ASAP: ANTI-SLEEP ALARM AND PROMPTER SYSTEM USING IMAGE PROCESSING FOR DROWSY DRIVERS

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ABSTRACT

As the number of accidents due to driver's drowsiness grows significantly, demand for drowsiness detection and anti-collision with automatic braking mechanism arises. In this research, the proponents developed an anti-sleep alarm and prompter system for drowsy drivers. The system comes with an automatic braking mechanism that pulls the physical brake pedal of the car when drowsiness or an obstacle is detected. Facial recognition, object detection, and the automatic braking mechanism of the prototype are performed and controlled by using a Raspberry Pi microprocessor and an Arduino Uno microcontroller. In drowsiness detection test drives, the automated braking system activated when the system detected that the driver's eyes were closed for more than 3 seconds above the EAR trigger value of 0.30. In anti-collision test drives, the automatic braking system activated between 10 to 5 meters from the obstacle.

Keywords: *Engineering education, image processing, drowsiness detection, obstacle detection, raspberry pi, Arduino, Philippines.*

INTRODUCTION

Sleepiness and driving in the Philippines are a dangerous combination. Most people know of the risks of drinking and driving, but they do not understand that driving with sleepiness can be as deadly. Sleepiness can reduce conscientiousness and judgment as much as alcohol does and raises the risk of crashing [1]. Even a short nod off may be extremely dangerous. Because it can mean you have a little longer than 30 meters without control at a speed of 100 km/h. Falling asleep for just one second, which is enough distance for a vehicle to hit a tree, a car to come, or worse, a pedestrian. This is mainly because not every car has drowsy detectors to warn drivers of the impending danger caused by drowsiness.

The growing number of accidents due to driver's drowsiness led researchers to propose a system that will help to prevent future accidents caused by drowsiness while driving. Most of these researches use image processing to determine the level of drowsiness of a driver. The technology suggested in detecting fatigue and distraction is a facial controller technology that can sense the driver's hypo vigilance (both fatigue and distraction) by eye and facial processing [2]. The Drowsiness Detection using Eye-Closeness Detection uses a camera and reliably measures the drowsiness level of the drivers with real-time analysis using a Raspberry Pi 3 Model B [3]. Vesselenyi et al. employed three methods in detecting drowsiness: electroencephalogram, electrooculography signal processing, and driver image analysis [4]. In witnessing the driver's sleepiness, the Viola-Jones detector method was also used [5].

Considering many factors by using this method is the location of the eyes and the dynamic changes in eye movement. [6]. Even if the driver wears glasses, the device functions effectively in low light settings if the camera produces a higher output. [7]. Nowadays, driver drowsiness is one reason for street mishaps and can prompt severe physical wounds, deaths, and critical financial misfortunes [8]. In evaluating safety performance from the perspective of road administrators, driving assistance systems can reduce car collisions [9]. The sensor-based front-end collision avoidance system can reduce and avoid road accidents caused by the driver's sleepiness and drowsiness [10]. Developing strategies to prevent forward collisions has been conducted by using active research. Introducing representative systems as a result from the research like Mercedes-Benz's PRE-SAFE Brake and Volvo's City Safety. [11]., Car manufacturers developed forward collision warning (FCW) systems using active sensors such as vision-based, acoustic-based, radar-based, and laser-based sensors to address the rear-end collision problem.

Collision warning models with fixed parameters are the basis of the FCW systems. [12]. Arduino-based forward collision detection is measured using a sensor and alarm to alert the driver or the passengers effectively. [13]. The ultrasonic sensor used in the study of Priyadarsini et al. [14] was able to reliably read distances from shorter distances allowing them to test the effectivity of ultrasonic sensors in detecting objects in front of the ground vehicles [15].

Previous studies involving drowsiness detection do not have braking and forward collision avoidance systems. Integrating an automated braking mechanism ensures that the car will stop if the drowsiness detection system detects that the driver is sleepy. Further, the addition of a forward collision avoidance mechanism providing that the vehicle will stop when an obstacle is detected within 5 meters ahead enhances the system's safety features.

