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Fatigue Prevention System

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***Abstract*—Fatigue is a prevalent problem in various sectors such as transport and healthcare, affecting safety, performance, and decision-making. This project advocates for an integrated system to prevent, detect, and counter fatigue risks in real time, utilizing technology to maximize awareness and enhance personal and industrial performance.**

The suggested fatigue prevention system(FPS) actively increases road safety through ongoing monitoring of the driver's physiological and behavioral indicators. A pulse band measures heart rate, and a camera observes eye movements to detect signs of drowsiness such as extended eye closure and excessive blinking. Upon detection of fatigue, information is sent to the Engine Control Unit (ECU), which engages a multilevel alert system—visual signals, an audio alarm, and flashing lights. In case the driver is not responsive, the ECU safely slows down the car to 5 km/sec without sudden braking.The system is easy to use, with an HCI optimized for human performance that has been tested for usability. The user-friendly software enables fast reaction to notifications. With the incorporation of heart rate and eye-tracking information, this real-time intervention system prevents fatigue-related accidents considerably, making early detection of drowsiness of drivers and prevents the fatigue accidents overall.

Index Terms—Fatigue Detection,Driver Monitoring System (DMS),Human-Computer Interaction (HCI),Real-Time Monitoring,Automotive Safety,Physiological Signal Processing,Pulse Rate Monitoring,Eye-Tracking Technology and Machine Learning in Safety Systems

I. INTRODUCTION

The drowsiness might also additionally ultimate for a couple of minutes however it's consequences can be disastrous. The main cause of sleepiness is typically exhaustion, which reduces alertness and attention, although other causes include lack of concentration, medications, sleep issues, drinking alcohol, or shift work. They are unable to predict when sleep may strike. Even though falling asleep while driving is dangerous, being tired makes it difficult to drive safely even when you are awake. One in twenty drivers is said to have fallen asleep behind the wheel. The most at risk for tired driving is truck and bus drivers with commutes of 10 to 12 hours. Driving a long distance while sleep deprived might make you drowsy, as can driving when you need to sleep.

According to National Highway Traffic Safety Administration (NHTSA), the police and hospital reports identified that 100,000 car accidents and over 1,500 deaths were caused due to drowsiness of drivers each year. Drowsy driving is thought to be responsible for approximately 1,550 fatalities, 71,000 injuries, and 12.5 billion in financial losses. A sleepy driver was a factor in 697 fatalities in 2019. NHTSA acknowledges that it is challenging to quantify the precise number of accidents, or fatalities caused by drowsy driving and that the reported figures are underestimates. Fortunately, Recognizing the complexities inherent to fatigue, the development of a comprehensive FPS emerges as a critical strategy to promote employee well-being and operational efficiency. The FPS is envisioned as a multi-faceted framework that encompasses awareness,assessment,intervention,and continuous monitoring of fatigue levels.The FPS will utilize evidence-based assessment tools to measure both subjective and objective indicators of fatigue,enabling organizations to tailor interventions.

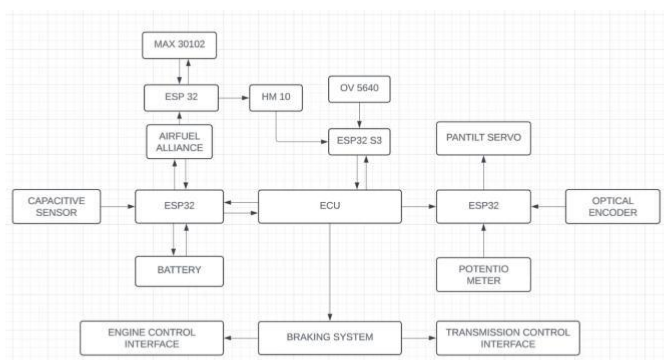

Fig. 1. Block Diagram of FPS.

