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Driver Drowsiness Detection with an Alarm System using a Webcam

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Abstract: Microsleep has contributed to 100,000 crashes, 71,000 injuries, and 1,550 fatalities on average every year. Blinking slowly and yawning frequently are the common symptoms of a drowsy driver, and they happen mostly when lighting conditions are at their worst between midnight and early morning. The aim of this proposed project is to design a driver drowsiness detection system based on eye and mouth behaviour that works with various light ranges. The system is integrated with an internal web camera and speaker as input and output tools, respectively. The drowsiness state can be determined by Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) algorithms that run in real-time using OpenCV and dlib 68 key points for facial landmarks. The project flow for this system is face analysis, followed by eye blinking and yawning detections that run concurrently after the web camera live streams the driver's face. An alarm sound will be played once the driver is detected as being drowsy. This system can detect the driver's drowsiness with or without the presence of eyeglasses in both ideal and poor lighting conditions. Experiments carried out throughout the study discovered that the proposed system has an accuracy range of 85% to 95%.

Keywords: Face Analysis, Drowsiness Detection, Alarm System

1. Introduction

Drowsy driving has been a big issue for road and transportation safety. Microsleep is admitted to be the main contributor to road accidents in many countries, including Malaysia [1]. According to the National Sleep Foundation's website [2], the riskiest time for drowsy driving is between midnight and early morning, when the lighting is at its dimmest. The common actions taken by a drowsy driver are blinking and yawning frequently, nodding off due to a heavy head, and the worst eye closing. As a result, a drowsy driver will have difficulties staying focused, delayed reaction times, and be unable to estimate the distance and speed [2]. As a consequence, the driver will drift out of the lane, including

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driving onto rumble strips and missing traffic signs. Thus, this project is proposed to test the effectiveness of the designed drowsiness detection system based on eye and mouth behaviour in real-time framework and analysed its performance with various light ranges.

This proposed project is focused on 68 key points face landmark specifically the Eye Aspect Ratio (EAR) and the Mouth Aspect Ratio (MAR) as the main parameters to detect drowsiness. The program is run on a personal computer occupied by an internal web camera as the input to live stream the driver's face, and the speaker as the output to play the triggered alarm sound. Three basic methods that can be used to measure drowsiness, which are vehicle-based, behavioural-based, and physiological-based [3]. Among all these, behavioural-based was used in this project and it suited to achieve the goals where a driver drowsiness detection system was designed based on eye and mouth behaviour that worked in real-time with different light ranges. The advantages of this method are it is non-intrusive as the monitored camera or device will not be placed on any part of the driver's body. In addition, the implementation is very simple compared to the other methods, as only the camera acted as an involved device. Therefore, it is convenient to be used even though the driver has zero experience with it. Even so, this method is limited by lighting conditions and the driver's distance from the camera. Therefore, the proposed project used the face landmark algorithm as it has better accuracy and can run in real-time despite of the implementation complexity. Next, because Python met the real-time processing requirement and has a plethora of open-source library packages, this project was carried out in Python to build the drowsiness detection system to execute the programmes. The output for the proposed project has been simplified by taking the common necessary output from the previous projects, which is that an alarm was triggered once drowsiness is detected.

2. Materials and Methods

In this section, there are three stages that lead to the project's success by acknowledging each software and hardware function.

2.1 Block Diagram

A block diagram is illustrated to aid in the most basic understanding of the system's software and hardware implementation. The relationship between input, process, and output is represented by the block and arrow. Figure 1 shows the block diagram for driver drowsiness detection with an alarm system. This project was developed using a Dell Inspiron 15 3000 laptop. The input medium for making the driver's face visible in the live stream is a built-in web camera with a resolution of 1280x720 at 30 frames per second. Python 3.10.4 is then used for drowsiness detection processes such as the face, eye blinking, and yawning. In addition, an alarm system is included in the same programme. Finally, an alarm sound was played through the built-in speaker once drowsiness is detected.

