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IoT-Based Driver Drowsiness and Fatigue Detection System

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Abstract: Driving in drowsiness condition is one of the factors that accident rates in Malaysia increase involving car, lorry, etc. Many researchers have come out the ideas on how to detect drowsiness with different techniques. One of them is by using a behavioral-based drowsiness detection system. Therefore, in this study, behavioral-based drowsiness detection system has been used since this method its non-intrusive nature. This research has been conducted to evaluate the accuracy of the behavioral-based drowsiness detection system. In order to achieve the objective of this research, Haar cascade classifier algorithm, eye aspect ratio (EAR) algorithm and mouth aspect ratio (MAR) have been implemented to detect drowsiness and fatigue. The system can detect drowsiness if the value of EAR is frequently below a threshold value (0.23), and the system will alert the driver through a speaker. Based on MAR value, this system is able to determine the driver is yawning or not. It can be said that these algorithms are good enough to detect drowsiness and fatigue.

Keywords: Drowsiness Detection System, Haar Cascade Classifier, Eye Aspect Ratio, Mouth Aspect Ratio

1. Introduction

The attitude of the driver who is always driving in drowsiness condition is highly inappropriate. This attitude will contribute the driver into an accident that will involve others. According to the Malaysian Institute of Road Safety Research (MIROS), driving under the influence of drowsiness is one of the most significant factors that cause drivers to lose concentration and cause accidents on the road [1]. Based on the statistic released by MIROS, human negligence included driving in drowsiness condition contributes more than 80% which it is more than four times higher than other factors. However, it cannot be denied that other factors such as roads and the environment as well as vehicles also play a role.

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Following these incidents, experts throughout the world began investigating ways for detecting and warning of drowsiness in advance of a car accident. Apart from that, several countries and government officials are putting a strong emphasis on implementing solutions that will increase driving safety.

Many studies support that the best ways to counter drowsiness are by taking short naps between journeys, drinking caffeine (coffee, energy drinks, etc.), or driving with a friend or companion [2]. However, many drivers skip these steps and end up suffering drowsiness while driving. Therefore, drowsiness detection is important and can be used as one of the methods to avoid drivers involved in an accident.

Many researchers have been working on driver drowsiness detection in the past few years by using different techniques [3]. The techniques including physiological measures, behavioral measures and vehicle measures [4]-[5]. All those methods have pros and cons [6]. However, this study has been made by only focusing on behavioral measures, since the technique is non-intrusive where it will not disturb driver attention while driving.

1.1 Definition of drowsiness

Drowsiness can be described as a biological state where the body is in transition from an awake state to a sleeping state [7]-[8]. A driver might lose focus in this stage and be unable to avoid head-on crashes or stop the car. There are indications when a driver is in a drowsy state, such as frequently yawning, frequently blinking and swaying the head forward.

1.2 Behavioral measures

A drowsy driver exhibits a number of distinguishing facial motions, including frequently blinking, nodding or swinging their head, and frequent yawning [9]. Behavioral methods that are non-intrusive and based on aberrant behaviors are extensively employed to determine the drowsiness level of drivers by observing their odd behavior [10]. Behavioral methods measure levels of drowsiness through the use of computer vision techniques in order to detect the changes in driver’s behavior. Therefore, in order to determine drowsiness and fatigue, this study will focus on eye blinking and yawning of the driver.

2. Methodology

In this section will discuss about the method that will be used in order to detect drowsiness and fatigue. The algorithm used and overall flowchart are being discussed

2.1 Image processing development

In order to detect face, eyes and mouth, the following libraries such as NumPy, Open CV, and Dlib are needed to be installed. Open Source Computer Vision Library (Open CV) is used to implement the Haar Cascade Classifier. OpenCV provides the Cascade Classifier class that can be used to create a cascade classifier for face detection.

Meanwhile, this project has used facial landmarks location of 68 coordinates (x, y) that map the facial points on a person’s face. “shape_predictor_68_face_landmarks.dat” must be downloaded and dlib library must be installed. Figure 1 shows an example of a facial landmark that will map on the face.