Figure 1 presents an efficient system that is applicable for automotive use, primarily operated by an ECU that takes in data from several sensors and feeds the outputs to an actuator. There are multiple data streams produced by the ESP32 microcontroller, one of which would be for the integration of MAX30102 sensor to monitor physiological signals such as heart rate and blood oxygen levels, monitoring vital signs of health. There is a connection to an OV5640 camera module via an ESP32 S3 bridge to intake visual data for recognition or surveillance. A wireless power transfer module is added -

called Airfuel Alliance. This increases the general mobility and versatility of this system. HM 10 It can connect to external devices and even apps on the phone via Bluetooth. An independent battery block addresses power needs for mobility. Again, another ESP32 drives a servo with an optical encoder for precise movement, which is very useful for dynamic applications such as camera positioning or robotic arms. A po-tentiometer allows for variable resistance, hence the user input for dynamic settings. The engine control unit interfaces with the braking system for the real-time monitoring and control of vehicle performance and related transmission functions-that is, sophisticated integration of technology in advanced monitoring and automation.

II. LITERATURE REVIEW

Drowsy driving is one of the common causes of fatalities in vehicle accidents. Truck drivers that travel for lengthy periods of time (especially at night), long-distance bus drivers, and overnight vehicle drivers are more vulnerable to this condition. Passengers in every country face the nightmare of drowsy drivers. Fatigue-related traffic accidents result in a substantial number of injuries and deaths each year. As a result, due to its wide practical application, detecting and indicating driver drowsiness is a hot topic of research. In general, there are three sorts of approaches for detecting drowsy drivers: vehicle-based, behavioral-based, and physiological based. A number of parameters such as steering wheel movement, accelerator or brake pattern,6 vehicle speed, lateral acceleration, deviations from lane position, and so on are continuously monitored in the vehicle-based method. Driver drowsiness is defined as the detection of any abnormal change in these parameters. Non intrusive driver tiredness detection uses cameras to analyze behaviors like blinking, yawning, and head movement and National databases such as NHTSA reports for statistics on drowsy driving accidents.[1]. As per study in 2004 the findings of study demonstrate that, like with automobile incidents, the risk of a TWMV driver causing a collision is substantially impacted by various individual factors. When speeding vi-olations were taken into account as a driver-dependent risk factor, our findings revealed that driving at an improperspeed for the road or traffic conditions was the strongest predictor of the probability of causing an accident for both mopeds and motorcycles. There was also a significant link between excessive speed and the chance of causing a collision, but to a smaller amount. The disparity in estimates for the two primary categories of speed-related offences is understandable, as excess speed refers to exceeding the legal speed limit, which moped and motorbike drivers, to a lesser extent, rarely do [15].Image processing, EEG, vehicular, and voice metrics are among the approaches used in the system. Any of these ap-proaches isn't guaranteed to yield 100 percent outcomes.EEG-based techniques yield the best results, but they're also the most obtrusive. Other procedures, however, have limits that prevent them from producing faultless outcomes [2].As per neural network based technique it is concluded that according to the circumstances, several strategies will be appropriate. Although EEG-based approaches are effective, wearing elec-trodes while driving is not practical. The technique based on Artificial Neural Networks is straightforward, however if you want a better outcome, 3 neurons are the best option. One of the most popular methods used by researchers is image processing. These are the methods. These methods are far more straightforward and user-friendly. This is complicated by the driver's spectacles, although research is underway to minimise this disadvantage. As a result, employing image processing to detect fatigue has great potential [7]. Several factors, including age of the driver, marital status, annual mileage, number of daily trips and ordinary and aggressive infractions, were found to affect accident participation in the study [14].

