel, a technique to detect edge in frame. Next, yawning detection is implemented as it detects the mouth region during yawning. Figure 2 shows the picture after the face and skin region of driver are detected while figure 3 shows the flow of eye detection.

Figure 2. Face detection and skin region found on the picture (Manu, 2017)

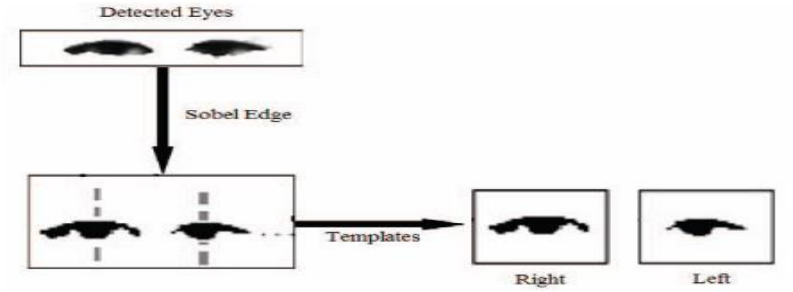

Figure 3. Process of eye detection (Manu, 2017)

This method eliminates influences of luminosity since it considers only chromatic components. It also use invariant to illumination and have a high drowsiness detection rate which reduces false alarms. However, this method is unable to predict drowsiness when head of driver was tilted right or left.

Another research by Naz et al., 2017 [12] analyses yawning, eye closure and head movement of driver to detect drowsiness. An alarm sounds badly if the driver leans his/her head when eyes are closed and a three level warnings are also blasted. In this method, warnings by level are given to irritate and alert the driver. Sequentially, the researchers in another journal used faced detection and eyes detection method to detect drowsiness of driver [13]. According to the system, it starts off with initialization phase in which face and eyes detection is conducted. Then, tracking of face and eyes in different frames carried out as to proceed to the next steps which are eyes state identification and driver state.

Besides, in another related journal by Akrout et al., 2016 [14], only yawning detection method is used for drowsiness detection. Akrout used Viola Jones technique for the stages of localization of face and mouth. Then, the stage of lips extraction is carried out followed by extraction of spatio-temporal descriptor in which calculation of the tracked lips surface and internal zone of mouth take place. However, yawn detection method fails most of the time due to bad localization of mouth. Other than that, if the drivers hide their mouth while yawning, the system will not function because yawning will not be detected.

3.3 Vehicle-based Approach

Vehicle-based approach refers to the method which detects drowsiness by using the data collected from the sensors fixed on the car itself. Those sensors monitors the changes such as lane deviation, angle of steering and acceleration on the pedal of the car [6]. An interesting research on safe driving by detecting lane discipline and driver drowsiness is proposed by Katyal et al. (2015) [15] which is a

vehicle-based approach method to detect drowsiness. Firstly, the authors used two cameras in the vehicle, one is to detect driver's face and another is to detect road lane. When the car changes lane without signal, error is detected, and a warning is sent to the driver to avoid accidents. Next, another camera which monitors driver's face capture one frame of video, performs Viola-Jones method to find eye localization, performs edge detection of the eyes and performs Hough circle to detect drowsiness. This method is known as face detection. This is an outstanding method because it warns the driver by audible sound (alarm) when the driver crosses lane without signaling and it immediately applies brake to slow down the vehicle. Another advantage is that when the system detects more than 10 frames of closed eyes, alarm sounds or brake applied and the vehicle is slowed down. Through face detection method, eyes are also detected even in the low light intensity condition. However, the method also will not detect drowsiness if the eyes are detected less than 10 frames which is obvious that it took long time to decide drowsiness and this might lead to fatal accidents. This vehicle warning system had become one of the widely used method of real-time face detection. Nevertheless, this system could not detect drowsiness if the driver wear sun glasses while driving.

4. Proposed Real Time Drowsiness Detection System for Vehicles

This project includes some improvisation to overcome some limitations in the existing systems by including some extra features. This project is separated into 4 phases as illustrated in figure 4.