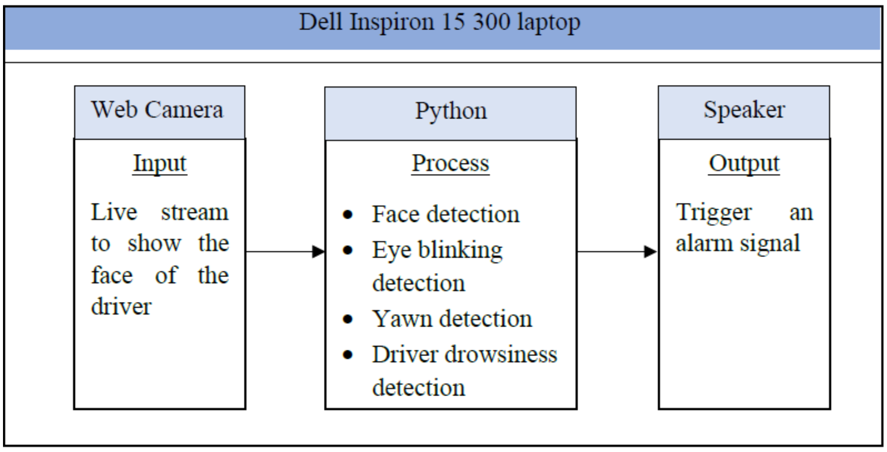

Figure 1: Block diagram of driver drowsiness detection with an alarm system

The system was created and runs on a laptop using the block diagram in Figure 1. It is admitted that using a laptop, the system is too inconvenient to be used in real-life applications. As previously stated, the primary focus of this study is system development, which entails creating a Python code prototype to validate design decisions before the actual device is created. With more time, a stand-alone prototype using the Raspberry Pi can be implemented to represent the actual setup in this project.

2.2 System's Operation

Figure 2 shows the flowchart of the driver drowsiness detection with an alarm system. The flowchart explained the techniques of how the system worked.

