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Fatigue driving and distraction detection system based on machine vision

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Abstract: The development of automobiles has brought great convenience to people's travel. However, the rapid increase in the number of vehicles leads to the increase of traffic accidents. Fatigue and distracted driving has become the important factor causing traffic accidents, and the detection of fatigue driving technology has gradually attracted the attention of researchers. In order to cope with different road conditions and complex in-vehicle environments, methods based on multi sensor have become the mainstream for application to driving detection, however, different driving habits and environments may lead to false information. In this paper, we propose an integrated-information method based on machine vision and deep learning, the Dlib library with 68 features is used to map the face, PERCLOS method is used to calculate the EAR (eye aspect ratio) and MAR (mouth aspect ratio) to evaluate the fatigue level of the face, also, we turn the key points of the 2D face into the 3D face model, and calculate the Euler angle of the head position in real time. A Yolov5 target-detected algorithm is used to identify and warn distracted behaviors such as smoking, drinking, and using mobile phones. The training accuracy reaches 90.23%, and the total detection frame rate is 4.78 frames per second. In our system, a UI is designed based on Wxpython, and thresholds such as eyes-closed and mouth-closed behaviors could be set in real time through a human-computer interface, the mode of monitoring behavior could be switched and the abnormal driving data will be recorded at the same time. The detection system designed in this paper is mainly divided into three parts: facial feature detection, head position prediction, distracted behaviors detection which realizes the evaluation and warning of the driver's fatigue driving and distracted state.

1. Introduction

The automobile industry has rapidly grown up as well as the economy, the automobile industry has become an integral part of China economic entity, the automobile industry in the national economic growth also provides great convenience for our life, but at the same time, the rapid increase in the number of vehicles also led to a series of problems, the increase of traffic accidents brought huge social casualties and economic losses.In 2021,61,703 people were killed, 2503,723 were injured, and the number of motor vehicle accidents reached 211,074. According to the National Transport Bureau, traffic accidents occurred between 2016 and 2020, and the number of accidents totaled about 1.15 million. According to previous statistics, among the many causes of traffic accidents, fatigue and distracted driving caused the largest number of deaths, with traffic accidents caused by fatigue driving accounting for 20% of the total number of accidents and more than 30% of the total number of road traffic accidents.[1]

Fatigue driving is due to mental or physical disorders caused by lack of sleep or long time driving, resulting in the driver's disability to control the vehicle and lead to traffic accidents. By finding out the causes and characteristics of fatigue driving and proposing detection methods according to the status characteristics of fatigue, it can reduce the occurrence of traffic accidents. At present, the topic of fatigue driving testing has won wide attention from researchers around the world. Among them, patents of fatigue driving testing technology based on image analysis are increasing year by year in Britain, the United States, Japan and South Korea.[2]

To sum up, in order to solve the safety problems of traffic accidents caused by fatigue driving effectively , it is necessary to find out a detection method based on a third party to urge drivers to drive safely.

In this paper, we propose a fatigue driving monitoring system based on the machine vision algorithm, using the camera to obtain the driver's head movement track and facial feature information, identifying the driver's behaviors such as smoking, drinking water, using mobile phones during driving, to ensure the life safety of drivers.

2. Related work

Target-detection tasks generally use various sensors or image acquisition devices to collect driver's physiological parameters, driver's behavior, vehicle parameters and so on. Fatigue would be evaluated by a analysis model consisting of the collected parameters. These methods are more objective and reliable than artificial methods. Related research of fatigue detection can be divided into two types: contact detection and non-contact detection [3], contact detection is based on driver physiological parameters such as EEG, ECG, EMG, non-contact is divided into the methods base on driver's facial features (face, mouth, head and other features) and vehicle driving parameters (steering wheel Angle, vehicle acceleration, accelerator brake pedal, etc.)[4].These methods could be classified shown in Fig. 1.

