Driver Drowsiness Detection and Notification Through Facial Pattern Analysis

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ABSTRACT
Drowsy driving is one of the primary causes of road accidents. This typically occurs when a driver has not obtained adequate rest. It can also be caused by untreated sleep disorders, drugs, excessive alcohol consumption, or shift employment. From 63,072 in 2007 to 116,906 in 2018, the number of car accidents in the Philippines has more than doubled. Every year, 12,000 Filipinos are killed or injured in road accidents involving passengers, drivers, and pedestrians, with 14,553 people killed or injured [1].

The proponents developed a project that can monitor drowsiness and may mitigate untoward incidents resulting from it. The project is composed of two sub-systems: an image processing module and a wearable alert device. The proponents used facial pattern analysis to determine drowsiness using an advanced method of facial recognition. The proponents also developed a web application to help the operator monitor the drowsiness status of the driver and the geolocation of the truck. If the driver became drowsy, the web application would notify the operator of the status of the driver. The web application has a map function that tracks the driver's location using a marker.

Keywords
Drowsiness Detection, Facial Pattern Analysis, Levels of Drowsiness, Trucks, Truck Drivers, Road Accidents.

1. INTRODUCTION
In recent years, there have been a lot of road accidents. Driving with complete awareness is necessary. The number of road accidents has increased over the last five years. Road accidents happen all the time. Overspeeding, driving under the influence of alcohol, and drowsy driving are the main causes of road accidents here in the Philippines. In 2017, there were 19,374 people injured on Metro Manila's roads due to overspeeding, driving under the influence of alcohol, and drowsy driving [2]. A project introduced in 2017 by Kickstarter is designed for drivers who can monitor drowsiness; the name of this project is STEER (Kickstarter, 2017) [3]. The main purpose of STEER is to warn the driver with vibration and gentle electric impulses so the driver does not fall asleep while driving. STEER has its own way of monitoring drowsiness, and it's through a heart rate sensor. On the other hand, this project utilizes image processing using multiple open-source software electronics. The project aimed to determine the different drowsiness levels of the driver and alert the driver based on drowsiness level. An open-source electronic platform was used as the main processing device for the project's modules and sensors. Bluetooth technology was used for communication between the image processing module and the wearable alert device. The image processing module is a device that processes real-time footage of the driver and applies outputs through the modules and sensors; it also sends the determined drowsiness level of the driver to the web application. An algorithm identifies the driver's drowsiness level based on facial features. The wearable alert device is equipped with Bluetooth technology and receives broadcast output from the image processing module. The web application is used to monitor the driver's drowsiness level and the location of the truck.

2. RELATED LITERATURE
There were studies related to the project that were used as the basis for this study. One of these is the study of Sadegh Arefnezhad entitled "Driver Drowsiness Classification Using Data Fusion of Vehicle-Based Measures and ECG Signals," where the proponents proposed the classification of drowsiness level based on the study criteria. This study used the facial features of the driver to detect the driver's drowsiness level [4]. The proponents used the different criteria to implement different types of alert notification to be applied to the different drowsiness levels.

In the study of Pratiksha Kolpe, entitled "Drowsiness Detection and Warning System Using Python," the proponents used the project as a guide in detecting the driver's drowsiness. According to this study, the detection of drowsiness involves the observation of a face, the detection of eye position, and the observation of an eye blinking pattern. To detect drowsiness, a webcam has been used that directly points towards the driver's face and detects eye movement. The techniques used in this study, such as the eye blinking pattern, webcam, and OpenCV library, were adopted by the proponents. When this is implemented, the proposed project will be more accurate in reading the driver's facial features [5].