Figure 1: Example of facial landmark that will map on the face

2.2 EAR algorithm development

Eq.1 has been used to calculate the value of EAR. The eye position is identified using six landmark points that are shown in Figure 1. Based on Figure 1, for the left eye, the points are taken from 37 to 42, while for the right eye, the points are taken from 43 to 48. As can be seen in Eq.1, |P38-P42| and |P39-P41| are the distance between the upper eye and lower eye, while |P37-P40| are the width of the eyes. In order to detect drowsiness, the value of EAR must be frequently below the threshold value (0.23).

$$EAR = \frac{\left||p38 - p42|\right| + ||p39 - p41||}{2\ ||p37 - p40||} \qquad Eq. 1$$

2.3 MAR algorithm development

Eq.2 has been used to calculate the value of MAR. The mouth position is identified using six landmark points that are shown in Figure 1. Based on Figure 1, the points that be used to detect yawning are 51,53,59,57,49 and 55. As can be seen in Eq.2, |P51-P59| and |p53-p57| are the distance between the upper lip and lower lip, while |P49-P55| is the width of the mouth. In order to detect yawning, the value of MAR must be above the threshold value (23).

$$MAR = \frac{|p51 - p59| + |p53 - p57|}{2|p49 - p55|} \qquad Eq. 2$$

2.4 Overall flowchart of this system

Figure 2 shows the overall flowchart of this system. This system has used a night vision camera to do a live video. And then, this system will convert every frame of video into grayscale. To make this system detect face, eyes and mouth, Haar cascade classifier algorithm has been implemented in this system. Facial landmarks have been implemented in this system to map the facial points on a driver's face. When the facial features are successfully detected, EAR algorithm can be implemented in this part. The system starts to calculate the value of EAR. If the system detects the driver keeps blinking, the system will alert the driver through speaker since it indicates the driver is in a drowsiness state. If the system is connected with WIFI, the system will send an alert to the driver's family via Whatsapp. If the value is above 0.23, the system will start counting the number of frames. If counter>7, the system will alert the driver since it indicates the driver is sleeping. Next, MAR algorithm can be implemented to detect yawning, and the system starts to calculate the value of MAR. If MAR>23, the system will detect the driver is yawning, and the system will alert the driver.

