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DEVELOPMENT OF ANTI-DROWSINESS AND ALERT SYSTEM FOR AUTOMOBILE DRIVERS

Nastaran Reza Nazar Zadeh[1]
Ramerson Abais
Maxine Joie Mananquil
Jhon Person Cabarles
Eireena Patricia Estudillo
Mary Donnabell Rivera

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ABSTRACT

Drowsy Driving has been one of the leading causes of traffic and road accidents. According to the National Safety Council (2021), sleepy driving causes 100,000 collisions and 71,0 injuries, including 1,550 deaths per year. The researcher developed an automated automobile system that prevents drivers from drowsy driving. The proposed methodology is divided into the following stages: face detection, eye detection, as well as steering wheel interactions. First, the Raspberry Pi camera streams, then the video data will be analyzed with an object detection algorithm and classifies using the Haar Cascade Classifier technique. As the result it detects areas of the face and eyes to determine drowsiness. In addition, the force sensor monitored the driver's steering wheel interactions, such as hand grip strength. Furthermore, the alert will be activated if two parameters, including Eye Aspect Ratio and Hand Grip Strength, drop below a certain threshold. On several test footage, the average accuracy rate for drowsiness detection without glasses was 96.94 %, whereas it was 92.29 % with glasses. Generally, the drowsiness detection system achieves 94.61 % accuracy in detecting the drowsiness of the driver's eyes in real-time. The proposed method was implemented using a Raspberry Pi 4 Model B with 8GB RAM plus Raspberry Pi NOIR Camera and an Arduino Mega 2560 with a force-sensing resistor. Sensor performance is expected to expand as technological advancement initiatives continue. As an outcome, it is possible to conclude that the provided method is an efficient solution to detect driver drowsiness.

1. INTRODUCTION

According to the MMARAS annual report MMDA, 2019, "self-accidents" are the second most lethal of the Top 5 forms of crashes. According to the Philippine Nation-al Police-Highway Patrol Group, 2019, a human mistake is one of the leading causes of car accidents, with 8,809 crashes occurring in the Philippines from January to September 2019. As shown in a survey

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[1] Corresponding author: Nastaran, Reza Nazar Zadeh
Email: Nastaran.rezanazarzadeh@jru.edu

conducted by the National Highway Traffic Safe-ty Administration, about 94 percent of daily car accidents are caused by human error, with drowsy driving being one of the most common reasons (Caroselli et al., 2021). The National Safety Council (n.d.) defines drowsy driving as a sensation of weariness while driving. Drunk driving is compared to drowsy driving in the article, with driving with only 4 to 5 hours of sleep having the same chance of crashing as driving with a.08 blood alcohol level. Microsleep is a brief and uncontrollable sleep that can last anywhere from a fraction of a second to ten seconds (Des Champs de Boishebert et al,. 2021) and it can cause serious accidents, an increase in the number of deaths, and injuries, property destruction, and long-term impairment.

Several devices have been created to prevent Microsleep, including Mercedes-Benz and Nissan's Anti-microsleep technologies. Mercedes-'Attention Benz's Assist' feature. This analyzed driver behavior while taking into account external elements such as road conditions and driver interactions with vehicle controls. As per the article, Mercedes-Benz employs an algorithm and sensor that records inputs from steering movements and steering speeds during the driver's first few minutes on the road (Laouz et al., 2020). The Attention Assist system, on the other hand, delivered audio and visual alerts when the driver should take a break. Nissan's Driver Attention Alert system sets a baseline to assess subsequent driving habits (Meireles & Dantas, 2019). The article noted that the system uses an auditory and visual message to address the driver's fatigue and inattention.

Other studies use facial recognition and several algorithms to detect drowsiness. In a study by (Zhu, Li, Li, & Dai, 2021), researchers used 68 plotted facial landmarks to detect blinking and yawning with the use of the eye aspect ratio. (Zhao et al., 2018), (Zhang & Hua, 2015). In the study of (Meireles & Dantas, 2019), along with a system for detecting fatigue, steering wheel prototypes were developed with vibration technology as simple buzzers were found to be inadequate at waking drivers. The study’s findings stated that the prototypes did not respond well with only one hand at the steering wheel. The identification of sleep in this study could not detect interme-diate phases such as being half-asleep, lack of attention, or lack of focus, according to the researchers. In a study by (Kwak et al., 2020), machine learning, facial and eye-blink recognition technology, and a Carbon Dioxide sensor were used to create a system that predicts drowsiness. The study stated the use of an audio alert, stretching recommendations, and the additional use of an air freshener as a means to prevent and reduce drowsiness. The group intends to develop an automated anti-drowsiness system for automobiles to prevent drivers from getting into crashes. The system takes into consideration the handgrip for detecting drowsiness in the driver and alert audibly once fatigue has been distinguished (Zhao et al., 2018), (Zhang & Hua, 2015), (Li et al., 2021), (Misal & Nair, 2019). Cameras would also be utilized to recognize the driver’s drowsy expression using facial and eye recognition technology for further precise fatigue identification.