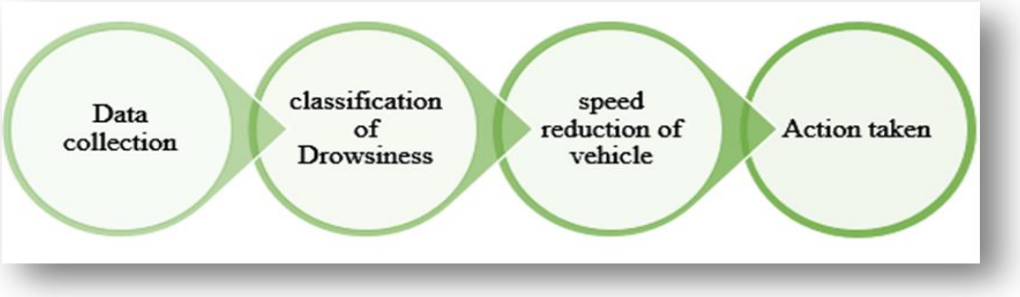

Figure 4. Phases in detecting drowsiness

The first phase involves data collection from all the sensors which are heart beat sensor and eye blink sensor. Once the driver is in the car, the eye blink sensor and heart beat sensor start to collect data by counting the eye blinking and heart pulse rate of driver. These sensors generate data for every 5 seconds to detect level of drowsiness. The data collected by eye blink sensor and heart beat sensor are used for further processing in order to detect driver's drowsiness which can be categorized into 3 types: awake, drowsy and sleepy.

Subsequently phase involves classification of drowsiness levels. As previously head movement, there are 3 levels of drowsiness which are awake, drowsy and sleepy. Normal alert for the driver is only effective when the driver is in less or drowsy state. However, if the driver is already in a sleepy state, the possibility for involving in fatal accidents is likely to be high, hence the alert alone might not be effective for drivers. In such case, extra precaution need to be implemented to ensure higher safety level for driver. Hence, the subsequent phase involves speed reduction of vehicle. When the danger level of drowsiness which is sleepy state is detected, an alarm will be triggered for 12 seconds and the speed of the vehicle will be slowly reduced. The speed will be reduced by 20km/h for every 4 seconds until the car is completely stopped. This phase implies the application of ignition lock which means the power, and engine of the vehicle will stop functioning once the ignition is locked. This is to avoid the driver from continuing driving in dangerous condition.

The last phase of the project is to implement the necessary auto-immediate action after the driver is found to be sleepy. This is to ensure the safety of driver. After the car has completely stopped, the system

tracks the location of the vehicle through GPS module and sends message notification through GSM module to a mobile phone of next of kin of driver. This is to inform the driver's current condition and location. This will help them to pick up or fetch the driver from the current location. figure 5 shows an architecture of the proposed system.