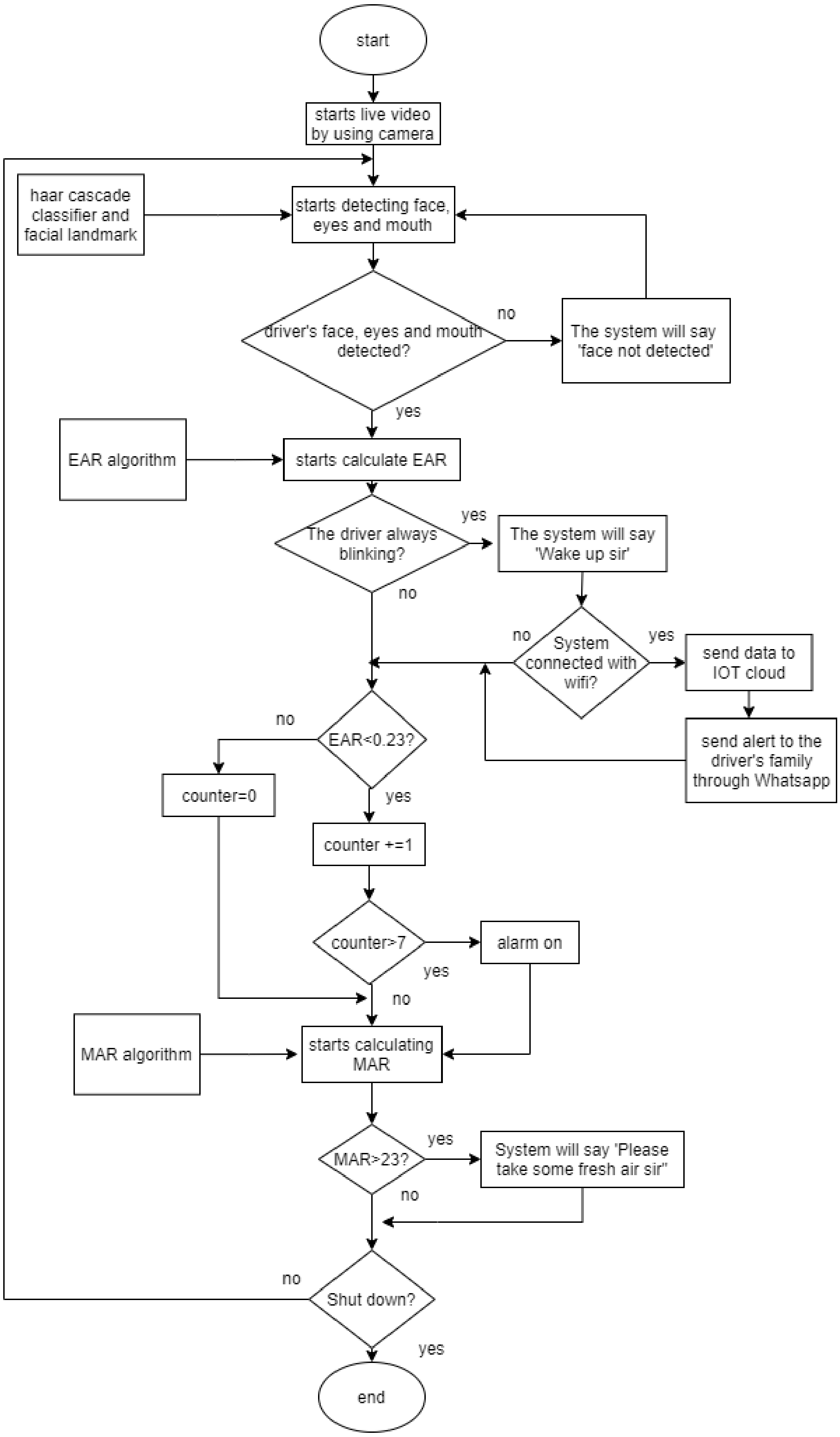

Figure 2: Overall flowchart of this system

3. Results and Discussion

The results and discussion are presented in this section. The main finding of the result is to know the accuracy of Haar cascade classifier algorithm, eye aspect ratio (EAR) algorithm and mouth aspect ratio (MAR) algorithm in order to detect drowsiness and fatigue. Result of Internet of Things (IoT) also is discussed in this section.

3.1 Face, eyes and mouth detection

To detect face, eyes and mouth, Haar cascade classifier algorithm has been implemented in this system. To know how far this algorithm is able to detect face, eyes and mouth, experiments with various conditions were conducted. The various condition including different lighting conditions (morning and night), subject's face posture and position and subject with spectacle. 6 drivers were recruited, and 30 frames of drivers were taken. Table 1 shows data taken when a driver is in various conditions. As can be seen in Table 1, it can be said that Haar cascade classifier algorithm is able to detect when a driver is in different lighting conditions (morning and night) and when a driver is in the right and left position in which the system's accuracy reached above 90%. But this algorithm is not able to detect when a driver's face rotates around 60 to 90 degrees, in which the system's accuracy reached 0%. Meanwhile, when a driver wears spectacle, this algorithm is able to detect face, mouth and eyes but sometimes this algorithm not able to locate the location of eyes. Therefore, the system's accuracy when a driver wears spectacle is about 35.6% only.

Table 1: Data taken when subject in various conditions

Subjects	Number of frames	Accuracy (morning) (%)	Accuracy (night) (%)	Accuracy (right position) (%)	Accuracy (left position) (%)	Accuracy (60-90 degrees) (%)	Accuracy (wears spectacle) (%)
1	30	100	100	90	93	0	36.7
2	30	100	100	93	90	0	40
3	30	100	100	86.7	93	0	40
4	30	100	100	93	93	0	30
5	30	100	100	90	86.7	0	33.3
6	30	100	100	86.7	90	0	33.3
Average		100	100	90	91	0	35.6

3.2 Eye aspect ratio (EAR) analysis

To detect drowsiness, EAR algorithm has been implemented in this system. The optimum threshold value for drowsiness has been set based on the range from the maximum value of EAR when a driver's eyes are closed to a minimum value of EAR when a driver's eyes are opened among 6 drivers. Therefore, the system has set the optimum threshold value is 0.23.

3.2.1 Awake state

Normally, when a driver in awake condition, eyes open are longer compared with eyes closed which mean the driver does not always blink their eyes. The system will assume a driver in awake condition if the value of EAR is not frequently below a threshold value (0.23). Figure 3 shows the graphical representation of EAR value in the awake condition. As can be seen in Figure 3, the frequency of value of EAR below a threshold value in 100 frames is very low, which is only 3 times. Even though at frame 21, the value of EAR is below threshold value (0.23), the system still assumes a driver in an awake state instead of a drowsy state since the value of EAR is not frequently below a threshold value (0.23). To indicate driver in awake condition, "AWAKE STATE" will pop up at the left top of the frame, as shown in Figure 4.