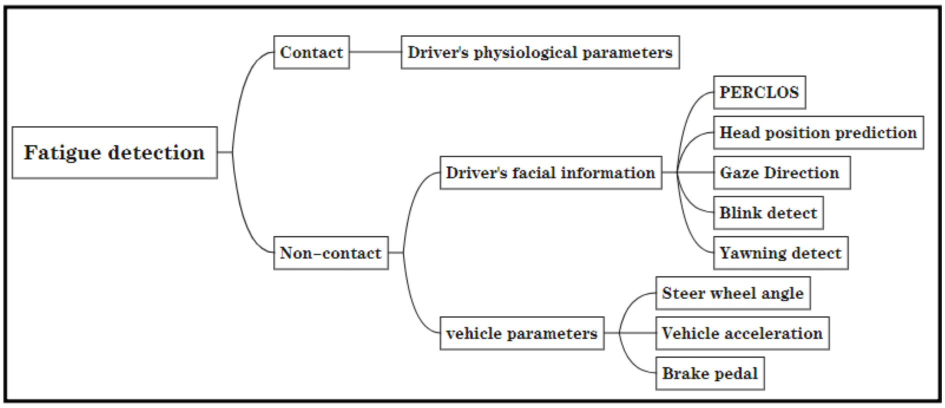

Figure 1. Classified methods of fatigue detection

3. Method

3.1 Detection method based on driver facial recognition features

When the driver is under fatigue, the face characteristic would be different from the state of consciousness. Therefore, by collecting and analyzing the driver's facial feature data continuously, we are able to obtain an effective method to detect driver's fatigue in real time. The detection methods based on driver facial features is mainly consist of PERCLOS, Blink frequency detection, and Mouth opening detection [5-7].

3.1.1 Extracted facial features

Face detection technology can be traced back to the 1960s and 1970s, with the development of computer technology, face detection technology has gradually become mature.This chapter mainly analyzes and studies the technologies used in the process of fatigue monitoring system. As a pre-processing part for the subsequent recognition, face detection technology determines the efficiency of the fatigue driving judgment.

In our proposed method, we perform gray scale and histogram equalization on the image in order to reduce the amount of computer calculation and enhance the facial features.Then, we apply facial detection algorithm based on SVM and HOG to extract facial features, the facial information will be transformed into array, and we can print out the position of each identified feature point in the interface. Even if the object is slightly blocked, the normal recognition of the unblocked part will not be affected.

3.1.2 PERCLOS and Blink detection

In 1998, driving research center of Carnegie Mellon university developed the PERCLOS (Percentage of EyeIid CIosure over the Pupil) [8] system, which indicated the ability is not exactly the same when different retina on different wavelengths of red light reflection, the system is based on this theory, their studies can track the retina according to different wavelengths, using mathematical formula to calculate the size and position of the eyes.PERCLOS can be express as:

$$\mathrm{PERCLOS} = \frac{\mathrm{EyeclosedFPS}}{\mathrm{TotalFPS}} \times 100\% \quad (1)$$

EyeclosedFPS represents the total number of frames during the eye closed, and TotalFPS represents the total frame over the detection time, the calculated PERCLOS can be divided into P80, P70 and EM standards according to different percentages, where P70, P80 represents the pupil area is more than 70% and 80%, when the area is over 70% or 80%, we consider it as a eye-closed and count. EM represents the area is blocked more than 50% when it starts count. Research have shown that P80 is more appropriate to explain eye closure and fatigue. By setting a proper threshold, we can rank different level for fatigue.

Inspired by PERCLOS, In 2016, the concept of EAR was proposed [9] by Soukupov et al. Their work derived the eye aspect ratio formula to calculate the eye aspect behavior. By calculating the Euclidean distance between the identified eye characteristic points, we can calculate the eye aspect ratio. The EAR can be used as an indicator to assist in detecting the status of tired driving. The feature points of eyes are shown in Fig. 2.