The main objective of this study is to develop an anti-sleep alarm and prompter system for drowsy drivers. Specifically, this study aims to: (1) develop a system for monitoring the level of vigilance of the driver by extracting visual parameters using image processing techniques; (2) develop a safety braking mechanism for a car that will automatically activate when driver drowsiness is detected; (3) develop a collision prevention system that detects the presence of obstacles in front of the vehicle.

The availability of a drowsiness detection system and forward collision avoidance system for vehicles is a great help in increasing drivers' safety while driving. And, with the integration of an automatic safety braking mechanism, car collision accidents can be minimized if not avoided.

Developing a drowsiness detection system with forwarding collision avoidance is the focus of this study. Implementing image processing using a machine learning algorithm, detects the driver's drowsiness. Placing an ultrasonic sensor in front of the car for the obstacle detection. If the sensor detects a flat vertical surface or an object perpendicular to the road at a ten-meter distance, the system will activate the braking mechanism prototype. The drowsiness detection system and forward collision avoidance were installed and tested using a 4-wheel drive 2014 Hyundai Accent. This study does not cover for the prototype to steer the car automatically. The prototype is designed only up to 30 kph maximum top speed in a straight road.

METHOD

A. System architecture

Figure 1 shows the architecture of the anti-sleep alarm and prompter system.

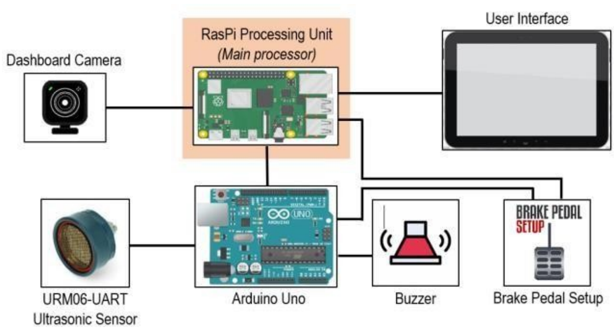


Figure 1. Anti-sleep alarm and prompter system architecture

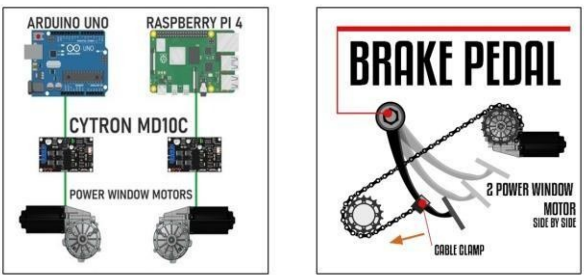
Inside the vehicle, a dashboard camera was installed, and it is also used for capturing the driver's face in real-time. A URM06-UART ultrasonic distance sensor is installed in the front bumper of the car to calculate the range across the vehicle and the object ahead to avoid a collision. This system uses a microprocessor and a microcontroller. The central processor is the Raspberry Pi, which handles the data for the anti-sleep alarm and triggers the brake pedal setup. The central processor also controls the user interface. The sub-processor is the Arduino Uno microcontroller for the prompter system, which collects the data from the ultrasonic sensor and triggers the alarm buzzer and brake pedal setup.

A touchscreen user interface is attached to the dashboard used for real-time face monitoring of the driver. This monitor also displays a real-time distance measurement between the car's bumper and the object in front. The monitor also prompts the driver by displaying a warning text on the screen. The touch screen user interface also provides an easy touch "System Reset" on the screen to reset the system to its default settings. Inside the car, a passive buzzer was attached. This buzzer will trigger if an object is detected at an unsafe distance from the vehicle, possibly causing a collision. A pulsive short beep indicates that a thing is in front of the car in the space of fewer than 5 meters. An "Auto-braking system activated" audio is played in the car's built-in speaker to alarm the sleepy driver before the braking system activates and stops the vehicle.

B. *Brake pedal setup*

As shown in figure 2 (a), two Cytron MD10C high voltage H-Bridge single motor driver modules are connected separately to the Raspberry Pi and Arduino Uno. The Raspberry Pi triggers the first motor driver for the drowsiness detection, while the Arduino Uno triggers the second motor for the anti-collision. These motor drivers will amplify the signals given by the GPIO pins on the Raspberry Pi and the Digital PWM pins on Arduino Uno. The motor driver controls the turning of the 12V DC power window motor. In figure 2 (b), above the brake pedal, the two power window motors were placed. Below the brake pedal, the two additional sprockets were installed. A bike chain links the power window motor and the brake pedal. To act as a guide for each of the chains, the two sprockets below the brake pedal were used and it was perfectly aligned with the motor above the brake pedal for maximum and easy pulling mechanism of the pedal.