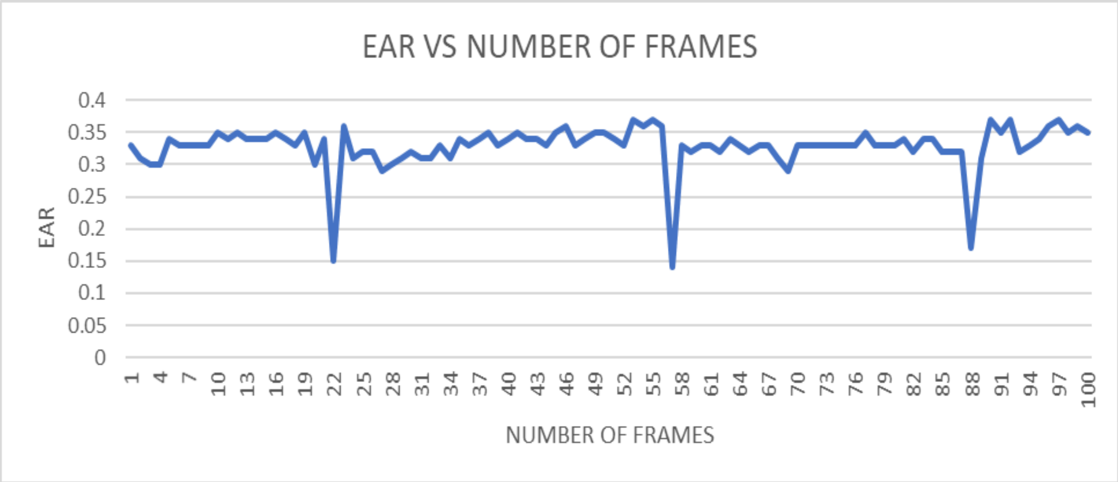

Figure 3: The graphical representation of EAR value in the awake condition

Figure 4: The result when driver in awake state

3.2.2 Drowsiness state

Most commonly, when a driver is in drowsiness state, they frequently blink their eyes. The system will detect a driver in a drowsiness state if the value of EAR is frequently below a threshold value (0.23). Figure 5 shows the graphical representation of EAR value in the drowsy condition. As can be seen in Figure 5, the value of EAR fluctuated during first 15 frames between 0.14 to 0.35. Therefore, the system has detected the driver in a drowsy state since the value of EAR is frequently below 0.23. To alert the driver, the system will say “WAKE UP SIR” through a speaker. Figure 6 shows the result when a driver is in a drowsy state.

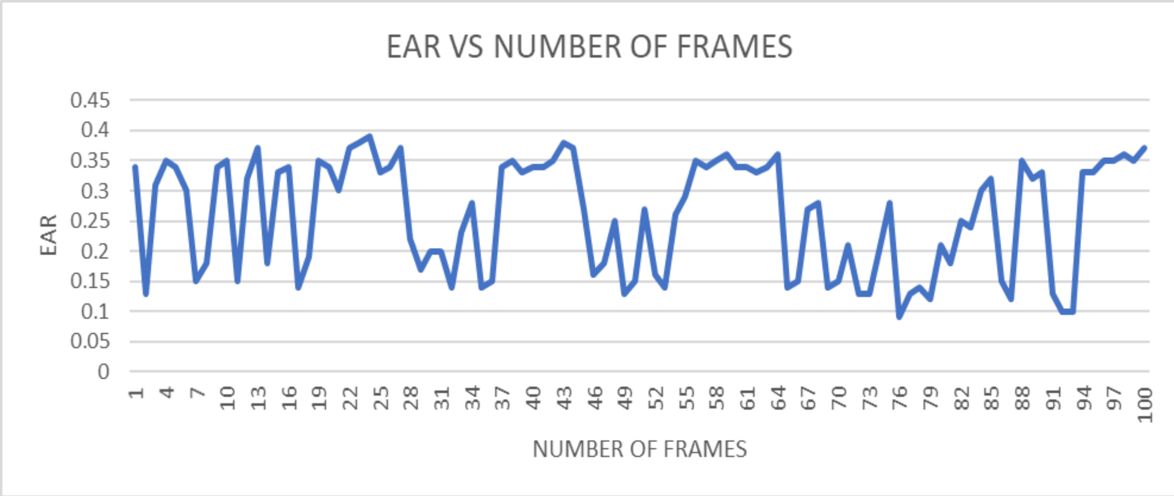

Figure 5: The graphical representation of EAR value in the drowsy condition

Figure 6: The result when driver is in drowsy state

3.3 Mouth aspect ratio (MAR) analysis

To detect yawning, MAR algorithm has been implemented in this system. The optimum threshold value for yawning has been set based on the range from the maximum value of MAR when a driver is talking to a minimum value of MAR when a driver is yawning among 6 subjects. Therefore, the system has set the optimum threshold value for yawning is 23.