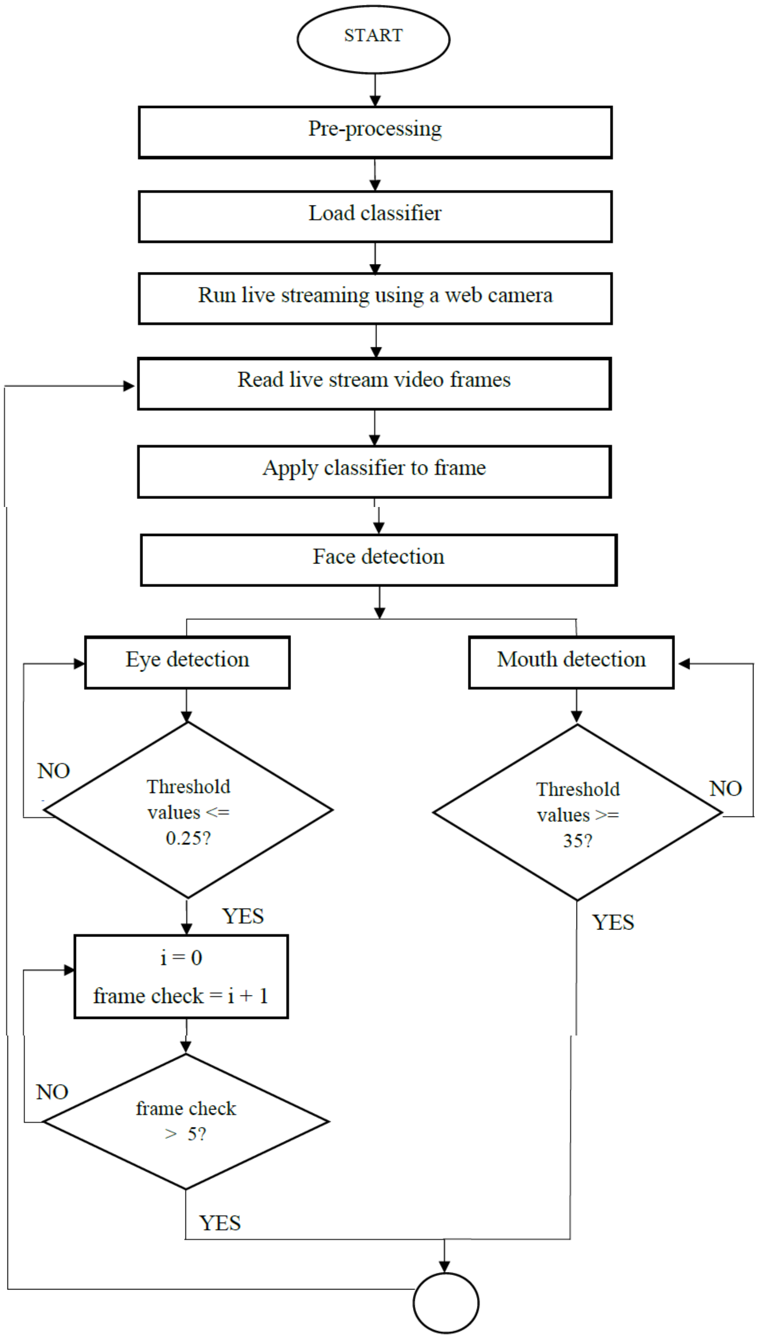

Figure 2: Flowchart of driver drowsiness detection with an alarm system

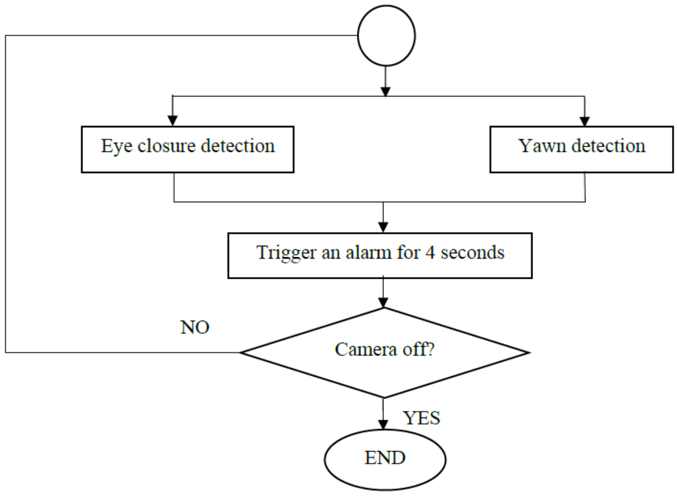

Figure 2: Flowchart of driver drowsiness detection with an alarm system (continue)

Based on Figure 2, this project starts begins with system pre-processing. All the libraries' dependencies should be imported into the notebook. Beforehand, the necessary Python packages must initially be downloaded. The dlib face classifier must then be loaded into the system along with the pre-trained network model that can be found on GitHub, *shape_predictor_68_face_landmark.dat*. The pre-trained model is pre-built in the dlib library and serves as a 68 facial key point detector capable of detecting face, eye, and mouth in real time. Next, a live streaming video was run using an internal web camera as the input tool. Following that, a live streaming video is performed with a web camera as the input tool. OpenCV was used to accomplish image processing and computer vision tasks, including face detection for image and video analysis. As a result, cv2 was able to open the webcam, read frames, and display video via the live feed. The face, followed by the eye, and mouth, were detected using the dlib facial landmark.

Two functions were run in parallel to detect drowsiness at this stage of the process. The first is eye closure detection, and the second is yawn detection. For eye closure, the system checked whether the driver's eye threshold values are less than or equal to 0.25. If the value is greater than 0.25, the system returns to the eye detection step and the process will be repeated. If the values satisfy the condition, the system performs a frame check. In contrast, the system always looped through the frames until the frame check value is greater than or equal to 5. During system execution, a frame check was used to reduce negative false positives. The system classified the driver as drowsy and sounded an alarm for 4 seconds to alert the driver after the loop has been repeated five times while the threshold value remains satisfied. Second, for yawn detection, the system looked to see if the driver's mouth opening threshold is greater than or equal to 35. If the value is less than 35, the system loops back to the mouth detection step and repeats the process. If the values met the condition, the system recognises the driver as yawning and sounds an alarm for 4 seconds to alert the driver.

Thresholding was used in both eye blinking detection and yawn detection as it has a point on the limitation of the conditions. By means of this, when the set threshold values were reached, the system is triggered, and the class of conditions is changed. Therefore, the task of this project is to determine the best threshold value. Lastly, the execution of the system was terminated if the camera is off. Contrariwise, the system continues to loop until it is turned off.

2.3 Programming algorithms

The developed system incorporated into three main system including face analysis, eye blink tracking, and yawn tracking.

