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Design of Real-Time Driver Drowsiness Detection Based Electromechanical Braking System for Heavy-Duty Vehicles

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Abstract - The increasing number of road accidents involving heavy vehicles due to driver drowsiness necessitates the development of advanced safety systems. This abstract presents a real-time driver-drowsiness-based electromechanical braking system designed specifically for heavy vehicles. The system uses a combination of sensors, including facial recognition cameras and fatigue monitoring sensors, to continuously monitor the driver's physiological and behavioral parameters. Machine learning algorithms analyze these data streams in real-time to identify signs of drowsiness, such as drooping eyelids, erratic steering behavior, and decreased responsiveness. Upon detecting drowsiness, the system triggers audible alerts, autonomous braking assistance, and remote monitoring and intervention. This method uses an electromechanical braking system to help stop the vehicle by determining the EAR (Eye Aspect Ratio) and LIP (Lip Aspect Ratio) using the haarcascade algorithm and Open CV. By integrating real-time drowsiness detection with proactive braking assistance, the proposed system aims to significantly reduce the risk of accidents caused by driver fatigue in heavy vehicles. When tiredness is identified, the project's implementation offers a possible way to improve road safety by warning drivers and activating braking devices.

Key Words: electromechanical braking system, facial recognition, Haarcascade algorithm, Open CV (Computer Vision), EAR (Eye Aspect Ratio), LIP (Lip Aspect Ratio).

1. INTRODUCTION

When it comes to heavy-duty truck safety, the possibility of driver fatigue puts passengers, cargo, and infrastructure integrity in danger. Acknowledging this, it becomes necessary to use cutting-edge technology to reduce any risks. This introduction describes the purpose and scope of developing an electromechanical braking system for heavy-duty trucks that is based on real-time driver sleepiness detection. Heavy-duty trucks require drivers to exercise more caution due to their size and load. Prolonged operation, however, can cause driver fatigue, which impairs response times and raises the risk of collisions. Although efficient, conventional braking systems are unable to anticipate situations involving fatigue. Creating a novel electromechanical braking system with real-time sleepiness detection is the main goal of this research project. In order to reduce accidents caused by careless driving and maintain control over vehicle speed to prevent property damage and loss, automatic braking systems are vehicle technologies that detect and prevent collisions by automatically applying brakes when sensing potential obstacles or hazards [7,9,10]. This technology utilizes cutting-edge sensor technologies and sophisticated algorithms to recognize indicators of driver fatigue and self-initiate brake actions to prevent accidents. By addressing driver weariness, the primary cause of accidents, the suggested solution has the potential to significantly improve the safety of heavy-duty vehicles. With the Arduino Uno serving as the central control system and microcontroller-based automated mechanisms, the advanced anti-collision system seeks to improve road safety through obstacle detection, automatic braking, and the reduction of collisions and related damages [6,8,10]. It reduces the danger of cargo damage and infrastructure integrity in addition to protecting people with an extra degree of security provided by real-time sleepiness detection and automated braking. In order to detect driver drowsiness, it presents a novel method that uses Long Short-Term Memory (LSTM) cells, including both 1-D LSTM (R-LSTM) and convolutional LSTM (C-LSTM), to model eye movements. The eye images from video frames are directly input into Recurrent Neural Networks (RNNs) without the need for a separate eye-tracking module [5].

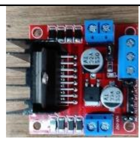
A work presents a novel approach to drowsiness detection (DD) that uses CNN architecture to process EEG signals [3]. It also uses an Emotiv EPOC+ headset to collect data, annotates EEG data for drowsiness detection using analysis of alpha and theta waves, studies electrode selection, suggests a seven-electrode system, and suggests integration with other physiological assessment tools for improved accuracy. Larger datasets collected in real-world driving scenarios will be used for validation [2,6,7,10]. A Naïve Bayes (NB) classifier analyses the final descriptor to identify tiredness in the driver drowsiness detection framework, which employs an enhanced technique with a Histogram of Oriented Gradient (HOG) descriptor to enhance detection accuracy [1,2,7,9,10]. A paper we investigated the accuracy of drowsiness detection, along with the optimization of algorithms and utilization of ensemble machine learning. To discuss the implementation of the classification system, we also evaluated the performance of classification not only using full hybrid measures (vehicle-based, behavioral, and physiological measures) but also using hybrid measures without physiological measures, as these are considered more difficult to implement than other measures [4].