Another study entitled "Real-Time Driver Drowsiness Detection Using OpenCV and Facial Landmarks" was proposed by L. Thulasimani, wherein the proponents used the method to extract the facial land marks of the driver to know the driver's drowsiness level [6]. The facial tone, eye blinks, and head tilting back and forth are all examples of different signs of drowsiness. These classifications improved the proponents' project. The proponents also used the OpenCV environment to detect the facial landmarks of the driver and used the studies EAR and MAR methods to detect the driver's drowsiness. The eye-aspect ratio was used to calculate the eye closure (EAR) of the driver. When EAR falls below the threshold value, drowsiness is confirmed, and the driver is notified through different types of modules. The calculation of the mouth-aspect ratio (MAR) is used to detect yawning. Longer glances, slower eye blinks, and yawning are classified by the authors of this study.

Lastly, in the article entitled "Google Maps API Implementation on IOT Platform for Tracking an Object Using GPS," the proponents used the study method to track the location of the truck using GPS. They used this as a concept and used a different API for navigation and location determination. The concept also helped in building the map function of the web application and using the Firebase database as storage to store the gathered data from the GPS module sent by the Raspberry Pi [7].

3. PRESENTATION OF ANALYSIS OF DATA

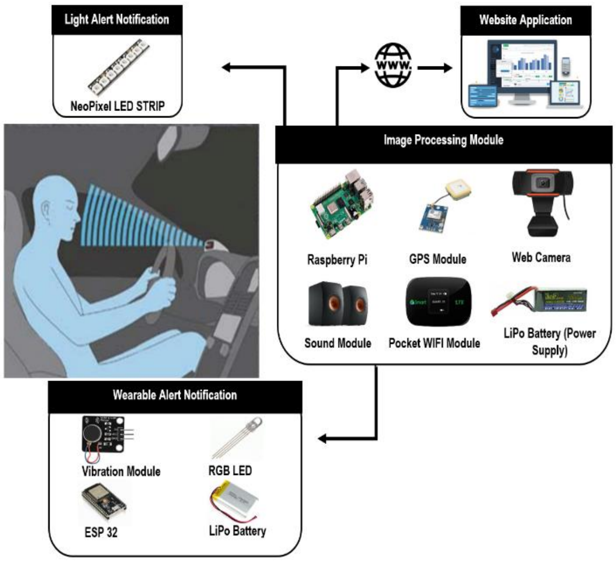

Figure 1: Operational Framework of the Project

Figure 1 shows the operational framework the proponents used for the entirety of the project. In developing this project, the proponents used two open-source electronic platforms for the image processing module, the brain of the system that processes the drivers' facial features using a programmed algorithm and sends the determined drowsiness level of the driver to the wearable alert device and web application. It also applies Light Notification to the corresponding drowsiness level using a Neo Pixel LED. The wearable alert device was used for receiving and applying the received data to the driver using different modules. The proponents also used Bluetooth for sending processing data from the brain of the system to the wearable alert device. Lastly, a GPS module, web camera, vibration module, speaker, and light-emitting diode (LED) were integrated into the project for tracking and alerting the driver.

The project setup consisted of the image processing module and a wearable alert device. The image processing module was used to determine the driver's drowsiness level through a programmed algorithm and apply actions corresponding to the driver's drowsiness level. It also sends the driver's status and truck location every 1-minute interval to the web application. The wearable alert device receives and applies the corresponding action depending on the driver's drowsiness level, such as "not drowsy," which outputs green light from the LED module; "moderately drowsy, which outputs yellow light and short vibration from the vibration module; and "extremely drowsy," which outputs red light and strong vibrations to alert the driver.

The project aims to accomplish the following functional and non-functional requirements:

Functional Requirements

- The system can capture the driver's facial features, the moment the trip begins.
- The system can detect the level of drowsiness during travel
- The system can evaluate the driver's facial features throughout a long trip.
- The system can locate or determine the location of the truck.
- The system can locate or determine the location of the truck.
- The system can notify or alert the driver of his drowsiness level.
- The system can alert the driver using visual and auditory notifications.