To work as a pulling mechanism to the brake pedal, the chains on each power window motors were welded firmly. At the end of the chain, a clamp is attached and fastened to the long metal part of the brake pedal. To ensure a working pulling mechanism, the clamp was securely installed to the brake pedal of the car. The chain will pull the pedal as the power window motor starts turning clockwise. The power window motor will rotate slowly to a clockwise direction (facing the passenger's seat) and stop at a specific post as the pedal meets its maximum distance from its original position. The motor will hold its place until the plan is reset and will turn counter clockwise to release the pedal from braking, going back to its initial brake position. If the driver brakes manually without the system was being triggered, the chain will only loosen without interfering with any of the motors, sprockets and the driver's foot.



(a) Hardware and connections of the set-up

(b) Side view perspective of the brake set-up

Figure 2. Brake pedal set-up diagrams and illustrations

C. *Drowsiness detection framework*

Drowsiness detection seeks to capture the facial data of the driver to extract the eye region from the face for the drowsiness detection algorithm to trigger the automatic braking mechanism. The system performs capturing of the input images to compute the EAR (Eye Aspect Ratio). Calculating the number of frames of the data where the eyes of the driver are closed was the basis of the analysis. In this study, as shown in figure 3, the significant components in the framework were discussed.

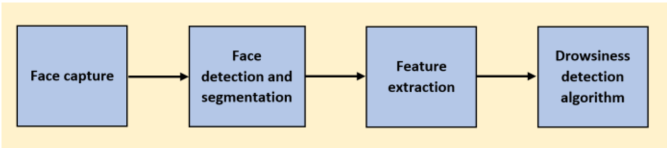


Figure 3. Drowsiness detection framework

1)Face capture

Capturing the video in real-time and monitoring a stream of faces and eyes uses a high-resolution 1080p web camera. The web camera also equips an image capture with low noise, low crosstalk, high level of sensitivity and must be located between 40 to 50 centimeters away from the driver. The distance given is roughly equal to the gap between the steering wheel of the car and the driver's seat. The web camera is angled 45 degrees away from the face of the driver. To capture a picture of the driver's face, the angle should be between 35 and 50 degrees. The eye is supposed to be a plane at 90 degrees to the camera's optical axis, which extracts the photo eye of the frame's middle proportion.

2)Face detection and segmentation

After capturing the image, the first stage of the algorithm is detecting the face image of the driver, segmenting the face region, and excluding the background portion. After segmenting the face, the algorithm will determine the rate at which the eyelids blink by applying the technique of Haar Cascade to detect and recognize drowsiness.

To recognize human faces, the Haar Cascade technique, which in OpenCV makes use of shade and light patterns, is used. The eyes of the driver are shaded dark, while the bright hue is the nose. By scanning and studying the arrangement of the black and white picture, the technique takes out the information of the driver's face.

The proponents used OpenCV's Haar cascades to determine the facial's bounding box of (x, y)-coordinates. Applying the landmark predictor of DLIB to create an enclosing box of 68 major facial boundary points in locating the eyes, brows, mouth, jawline, and nose, as shown in figure 4 [16].

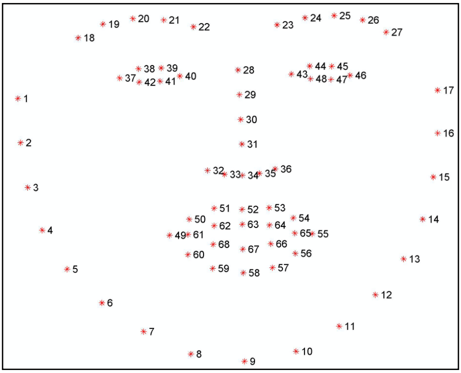


Figure 4. The DLIB facial landmarks with 68 points coordinate

The 68 points coordinate of landmarks in the human face are movable, allowing uncomplicated Python array segments to remove various structures of the face. The face landmarks, correlated with an eye, supplied the Eye Aspect Ratio (EAR) algorithm.