One of the major contributors to traffic and road accidents is drowsy driving. National Safety Council (2021) stated that drowsy driving is responsible for roughly 100,000 crashes, 71,000 injuries, and 1,550 deaths annually. The development of fatigue detection and anti-drowsiness devices may reduce and prevent the occurrence of accidents and crashes related to drowsy drives. In another study (Al-Saedi, 2022) researchers tried the Camshaft algorithm, finding it unable to correctly detect objects and features against various color backgrounds. In the same study, the histogram-based algorithm was restricted by different lighting conditions and was inadequate for situations where the object of interest shakes or moves. As indicated in the paper of Danisman et al. (2010) a new method to detect eye blink using the symmetry property is used, with an accuracy of 94%. The researchers of the current study intended to use the Viola-Jones Algorithm as it is stated to be effective in the face and eye recognition with an overall accuracy of 98.78%), (Misal & Nair, 2019). To address and counter inaccuracies, due to the movement of the object or target, a camera with anti-shake capturing technology was used.

The main objective of this research was to develop an automated system for automobiles that prevents their drivers from drowsy driving. The system aimed to detect if the driver showed signs of fatigue and drowsiness, and would respond to this with an alert to restore the driver's concentration. Specifically, the study addressed the following: 1. To develop a system that identifies the state of drowsiness using face and eye recognition technology. 2. To determine if the driver is drowsy by tracking their steering wheel interactions such as handgrip strength and hand placement. 3. To remove the driver’s drowsiness, with the use of an auditory alarm.

The development of the study's device would prevent drowsiness in drivers and re-duce the risk of crashes and accidents due to drowsy driving. First and foremost, the study was expected to reduce the number of fatalities and injuries caused by drowsy-driving crashes.

2. METHODOLOGY

The researchers discuss the research methodology and provide comprehensive de-scriptions of the research in this chapter. The sections covered in this chapter include research design, conceptual framework, flowchart, system architecture, and hardware requirements. Furthermore, this chapter consists of a method for collecting data, a testing plan, and a performance evaluation.

2.1 Research Design

Fig. 1 summarizes the systematic approach of the researchers in developing an Anti-Drowsiness Device and Alert System for Automobile drivers using image processing and force-sensing resistors. In this section, it was also indicated how the system would work. It also included the functions of every system that is integrated into the design. Finally, it shows the input parameters of the drivers to be used in detecting and preventing drowsy driving, such as the driver's appearance being measured simultaneously as a video for observation.

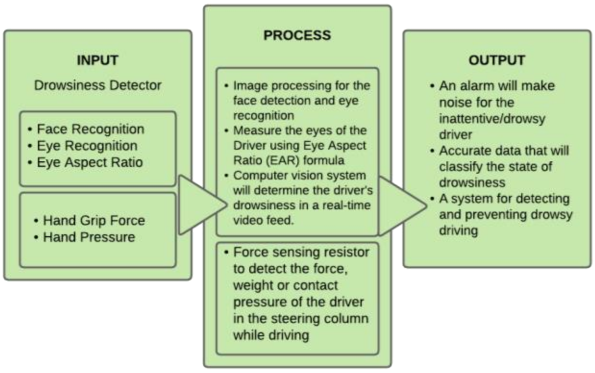

Figure 1. Conceptual Framework

The microprocessor (Arduino Mega 2560) configures the sensors while Raspberry Pi Camera Module 2 is connected to a microcontroller (Raspberry Pi 4). These two are operated by the mentioned components, which is used to detect the values of force on the steering wheel, while the Raspberry Pi Camera Module 2 are responsible for detecting the eye aspect ratio and blink rate of the drivers (see Fig. 2). In addition, the auditory alarm functions as the vehicle's warning system.