Non-functional Requirements

- The camera capturing the video should be of operable resolution.
- The system should work even in low-light conditions.
- The web application should be controlled by an authorized person only.
- The wearable device should be comfortable to wear.
- The visual and physical notifications should not hinder the driver's focus on the road.
- The wearable device should be practical in size.
- The web application should have a straight forward interface.

The schematic diagram of the wiring layout of the driver's Drowsiness Detection and Notification Through Facial Pattern Analysis The schematic diagram contains the wiring of the modules and sensors to the brain and sub-brain of the system, which are the Raspberry Pi and ESP32, respectively.

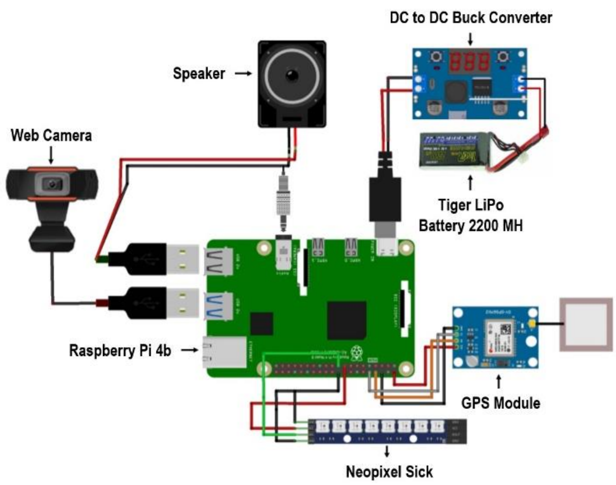

Figure 2: Schematic Diagram of Image Processing Module

Figure 2 illustrates the schematic diagram for the image processing module and the connectivity of the modules. The Image Processing Module contains various components, such as the Raspberry Pi, which is the main brain of the module. This will analyze the captured facial tone coming from the web camera and identify if it is drowsy. The function of the speaker is to alert the driver according to the level of drowsiness the driver is exhibiting. A Neopixel stick to notify the driver with a non-blinking green light notification for "not drowsy,", a slow yellow blinking light notification for "moderately drowsy,", and a rapidly red blinking light notification for "extremely drowsy."

The proponents also used a GPS module to locate the driver. An 11-volt Li-Po battery will power up the Raspberry Pi. Due to the maximum output voltage of the Raspberry Pi being 5 volts, a DC to DC Buck Converter will be connected to the Li-Po battery to lower the output voltage of the battery.

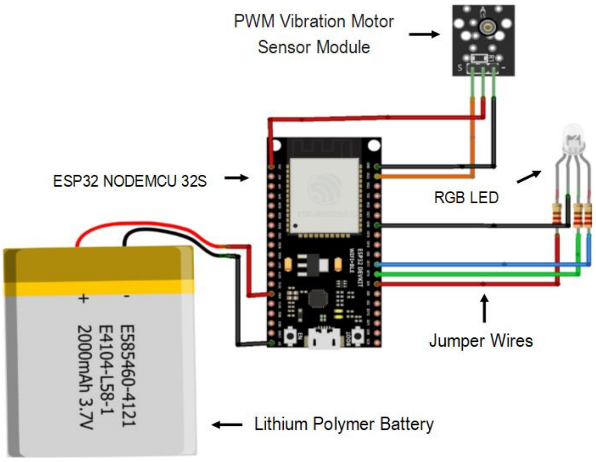

Figure 3: Schematic Diagram of Wearable Alert Notification

Figure 3 displays the Wearable Alert Notification's schematic diagram; wearable alert device contains the connectivity of the modules to the ESP32. The Wearable Device contains a vibration module and an RGB LED, which were used as project outputs. The vibration, like the RGB LED, vibrates in response to the data sent by the Raspberry Pi.

The Raspberry Pi has built-in Wi-Fi connectivity, so the proponents utilized the Wi-Fi to access the internet and send the data gathered to the web application. The connectivity of the Raspberry Pi and ESP32 was Bluetooth. Using Pybluez as the main connectivity of the Raspberry Pi 4 and ESP32, data and given functions coming from the Raspberry were sent to the ESP32 through Bluetooth.

