Kufa Journal of Engineering
Vol. 16, No. 1, January 2025, P.P. 26-42
Article history: Received 15 March 2024, last revised 23 May 2024, accepted 7 June 2024

A NEW INTELLIGENT DRIVER VIGILANCE SYSTEM DESIGN USING TILT SENSORS

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https://doi.org/10.30572/2018/KJE/160103

ABSTRACT

A significant number of causes for people killed by automobile accidents on both public and interior roads are the driver's failure to pay attention to the roadway, as well as other factors such as tiredness, sleep during driving, using the phone, or even the driver being intoxicated, etc. This work aims to identify sleepy status, pinpoint the onset of sleep, and alert the driver when their level of alertness drops below a level that does not improve productivity or the vehicle's overall safety protocols to prevent drowsiness-related crashes. In this article, we present a new method for implementing drowsiness detection inexpensively, using a Raspberry Pi as a central processor board that connects all practical measurement components. In addition, the proposed method includes the following activities: tracking the driver's head vibration while driving using tilt sensors. Moreover, a camera was mounted in front of the driver to take photos and record videos of the driver's health. As a result, the results were entirely satisfactory, and if the driver was operating the vehicle while fatigued, the response was 95% reliable and fast.

KEYWORDS

Raspberry Pi, Tilt Sensor, Tilt Detection Techniques, NHTSA, USB Web Camera, Mini Piezo Buzzer, SD Card, Angles Tilt Algorithms, Driver Vigilance System.

1. INTRODUCTION

A major issue for society is the rise in auto accidents brought on by drivers' lowered levels of alertness (Ali & Muttair, 2023; Chen et al., 2022). Reliability for fatigued drivers is estimated to be a factor in between 10% and 20% of all motor vehicle accidents in Europe (Tonni et al., 2021; Muttair et al., 2022). The transportation reports that driver overstrain accounts for about 60% of fatal car accidents (Tamanani et al., 2021; Al-Asadi et al., 2022) and it is the primary cause of big truck accidents (Zolnercikova et al., 2021). The National Highway Traffic Safety Administration (NHTSA) in the United States estimates that sleeping behind the wheel causes at least 100,000 car accidents per year (Linnebur et al., 2019). Each year, these collisions result in 40,000 non-fatal accidents and 1550 fatalities on average (Arefnezhad et al., 2022). Only collisions involving a single vehicle that happened between 6 and 12 a.m. are included in these statistics (Zihui et al., 2022).

Moreover, a sober driver drives alone in a car, which includes pulling off the road without attempting to avoid an accident (Lawlor, 2022). These statistics understate the full extent of drowsiness contribution since they exclude daytime collisions involving numerous cars, intoxication, passengers, or aggressive maneuvers (Zhu et al., 2022; Muttair et al., 2022). It is believed that distracted driving causes more accidents than it does, but these statistics do not address this matter (DeLucia et al., 2022). As automakers incorporate cutting-edge car technology to meet consumers' increasing demand for a world with wireless connections, the cognitive load on drivers rises (Hancock et al., 2020). In other words, there are more distractions from the primary task of operating the car when there are additional assistance systems for communication, comfort, or navigation (Calvert et al., 2020).

In light of this, it is crucial to create systems that can track a driver's state of alertness and warn them when they are not paying enough attention to the roadway to prevent collisions (Bhuiyan et al., 2022). This study suggests a novel method for monitoring driver inattention that concentrates on the tiredness or sleepiness classification category. We will employ driver tiredness warning systems in certain situations to inform the driver when their level of awareness is insufficient to ensure the safety and reliability of the vehicle. While it is possible to use the device that way, the purpose of the device is not to help the driver stay awake while driving for long periods. Rather, the gadget should temporarily raise the driver's awareness to avoid a collision.

In addition, driver tiredness warning systems have the potential to improve traffic safety dramatically. However, effective implementation is affected not just by technological advancements, but also by many institutional and social contexts (Körber et al., 2015).