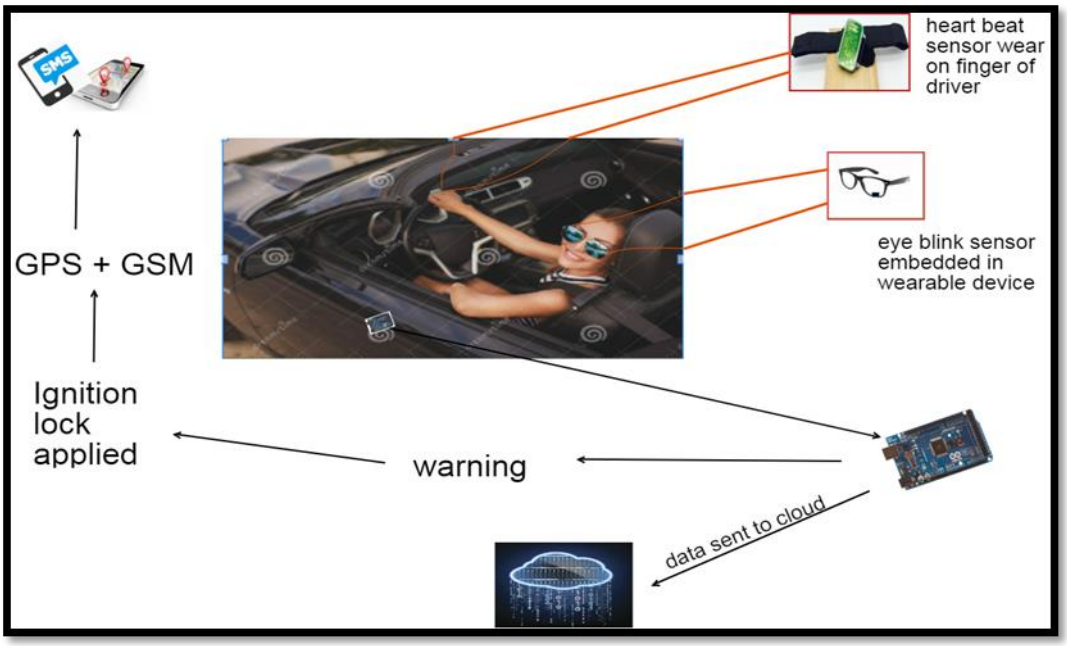

Figure 5. System Architecture

As shown, eye blink sensor is fixed in the wearable device (glasses) of driver and heart beat sensor is attached on driver's finger. The driver must wear the glasses and the heart beat sensor for safety reason. The enforcement to wear these two devices is as important as wearing seat belt in the car. Practically, in real implementation, the eye blink sensor will be embedded in the glasses so that it will not disturb the driver's view. However, for testing purposes, the eye blink sensor is visible in this project. Then, all the sensors are connected to Arduino Mega which receives and verifies all the data from the sensors and sends them to cloud data environment. The microcontroller also sends warning to driver every time when abnormalities or danger is encountered. Upon the last warning, where the driver is considered as sleepy, the GPS module generates the location of driver and a message is sent to their relatives or friends with location details to let them know the status of driver. Overall process flow and block diagram of the proposed system is shown in figure 6.

4.1 Detecting drowsiness by counting eye blinking

There are 3 conditions for eye blinking sensors which have been set to differentiate different levels of drowsiness. Setting many conditions like in this system will be helpful in monitoring each and every activities/ behaviors of driver in order to reduce the chance for accidents due to silly mistakes of drivers. Eye blink sensor starts to collect data from driver every 5 seconds. The detection of eye blinking is based on the presence of light or proximity. When the eyes are closed, the proximity is less whereas when they are opened, the proximity ranges up to 4.6.

At first, eye blink sensor checks whether the proximity is between 3.00 and 4.00 (3.00>=Proximity<=4.00). If it is not within this range, the eye blink sensor checks for further conditions such as proximity between 2.00 and 2.90 (2.00>=Proximity<=2.90) and proximity between 1.00 and 1.90 (1.00>=Proximity<=1.90). Each conditions refers to each level of drowsiness. First condition is considered as less drowsy (awake), while second and third condition is referred as drowsy and sleepy

state respectively. The last two conditions need to be analyzed with another sensor as an extra confirmation of the driver's condition.

In first level of drowsiness (3.00>=Proximity <=4.00), an audible warning will be alarmed for about 4 seconds. In second level of drowsiness, if the proximity is 2.00>=Proximity<=2.90, the alarm will sound for about 8 seconds. In third level which represents high level of drowsiness, the proximity will be in the range of 1.00>=Proximity<=1.90 where the buzzer will be alarmed non-stop. When this third level of drowsiness (sleepy) is reached, it could be danger to driver since the driver would have fall asleep by that time. In such situation, the process of controlling speed of vehicle that is process C will be engaged (ignition lock control).