As shown in Figure 2, explains the mechanism of the study. The microprocessor (Arduino Mega 2560) configures the sensors while Raspberry Pi Camera Module 2 is connected to a microcontroller (Raspberry Pi 4). These two are operated by the mentioned components, which is be used to detect the values of force on the steering wheel, while the Raspberry Pi Camera Module 2 is responsible for detecting the eye aspect ratio and blink rate of the drivers. In addition, the auditory alarm functions as the vehicle's warning system.

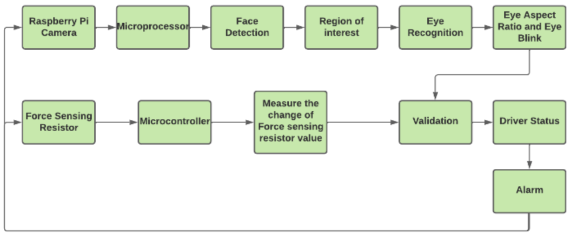

Figure 2. Block Diagram of the System

The system is a plug-and-play system, see Fig. 3; the power starts through the USB connection when the car engine is on. The Raspberry Pi Camera Module 2 is mounted into the car dashboard and is used to monitor the driver's facial expressions and eye development constantly and to do image processing using OpenCV (Villán, n.d.). Then Haar (Sharma et al., 2019) is used since this feature is not only used to detect facial images but also for eyes. When the facial landmarks for both eyes are detected, the eye aspect ratio for every eye, right and left, is computed (Williamson et al., 2011), (Sathasivam et al., 2020), (Mehta et al., 2019). Whenever the values collected in eye recognition are out of range, it goes through the hand grip strength to differentiate and identify whether the hand grip is active or on an average force. When the data remains out of range, an auditory alarm notifies the driver to be awake. However, when the values remain within the average range, the program loops back to identify the face and eye as well as start measuring the hand grip strength.

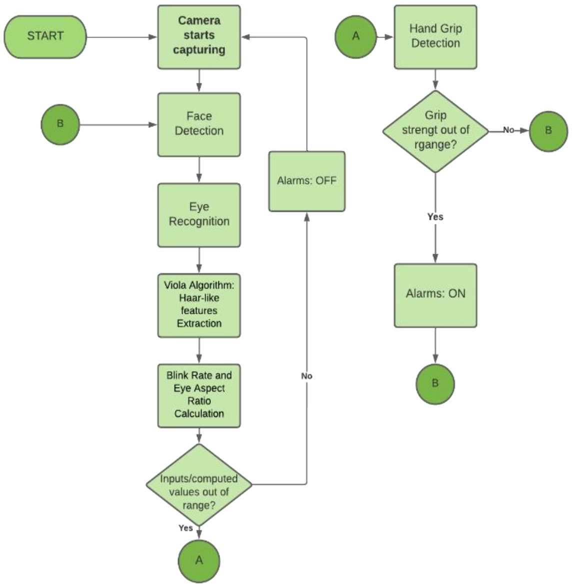

Figure 3. System Flowchart

2.2 2.2 Viola-Jones Algorithm Design

The Viola-Jones (Zarkasi et al., 2021) method combined four general keys: the Haar Like Feature, the Integral Image, the Adaboost learning, and the Cascade classifier (Chang & Fan, 2019), (Shamrat et al., 2022). The difference in the number of Haar-like features was the difference in the number of pixels from the rectangle's inner surface. The proposed system is using the Viola-Jones method, which detects objects in the images including such detection of a face as well as eye localization, and it is done by Haar-like features. With this Haar, it identifies both the left and right eye. Then the closed and open states of the eye is used as a parameter to determine whether the driver is drowsy or in an alert state.

2.3 Data Collection

Before taking a seat in front of the driving wheel, every participant was briefed on the tests, objectives, and procedures. The test was conducted by 20 people ranging from 18 to over 66 years old, with the five trials consisting of 8 force-sensing resistors at the steering column. This data collection involved data collected directly from a force-sensing resistor surrounding the steering wheel. It was used to measure when force was applied to a force-sensing resistor; the conductance response as a function of force was linear. In addition, the Eye Aspect Ratio was instantly acquired from a Raspberry Pi Camera utilizing OpenCV's built-in Haar cascades. The RPi Camera constantly recognized the streamed face and was used to record the movement of the drivers and recognize the eyes. All the collected datasets were validated through the algorithm process to determine if the driver was in a drowsy state or an alert state. The acquired data was employed to determine a threshold that generated a warning sound in real-time if the value drops below the given threshold value.