III. WORKING ALGORITHM

The proposed solution works to address driver fatigue and drowsiness is an advanced FPS that offers a proactive, real-time approach to improving road safety.It uses a camera and a pulseband to continuously track the driver's heart rate and eye movement's. Here we are going to arrange a seperate compartment for the pluseband aside of gear box and the charging of the pluse band is wireless. If the person changes the seat postion then it get detected by the optical encoder and the optical encoder passes the information about the angle/degrees changed to the pantilt servo then the pantilt servo changes accordingly and alligns the seat to the camera to detect the driver facial expression's .Camera monitors the driver's eye movements to detect signs of drowsiness, such as prolonged eye closure, frequent blinking When drowsiness is detected through a combination of heart rate and eye movement data, the system sends this information to the vehicle's ECU.The camera captures 3 images per second and after every 2 minutes the captured images gets deleted. The proposed solution takes 4 seconds for fatique detection as 1.5 seconds for image caputuring and 1.5 seconds for detecting the drowsiness and 1 second for passing the signals(alerts the driver via a visual display(pop up messages), sound alarm, and flashing parking lights. When the HR and the eyemovements for dwrosy driving is detected then the ECU activates a multi-level warning system that alerts the driver via a visual display(pop up messages), sound alarm, and flashing parking lights for two times If the driver fails to respond, the system automatically slows the car down to a safe speed of 5 km/sec, ensuring the vehicle remains under control without abrupt or dangerous movements. The wearing of pulseband is mandatory at the night time from 8PM - 6AM and if the vehcile speed is above 80km even in the day time the driver should wear the the pluse band if the driver doesn't wear the pulse band the car does not start .Here the capacitive sensor detects the pulse band and gives the information to wear it .The system is designed to be user-friendly, with optimized HCI.It has undergone usability testing to ensure the interface is simple, efficient, and easy to use. The software is intuitive, allowing drivers to understand and respond to alerts quickly. By combining data from both the heart rate monitor and the eye-tracking camera, the system accurately detects drowsiness in real-time and intervenes. This innovative solution effectively reduces the risk of accidents related to driver fatigue. The Figure 2

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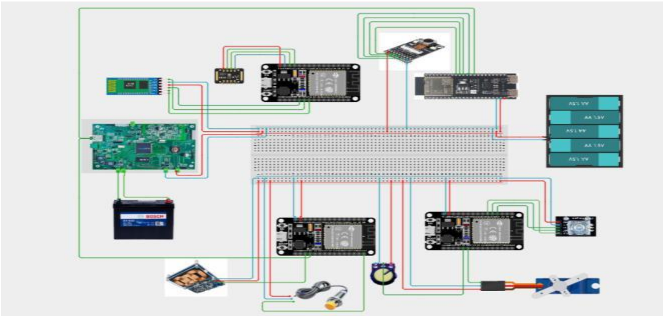

Fig. 2. Circuit Diagram of FPS.

illustrates a complex system with many interconnects, color-coded for ease of identification. The green wires supply all the major components with power from the battery, along with the ECU and ESP32 microcontroller's. Red wires highlight the connections which indicate interaction with each ESP32 unit and sensor such as the MAX 30102 used for monitoring heart rate and oxygen saturation levels and the OV 5640 camera for capturing video data. Connects blue-coloured wires to HM 10 Bluetooth Module that allows for wireless communication with external devices. In addition, green-colored connect capacitive sensor for touch inputs i.e to detect the pulseband in the compartment and potentiometer for variable resistive inputs are connected through green-color wires. Red wires connect a servo motor that is powered by one of the units to control its position to send feedback to an optical encoder.

IV. RESEARCH METHODOLOGIES

Sensor-Based Data Collection. In order to accurately mea-sure fatigue, a multi-sensor framework is employed.[12] Heart Rate Monitoring: A pulse sensor continuously measures HR and abnormal patterns associated with fatigue. Eye-Tracking Technology: A camera-based system evaluates blink rate, eye closure length, and movement of the eyes to recognize signs of drowsiness.[10]

Accelerometer & Gyroscope Sensors: In order to measure micro-sleep behavior and head movements.[13]

Data Acquisition Process: The participants (drivers) are observed under experimental conditions (day/night simula-tion tests).Information is gathered from several sensors and synchronized for real-time processing. Physiological readings are measured as a baseline for comparison with fatigue-induced changes.Real-Time Integration with Engine Control Unit (ECU) The system transmits fatigue detection signals to the vehicle's ECU. Based on the severity of drowsiness, a multi-level warning system is activated.[5] Visual Alert (Dashboard display).