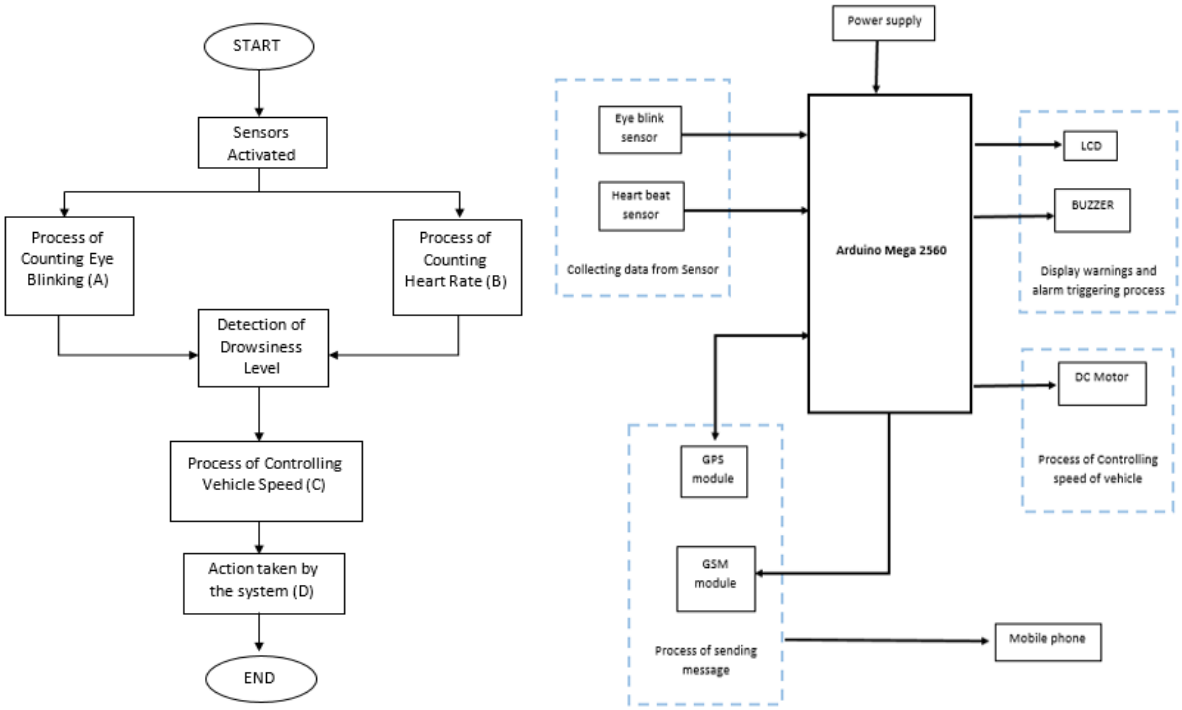

Figure 6. Overall flowchart and block diagram

4.2 Detecting drowsiness through heart beat sensor

The heart beat sensor collects pulse rate of driver every second. Normal heart beat rate of a person is between 60 to 100 per minute. The heart beat per minute varies depending on how active the person is. For example, heartbeat of athletes per minute will be faster and ranges from 40 to 60 under normal condition (PICKUT, 2017). Since this system is only covers normal people who has the range of heart beat rate between 60 to 100, the threshold level to detect heart rate is set to range of 60 to 100 (60>= r <=100). Therefore, if the heart rate of driver falls between 70 to 84, a 4 seconds alarm will be triggered, otherwise the sensor carries on collecting the heart beat rate of the driver. Next, if the pulse rate of the driver is between 65 to 69, the second alarm will be triggered for about 8 seconds. If the system does not activate alarm on time as per conditions set, the driver might drive very fast and rush in order to reach their destination as early as possible despite being tired.

However, at this stage, the first alarm only sounds when the eye blink sensor proximity is 2.00>=proximity<=2.90 and heart rate is 70>=r<=84. This indicates that the data of eye blink sensor and heart beat sensor need to be analyzed together to decide the state of the drive. Similarly, the second alarm will be activated when the eye blink sensor proximity is 1.00>=proximity<=1.90 and heart rate is 65>=r<=69. This is because the closing and opening of eyes might vary for different person. Therefore, eye blink sensor alone cannot accurately detect drowsiness as it need another sensor to be more accurate

in detecting drowsiness. Heart beat sensor is selected to aid eye blink sensor as heart beat sensor detects internal changes of body (heart beat) and eye blink sensor detects external changes (eye blinking) of driver. After the second alarm which sounds for 8 seconds, sleepy stage is detected and the system proceeds with process C which is about controlling the speed of vehicle and ignition lock.

4.3 Ignition Lock Control

When the third level of drowsiness is detected (sleepy state), the speed of the vehicle is reduced gradually until the speed reaches 0km/h. This causes the car to stop slowly where ignition lock is applied. For safety reason, the speed is reduced for every 4 seconds. This is to maintain a gradual reduction in speed and to alert the other drivers on the road to be more cautious in order to avoid accidents. If the speed is immediately reduced to 0km/h without delay, there is high chance for fatal accidents to happen. The delay is also for the other vehicles to be aware about the current situation of the car. The subsequent step involves with process D which is the action taken by the system to ensure safety of driver.