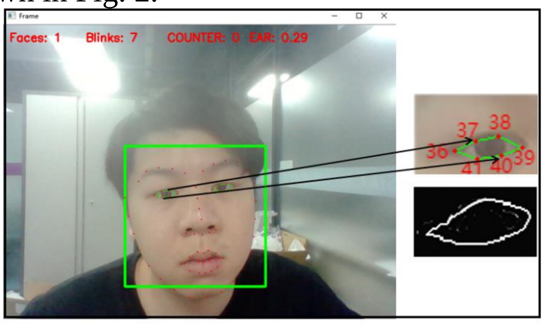

Figure 2. Blink detection

EAR could be expressed as

$$\mathrm{EAR} = \frac{\|y_{37}-y_{41}\|+\|y_{38}-y_{40}\|}{2\|x_{39}-x_{36}\|} \tag{2}$$

3.1.3 Yawning detection

Yawning is also a typical phenomenon of human fatigue, when the driver is tired, the brain may suffer from transient hypoxia, human body can obtain more oxygen through yawning. Similar to blink detection, We can evaluate the opening and closing state of the mouth over a period of time by calculating the MAR (mouth aspect ratio) and the Euclidean distance of the characteristic points. MAR tends to be much bigger while yawning, and it is easy to distinguish from speaking. The feature points of mouth are shown in Fig.3

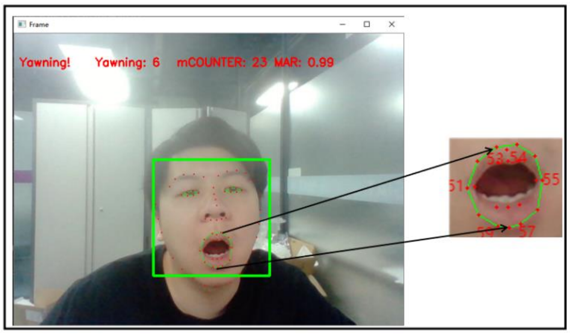

Figure 3. Yawning detection

MAR could be expressed as

$$\mathrm{MAR} = \frac{\|y_{53}-y_{59}\|+\|y_{54}-y_{57}\|}{2\|x_{55}-x_{51}\|} \tag{3}$$

3.2 Detection method based on Head position

Head Pose Estimation (head track detection) technology has become a popular research direction in human posture detection and fatigue driving detection

Currently head position detection based on the non-contact method has two mainly divided into two schemes: (1) Nose movement detection of the specific frame (2)Utilize the coordinate conversion algorithm to predict the angle of the whole head.

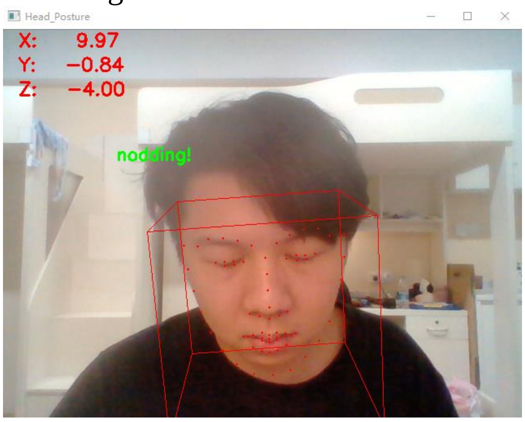

Figure 4. Nodding detection

In 2014, Kazemi et al. [10] developed a method for face alignment, inspired by their work, we proposed a method which can turn 2D feature points into 3D angle. According to the principle of coordinate axis conversion, we successfully realized the tracking and prediction of the head trajectory, with the nasal features, we can finally identify the driver's nodding behavior. Head angle prediction and Nodding detection are shown in Fig.4 .

3.3 Distracted behaviors detection

Distracting driving detection is equally important for driver's safety, we train a group of distracting behaviors through YOLOV4, and successfully identify distracting behaviors such as drinking, smoking and phone using. Considering that drivers need to wear masks during the pandemic, we have also trained and recognize face mask in our proposed system.

3.3.1 Datasets

Before the training began, in order to ensure the accuracy and detection speed of the acquired model, we download the pictures with related keywords such as smoking, drinking and making phone calls from baidu Pictures and Google Pictures through a spider algorithm. Then we manually picked out the unrelated data and annotated the objects need to be identified using label-master.