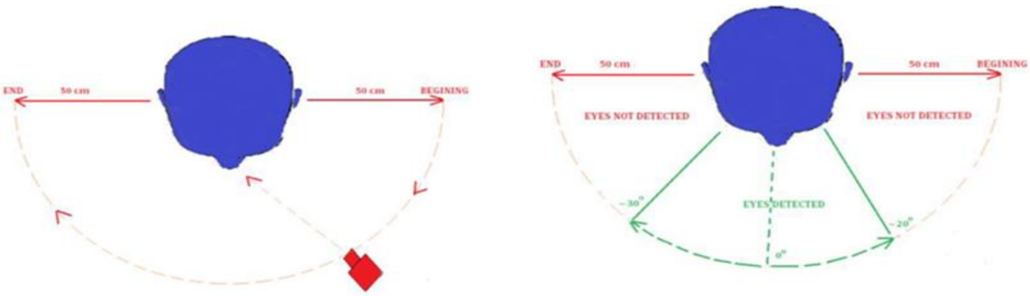
Moreover, driver impairment caused by tiredness or other periods of inattention is something that driver alertness monitors try to identify. The impaired condition may be brought on by sleepiness, weariness, lack of sleep, or even medicine, drug use, alcohol misuse, naturally occurring stresses, and environmental variables (Muttair & Mosleh, 2023).

This mechanism is a byproduct of the sleep-wake cycles that make up the typical human biological rhythm. Both homeostatic and biological variables influence the snooze cycle. Homeostasis has to do with the neurobiological requirement for sleep. The longer the period of alertness, the more pressure there is to go to bed, and the harder it is to fight the urge. A biological clock known as a "synchronous pacemaker" repeats a cycle approximately once each day (Muttair & Mosleh, 2023; Wörle et al., 2020).

The remaining sections are presented in the following order: Section 2 will provide a detailed presentation of the features of detection and extraction techniques. In Section 3, the basic hardware components proposed in this study will be presented. In Section 4, the proposed mechanisms of action scenarios will be presented in detail. In Section 5, the results will be presented and discussed. In Section 6, the conclusions will present the ideas presented in this paper with a brief overview of future work.

2. DETECTION AND EXTRACTION TECHNIQUES FEATURES

In general, any system intended to detect, identify, and track the motion of an item of interest across time must be able to do so. In computer vision systems, the phases of tracking and detection are predicated on building models that characterize the object of interest and extracting meaningful properties from the input of pixel data (Wörle et al., 2020; Muttair et al., 2022). Driver drowsiness detection (DDD) systems are designed to evaluate a driver's level of sleepiness by examining various facial features, specifically focusing on the head, face, and eyes, as illustrated in Figs. 1 (a) and (b). The popular features of the face and the corresponding feature extraction methods are described in the following paragraphs (Al Redhaei et al., 2022).



(a) (b)

Fig. 1. Restrictions of changing the attitudes of angles for the human head (a) setup of the tests and (b) the result of the change in the face angles range.

In addition, light intensity differentiation occurs when a face is represented in grayscale. It may be a collection of bright and dark parts, with the eyes often being significantly darker than the cheeks and nose and the bridges of the nose being lighter (Muttair et al., 2022; Al Redhaei et al., 2022). Assuming all those regions are just simple rectangles with either light or dark values, we can explain each using thirty haar-like characteristics. Simply put, the darkening rectangle sits on top of the lighter one when seeing the eyes and cheeks as two rectangles are vertically next to each other (Al Redhaei et al., 2022). In the second scenario, three horizontally adjacent rectangles were desired, two of which would be dark for both eyes as shown in Fig. 2, and one light for the middle nose (Muttair et al., 2022). Thus, the face can be represented by a unique arrangement of bright and dark rectangles. To find the best matching of rectangular patterns, algorithms that use haar-like characteristics scan the entire image (Al Redhaei et al., 2022; Muttair et al., 2022).

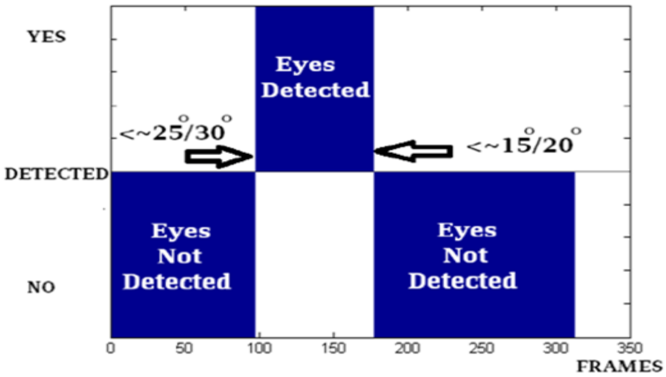


Fig. 2. Consistency results for human eye contouring.