4.4 Sending Notification

After the car is stopped (due to ignition lock), GPS module is activated in the car to detect the location of the vehicle and GSM module is used to send a short message containing the current situation of the driver with detailed location of the car to their relatives or friends so that they will be alerted with the current situation of driver.

5. Results and Discussion

This real-time drowsiness detection system is designed using Arduino IDE platform. The hardware used in this project involve eye blink sensor (QRD1114), heartbeat sensor or pulse sensor, Arduino Mega 2560 board, 16X2 LCD display, a piezo buzzer, LED, a GSM SIM900A module, DC motor which are attached to the mini smart car kit and a GPS (GY-NEO6MV2) module as shown in figure 7.

5.1 Data Collections

Figure 7 shows a prototype and device connection for the whole project. As shown in figure 7(c) and figure 7(d), an eye blinking sensor is attached with the wearable glass and must be worn by the driver while driving according to the scope of the project. The heart beat sensor will measure and sense the heartbeat of the driver and sent it to microcontroller for further processing. In actual implementation, the heart beat sensor will be placed on the seat belt so that when the driver fastens the seat belt, the sensor will be close to the heart and can get the heart rate easily. Other than that, this sensor also can be fixed around one of the fingers of the driver to read his/her heart beat.

5.2 Warning and Alerts

Some conditions have been set for the eye blink and heart beat sensors to detect driver's drowsy conditions. When the conditions are fulfilled, the buzzer will be triggered to alert the driver so that they can get awake and the same time warnings will be displayed on the LCD screen in the car. This will avoid the driver to sleep while driving and at the same time avoid accident from happening. At the very least, this alert system can wake them up to freshen up and remind them to be more careful while driving.

According to the pre-defined conditions, there are three conditions of eye blink sensor which detects drowsiness of driver. At lowest level of drowsiness which is when 3.00>=Proximity<=4.00, the driver will still be awake, but need to be more careful since this is initial indicator of drowsiness that could lead to worse condition. At the second level when 2.00>=Proximity<=2.90, the driver feels drowsy and the possibility of the driver to close his eyes frequently is very high. At this point, the buzzer is triggered for 8 seconds to alert the driver. Next, at the highest level of drowsiness (level 3) when 0.00>=Proximity<=1.59, the driver will feel sleepy as he might close the eyes for even longer. Since this is a very dangerous and critical condition, the buzzer will be alarmed non-stop and the speed of the car will be slowed down to finally stop the car. The level of drowsiness is determined using the amount of presence light on the eye blink sensor which is attached on the spectacles. When eyes are closed, it

indicates the absence of light whereas the presence of light is indicated by the opened eyes of driver. Upon detection of each level, a buzzer sound will be triggered at different frequency to alert the driver. This is to alert and awake the driver from sleeping.