2.3.1 Facial landmark

Facial landmark detection is a machine learning method that detects and tracks key landmarks on the human face. It maps facial features including the eyes, brows, nose, and lips. The face detection algorithm used in this project is dlib's 68-face landmark. Dlib has provided a pre-trained facial landmark detection algorithm that can detect 68 points on a face. First, the algorithm found a human face and returned a rectangle in x, y, w, and h coordinates. Then it traversed the points within the rectangle. Figure 3 illustrate the 68 points on the face.

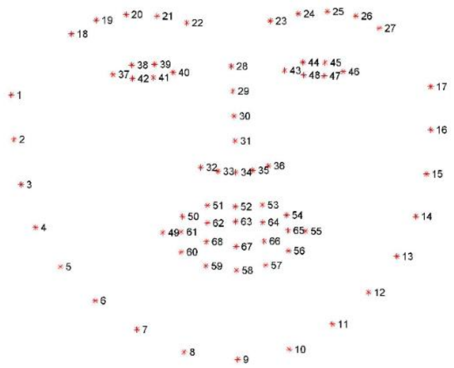

Figure 3: Dlib's 68 points model

In Figure 3, each facial feature is represented by a set of points. For instance, mouth tracking can be accomplished using points 49 to 68. The same goes for eye tracking, where points are 37 to 42 for the right eye and 43 to 48 for the left eye. As the face landmark detector is a pre-trained model, the DAT file code is available on GitHub.

2.3.2 Eye Aspect Ratio (EAR)

Czech Technical University proposed a method for detecting eye state which was widely recognised as Eye Aspect Ratio (EAR) [4].

$$EAR = \frac{||p2 - p6|| + ||p3 - p5||}{2||p1 - p4||} \qquad Eq. 1$$

EAR can be found by calculating the Euclidean distance between the corresponding eye coordinates and plugging it into the Eq. 1. Figure 4 shows the points of an eye. The point concept is the same as that explained in Figure 3.

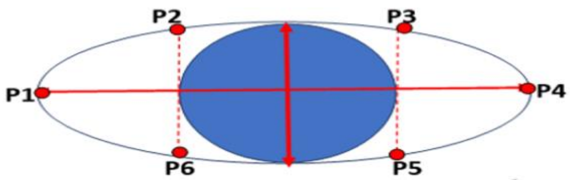

Figure 4: EAR points model

Referring to Figure 4, there are 6 points on a single eye tracker. EAR indicates eye closure. The higher the EAR value, the wider eye is open and vice versa. Therefore, a minimum threshold value needs to be defined in order to determine eye closure. For instance, a threshold value of 0.25 indicated that the eye is considered close if the calculated EAR is less than the threshold value.

2.3.3 Mouth Aspect Ratio (MAR)

Mouth Aspect Ratio (MAR) is a yawning detection method that uses information from the mouth's lip feature points via the dlib face landmark. In practise, the MAR calculation is the same as the EAR calculation shown in Eq. 2. However, as shown in Figure 3, the feature points of a mouth are 20, which correspond to points 49 to 68. As a result, Figure 5 depicts the critical points of a mouth involved in the MAR calculation.

$$MAR = \frac{||p2 - p8|| + ||p4 - p6||}{2||p1 - p5||} \qquad Eq.2$$

Figure 5: MAR points model

Based on Figure 5, the inner points of the lip that are crucial in calculating MAR are 61, 62, 64, 65, 66, and 68. The key points P2, P4, P6, and P8 are the values of the longitudinal coordinates 62, 64, 66, and 68, respectively. Meanwhile, the horizontal coordinate values 61 and 65 correspond to the key points P1 and P5. Calculating the lips points based on these key points and plugging them into the Eq. 2 yields MAR. The distance between the longitudinal key points in the middle of the inner lip varies greatly during mouth opening. As a result, the mouth condition and yawn status can be determined. The higher the MAR value, the wider mouth is open and vice versa. Therefore, a minimum threshold value needs to be defined in order to determine mouth opening. For instance, a threshold value of 35 indicated that the mouth is yawning and the calculated MAR is more than the threshold value.

3. Results and Discussion

This chapter discusses the results obtained throughout the development of the driver drowsiness detection system. In this section, all the testing has been done on both internal and external web cameras. The testing results achieved were compared and observed to analyse the final system performance. The output results were reviewed based on the accuracy of the proposed algorithm to detect driver drowsiness based on eyes and mouth in real-time and investigation of the capability of drowsiness detection in different light conditions.