3. PROPOSED HARDWARE COMPONENTS

This section will introduce the proposed hardware components for the work presented in this paper. In addition to the traits and significance of every element in the design and implementation.

3.1. Raspberry Pi (Model B)

The Raspberry Pi is a simple computer board that was created to support and help with the teaching of computers and programming. It is also a great point to start creating projects for the Internet of Things (IoT). The Raspberry Pi is a plug-and-play, inexpensive board with many connectivity options. It is also a perfect experimental instrument, whether you want to use it as a computer, entertainment center, server, or home security and monitoring system. As a result,

Fig. 3 (Vappangi et al., 2022) displays all the justifications and characteristics that set the Raspberry Pi (Model B) piece apart.

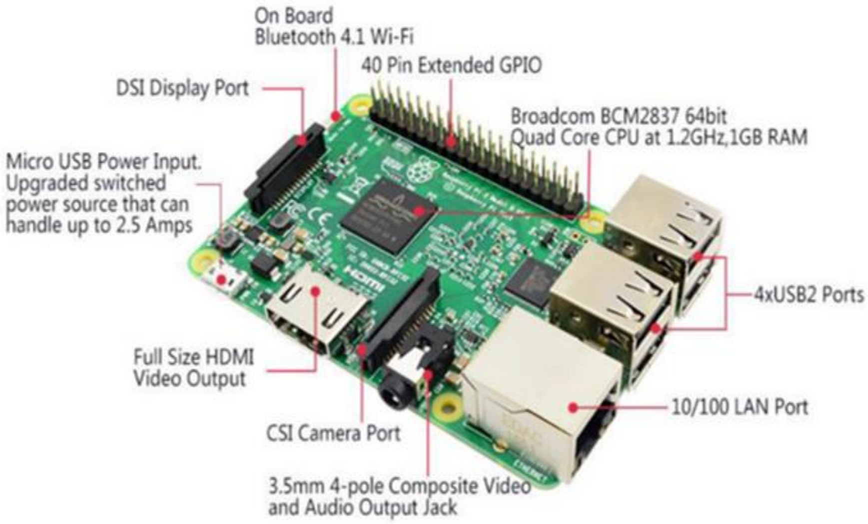


Fig. 3. Description of pins in the Raspberry Pi 3 (Model B) board (Vappangi et al., 2022)

3.2. Tilt Sensor

Tilt sensors are useful in various applications, including smartphones, drones, gaming systems, and more. Useful experiments were conducted with the SW520D tilt sensor. The SW520D is a standard ball-tilt switch consisting of two conducting electrodes and a metal ball, as shown in Fig. 4 (Łuczak et al., 2022).

Fig. 4. Tilt sensor.

To start the circuit, the tilt-ball switch moves at various degrees of inclination. The tilt module's D0 will produce a low level whenever the SW520D tilt switch is vertical, which will cause the metal ball to meet the conductive electrode and open the circuit. When a tilt is applied to the tilt switch, this will result in the signal indicators turning on, as illustrated in Fig. 5. The signal indication turns off when a metal ball touches a conducting electrode, breaking the circuit and causing D0 of the tilt module to output at a high level. The module's principal diagram for the SW520D tilt sensor is represented in Fig. 6 (Łuczak et al., 2022).