3) Feature extraction

After detecting and segmenting the face region, the system should catch the eye region. This region is the decision parameter to determine the drowsiness of the driver. When recognizing the eye state, if the eyes are closed within ten frames or 3 seconds, the Raspberry Pi sends the triggering data to the microprocessor, activating the brake pedal setup [17].

As shown in figure 5 [18], the eye is open, resulting in the eye aspect ratio remaining constant, then dropping rapidly to near zero, then rising once more, implying a blink has occurred. The system checks to see if the eye aspect ratio drops but does not rise again, indicating that the eyes of the driver have closed.

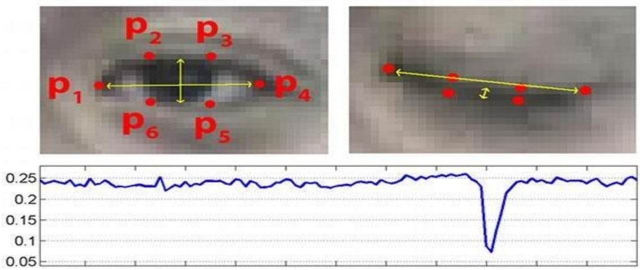


Figure 5. The eye landmarks visualization. On the top-left, the eye is wide open. On the top-right, the eye is closed. The bottom is where the eye aspect ratio is plotted over time. A blink is indicated by a decrease in the eye aspect ratio (Image credit: Soukupová and Čech).

4) Drowsiness detection algorithm

The main algorithm of the drowsiness detection is the EAR. As soon as the eye opens, the Eye Aspect Ratio is continuous, but when the eye is immediately closed, it quickly drops to 0. Equation 1 shows the formula for computing the Eye Aspect Ratio.

$$EAR = \frac{||P2 - P6|| + ||P3 - P5||}{2\,||P1 - P4||} \qquad \textbf{\textit{Eq. 1}}$$

Where P1, …, P6 are 2D facial landmark locations.

If the ratio drops below 0.2 within 30 frames (approximately 4 seconds), the algorithm acknowledges that the eyes are closed, but if the ratio is above or maintained at 0.25 (or 0.3), both eyes are open. Once implemented, the system monitors the closing of the eyes through the eye aspect ratio to raise the alarm and sends a trigger to the motor driver to activate the brake pedal setup.

D. Collision avoidance block diagram

Collision avoidance is used for measuring the distance between the car and the object in front of the car's bumper, alarming the driver via buzzer noise, and for triggering the brake setup to avoid a collision. As shown in figure 6 in this study, the significant components in the block diagram were discussed.

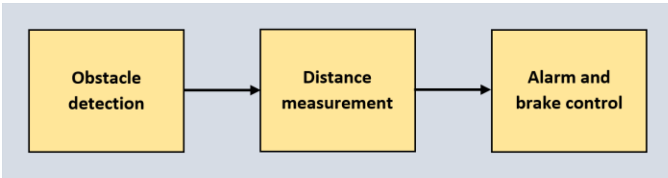


Figure 6. Collision avoidance block diagram

1) Obstacle detection

This system uses an ultrasonic distance sensor. The procedure starts with the sensor installed in the front bumper detecting an object in front of the car. The ultrasonic sensor URM06-UART SEN150 has a detection from short-range to long-range. The sensor is housed in a compact, durable PVC housing and is compatible with 35-millimeter electrical pipe mounting. It has a UART interface and produces a lot of acoustic power. Aside from ranging from 20-centimeter to 1000-centimeter object detection, the ultrasonic sensor provides extensive information with 1-centimeter resolution. Figure 7 [19], the URM06 has 15 degrees (left or right) beam angle, which has excellent receive sensitivity.

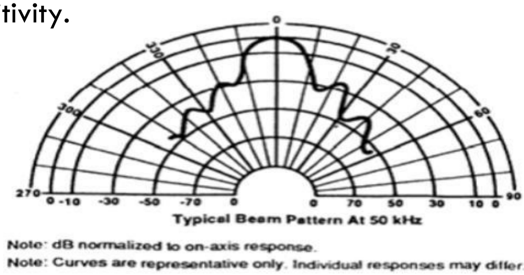


Figure 7. URM06-UART accuracy in beam pattern at 50kHz

Ultrasonic pulses are emitted by the sensor, calculating the sensor's distance from the thing targeted by the time the ultrasonic vibration hits the object and returns to the transducer.