3.1 Hardware Setup

This project is primarily concerned with system development and output testing. Thus, the hardware used is the laptop itself, which contains a microprocessor that run the system, a web camera that streamed the driver's face in real time, and a speaker that acted as an alarm to alert the drowsy driver. The web camera and speaker are built into the laptop. Figure 6 shows a testing setup in a car to illustrate a practical application in real life that can also be applied to a truck.

Figure 6: Positions of the web camera and speaker

Figure 6 represents the prototype's webcam and speaker positions. A web camera was mounted on the dashboard to capture the driver's frontal image. The distance between the driver and the web camera is between 40 and 60 cm, and a speaker was placed 15 cm next to it. As previously stated, the main focus of this project is system development. Thus, the experiment to obtain the project's output results was carried out exactly as shown in Figure 6.

3.2 Experiment 1: Drowsiness detection during daytime

The drowsiness detection experiment is carried out in the car during the day, with appropriate lighting. The output results were depicted in Figures 7 and 8. The driver is seated 30 cm to 50 cm from the camera in this experiment. Both yawning and eye blinking were tested simultaneously to ensure that this system worked for both algorithms. The experiments were carried out with the participation of five subjects in order to provide a flexible system for various drivers' eye sizes. Each subject was tested twice for the programme.

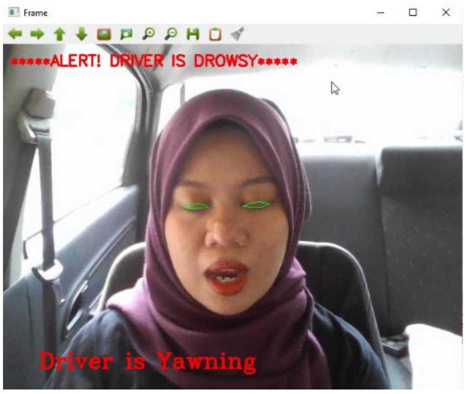

Figure 7: Drowsiness detection of a spectacle-less driver during daytime

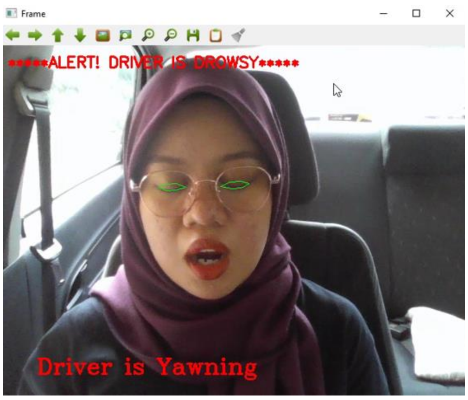

Figure 8: Drowsiness detection of a spectacled driver during daytime

Figures 7 and 8 show the results of drowsiness detection without and with the presence of spectacles. Both conditions tested have achieved positive outcomes. During the experiment, the eye was closed, and the mouth was opened to let the system run concurrently. Then, an alarm was triggered if one or both functions are detected. Given the cultural practice of covering the mouth with a hand when yawning, this system sounded an alarm if the mouth is covered. Table 1 displays the accuracy results for both parameters in order to investigate the factors that influence the developed drowsiness detection system.

Table 1: Drowsiness detection accuracies during daytime

Parameter	Experiment										Accuracy (%)
	1	2	3	4	5	6	7	8	9	10	
Spectacle-less	/	/	/	/	x	/	/	/	/	/	90
Spectacled	/	/	/	/	/	/	/	/	/	/	100

Table 1 illustrates the drowsiness detection accuracy during the day. From the table, it can be seen that the spectacled driver has achieved a higher accuracy percentage than the spectacle-less driver. Therefore, it can be concluded that a spectacle or eyeglass does not affect the performance of drowsiness. Instead, the lighting conditions played an important role in the drowsiness detection process during the day. In this case, the excessive light behind the driver has led to the undetected presence of drowsiness.

3.3 Experiment 2: Drowsiness detection at night

The drowsiness detection experiment is carried out in the car at night, with dimmed lighting. The output results are depicted in Figures 9 and 10. The driver is seated 30 cm to 50 cm from the camera in this experiment. Both yawning and eye blinking are tested simultaneously to ensure that this system worked for both algorithms. The experiments were carried out with the participation of five subjects in order to provide a flexible system for various drivers' eye sizes. Each subject was tested twice for the programme.