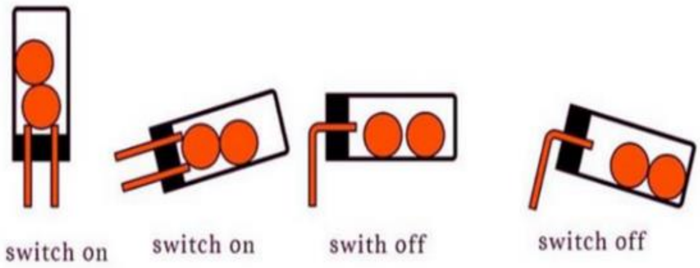


Fig. 5. Schematic for the SW520D tilt sensor

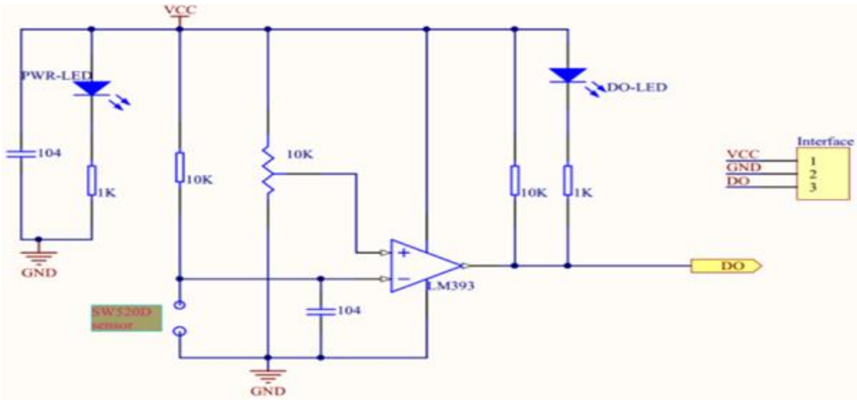


Fig. 6. The internal principal diagram of the SW520D tilt sensor (Łuczak et al., 2022)

3.3. Mini Piezo Buzzer

The buzzer doesn't need an alternating current (AC) signal like a standard piezo does. The driving circuitry and a piezo element are both located within, causing it to vibrate at a frequency of 2 kHz. The pin spacing of the piezo buzzer is suitable for 5 V TTL logic and is conducive to breadboard use. It features a built-in driving circuit of its own, as shown in Fig. 7. It has modest current requirements utilized in the manufacture of products like computers, alarm clocks, pagers, etc. (Zulkifli & Nasir, 2021).

Fig. 7. Mini Piezo Buzzer is operated from 3 to 5 V using DC (Zulkifli & Nasir, 2021)

3.4. Web Camera

A camera is an instrument used to see objects that record or capture pictures that can be kept locally, sent to another place, or both. The photos might be single still pictures or groups of pictures that make up films or movies. The camera is indeed a remote-sensed device because it detects objects without coming into contact (Dabre & Dholay, 2014). A Logitech USB-type camera was used to carry out the idea presented in this research paper, as Fig. 8 illustrates.

Fig. 8. USB Web Camera (Dabre & Dholay, 2014)**.**

3.5. Storage Capacity

A Secure Digital (SD) card is a compact flash memory card created for high-capacity memory and a variety of portable devices, including personal computers, digital cameras, media players, cellphones, PDAs, digital video recorders, and automobile navigation systems. Therefore, the minimum suggested SD card size for the Raspberry Pi is 8 GB as shown in Fig. 9 (Long, 2022).

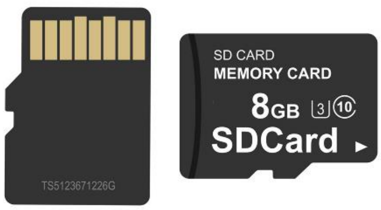


Fig. 9. The SD card has 8GB used to implement the proposed idea design.

4. PROPOSED WORK MECHANISM

In this section, the diagram circuit scenario of the method proposed in this paper will be presented in addition to presenting the installation scenarios to someone to test its performance and efficiency in practice.

4.1. Structure Diagram for Proposed Idea

The structural diagram of the hardware components proposed in the project is shown in Fig. 10. So, the main controller of this project is Raspberry Pi. The project objectives and work mechanisms have been achieved in terms of providing sensors to determine and monitor the inclination of the driver's head when driving the vehicle.