The creation of the electromechanical braking system requires a multifaceted strategy that takes into account mechanical design concerns, data processing algorithms, and sensor integration. By utilizing the latest developments in computer vision, machine learning, and vehicle dynamics, the system will be able to quickly and correctly identify faint indications of driver fatigue and apply the brakes. The goal of this project is to create a proof-of-concept prototype for an electromechanical braking system for heavy-duty trucks that detects driver fatigue in real time. A study suggests an algorithm for detecting drowsiness based on heart rate variability (HRV) analysis, which eliminates the need for specialized devices installed in vehicles. It is then validated by comparing the results with sleep scoring based on electroencephalography (EEG), tracking changes in sleep quality that impact HRV using eight HRV features, and multivariate statistical process control [3]. Although the first implementation could focus on particular car types or operating situations, the main objective is to create a framework that is scalable and adjustable to different fleet needs and legal constraints. To sum up, the development of an electromechanical braking system that detects driver fatigue in real time is a proactive measure to improve the safety of heavy-duty vehicles. Through the use of creativity and the incorporation of advanced technologies, this endeavor seeks to redefine the standards of operational excellence and accident prevention in the realm of commercial transportation. The sleepiness detection system used in the current situation is intended to generate notifications in the form of buzzers. Our design of the buzzer alarm system, which we integrated with the electromechanical braking system for the driver drowsiness selection, was based on this technology.

2. Design of driver drowsiness detection based on electromechanical braking system

We began the fabrication of the prototype by using the following components mentioned below: First, we have taken a wooden board and made connections between the components, such as the NodeMCU, Li-Po batteries, buzzer, L298 driver motor, switch, and DC motor. The wheel is placed at a certain level from the base of the wooden plate to attain stability. The winding terminals are connected to the DC motor to provide power and control for the wheel. The batteries are provided to run the system during implementation. By using a serial cable, we established communication between the laptop and the prototype.

Table -1: *List of Components*

S.NO	COMPONENTS	PICTURE
1.	DC MOTOR	
2.	WHEEL	
3.	L298 MOTOR DRIVER	
4.	LITHIUM BATTERIES	
5.	NODEMCU	
6.	BUZZER	
7.	SWITCH	
8.	SERIAL CABLE	
9.	BATTERY CHARGER	

2.1 METHODOLOGY

First, facial landmark detection is used to localize the face in the picture. Next, the eye and lip characteristics of the face are detected using shape prediction techniques. OpenCV is integrated with pre-trained HAAR cascades to perform face detection. The second phase involves pre-training a facial landmark detector to determine the position of 68 (x, y) coordinates that map to face structures. In order to calculate the EAR for drowsiness detection, the ratio of the distances between the horizontal and vertical ocular landmarks (surface centres) is used. The distance between the upper and lower lips will be used to calculate a YAWN value, which will then be compared to a threshold value in order to detect yawns. When a driver feels tired or yawns, the text-to-speech synthesizer, or eSpeak module, is employed to provide the relevant voice alerts. Connecting the laptop and prototype via a serial cable is the first step. When the camera detects drowsiness, the NodeMCU gets signals from it via a serial connection. The NodeMCU sends electrical impulses to the driving motor and buzzer, telling them to stop the engine. If the camera notices that the driver is simply yawning, it will inform them verbally. Electrical impulses are transmitted to the voice alarm, buzzer, driving motor, and NodeMCU via NodeMCU when the camera detects an eye closure. When the driving motor receives signals, it stops the DC motor's electrical supply and turns off the engine of the vehicle.

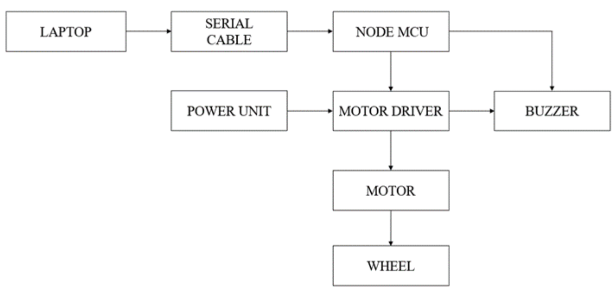


Fig -1: *Block Diagram*

2.2 EXPERIMENTATION RESULT AND DISCUSSION

Firstly, the operation begins by turning on the switch and running the code on our laptop to detect the drowsiness. If drowsiness is detected, it alerts the driver through a voice alert and sends instructions to the NodeMCU through the serial cable. The NodeMCU receives the instructions and sends the signals to the driver motor and buzzer. The driver motor stops sending the electrical supply to the DC motor in order to stop the wheels in the vehicle. The vehicle doesn't start until it is again started by the driver. If the driver only yawns for a prolonged time, it alerts the driver only through a verbal alert, and there is no stoppage of the wheels.

