Based on PERCLOS - Driver Fatigue Detection System

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Abstract: ***This article describes the mechanism of PERCLOS testing for driving fatigue and introduces fatigue algorithm recognition. Firstly, use a skin color model to roughly detect the entrance and exit areas of the face, and accurately locate the eyes based on the geometric features of the driver's face. Then, based on the number of white pixels in the eye area and the duration of eye closure, determine the driver's condition. Finally, the fatigue detection decision was implemented, and the results showed that the system could accurately locate the eyes and determine the driver's fatigue status.***

Keywords: PERCLOS; Driving fatigue; Facial recognition; Fatigue detection system.

1. INTRODUCTION

With the development of transportation, traffic accidents are receiving increasing attention in people's daily lives. Research has shown that the key cause of traffic accidents is human factors, leading to approximately 89.95% of traffic accidents and 78.54% of deaths being caused by accidents one of which is driving fatigue. Every year, over 6000 traffic accidents occur due to driver fatigue, resulting in over 3000 deaths and direct monetary losses of $12.5 billion. The driver's drowsiness and distraction can be identified as the main reasons for the driver losing attention behind the steering wheel.

At present, various driving fatigue detection technologies exist in different countries, among which the most common are pulse monitoring, EEG monitoring, DCG monitoring, head position detection, and PERCLOS monitoring. Among these technologies, PERCLOS is considered the most effective compared to other technologies in terms of reliability, convenience, and practicality. In April 1999, the Federal Highway Administration of the United States convened experts and scholars to compare the effectiveness of PERCLOS with other measurement methods for eye activity. This study suggests that priority should be given to the measurement of PERCLOS for motor vehicle drivers, which can be a real-time, non-contact method for fatigue assessment. This is the first time PERCLOS has been proposed as a feasible method for predicting driver fatigue in motor vehicles. This article will introduce advanced and effective methods for estimating PERCLOS, which is ultimately crucial for preventing these tragedies. Yang et al. (2024) proposed a deep learning-based approach for large scene adaptive feature extraction, demonstrating its effectiveness in handling complex spatial data [1]. In natural language processing, Fan et al. (2025) explored incremental learning for retrieval-augmented generation (RAG) models, enhancing their adaptability in dynamic environments [2]. Zhou et al. (2024) optimized automated garbage recognition models using ResNet-50 and weakly supervised CNNs, contributing to sustainable urban development [3]. Xu et al. (2025) developed AI-enhanced tools for cross-cultural game design, facilitating collaborative character conceptualization and sketching [4]. In finance, Bi and Lian (2024) applied deep learning techniques to portfolio management, improving investment strategies through machine learning models [5]. Peng et al. (2024) advanced 3D vision-language models with Gaussian splatting, offering innovative solutions for multimodal data representation [6]. In graph theory, Yang et al. (2023) introduced HGMatch, a hyperedge-based approach for subgraph matching, addressing challenges in hypergraph analysis [7]. Tang and Zhao (2025) investigated the relationship between aging population distribution and real estate market dynamics using neural networks, providing insights into demographic impacts on housing markets [8]. Huang et al. (2024) highlighted the role of federated learning in promoting trustworthy and responsible AI, emphasizing its potential in ensuring ethical AI practices [9]. In energy storage, Yin et al. (2024) utilized deep learning for crystal system classification in lithium-ion batteries, showcasing its potential to enhance battery performance [10]. Lastly, Lyu et al. (2024) optimized convolutional neural networks (CNNs) for rapid 3D point cloud object recognition, improving efficiency in processing spatial data [11].

2. PERKLOS DETECTION THEORY

PERCLOS is an abbreviation for the percentage of pupil closure over time, which means the unit time of the proportion of eye closure. Here, we choose P80 (80% of the time spent with closed eyes) as our criterion to determine if there is fatigue, as it best matches the actual situation.