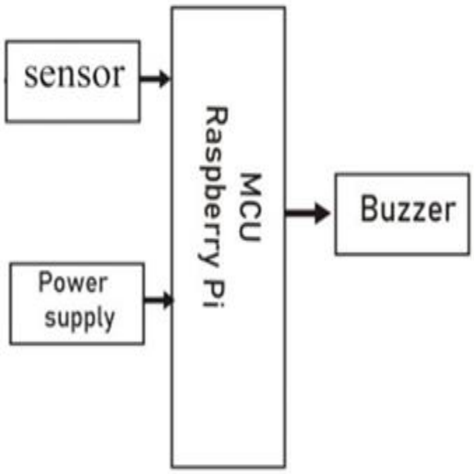


Fig. 10. The structure diagram for the proposed project system.

4.2. Project Installation Scenarios Stages

When a driver is sleeping while operating a vehicle, this will modify the head's angle up, down, or to the side. As a result, the sensor will activate the alarm, which guarantees that such a driver is not paying attention to the roadway he is traveling on. Due to the risks and consequences associated with driving while sleepy, this work was developed to help people become familiar with the Raspberry Pi programming environment and libraries. The practical implementation stage of the proposed idea is divided into the following three stages:

First stage: the driver installs the sensor while driving using a plastic strap. Usually, the measurements remain unchanged if the driver's head is not oblique as shown in Fig. 11.

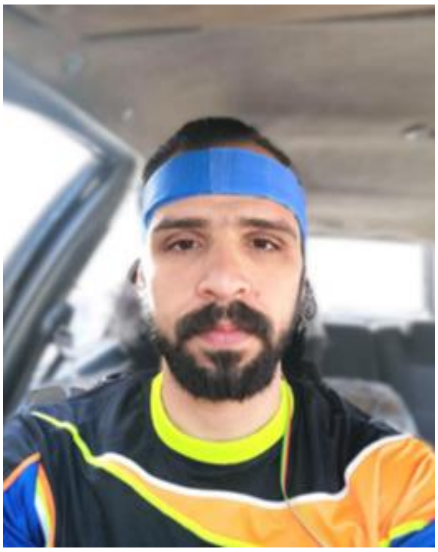


Fig. 11. Installing the sensors attached to the plastic belt on the driver's head.

Second stage: The camera must be positioned in the driver's front, near the speed panel as shown in Fig.12, to view the state of the driver's face, display the findings on the screen, and monitor the driver during driving.

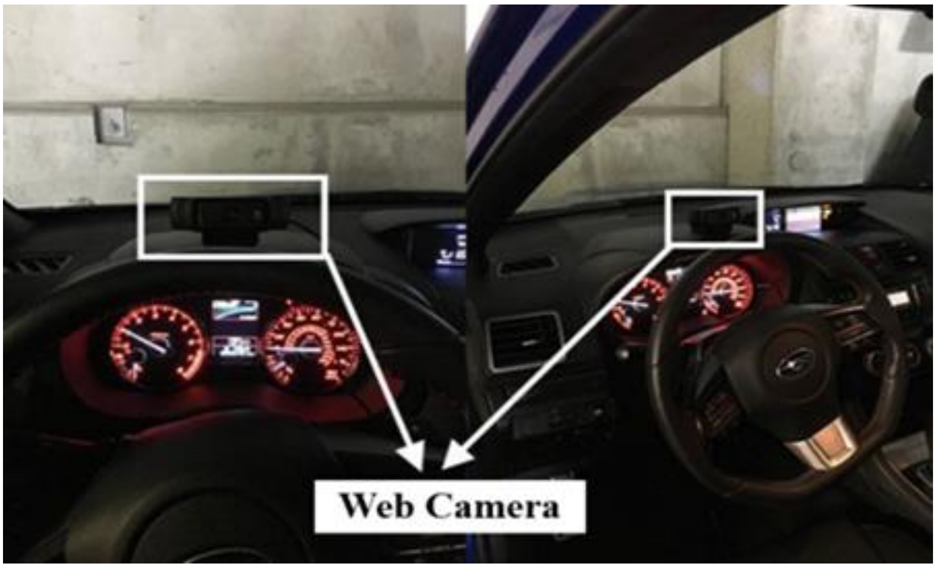


Fig. 12. Installing a camera near the dashboard to monitor driver status.

Third stage: when riding in a car, we try to tilt the head while driving to test the sensing system and display an alarm to return the driver to its usual position, as shown in Fig. 13.

Fig. 13. Head tilt down to detect sensor response.