2) Distance measurement

After detecting an obstacle less than 7 meters in front of the vehicle, the sensor sends data to the microcontroller and alarms the buzzer. The frequency converted by the sensor forms the data. When an object approaches, the frequency reflected in the form of an echo. Calculating the time between the sound wave and the echo received determines the distance. Electrical signals are converted into 49.5 kHz ultrasonic sound pulses by the transmitter. The transmitted pulses are then listened to by the receiver. To determine the pulse's distance travelled, the sensor's receiver must receive the transmitted pulses and produce an output pulse.

When a transmitted pulse with a duration of at least ten µS (microseconds) is given to the Tx pin, as shown in figure 8 [20], in return for that, the sensor sends out an eight-pulse sonic burst at 49.5 kHz. The device's unique "ultrasonic signature" of the 8-pulse way allows the receiver to separate the transmitted pattern of the ambient ultrasonic noise. At a distance from the transmitter, the eight pulses of ultrasonic move through the air.

Also shown in figure 8, the Rx pin also switches to HIGH, forming from the beginning of the echo-back signa. Assuming those transmitted pulses do not return, pause after 38 ms (milliseconds) of the echo signal and go back to low. Therefore, a pulse of 38 ms indicates no blockage or hindrance inside the sensor's range. As the signal is received and reflects the vibrations, the Tx pin switches to low. Producing a pulse with a width ranging between 150 to 25 mS (microseconds) receives a call reliant on time.

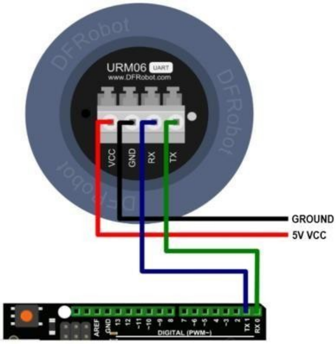


Figure 8. URM06-UART pin configuration with Arduino Uno

3) *Alarm and brake control*

The anti-collision alarm will activate if the ultrasonic distance sensor detects an object less than 10 meters in front of the car. If the vehicle is less than 7 meters from the thing ahead, the brake pedal setup will activate and slows the car until it stops. Whichever comes first, the drowsiness detection or the anti-collision system can start the brake pedal setup. The microcontroller triggers the buzzer to produce loud pulsive beeps as a warning alarm for the driver in a possible collision situation. To stop the warning buzzer from starting, the driver must slow down or reverse the car to increase the distance between the vehicle and the object.

RESULTS AND DISCUSSION

The proponents developed an anti-sleep alarm and prompter system for drowsy drivers. The researchers designed a safety brake pedal mechanism that can pull the physical brake pedal of the car to its full brake position. This section covers the discussion of the creation and testing of the prototype, the materials used in the overall system, the obstacle detection, and the image recognition algorithm.

To monitor the driver's alertness, the researchers developed a facial recognition and drowsiness detection system using an image processing approach. Using a high-resolution 1080p web camera to watch the stream of the driver's face. The researchers installed a touchscreen user interface located at the infotainment area of the car, as shown in Figure 9. This interface helps the driver monitor the system in real-time.

Figure 9. User Interface of the system inside the car

A touchscreen user interface, a Raspberry Pi microprocessor, an Arduino Uno microcontroller, and two (2) Cytron motor drivers are placed in the infotainment area of the car as shown in Figure 10. This area serves as the brainpower of the overall system where the operation of the anti-sleep alarm and prompter system integrates the image processing and obstacle detection.