Omra No.1: $\int = \frac{l_3 - l_2}{t_4 - t_1} \times 100\%$

In the formula, f represents the percentage of closed eye time, in PERCLOS:

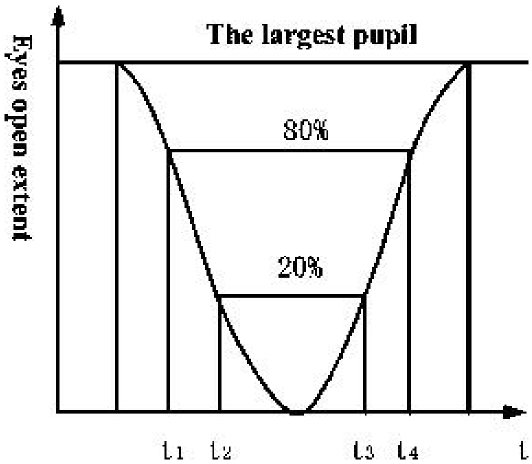

Figure 1: Pockels principle

t 1: The time required to close the largest pupil of the eye to 80%;

t 2: The time required to close the largest pupil of the eye to 20%;

t 3: The time from the natural state of the eyes to the next 20% of the pupils reopening;

t 4: The time from the natural state to the next 80% reopening.

When the system detects PERCLOS exceeding 80% and eye closure time exceeding 3 seconds, it will determine whether the driver is fatigued and take emergency measures.

3. ANALYSIS OF RECOGNITION ALGORITHMS

Facial recognition adopts Gaussian mode based on skin color features. Firstly, the skin color similarity in YC_bC_r chromaticity space is calculated and converted into a binary image. Afterwards, the vertical histogram and water histogram of the binary image are used to determine the top, bottom, left, and right boundaries of the face, and then the face is segmented and grayed out. Then, using horizontal and vertical gray projection images, the skin color is segmented and morphologically characterized to obtain the eye area and locate the left and right eyes; The ratio of the eye area to the maximum eye area in each frame was also calculated to determine the opening and closing of the eyes. The PERCLOS value was calculated by counting the number of frames of eye opening and closing to determine whether the eyes were fatigued.

3.1 Face detection based on skin color

In the YC_bC_r color space (where Y represents table brightness, C_b represents blue differences, and C_r represents red differences), skin color has good clustering. The color information Cb and Cr of different ethnic skin tones have certain distribution characteristics in the color space YC_bC_r, and have little effect on brightness; The clustering algorithm is easy to implement in the chromaticity space because it is discrete and has a two-dimensional independent distribution, which can limit the distribution of skin color. The image lattice obtained from the camera is usually in RGB format. In order to promote face detection, it is necessary to convert to YC_bC_r color space. The formula for this process is:

Omra No.2: $$\begin{bmatrix} Y \\ C_b \\ C_r \\ 1 \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 & 0 \\ -0.169 & -0.331 & 0.500 & 128 \\ 0.500 & -0.419 & -0.081 & 128 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Assuming that the skin color distribution follows a unimodal Gaussian distribution, we establish a simple Gaussian model on the two-dimensional chromaticity plane of C_b and C_r. Assuming that the similarity p represents the similarity between pixels obtained from the Gaussian distribution center and skin color, calculate the similarity of π xels in the YC_bC_r color space to obtain a similarity grayscale image. In an image, the grayscale value of each pixel represents its similarity to skin color.

The formula for calculating p is:

Omra No. 3: $$\begin{Bmatrix} P(C_bC_r) = exp[-0.5(x-m)^r C^{-1}(x-m)] \\ x = (C_bC_r)^r, C = E|(x-m)(x-m)^r| \end{Bmatrix}$$

In the formula, *m* is the average value, *m=E (x)*; *C* is the covariance matrix.

We can obtain the similarity P (C_b, C_r) based on formulas 2 and 3, and then multiply it by 255 to display the probability that the pixel represents skin color. Set the pixel with the highest similarity to white (with a grayscale value of 255) and the grayscale values corresponding to other pixels to obtain a similar image. By using the function level = graytresh (), we can calculate the optimal threshold for binarization. By binarizing the similarity map, we can obtain a binary image. Then, we calculate the binary histogram and determine the upper and lower boundaries of the face through the vertical histogram. The horizontal histogram determines the left and right boundaries of the face and ultimately segments the face.