The project's success was confirmed when the camera captured the driver's face. The sensor was also able to detect the driver's head tilt by adjusting the head angle downward, upward, and to the sides so that the response speed reached 95%. So, the flowchart for implementing the stages of the idea proposed in this article to alert drivers is shown in Fig. 14.

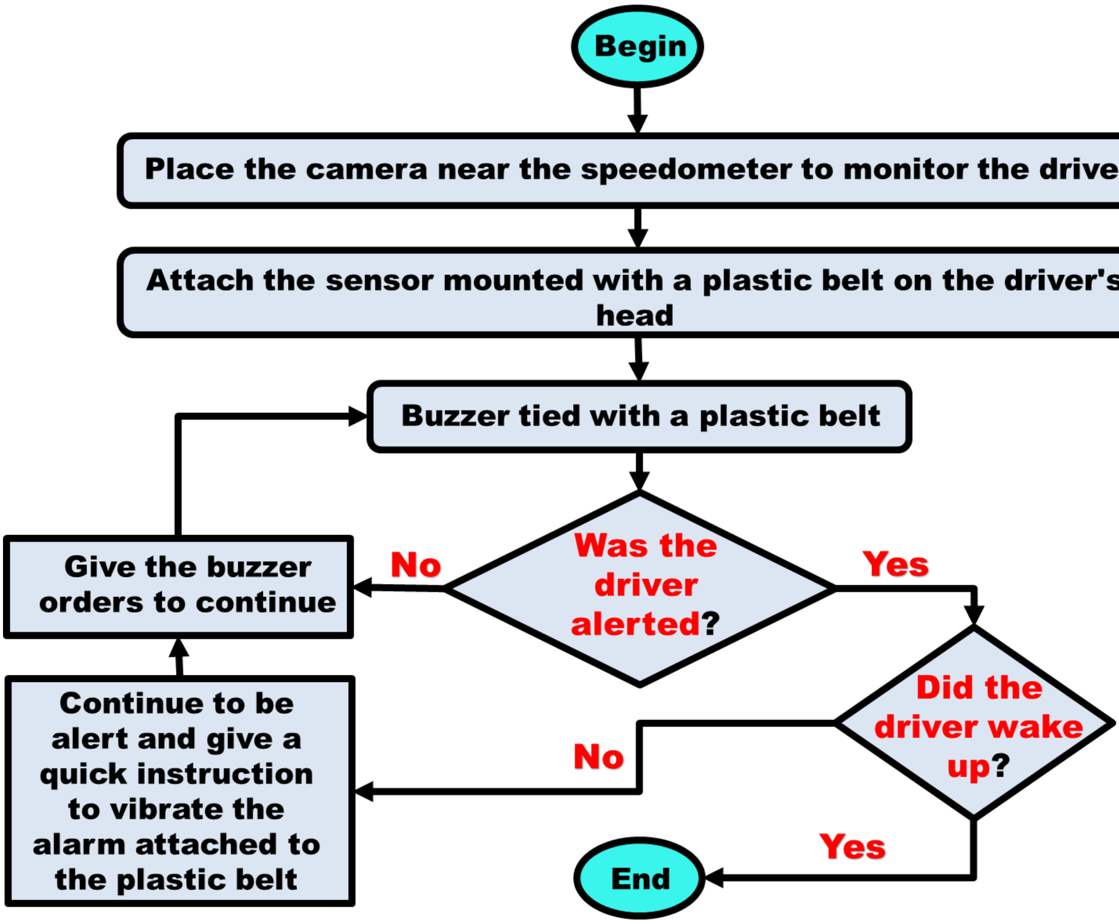


Fig. 14. Flowchart for the implementation of the proposed stages to alert drivers.

5. RESULTS DISCUSSION

The design and implementation of a driver drowsiness detection system using an innovative combination of technologies is presented. The practical experience we had earlier and watching the modifications the driver made to his or her facial tilting allowed the results to become evident. The camera's function is to monitor those changes and display them on the screen when the sensor detects a change in the driver's head angle as a result of tilting. This action helps prevent accidents by alerting the driver and allowing the sensor to return to its usual position. The sensor functions by monitoring changes in the tilt angle, and because it is fastened to the head, any change in the tilt angle results in a severe departure of the head to the bottom, right, as well as left as shown in Figs. 15 (a) and (b).