Audio Alarm (Beeping sound).

Flash Parking Lights (External notification).

Vehicle Speed Control (Gradually slows down to 5 km/sec if no response).

V. DATA ANALYSIS AND RESULTS

Figure 3 shows the data of FPS where it finds important applications in industry, especially in transportation, logistics, and public security. In India, where the use of self-driving cars is prohibited, FPS becomes critical in making drivers safer. From data analysis, driver sleepiness accounts for most of the road accidents involving passengers as well as fleet owners. Using FPS in commercial vehicles decreases the number of accidents due to driver fatigue, streamlines fleet operations, and facilitates real-time driver tracking. Besides, it increases passenger safety in public transport, maximizes driver schedules, and reduces insurance risks. The findings indicate market potential for FPS in India and the world at large, in line with smart automotive technologies.

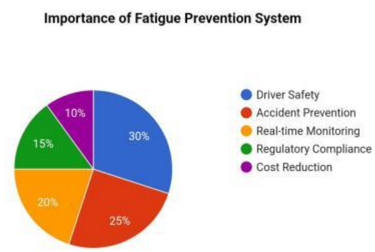

Fig. 3. Industrial applications

Figure 4 illustrates the present study, healthy subjects who were preparing for a long-distance journey were monitored with a 24-hour Holter device. Six volunteers participated, and the average driving time was 297.7 ± 111 minutes. The average driving time of sleepiness was noted as 27 ± 24.5 minutes.

An upward trend of more HR on driving compared with average daytime HR was noted, increasing from 85 ± 5.6 to 89.8 ± 5.6 beats per minute (7percentage rise, P = 0.093). On the other hand, when feeling drowsy, the mean HR fell significantly to 81.5 ± 9.2 beats per minute, showing a fall of 9.3percentage ± 7.4percentage (P = 0.046). This initial study is the first to demonstrate that HR falls when drivers feel drowsy.Identification of driving while drowsy is important in order to avoid accidents, especially over long distances on boring roads. Driving while drowsy is a significant threat, which can result in severe crashes, injuries, and deaths not only to the driver and occupants but also to other people on the road.[3]

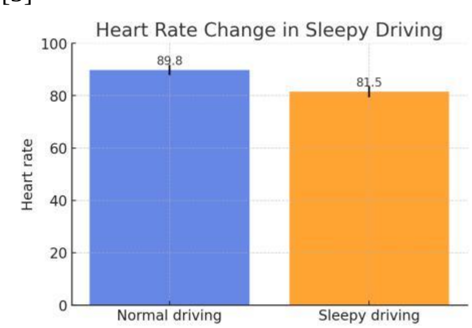

Fig. 4. graph on Heart rate versus normal sleepy driving

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Figure 5 shows the clear source on four healthy male subjects, with a mean age of 39.5 ± 5.6 years (median: 39.5, IQR: 9), volunteered for a study while getting ready for a long drive. Their mean driving time was 297.7 ± 111 minutes, with a median of 280.5 minutes (IQR: 151), mostly on an expressway. They described themselves as feeling sleepy around 2 ± 1 hours into their journey, with mean and median duration of sleepiness being 27 ± 24.5 and 26.5 minutes (IQR: 48), respectively.

An elevated HR was noted during driving, increasing from a total journey HR of 80 ± 4.7 beats per minute to 89.8 ± 5.6 beats per minute—a 12.6percentage increase (P = 0.028, Wilcoxon signed-rank test). In addition, the driving HR had a tendency to increase from the mean daytime HR of 85 ± 5.6 beats per minute (7percentage increase), but this was not statistically significant (P = 0.093, Wilcoxon signed-rank test). During sleepier driving, the mean HR decreased significantly by 9.3percentage ± 7.4percentage, from 89.8 ± 5.6 beats per minute to 81.5 ± 9.2 beats per minute.