The recognition and localization of distinct locations on the face are facial landmarks, including eyes, nose, mouth, and more (Shukla et al., 2023). Fig. 4 depicts the indices of the 68 coordinates. Furthermore, employing facial landmarks in real-time may generate higher predictions.

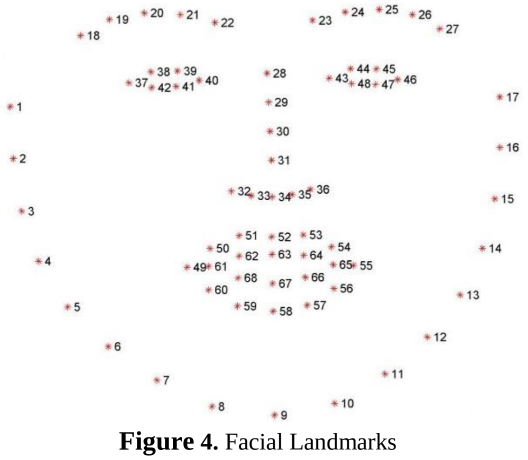

Figure 4. Facial Landmarks

2.4 Eye Aspect Ratio

The Eye Aspect Ratio is used as an estimate for the opening state of the eyes. As seen in Fig. 5, it was shown that the eyes have six facial landmark points which are used for the formula of the EAR to determine the distance between two points (Liu, Li, Xie, Yu, Wang, & Lin, 2019). Moreover, the higher the measurement of the EAR, the more open the eye is.

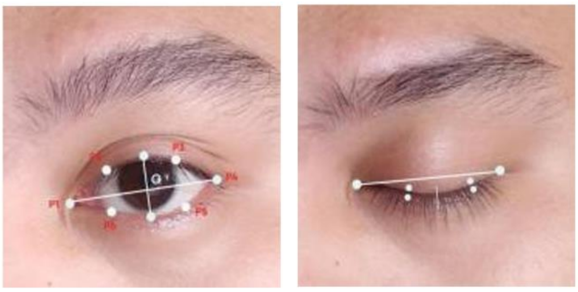

Fig. 5. Eye Aspect Ratio

2.5 Project Technical Structure

The project entitled Anti-Drowsiness and Alert System for Automobile Driver is a device that detects the driver's drowsiness using the Eye Aspect Ratio. A camera module is integrated to identify the driver's eye aspect ratio and blink rate, and an Arduino reads the data from the Force Sensing Resistor to measure the driver's grip strength on the steering wheel. Once the device detects a low eye aspect ratio and low grip strength, the device alerts the driver by playing an alarm through the speaker, which aims to prevent the driver from experiencing drowsiness.

The system uses Eye Aspect Ratio by comparing the set threshold to the captured EAR, which determines the driver's drowsiness. Whereas in the force-sensing resistor, once the driver puts their hands on the steering wheel (Udayashankar et al., 2021), the FSR records the grip strength exerted. The project uses both the Raspberry Pi and Arduino Mega to measure the Eye Aspect Ratio and the drivers' grip strength and pass the data to determine if the alarm is played.

2.5 2.6 Project Prototype

The project prototype, as it is presented in Fig. 6, comprises the eye detection system where placement is located on the dashboard close to the steering wheel. In the steering wheel prototype, eight force-sensing resistors are placed on the wheel covered by a cloth with foam acting as its protection when the user puts their hands on the wheel.

Figure 6. Prototype Design

The mock-up wheel in Fig. 7 is composed of a gaming wheel covered with cloth and foam, which acts as protection for the force-sensing resistor once the user places their hand on the wheel. Moreover, the steering wheel cover is secured with velcro so it does not slip while in use.

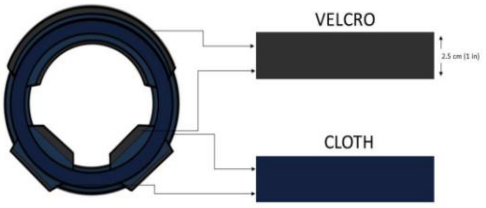

Figure 7. Mock-up Steering Wheel Dimension

Fig. 8 shows the schematic diagram of the system, where the Raspberry Pi NOIR camera is connected to the CSI connector of the Raspberry Pi 4, whereas Raspberry Pi 4 is connected to the USB serial communication of the Arduino Mega 2560. In relation to that, the force-sensing resistors placed in the steering wheel are individually connected to a 10 Kilo Ohm resistor in order to create a voltage divider, which is then connected to the analog pins of the microcontroller.