3.3.1 Driver is talking

This experiment is important because the system does not know either the driver is talking or yawning. Figure 7 shows the graphical representation of MAR value when a driver is talking. As can be seen in Figure 7, the value of MAR fluctuated until 100 frames between 4 to 22 to show that the driver is talking. In this case, the system will detect the driver is talking instead of yawning since the value of MAR goes constant below a threshold value (23) for 100 frames. Figure 8 shows the result when a driver is talking. “Driver is talking” will pop up at the left top of the frame to indicate the driver is talking.

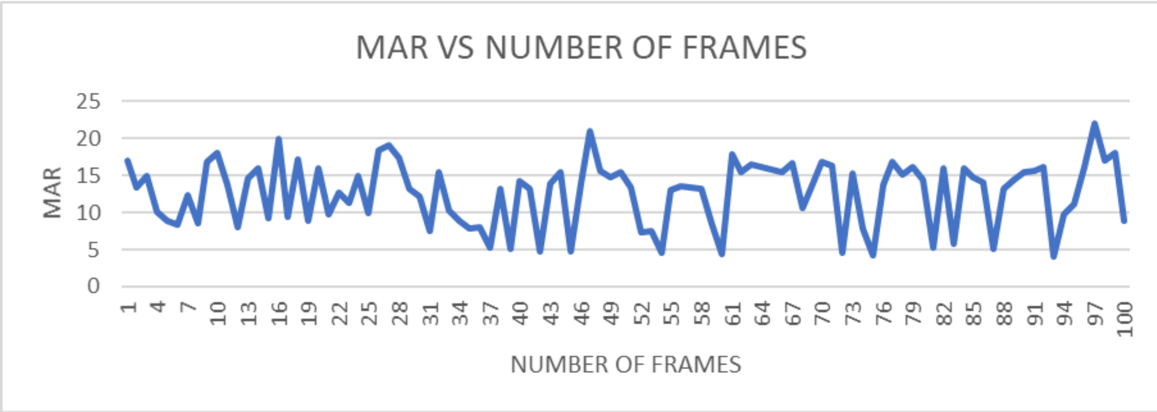

Figure 7: The graphical representation of MAR value when driver is talking

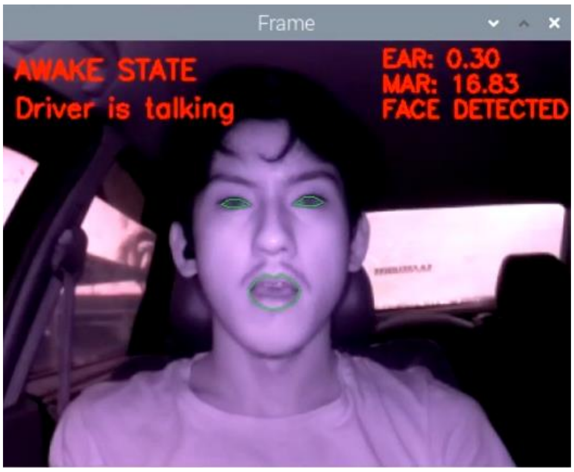

Figure 8: The result when driver is taking

3.3.2 Diver is yawning

The system will detect the driver in a yawning state if the value of MAR is above a threshold value (23). Figure 9 shows the graphical representation of MAR value when a driver is yawning. As can be seen in Figure 9, the value of MAR increases drastically at frame 46 from 17 to 25. Therefore, the system has detected the driver is yawning since the value of MAR is above 23. To alert the driver, the system will say “PLEASE TAKE SOME FRESH AIR SIR” through a speaker. Figure 10 shows the result when a driver is yawning.