No	Age (yr)	Gender	Driving Time (mi)	Sleepy Driving Time (min)	Mean HR / Max HR	Day Time Mean Driving Mean HR	Sleepy Driving Mean HR	Sitting in Passenger Seat Mean HR	Night Sleeping Time Mean HR	Night Sleeping Time Mean HR (beat/min)
1	45	Men	298	50	80/56/114	80	94	76	NA	70
2	30	Men	500	43	74/41/130	82	95	76	NA	61
3	45	Men	263	10	78/53/108	78	84	79	73	67
4	41	Men	180	2	77/56/117	82	92	84	NA	64

Fig. 5. experimental results

The figure 6 shows the results of clear pulse wave signal that can be obtained by the HRV frequency domain of subject's heart rate time series the LF/HF ratio. The LF/HF ratio shows in Figure 6 decreased as the drivers went from the state of being awake to being drowsy. So a number of road accidents could be avoided if an alert is sent to a driver who seems to be getting drowsy while driving.[9]

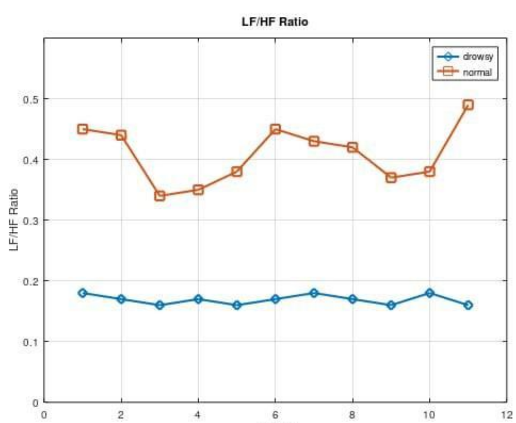

Fig. 6. Heart rate versus time in seconds

VI. CONCLUSION

In conclusion, the FPS represents a pivotal advancement in vehicle safety technology, serving as a vital tool in preventing injuries and fatalities resulting from drowsy driving incidents. Early detection and timely alerts are essential in averting potential accidents and saving lives on the road. The proposed system utilizes image processing techniques, detection of the pluse by plusemeter, to gauge the level of driver drowsiness. By establishing a camera and plusemeter the value indicative of drowsiness, the system can effectively identify and alert drivers to mitigate the risk of accidents. Currently, the detection system demonstrates consistent performance in identifying driver drowsiness with minimal limitations. The Fatigue Prevention System functions reliably, providing timely alerts to drivers, thereby reducing the incidents of accidents caused by drowsy driving.

In summary, the ongoing evolution of drowsiness detection technology holds immense promise in enhancing road safety and reducing the toll of accidents attributed to driver fatigue. By leveraging advanced image processing techniques, detection of pluse and incorporating adaptive alarm systems, future iterations of the driver drowsiness detection system will further bolster vehicle safety standards, ultimately saving lives and preserving well-being on our roads.

VII. FUTURE SCOPE

This feature enhancement proposal aims to integrate advanced sensory technologies into modern automobiles for improved safety, comfort, and driver assistance:

1.Brain Wave Sensors: Monitor drivers' cognitive states (e.g., fatigue, distraction) in real-time,alerting them to take breaks or switch to autonomous driving mode if needed.[4]

2.Heart Rate sensor: Continuously tracks the driver's heart rate to detect irregular patterns that may signal stress or medical emergencies, automatically notifying emergency services if necessary.[4]

3.Infrared Camera: Enhances night vision and visibility in adverse weather conditions by detecting heat signatures, improving safety for both pedestrians and drivers.[6]

4.Advanced Driver Assistance Systems (ADAS): are technolo-gies in cars designed to enhance vehicles safety and improve the driving experience by automating and augmenting certain tasks. These systems rely on sensors, cameras, radar, and software to monitor the environment around the vehicle and assist the driver in various ways.[8]

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