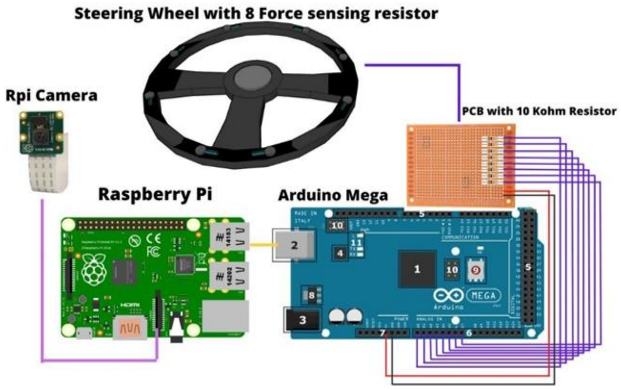

Figure 8. Schematic Diagram of the System

3. RESULTS AND DISCUSSION

The study's results are presented and analyzed in this section with regards to the re-search objective, which is to determine the state of drowsiness utilizing face as well as eye recognition technologies and also measuring individual steering wheel interactions such as handgrip strength and hand placement.

3.1 Driving Simulation

The system was tested using a driving game that is acting as a driving simulator, as shown in Fig. 9. First, the participants replicated driving on the simulator's map, then the data for eye recognition and grip strength was collected. The proponents collected the data such as force grip in a pounds-force unit from the driver's interactions with the steering wheel's force-sensing resistor. Moreover, drowsiness detection through eye recognition (eye aspect ratio) was also tested on the drivers using the driving simulator within the given duration of testing.

Figure 9. Driving Simulation

The equivalent of measurement from the force-sensing resistor by converting the analog reading of FSR to the Pound-force (lbf) is presented in Table 1. As shown in Figures 9 and 10, force sensors were mounted on the steering cover, which is posi-tioned on the steering wheel. These thresholds were qualitatively defined based on force measurements obtained from testing and trials.

Table 1. Parameters for Pound-force of Force Measurement

Pounds-force Value	Equivalent
0.01 - 0.02 lbf	Light touch
0.03 - 0.15 lbf	Light squeeze
0.16 - 1.07 lbf	Medium squeeze
1.08 - above	Strong squeeze

3.2Hand Grip Measurements

Table 2 summarizes the system's functionality using both evaluations (Eye Aspect Ratio and Force-sensing Resistor Hand Grip). Initially, if the eye aspect ratio is more than or equal to the set threshold and the hand grip strength, nothing will happen. However, when both are below average, indicating that the driver has a lower Eye Aspect Ratio, yet grip strength is weak for a few seconds, the alert activates to assist the driver to regain concentration.

Table 2. Confusion Table for Validation of Two Parameters

		Hand Grip Strength	
		Average >=	Average <
Eye Aspect Ratio	Average >=	No Alarm	No Alarm
	Average <	No Alarm	Alarm ON

The hand grip average is calculated by Equation 1.

$$Average = \frac{(FSR1 + FSR2 + FSR3 + FSR4 + FSR5 + FSR6 + FSR7 + FSR8)}{8} \quad (1)$$

The average pound-force of participants where they are instructed to hold the steering wheel as if they are driving were measured and presented in Table. 3. The subject's average pound-force in the table is obtained by computing the average of the two force-sensing resistors that detected the hand grips of the subject within the 180-second duration. The duration of testing phase lasted for 180 seconds, with various trials made and indicated with it is the classification of the grip exerted by the subjects. Parameters for Pound-force of Force Measurement, it reflects the degree of hand grip of the driver on the steering wheel column wherein these equivalents are used as reference for the classification column in this table.