All measurements were evaluated, and the head tilting was effectively recognized, followed by the camera shooting these variables to monitor the driver's health while driving. After that, it is deemed a typical flash and is executed, with the sensor sounding loud to inform the driver. The project's success was validated when the sensor was able to recognize the driver's head tilt by adjusting the angle of the head down up and to the sides as shown in Figs. 13 and 15. So, the response speed reached 95% and this response is considered good, especially in practical aspects, and is also considered better when compared with the works presented by previous authors. Furthermore, the driver operates the vehicle in a naturally occurring manner. It moves, adjusting the mirror and his seat, and he turns to face the other passengers. As illustrated in Fig. 16, we aim to determine the volume and reliability of false positives in the basis detection algorithm. It exhibits fairly good consistency, except for a single spike that lasts for a single frame and this spike is a true positive.

(a) **(b)**

Fig. 15. Head tilt at different angles (a) head tilt to the right and (b) head tilt to the left.

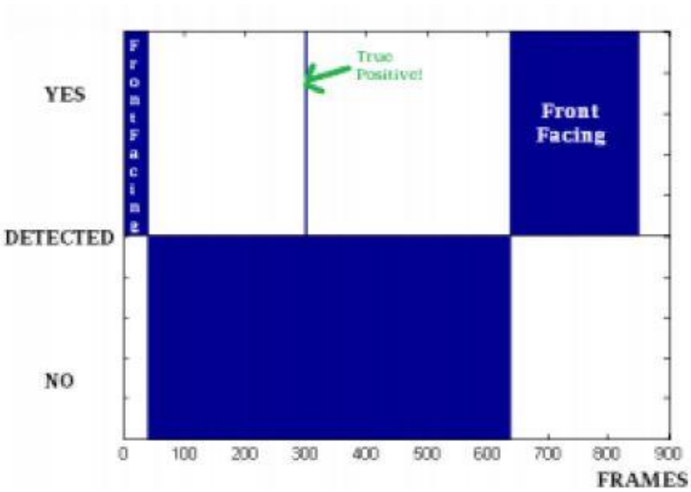


Fig. 16. Real test results to monitor driver status.

Table 1 compares the works presented in previous articles with the work proposed in this article. This comparison focused on the most important parameters and metrics distinguishing the difference between the proposed modern works.

Table 1. A comparison between the research papers written by other authors and the work suggested in this paper.

References	Sensors	Scope	Response Accuracy (%)
(Misbhauddin et al., 2019)	E4 wristband	This study covers methods based on neuroimaging technology to monitor the state of vehicle drivers.	80
(Cardone et al., 2021)	Thermal camera	The paper discusses commercial options based on the vehicle driver's and behavioral characteristics.	56
(Kajiwara, 2021)	Visible-light and thermal cameras	The study covers the features of vehicle driver status monitoring based on computing architectures.	90
(Tashakori et al., 2022)	Thermal camera	This study examines how drivers respond to various scenarios, including those with single and multimodal characteristics.	82
The work proposed in this article	Tilt sensors and web thermal camera	This article's study covers the most important methods adopted in modern technology to monitor the conditions of vehicle drivers when they face fatigue and stress when driving vehicles.	95

6. CONCLUSION

In this paper, we have cleverly combined some off-the-shelf algorithms with some novel approaches to describe designing and implementing a DDD system. This aims to identify the signs of drowsiness, pinpoint the point at which sleep begins, and alert the driver when alertness falls below the threshold necessary for the vehicle to be operated safely. This will help prevent accidents brought on by drowsiness, tiredness, sleep deprivation, medications, drug, and alcohol use, as well as environmental stresses and naturally occurring stresses. We concluded that when the alarm goes off, the driver is either asleep or not paying attention to the road, and the actual response speed reached 95%. The alarm sound wakes the driver up and gets his or her attention back, which helps to prevent accidents, lessen casualties, and save money on property damage. In future work, a project will be designed to detect eye drowsiness and provide an alarm or warning signal that may be audio or use other methods.

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