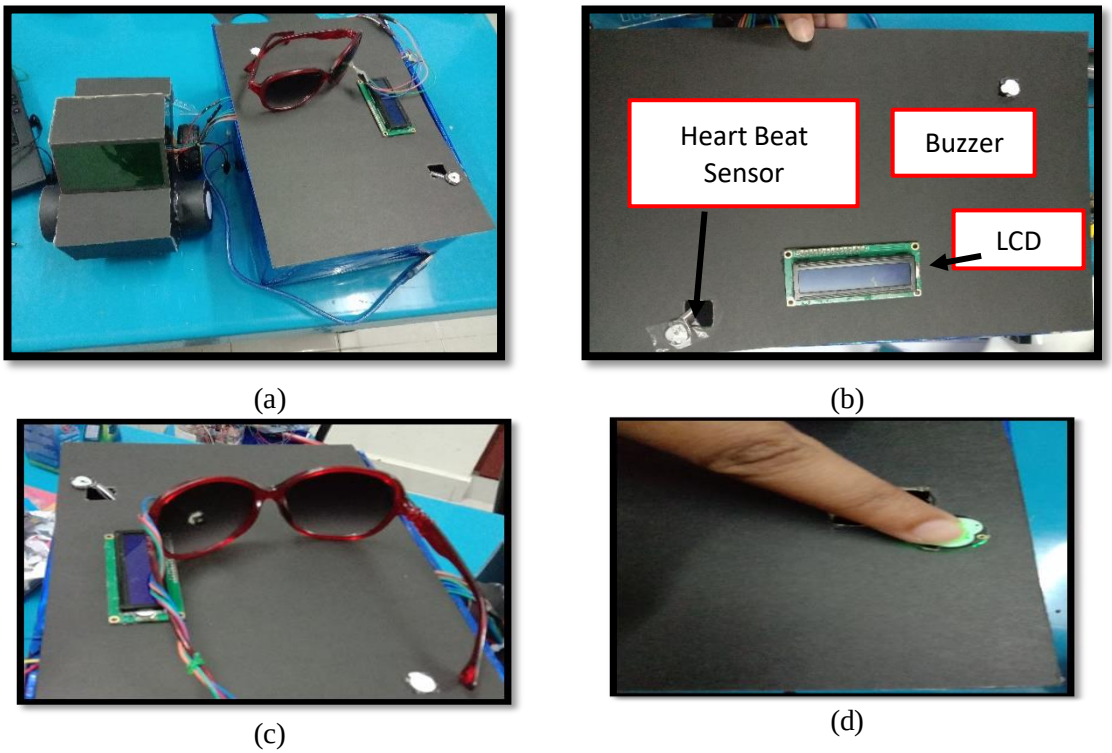

Figure 7. Prototype of the proposed work

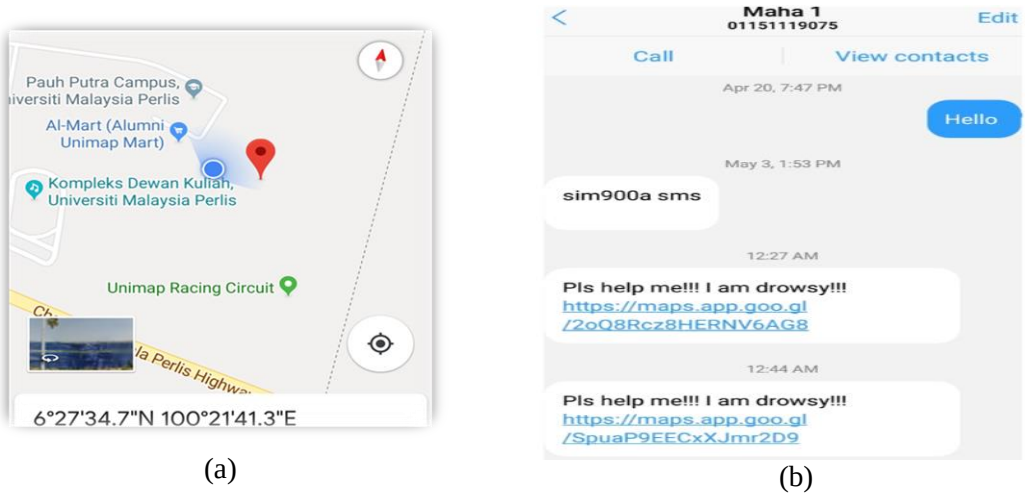

Figure 8. GPS location and SMS

5.3 GPS tracking and SMS

When the third level of drowsiness is detected, the motor will slow down and the engine stops functioning. Then the GPS module detects the location of the vehicle and a message will be sent to the driver's next of kin through GSM module with the location details. Figure 8 shows the outcome of GPS

module latitude, longitude of driver's current location (e.g. 6.459648 and 100.361457). When these latitude and longitude are checked on Google MAPS, it clearly shows the current tested location of PFi2, Universiti Malaysia Perlis (UniMAP). Figure 8(b) shows an SMS resulted at 3rd level of drowsiness which includes detail location of the vehicle. The module was tested at Kolej Kediaman Tuanku Tengku Fauziah (PFi2) and when the location is tracked, a message which includes the location of the driver was sent to the driver's relative or friends.

6. Conclusion

This real-time drowsiness detection system for vehicles has overcome the problems and limitations of various similar projects that had been proposed earlier. By developing this system, basic road security against drowsy drivers can be established with low cost and effective. This project includes drowsiness detection, alert system for drivers (triggering alarm), speed control once for high level of drowsiness and sending message with the details location of driver. The real implementation of this project can indirectly reduce the number of accidents due to drowsiness or sleepiness of drivers.

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