3.3.2 Training method

In our datasets, 500 pictures of mobile phone as well as face mask, 300 pictures of drinking and smoking behaviors have been put into training and testing datasets for model iteration under the structure of YOLOV4. In this paper, the training was run on Ubuntu16.04 operating system, Pytorch 1.2.0-GPU environment, with NVIDIA GeForce RTX 2080 Ti, to speed up the training process, the corresponding version of CUDA accelerator is also enable. Take phone detection as an example, the procedure are shown in Fig. 5.

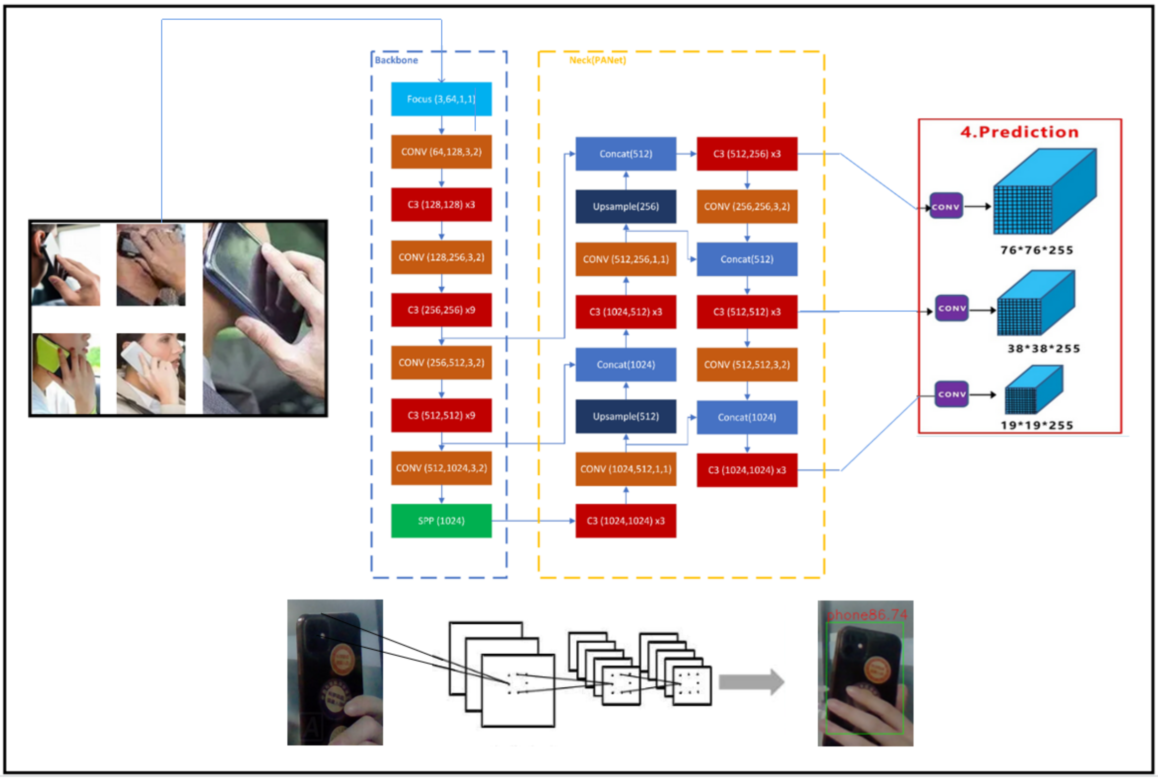

Figure 5. Mobile phone detection procedure

3.3.3 Result and evaluation

Average precision would become the basis for judging the accuracy of our training model. In our acquired model, AP of smoking behavior detection could reach 87.2%, drinking behavior detection could achieve 86.4%, phone and face mask detection could achieve 92.6% and 90.3%. AP curves are shown in Fig 6.