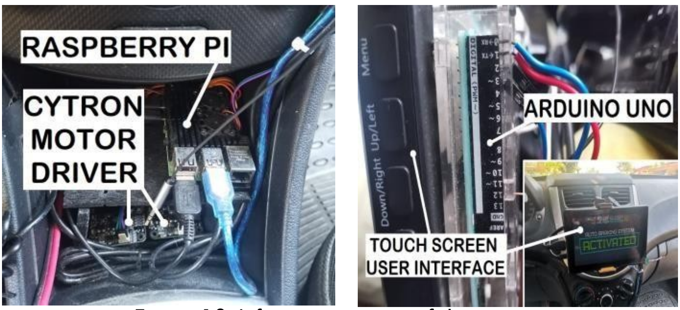
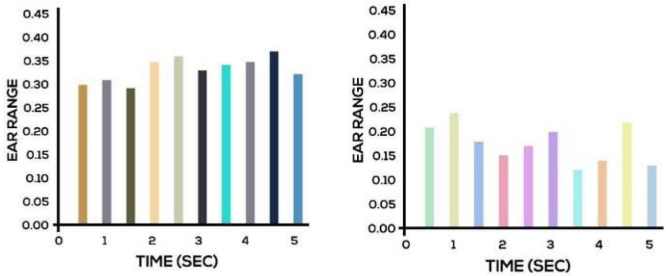


Figure 10. Infotainment area of the car

Upon recognizing the driver's face, the eye region was digitally extracted by applying the facial landmark detection. After the eye region was separated, the Raspberry Pi module computes the Eye Aspect Ratio (EAR) values to determine whether the eyes were opened or closed. Figure 11 shows the plotted EAR values.



(a) EAR mapped when eyes are opened

(b) EAR mapped when eyes are closed

Figure 11. Open and close EAR plot values

Figures 12 to 14 are the line graphs that show the actual testing results during the three (3) test drives. The area above the red dashed line in the chart triggers the automatic braking system. Voice alarm and the automated braking system were activated when the system detected that the eyes were closed for more than 3 seconds above the EAR trigger value of 0.30. As shown in Figure 12, during 12 to 15 seconds in the testing process activates the automatic braking system. The sudden drop of the orange line indicated that the camera had stopped capturing the driver's face. This prevented the camera from capturing the driver's sleepy eyes multiple times after activating the system.