Table 3. Avarage Hand Grip within 180 Seconds

Subject	**Average (lbf)**	**Classification**
P1	0.35	Medium Squeeze
P2	0.09	Light Squeeze
P3	0.12	Light Squeeze
P4	0.55	Medium Squeeze
P5	0.22	Medium Squeeze
P6	0.23	Medium Squeeze
P7	0.09	Light Squeeze
P8	0.05	Light Squeeze
P9	0.55	Medium Squeeze
P10	0.18	Medium Squeeze

The system was tested under various lighting conditions considering detecting systems that are easily affected by lighting, shadows, weather, as well as other variables, see Table 4. The table shows the average E.A.R. of the respondents which were recorded for both in a daylight and night light setup. The average values were obtained by recording the E.A.R. of the respondents for 60 seconds, and the proponents recorded the output values every 5 seconds. However, it could still identify the driver's eyes. Based on the E.A.R values gathered, the average value for open eyes is 0.30, which is close to the 0.339 Ratio attained by the study of (Sathasivam et al., 2020),. As indicated in the third column of Table 4. There is a small discrepancy between the two factors used to identify eye aspect ratio in the night light and daylight setups. It is computed by subtracting daylight's EAR value from nightlight's EAR value. The largest difference is 0.7; the smallest discrepancy is 0, as well as the average for such parameters is 0.28. In connection with the gathered data, the averages obtained for both daylight and night light setups are 0.3. This leads to the conclusion that there is not much difference in detecting the EAR of the subject for both the daylight and night light setup and that it still accurately detect the EAR value of the subject.

Table 4. Average of Eye Aspect Ratio with Daylight Setup and in Night Light Setup

Subject	**Average E.A.R. with Daylight Setup (Ratio)**	**Average E.A.R. with Night Light Setup (Ratio)**	**Differences**
P1	0.23	0.24	0.1
P2	0.30	0.29	0.1
P3	0.35	0.34	0.1
P4	0.20	0.20	0.0
P5	0.34	0.32	0.2
P6	0.36	0.32	0.4
P7	0.40	0.33	0.7
P8	0.39	0.34	0.5
P9	0.32	0.30	0.2
P10	0.36	0.31	0.5

Table 5 displays the visuals and the numerical total number of eye blinks observed during the prototype test including all participants in an 180-second duration. In general, all of the participants used to have a modest blink count in the first phase, which steadily increased until the completion of the test. The participants showed an average blink count of 19.73 at the 180 seconds, which was based also on the average blink count according to the study of Abusharha (Bolosan et al., 2016), while the subjects P1 and P3 showed a relatively high blink count at the same duration. Furthermore, as described in the classification column of Table 4, the status of awake and drowsy were based on the comparison of the subject's average blink per minute and the overall average blink count, which is 20 blinks. The awake status indicated that the average blink exerted by the subject exceeds the normal number of blinks and is drowsy if otherwise.

Table 5. Eye Blink Detection

Subject	**Total Blinks in 180 seconds**	**Average Blink per Minute**	**Classification**
P1	83	27.67	AWAKE
P2	75	25	AWAKE
P3	76	25.33	AWAKE
P4	62	20.67	AWAKE
P5	53	17.67	DROWSY
P6	39	13	DROWSY
P7	60	20	AWAKE
P8	44	14.67	DROWSY
P9	54	18	DROWSY
P10	46	15.33	DROWSY

In Fig. 10 A, and B, the graph showed the average grip of both men and women.

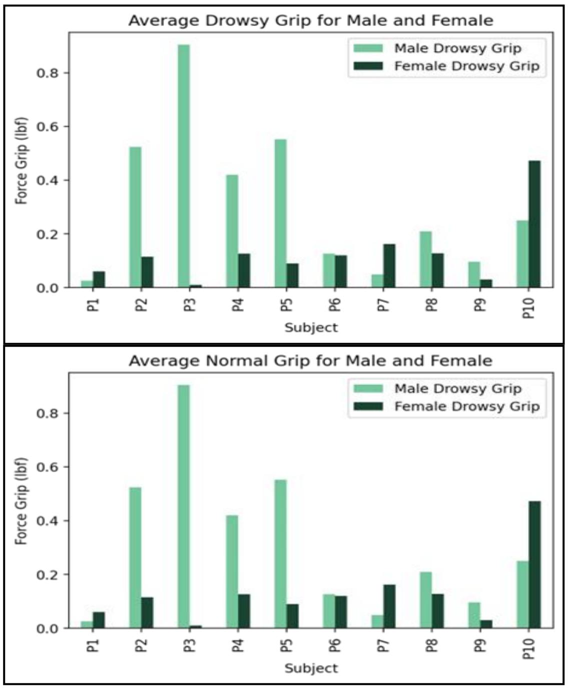

Figure 10. A. Drowsy Grip, B. Normal Grip

The researchers gathered 20 people who were asked to hold the steering wheel prototype embedded with the Force-sensing Resistor (FSR) and recorded the 5 trials produced. In Figure 13, the graph shows the average normal grip, while the proceeding figure shows the average grip in a drowsy state. The grip values for this graph were obtained to know the threshold needed for the system.