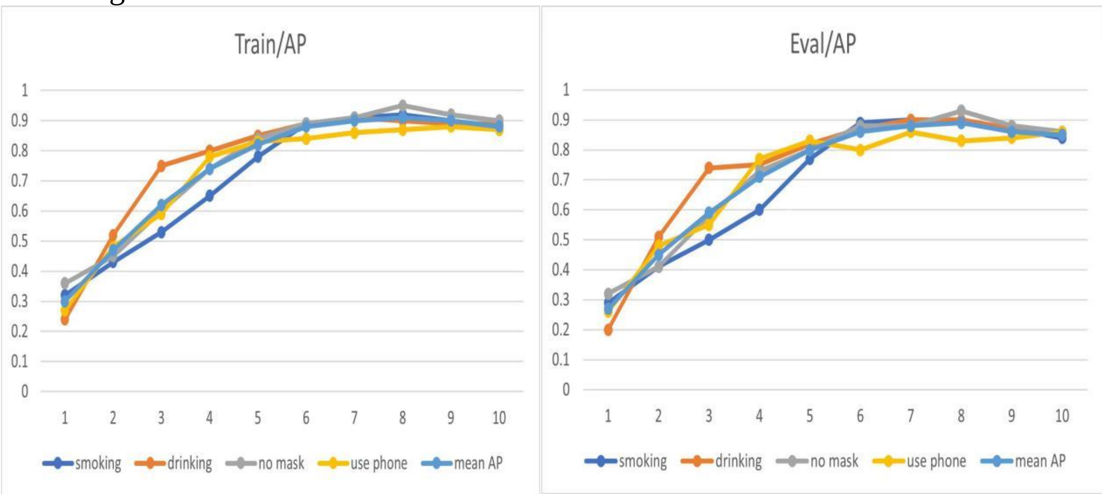

Figure 6. Average precision Curve

4. Total detection

Thread is the minimum execution unit of a process as well as the smallest dispatching unit in the operating system, and the system resources of the computer are limited. In order to ensure the efficiency of each detect tasks, our proposed system utilize a thread manager to manage the operation of each task, update of UI serves as the main thread task, and the detection tasks serve as the sub-thread task. Creating a detect task is equivalent to creating a sub-thread, We divide the software part into several modules: face detection, head trajectory prediction, yawn detection ,blink detection, distracted behavior detection. A total assessment would be finally used to determine the driver status, all these status would be recorded and the sign of warning would be show up on the interface. A total fatigue parameter which is used to evaluate the state of driver could be expressed as:

$$\mathrm{FATIGUE} = \Delta\mathrm{EAR} * \mathrm{K_{EAR}} + \Delta\mathrm{MAR} * \mathrm{K_{MAR}} + \Delta\omega_{\mathrm{HEAD}} * \mathrm{K_{HEAD}} \quad (4)$$

Where $\Delta\mathrm{EAR}.\Delta\mathrm{MAR}.\Delta\omega_{\mathrm{HEAD}}$ represents the variance ratio of EAR,MAR and the angle of head movement. According to our experiments, the values of $\mathrm{K_{EAR}}, \mathrm{K_{MAR}}, \mathrm{K_{HEAD}}$ could be set to 0.45,0.55 and 0.65 respectively, which can evaluate the driver's fatigue status steadily. Then we scale the FATIGUE into 0 to 1 through Normalization, then we could obtain a relationship between FATIGUE and driver’s status, shown in table. 1.

Table. 1 Relationship between FATIGUE and driver’s status

Status	Awake	Mild	Medium	Serious
FATIGUE	<0.55	0.55~0.75	0.75~0.9	>0.9

Unlike to fatigue detection, the distraction behavior would not be evaluate through equations since the distracted behaviors are easy to identify. Once the distracted behaviors are detected, warning would show up on the interface immediately. Procedure of detection are shown in Fig 7.

Figure. 7 Different level of fatigue detection

5. Conclusion

This paper summarizes the development and main approaches of driver-detection technology, and we propose a fatigue-driving and distracted behaviors detected system, which utilizes facial feature map algorithm to extract the characteristic points of eyes, mouth, nose. According to the features, we could evaluate different level of the fatigue state through a total fatigue parameter which is related to EAR, MAR, and also the head position prediction. Besides, we also train and recognize the distracted behaviors such as drinking and smoking, Phone and face mask are also the detected target in our system. Under the structure of YOLOV4, we successfully identify distracted behaviors and give out warning instantly.

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