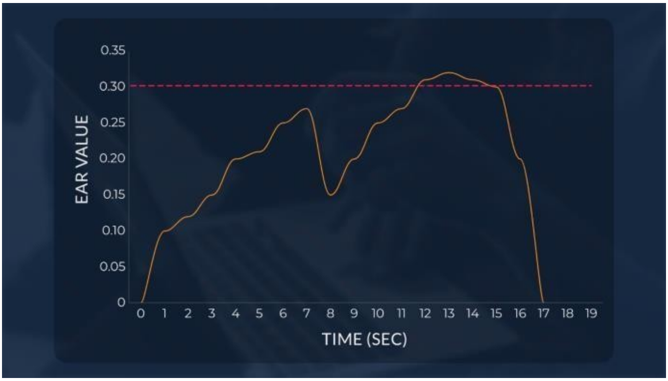


Figure 12. Line graph result from test 1

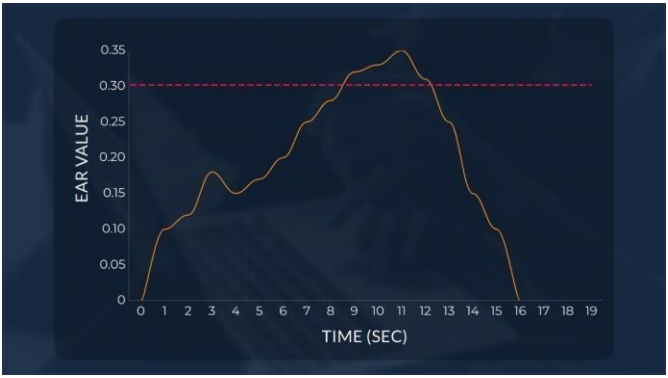


Figure 13. Line graph result from test 2

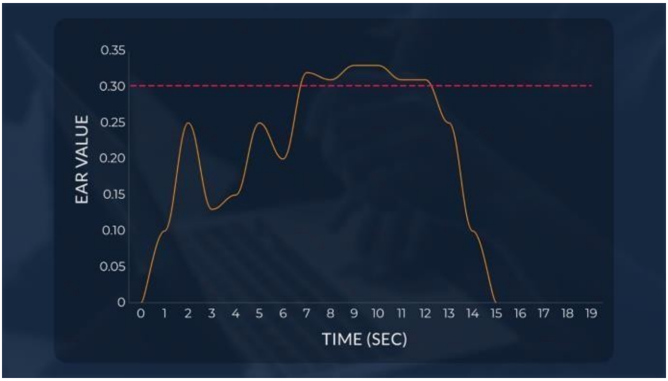


Figure 14. Line graph result from test 3

Figure 15 shows the actual mechanical prototype of the brake pedal set-up. The seven (7) major components in the prototype were labeled as follows: (M1) Drowsiness detection power window motor, (M2) Anti-collision power window motor, (S1) Large sprocket – left, (S2) Large sprocket – right, (S3) Small sprocket – left, (S4) Small sprocket – right, and the (BC) bicycle chain. Every power window motor has a high-voltage H-bridge motor driver that controls the turning of the sprocket in the prototype. The S1 sprocket was welded in the M1 motor, while the S2 sprocket was welded in the M2 motor.

The M1 and M2 motors were used to rotate the S1 and S2 sprockets to pull the physical brake pedal of the car using the BC. There are two (2) short BCs used in the prototype. The first BC was welded on the S1 sprocket then connected to the physical brake pedal of the car. The second BC was welded on the S2 sprocket then connected also to the physical brake pedal of the vehicle. The S3 and S4 sprockets, below the S1 and S2 sprockets, were used as chain guides for the precision and stability of the BC. An external car battery source hidden below the driver's seat supplies the mechanical prototype's power.

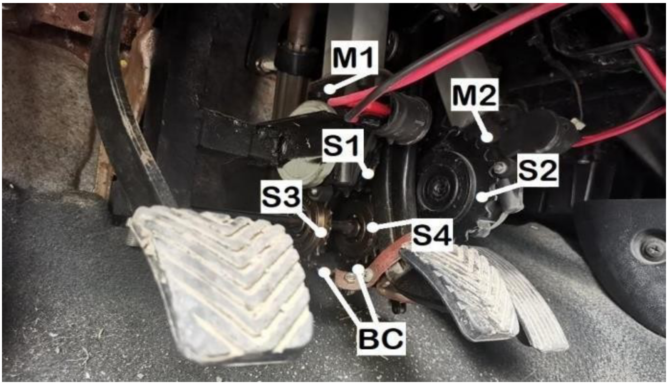


Figure 15. Safety brake pedal set-up prototype

The anti-collision prompter system consisted of hardware and software. Obstacle detection used an ultrasonic sensor within 10 meters or less. The sensor was placed in front of the car with a metal bracket bolted and the car's front plate number, as shown in Figure 16.

Figure 16. The ultrasonic sensor with metal bracket installed at the front bumper

The Arduino Uno microcontroller and an Arduino code handled the software part of the system. When the sensor detected an obstacle within 7 meters in front of the car, the sensor sent trigger data to the microcontroller to activate the braking system. Figures 17 to 20 are trial run results for five kph, ten kph, fifteen kph, and twenty kph car speeds. Between 10 to 5 meters from the obstacle, activates the automatic braking system, as shown in figures 17 to 19. The gradual drop of the colored lines indicated that the car decelerated until it completely stopped.