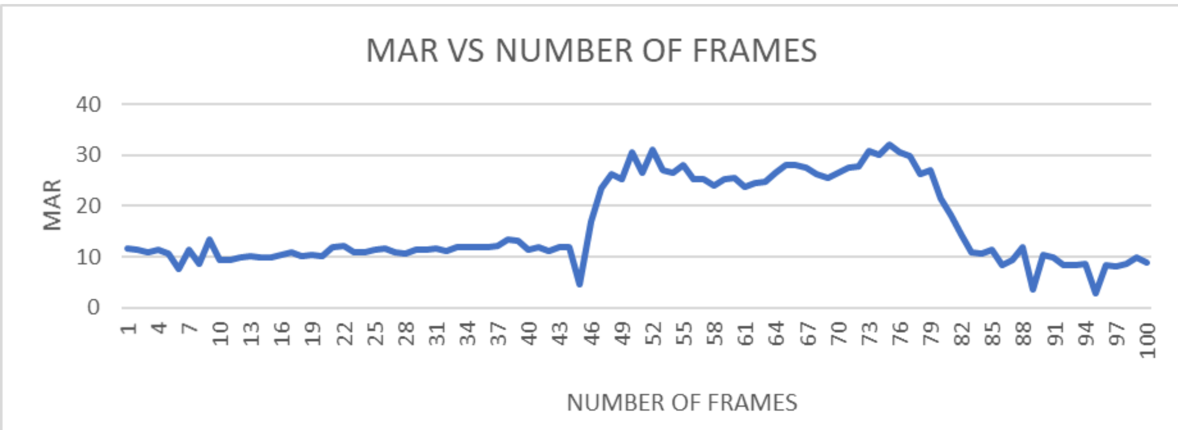

Figure 9: The graphical representation of MAR value when driver is yawning

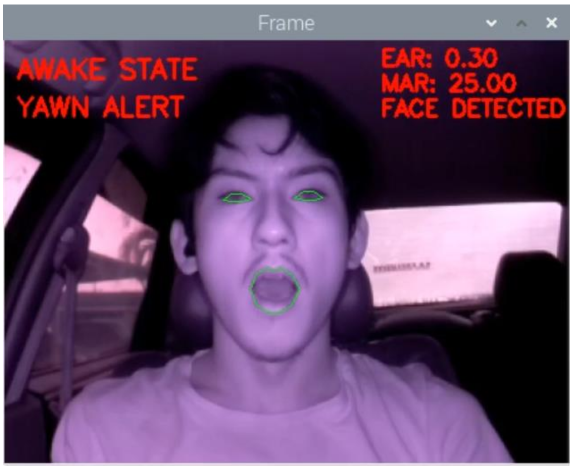

Figure 10: The result when driver is yawning

3.4 Internet of Things (IoT) analysis

Twilio has been used in order to alert a driver's family. The system only sends the alert through Whatsapp only if a driver is in drowsiness state. Figure 11 shows the result from Twilio. As shown in Figure 11, the system has successfully sent the alert to the driver's family via Whatsapp.

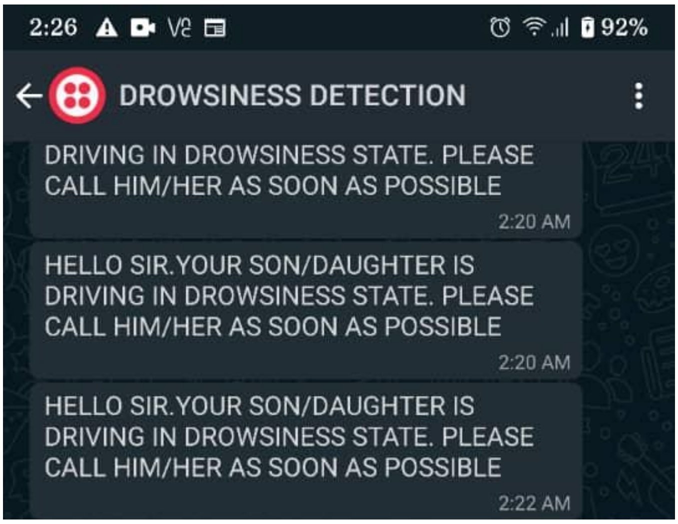

Figure 11: The result from Twilio

4. Conclusion

In conclusion, the objectives of this research have been successfully achieved. IoT based driver drowsiness and fatigue detection system has been successfully developed. The implementation of image processing based on three types of algorithms which are Haar cascade classifier algorithm, eye aspect ratio (EAR) algorithm and mouth aspect ratio (MAR) algorithm, have been successfully developed and tested in this study. Based on the experiment conducted, overall, the accuracy of these algorithms are good enough to detect drowsiness and yawning but in certain conditions only (which are when subjects are in different lighting conditions (morning and night) and when a subject's face is right and left position). It can be said that this system is useful and safe to be tested in a car environment if the driver is in those conditions only.

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