Fig. 11 shows the average Eye Aspect Ratio of the subjects in both daylight and night light setups. During the simulation, 10 participants were measured with their E.A.R for 60 seconds and the averages that were obtained during the simulation equaled 0.30 Ratio having a minimum and maximum of 0.20 Ratio and 0.35 Ratio respectively on the daylight setup while having a minimum of 0.20 Ratio and a maximum of 0.40 for the night light setup.

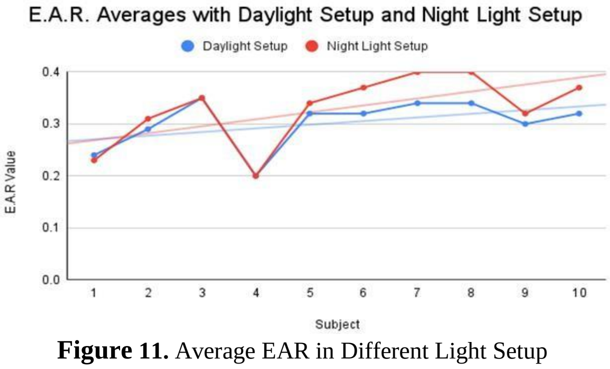

Figure 11. Average EAR in Different Light Setup

The graph in Fig. 12 indicates the response time of the alert system from once it detected that the user is drowsy until the user is notified. It can be seen that the response time is plotted with regards to how many seconds is its interval in alerting the person after it is detected that it is drowsy.

Figure 12. Response Time

4. CONCLUSION

The study was conducted to develop a system for automobile drivers to prevent them from being drowsy by detecting if the driver shows any signs of fatigue through their grip strength and eye aspect ratio. Furthermore, the system has an accuracy rate of 96.50% in detecting drowsy drivers. During the simulation, the system was able to identify the driver's state of drowsiness using eye recognition technology. Using the Raspberry Pi Camera, the camera measured the eye aspect ratio and the blink rate of the participant while holding the mock-up steering wheel for 180 seconds. The results indicated that the average eye blink of the participants was 0.31 R and had 20 blinks per minute.

Participants were made to hold the mock-up steering wheel embedded with 8-force sensing resistors to measure the grip strength exerted in both normal and drowsy situ-ations. The proponents obtained the average pounds-force by having the participant have each force-sensing resistor be measured in different hand placements. As a result, the average pounds-force measured 0.06 lbf. Once the system detected a low eye aspect ratio and low grip strength, a text-to-speech alarm played to notify that the driver was experiencing drowsiness. The alarm was tested during data gathering wherein the participants, when detected with low EAR, would be alerted to audio indicating they should wake up.

5. RECOMMENDATION

The researchers proposed the following recommendations for future studies: First, the researchers suggest adding an SMS notification that alerts an emergency contact of the driver once the system detects that the driver's drowsy status is unchanged. Second, a yawning detection is suggested as an added validation together with the eye detection to have a more accurate drowsy detection for the driver. Third, the researchers suggest that once the prototype is up for commercialization, it is suggested to find a manufacturer and supplier that designs the steering wheel cover for it to be purchased by a customer and attached to their cars. Fourth, with regards to the alert system, it is recommended to try increasing the pitch of the alarm once the system detects that the drowsy status has not changed for a long period. In addition to that, it is also recommended to add an alert feature that identifies if the driver is distracted. An example of this notifies the driver to keep their eyes on the road to prevent accidents due to distracted driving.

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Nastaran Reza Nazar Zadeh
Jose Rizal University
80 Shaw Boulevard, Mandaluyong City
Nastaran.rezanazarzadeh@jru.edu
ORCID 0000-0002-3641-8623

Ramerson Abais
Jose Rizal University
80 Shaw Boulevard, Mandaluyong City

Maxine Joie Mananqui
Jose Rizal University
80 Shaw Boulevard, Mandaluyong City

Jhon Person Cabarles
Jose Rizal University
80 Shaw Boulevard, Mandaluyong City

Eireena Patricia Estudillo
Jose Rizal University
80 Shaw Boulevard, Mandaluyong City

Mary Donnabell Rivera
Jose Rizal University
80 Shaw Boulevard, Mandaluyong City