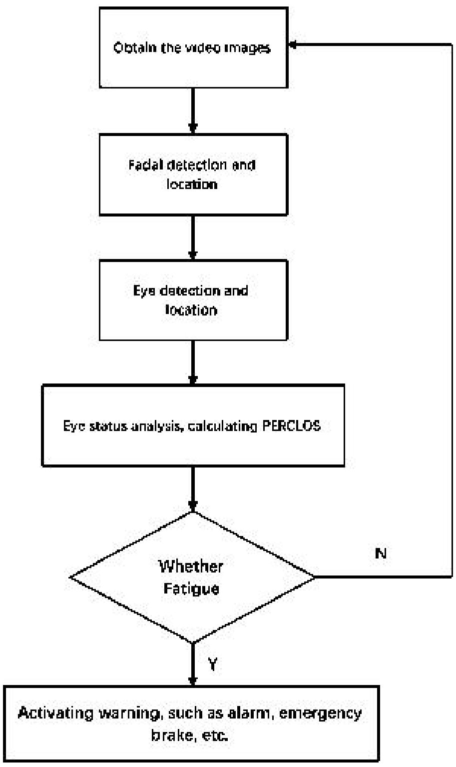

Figure 2: Identification Algorithm Block Diagram

3.2 Eye Area Localization

Firstly, we perform grayscale integration projection on the binary image of the face and use the grayscale value difference between the eyes and other facial feature points (nose, forehead, etc.) to perform rough eye localization; Then find e based on the relationship between skin color segmentation and facial features. Next, perform binarization and on-off operations to eliminate noise, erase holes, reconstruct facial images, corrode, dilute, and reprocess human eyes. Finally, we subtract the binary human eye region and the reprocessed human eye region to obtain the human eye feature map.

Figure 3: Eye feature image

3.3 Determination of Eye Condition

The eye area is defined as the number of white pixels in the eye area. As shown in Figure 1, area = the maximum number of white pixels in the maximum height and width. When the eyes are fully open, the white pixels have the most, that is, the area is the largest, set to max S. Based on max S, we calculate the eye area of the next frame (referred to as P). If max S/P<5, the eyes are considered open, otherwise they are closed.

4. RESULTS AND ANALYSIS

According to the fatigue recognition algorithm mentioned above, facial images of 5 tired students (wearing glasses and not wearing glasses) were tested and numbered. Five students each took a 1-minute shot and then processed the images, recording the number of frames with their eyes open, closed, PERCLOS value, and the number of times they closed their eyes for 3 seconds, where PERCLOS = closed eye frame / (open eye frame + closed eye frame) × 100%. The purpose of the experiment is to verify the accuracy of the fatigue detection system by verifying whether the number of times the eyes are closed for 3 seconds is at least once when the PERCLOS value is greater than 40%. According to our results, the average PERCLOS of volunteers was 41.77%. When the PERCLOS value was greater than 40%, the eyes were closed more than once and the closure time exceeded 3 seconds. The fatigue level of the system driver has reached the limit that is not allowed for safe driving operations. In addition, in the experiment, the eye positions of 4 people were accurate with an accuracy rate of 80%, and one student was unable to obtain accurate results due to strabismus.

5. CONCLUSION

Experimental results have shown that the software and hardware system used in this article can meet the real-time requirements of driver fatigue detection, accurately locate the position of human eyes, and calculate eye area. Finally, the accuracy of the PERCLOS algorithm can be verified by determining whether the driver program is fatigued. However, the system constructed in this article still has some shortcomings: when the driver is not facing forward or the driver's head is not aligned with the camera, the accuracy of driving fatigue detection will decrease; The lighting conditions inside the car also lead to a decrease in the accuracy of driving fatigue assessment. In addition, the incomplete closure of the driver's eyes during sleep and the wearing of glasses by the driver result in inaccurate fatigue detection. To overcome these issues, it is evident that further investigation into driver fatigue detection will be necessary in the future.

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