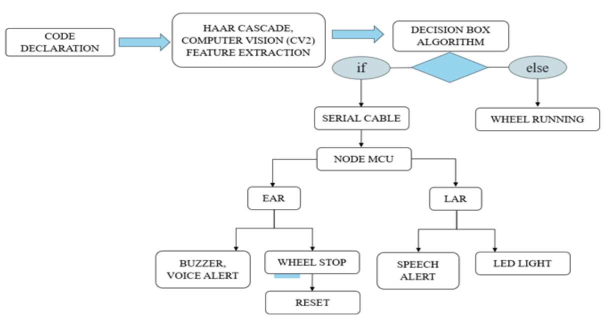


Fig -2: *Flow Chart*

2.2.1 CALCULATIONS

To calculate the Eye Aspect Ratio (EAR) and Lip Aspect Ratio (LAR).

The facial landmarks are detected using the haarcascade and OpenCV algorithms. They locate key points that include eyes (e.g., corners, center) and lips. Once we have the co-ordinates we can calculate EAR and LAR.

P1, P4: Topmost and Bottommost point of the eye
P2, P5: Inner and Outer of the eye
P3, P6: Midpoint of the upper and lower eye lid
||P1-P4||: Vertical distance between top and bottom eyelids
||P2-P6||: Horizontal distance between the corners of the eye
||P3-P5||: Vertical distance between the inner and outer corners of the eye

(Threshold value in between 0.2 to 0.3)

$$EAR = ||P2-P6||+||P3-P5||/2.||P1-P4||$$

Table -2: *Observations of EAR*

S.NO	EAR	Drowsiness detection
1	1.33	Yes
2	0.816	Yes
3	0.15	No

P1: Left corner of the lip
P2: Right corner of the lip
P3: Upper lip center
P4: Lower lip center
P5: Left point on the upper lip
P6: Right point on the upper lip

Table -3: *Observations for LAR*

S.NO	LAR	Voice Alert
1	0.54	Yes
2	0.08	No
3	0.25	Yes

$$LAR=||P2-P6||+||P3-P5||/2\times||P1-P4||$$

$V = r\omega$

$\omega = 2\pi N/60$

$d_1 = u\times t_1$

$v = u+at_2$

$d_2 = ut_2 + 1/2at_2^2$

Total distance = $d_1 + d_2$

Table -4: *Observations for wheel*

S No.	Velocity (kmph)	Time taken from initial point (sec)		t=t_2-t_1 (sec)	Acceleration (m/s^2)	Total displacement(m)
		t_1	t_2			
1	60	3.43	5	1.57	-10.57	70
2	80	3.43	5	1.57	-14.14	93.56
3	100	3.43	5	1.57	-17.64	116.74

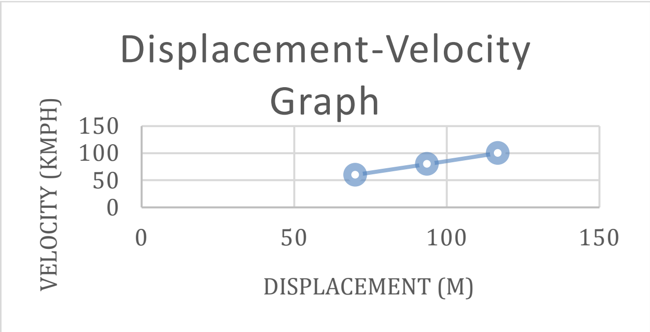


Fig -3: *Displacement-Velocity Graph of the wheel*

The calculations are performed to find the ratios of eyes and lips to detect the drowsiness level and also to find the displacement of the wheels when they are traveling at certain velocities by calculating the acceleration and time taken to give alert when the eye blinks and the wheel is stopped from the initial point.

3. CONCLUSION

The project aimed to develop a drowsiness detection and automatic braking system to improve driver safety. It used Haar cascade classifiers in OpenCV to accurately detect facial features and eye movements, enabling reliable monitoring of driver drowsiness. The system integrated computer vision techniques with an automated braking system, enhancing road safety. Real-time analysis of driver behavior allowed the system to intervene when signs of drowsiness were detected, mitigating the risk of accidents caused by fatigue-induced impairment. This integration of cutting-edge technology is a significant step forward in automotive safety systems, potentially saving lives and preventing collisions on the road. The project achieved its objectives and has the potential to significantly reduce accidents caused by drowsy driving. Future enhancements could include integrating additional sensors for improved accuracy and incorporating machine learning algorithms for advanced drowsiness detection capabilities. Overall, the project represents a significant step forward in intelligent systems for improving road safety.

3.1 FUTURE SCOPE

One of the model's future implications is to integrate Advanced Driver Assistance Systems (ADAS) technology, such as automatic emergency braking, collision avoidance, and lane departure warning, to improve driver safety. Putting money into new infrastructure and putting V2X communication technologies in place improves driver safety. Drowsiness detection systems for drivers will be made possible by enhanced sensor technology, additional AI integration, and machine learning methods.

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