As all the sensors and modules are connected, not all positive pins are connected to a 5-volt power supply. The other pins are connected to a 3-volt power supply, and all negatives are connected to the negative pin. After connecting the modules and sensors to the microcontrollers, the dashboard prototype was created using plywood, glue sticks, printed gauges, spray paint, and sticks where sensors and modules would be installed.

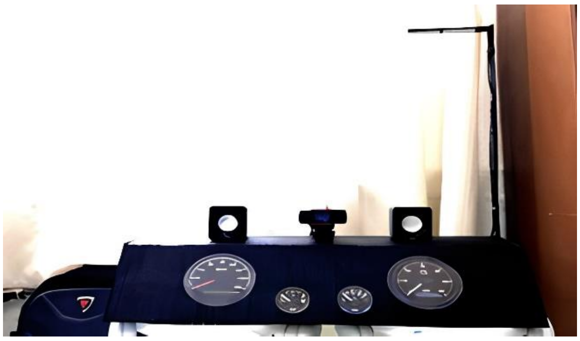

Figure 4: The actual model of the dashboard prototype

The actual model of a dashboard prototype with the modules and sensors installed and placed in their proper positions (figure 4). The camera is attached to the top of the dashboard to detect the driver's facial expression, and the camera determines whether the driver is drowsy or not as soon as they sit inside the truck. Along with it is the speaker, which is one of the project's outputs. The function of the speaker is to alert the driver depending on what level of drowsiness the driver is exhibiting.

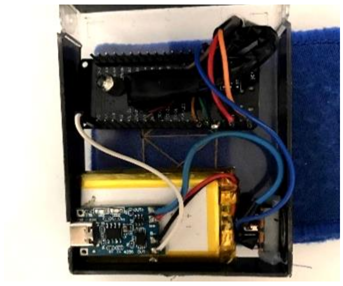

Figure 5: Connected microcontrollers to the wearable alert notification

With all of the sensors and modules connected, the wearable alert notification is nearing completion. The wearable alert notification's proponents used a plastic container to store all of the connected microcontrollers.

The ESP32 includes RGB LEDs and a vibration module. The RGB LED has four pins: one for ground, one for red, one for green, and one for blue, while the vibration module has three pins: one for ground, one for VCC, and one for OUT. The RGB LED performs the same function as the Neopixel; it blinks whenever the image processing module receives a command regarding drowsiness detection from the driver. The vibration module will perform according to the command sent from the image processing module.

$$Avg.\ EAR = \frac{EAR(L)+EAR(R)}{2}$$

Equation 1: EAR Formula

To determine the average eye closure and used this for the computation of the drowsiness using the EAR (Eye Aspect Ratio) formula (equation 1). To distinguish between the open and closed states of the eye, the proponents used an EAR threshold of 0.3.

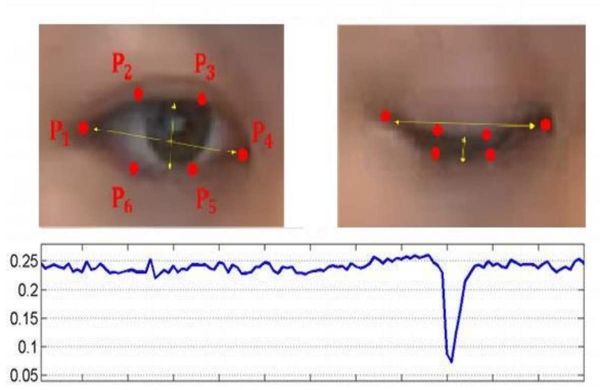

Figure 6: Average closed eye point

Figure 6 shows the average of the eyes closed using the Eye Aspect Ratio (EAR) formula. This formula was used to test and get values needed for the implementation of drowsiness detection.