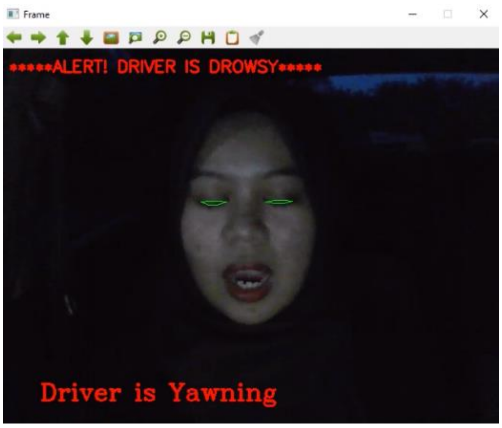

Figure 9: Drowsiness detection of a spectacle-less driver at night

Figure 10: Drowsiness detection of a spectacled driver at night

Figures 9 and 10 show the results of drowsiness detection in the car without and with spectacles in dim light conditions to demonstrate the system's real-world application. Both conditions tested produced positive results. The eye was closed and the mouth was opened during the experiment to allow the system to run concurrently. An alarm was triggered if one or both functions were detected. In order to investigate the factors that influence the developed drowsiness detection system, Table 2 displays the accuracy results for both parameters.

Table 2: Drowsiness detection accuracies at night

Parameter	Experiment										Accuracy (%)
	1	2	3	4	5	6	7	8	9	10	
Spectacle-less	/	/	x	/	/	/	/	/	/	/	90
Spectacled	/	/	/	/	x	/	/	x	/	/	80

Table 2 illustrates the drowsiness detection accuracy at night. According to the table, the spectacle-less driver achieved a higher accuracy percentage than the spectacled driver. In comparison, the accuracy obtained for both parameters are less than 10% of the accuracy of a single programme tested. As a result, it is possible to conclude that the integrated programme system performs lower than the individual programme system. This can be said because the integrated system has missed detecting drowsiness in one test performed compared to the experiment of a single programme.

3.4 Analysis of drowsiness detection

In summary, the lighting conditions have major effects on the implemented drowsiness detection system. Based on the results obtained from the experiments performed, ideal lighting aided the system in accurately detecting the driver's drowsiness Even though the experiment was carried out during the day, excessive lighting can cause the detection system to fail. On the other hand, insufficient lighting is still able to detect drowsiness, albeit with a lower degree of accuracy.

As the implemented system is based on eye and mouth behaviour, deciding the best threshold value to be used in the programme for both eye and mouth distance is crucial in determining driver drowsiness. The purpose of finding the appropriate threshold value is to avoid false positives and negatives despite the drivers' activities, including talking and laughing.

In addition, a spectacle had a minor impact on the drowsiness system's performance. The system can detect the driver's eye blinking while wearing spectacles, as long as there is no reflected light on the glass. This difference in accuracy between spectacled and spectacle-less drivers occurred at night, whereas there is no difference in natural light during the day.

Finally, the camera placement affects the performance of the driver drowsiness detection system. The best camera position is shown in the Figure 6 setup. This position resulted in a frontal view of the driver's face, which is the best angle for the face analysis. Based on the previous experiments, eye blinking and yawning are easily detected if a frontal face view is shown in the live feed video.

4. Conclusion

In conclusion, the proposed driver drowsiness detection with an alarm system using a webcam successfully detected drowsiness relying on eye blinking and yawning with various lighting conditions based on the results obtained in the integrated program. The accuracy percentage presented is acceptable, at 95% during the day and 85% at night. However, there are factors that contribute to the system's inability to detect drowsiness, such as the microprocessor used, eyeglass involvement, and camera placement. Therefore, the microprocessor used must be compatible to avoid the lagging issues that affect the entire system and upgrade the web camera to a night vision camera to increase light intensity for better detection in low-light situations. The recommendations for future work for this proposed project are to improve the output audio by producing up to 80 dB of vibrations for deaf people to be triggered by the alarm when drowsiness is detected and to use the Raspberry Pi to build a system prototype that is suitable for real-world applications. All in all, it can be concluded that this project has successfully achieved its objectives.

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