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The Design and Implementation of a Drowsiness Detection and Alarm System

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ABSTRACT: Drowsy driving poses a significant and increasing threat to road safety, leading to a high proportion of traffic accidents and substantial economic burdens. This paper presents the design and implementation of an innovative drowsiness detection and alarm system aimed at mitigating these risks. The proposed system employs a camera module for real-time facial monitoring and leverages an AI model, specifically Google's MediaPipe FaceLandmark, to analyze key indicators such as eye blink frequency, duration of eye closure, and head movements [2]. By integrating image preprocessing techniques like histogram equalization and a sophisticated drowsiness detection algorithm based on Eye Aspect Ratio (EAR) and head pose estimation, the system accurately identifies various states of driver drowsiness [1], [3]. Upon detection, it activates an audible alarm via a buzzer controlled by Raspberry Pi's GPIO pins, effectively alerting the driver. Experimental results demonstrate the system's efficacy in detecting all predefined drowsy states—frequent blinking, head nodding, head drooping, and prolonged eye closure—and triggering the alarm successfully within a vehicle environment. This technology offers diverse applications beyond driving, including industrial safety, academic efficiency, healthcare monitoring, and home safety, promising significant improvements in accident prevention, productivity, and overall quality of life [4], [5], [6], [7]. Future work will focus on algorithm refinement, testing in varied environments, and incorporating user feedback to enhance accuracy and user comfort [8], [9], [10].

KEYWORDS: Drowsiness Detection, Driver Safety, Real-time Monitoring

I. INTRODUCTION

The proportion of accidents occurring during road driving is increasing every year, with driver drowsiness leading to insufficient 前方視認 (forward visibility) being a major cause [2]. Drowsy driving is recognized as a significant factor in road safety issues, and the number of accidents caused by it shows an increasing trend annually. This study was therefore conducted with the goal of reducing accidents caused by drowsy driving.

The increase in fatalities due to drowsy driving persists despite a general decrease in the total number of road traffic fatalities. Drowsy driving has a higher fatality rate compared to other accident causes because it results from the inability to maintain forward visibility, thus reducing a driver's ability to react to accidents [3]. Furthermore, drowsy driving is considered a serious problem from the perspective of driver and public safety, especially for bus drivers and long-haul transport workers who are often required to drive for extended periods, putting them at a high risk of drowsy driving accidents. Such situations not only endanger drivers but also passengers and other road users. Given that these professionals frequently operate large vehicles, accidents can result in substantial human casualties. Moreover, accidents caused by drowsy driving also lead to significant insurance and economic costs, including medical expenses and insurance premiums, placing a considerable burden on individuals and society as a whole [4].

Against this background, this study aims to improve driver and public safety and reduce economic costs by researching the development and application of new technologies for preventing drowsy driving accidents [5]. Therefore, this research seeks to achieve these goals through the development of a more efficient and accurate drowsiness detection system. Under the aforementioned circumstances, this study intends to conduct research on the development and application of new technologies for preventing drowsy driving. The objective is to reduce the incidence of accidents caused by drowsy driving and, consequently, to mitigate the associated social and economic costs. Current automotive technologies that assist drivers in accident-prone situations include automatic emergency braking, forward collision avoidance, and lane-keeping assist systems. These technologies are significant in that they help compensate for the reduced reaction capabilities of drowsy drivers [6]. Our approach focuses on preventing drowsy driving by addressing the root cause of diminished reaction ability, aiming to develop a device that alerts users in advance and enhances their vigilance.

II. SYSTEM DESIGN

(1) Image Preprocessing

To ensure the system functions correctly under various lighting conditions encountered during driving, such as at night or in tunnels, images captured in real-time undergo histogram equalization using the OpenCV library. This process homogenizes the contrast distribution of the images, thereby improving the accuracy of facial recognition [7].

(2) Face Recognition and Landmark Extraction

For face recognition and landmark extraction, Google's MediaPipe FaceLandmark model was utilized. This model extracts 468 unique landmarks, offering higher accuracy compared to other models [2]. The model identifies faces and extracts landmarks from preprocessed images, thereby pinpointing key features like eyes and nose. These landmarks are then converted into coordinate values to detect behaviors such as blinking and head nodding.