Figure 7: Testing of the EAR and MAR formula to acquire the threshold

The proponents started with the prior testing (Figure 7) of the EAR (eye angle ratio) and MAR (mouth aspect ratio) formulas to acquire the threshold. In this testing, the proponents test the main part of the system, which is getting the land points of the eyes, mouth, and head shape.

The proponents tested the functions of the prototype starting from the first drowsiness level, which is "not drowsy," the second level, which is "moderately drowsy,", and the last level, which is "extremely drowsy". The proponents tested if the Neopixel, sound, and vibration were working properly and were programmed with the right color.

Figure 8: Demonstration of the Prototype to the Driver and companion

The proponents discuss how the prototype will alert the driver and companion through sound, vibration, and light notifications (Figure 8). The proponents discuss how the prototype will alert the companion through sound and light notifications. While the driver will notify with vibration, light, and sound notifications. Both the driver and companion will hear a sound alert notification coming from the speaker that is attached to the prototype, while the light alert notification will blink whenever the driver is drowsy.

The proponents discussed the functions of the web application, such as the login page and what would happen if an incorrect input was applied; where the login page would take her after logging in with the correct inputs; the fact that only authorized personnel can log in and access the data in the web application; the map on the web application, which indicates the truck's location; the status function; and the drowsiness level of the driver during travel.

Table 1 shows the effectiveness and efficiency of driver drowsiness detection and notification through facial pattern analysis using the computed effectiveness of the project. The project received a 95.31% level of effectiveness and efficiency based on the computed results. With this calculated percentage of the effectiveness and efficiency results, the proponents concluded that the project is nearly perfect, with only a small amount of room for improvement.

Table 1. Drivers, Companion, Manager, and Owner evaluation result.

Drivers (2)	100%
Companion	81.25%
Manager	100%
Owner	100%
Total:	**95.31%**

4. RESULTS

During the course of the study, the proponents discovered different strategies and approaches used in the study. The Eye Aspect Ratio (EAR) formula identifies the values used to determine the drowsiness of the user. Another formula known as the mouth-aspect ratio (MAR) was used to assess the level of drowsiness. In addition, the proponents encountered difficulties in achieving ideal results but were able to get accurate outputs through trial and error and certain modifications to the algorithm.

After the integration of the necessary algorithms, the proponents were able to develop driver drowsiness detection and notification through facial pattern analysis. This will help to lessen the risk drivers may encounter on the road.

5. CONCLUSIONS, RECOMMENDATIONS

In the process of developing driver drowsiness detection and notification through facial pattern analysis, the system was able to determine the different levels of drowsiness, which are as follows: not drowsy, moderately drowsy, and extremely drowsy. This assessment became one of the foundations for developing the project. In addition, the proponents were not able to achieve all the criteria for levels of drowsiness. The proponents only achieved "yawning" for "moderately drowsy", and "head bending or tilting back and forth" for "extremely drowsy".

Additionally, the system was able to alert the driver of his drowsiness using the criteria. In the Not Drowsy state, the system was able to notify the driver of his non-drowsiness level using the Light notification. The system was able to determine the driver of his moderately drowsy state using the light, audio, and vibration notifications. The system was able to inform the

driver of the driver's extremely drowsy state using light, audio, and vibration warnings. Lastly, the proponents were able to evaluate the effectiveness and efficiency of driver drowsiness detection and notification through facial pattern analysis using the survey conducted with the stakeholders, wherein the project got a 95.31% level of effectiveness and efficiency based on the computed results shown in Table 1.
For future users of this project, the proponents recommend using more advanced technology to achieve a more accurate and reliable outcome. The accuracy of this project will be greatly improved with state-of-the-art technology.

Proponents believed there was still room for improvement in driver drowsiness detection and notification through facial pattern analysis. Future researchers with the same focus are advised to broaden the study's scope and address the project's drawbacks. The prototype can be made more compact, the vibration level can be raised, and the Bluetooth connection algorithm can be improved.

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