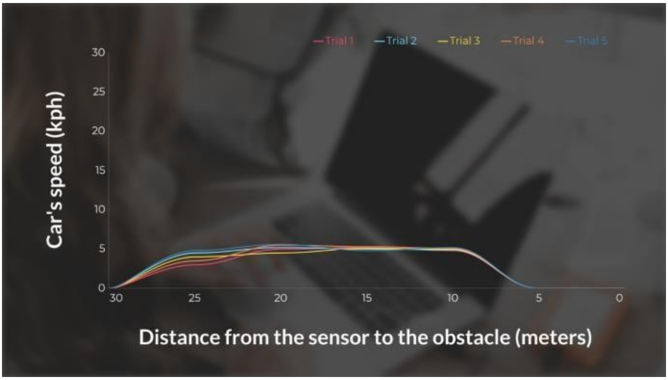


Figure 17. Line graph results in 5kph test drives

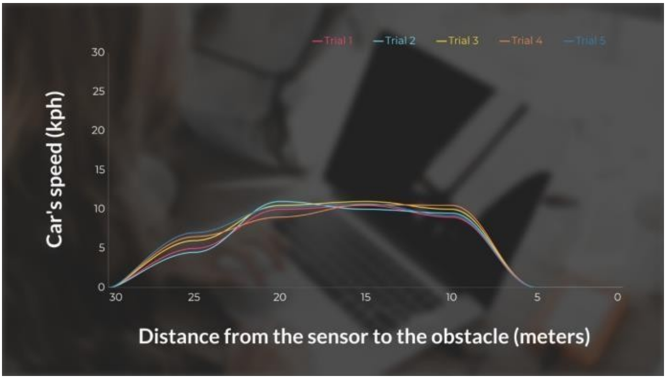


Figure 18. Line graph results in 10kph test drives

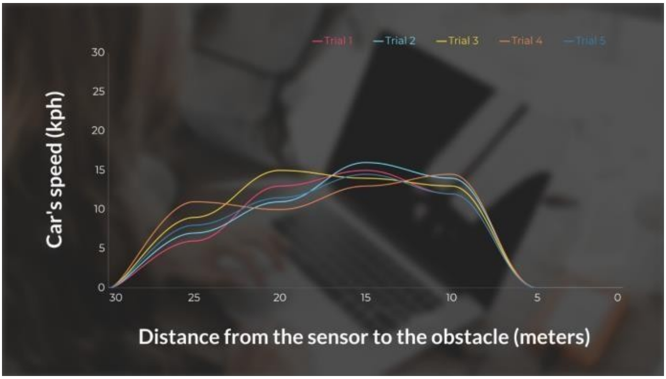


Figure 19. Line graph results in 15kph test drives

With the car's increased speed, and with the system suddenly pulling the brake pedal at a top position when sensing an obstacle within a preset distance, the car is immediately forced to stop, resulting in a sudden drop in speed, evident in the steep colored lines as shown in Figure 20, from 10 meters to 5 meters. The proponents observed the car without an anti-lock braking system (ABS) installed, the vehicle skidded and left a little trail of tire markings on the road when immediately forced to brake at a speed of 20 kph.

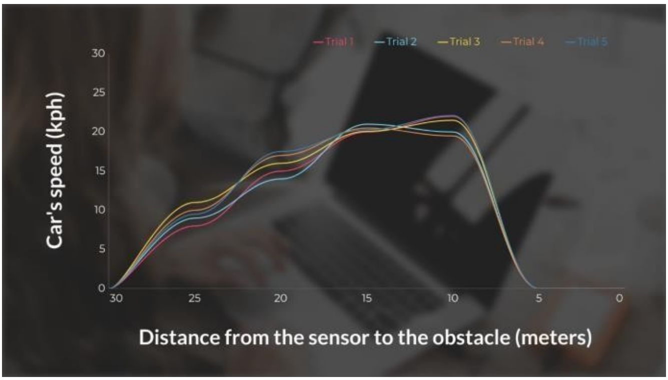


Figure 20. Line graph results in 20kph test drives

The researchers developed a drowsiness detection system and forward collision avoidance system. The system used an image processing technique and a high-definition web camera for drowsiness detection, while for the anti-collision, an ultrasonic sensor employed an obstacle detection technique. Based on the results conducted by the proponents for the drowsiness detection system, the automatic braking system was activated when the eyes were closed above the 0.30 EAR trigger value for more than 3 seconds. For the forward collision avoidance system, based on the test drives conducted by the researchers, the automatic braking system was activated 10 to 5 meters from the obstacle at a car speed of 5kph to 20kph. The proponents concluded that the car, without an ABS installed, skidded on the sudden pulling of the brake pedal with increased rates beyond 15kph. The car also left a trail of tire markings on the road. The proponents also concluded that the mechanical prototype was a bulky mechanism and needed a heavy-duty car battery as a power source. For future works, to prevent the wheels from locking up and sending the vehicle into a skid, it is recommended to use an alternative car with an ABS. Also, upgrading the mechanical prototype into an electronic prototype of the brake pedal setup is recommended which eliminates the physical sprockets, chains, and motors, as well as the necessity for an external car battery.

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