(3) Drowsiness Detection Algorithm

Given that drowsiness detection is a critical safety matter, the system was designed to accurately detect drowsiness based on four conditions: frequent blinking, frequent head nodding, prolonged eye closure, and head drooping.

(3-1) Frequent Blinking and Eye Closure Detection

Both conditions primarily require the ability to detect eye blinks. The Eye Aspect Ratio (EAR) algorithm was employed to achieve this. The EAR algorithm measures the degree of eye openness by calculating the ratio of distances between various landmarks around the eye [1]. In accordance with the 468-point FaceLandmark Model, specific eye-region indices are designated. The calculated EAR value is then compared to a threshold for closed eyes. If the value falls below this threshold, a frame counter increases. Depending on the set range of the frame counter, the system determines whether the driver is blinking or keeping their eyes closed. For frequent blinking detection, after a blink is detected, the time until the next blink is measured. If this time interval is short and repeats frequently, it is identified as drowsiness. For eye closure detection, if the frame counter continues to increase beyond a set range, it is determined that the eyes are closed.

(3-2) Frequent Head Nodding and Head Drooping Detection

Both conditions also require the ability to detect head nods. Using the y-coordinate value of a central facial landmark, the system establishes an initial baseline head position from the first frame upon system activation. This serves as a reference for detecting head movements [3]. The system distinguishes between "head lowered" and "head raised" states. If the current head position exceeds the baseline by a certain threshold, a frame counter increases. If this counter surpasses a predefined value, it indicates that the head has been lowered, incrementing the 'head lowered' variable. Conversely, if the current head position falls below the threshold, the frame counter resets to zero. If the 'head lowered' variable is not zero at this point, it signifies that the head has been raised, incrementing the 'head raised' variable. Subsequently, if both variables are greater than zero, a head nod is detected, and both variables are reset to zero. For frequent head nodding detection, similar to frequent blinking, the system measures the time between consecutive head nods. If the interval is short and repeats often, it is identified as drowsiness. Similarly, for head drooping detection, if the frame counter continuously increases beyond a set range, it is determined that the head is drooping.

(4) Driver Drowsiness Warning

When drowsiness is detected based on the aforementioned conditions, a buzzer sensor connected via GPIO pins is activated to emit a loud sound, thereby warning the driver.

III. IMPLEMENTATION

Upon power connection, the video input from the camera lens undergoes preprocessing to facilitate recognition by the program. Subsequently, the preprocessed video is subjected to the drowsiness detection algorithm. If drowsiness is detected by the algorithm, the buzzer activates, providing an alert to the user.

Figure 1. If the driver bows their head for a certain period, an alarm sounds

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Figure 2. If the driver closes their eyes for a certain period, an alarm sounds.

As shown in Figure 1, if the driver bows their head for more than a certain period, a warning is issued. As shown in Figure 2, if the driver closes their eyes for more than a certain period, a warning is issued. Warnings are not issued for momentary nodding or brief eye closure.

Figure 3. The appearance of the drowsiness prevention device

Figure 4. The device installed in an actual car

Figure 5. The device issuing a warning to an actual driver.

IV. CONCLUSION

In-vehicle drowsiness detection systems operate by continuously monitoring a driver's face and blinking patterns, activating an alarm when drowsiness is detected to rouse the driver. This significantly helps prevent traffic accidents and enhances road safety.

In industrial settings, especially for workers operating heavy machinery or performing high-risk tasks, drowsiness detection systems can serve as a crucial safety measure. Real-time monitoring provides immediate warnings upon drowsiness detection, preventing accidents during work.

For students or office workers experiencing decreased concentration and drowsiness during long working hours, a drowsiness detection system can issue an audible warning to re-engage their attention, thereby helping to improve work or study efficiency.

The system can be utilized in the medical field as a patient monitoring system. Particularly, if drowsiness is related to a patient's condition, detecting it can provide immediate alerts to medical staff, enabling prompt intervention.

Within the home, the system can detect drowsiness in the elderly or children, helping to prevent accidents. For instance, it can reduce the risk of an unattended child having an accident due to drowsiness [9].

This study has several limitations. For example, the accuracy of drowsiness detection and the timeliness of alarms may vary in different environments. Also, system users may experience discomfort or false alarms. Furthermore, potential user discomfort or system malfunctions must be considered. Future research should address these limitations by refining detection algorithms, conducting experiments in diverse environments, and improving the system based on user feedback.

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