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Research on Fatigue Driving Assessment Based on Multi-source Information Fusion

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Abstract: Fatigue driving has become one of the main causes of traffic accidents. At present, many driving fatigue detection methods are based on the image processing technology, whilethese methods are easy to be affected by the driving environment, which limits the accuracyand reliability and accuracy of the detection.For this limitation,this paper introduces the multi-source information detection and fusion technology, using sensors to get kinds of information, includingPERCLOS value,attitudefeature, facial expressions and body temperature, then uses the neural network learning methodto identify the driver's state based on the fused information, whichcould improve the improve the accuracy and reliability of driving fatigue detection.Experiments have been carried out to prove that the proposed method is considerably effective.

Keywords: fatigue driving, information fusion, neural network

1Introduction

With the rapid development of transportation and increase of vehicle ownership, traffic accidents have increased at an alarming rate, which is harmful to an individual’s safety and daily life. According to latest statistics, about 1 million 250 thousand people die each year from traffic accidents in the world. One of the main reasons for the traffic accidents is fatigue driving [1].

Therefore, in order to prevent the fatigue driving, the fatigue driving detection and early waning technology has become the key research topic in domestic and foreign .The research topic mainly includes: fatigue driving detection based on the physiological signal (EEG, ECG, pulse and so on), fatigue driving detection based on the physiological reaction of the driver (the degree of the head tilt, the closing frequency of the eyes, the driver's control of the vehicle steering wheel), fatigue driving detection based on the vehicle parameters (speed, acceleration, lateral displacement of the steering wheel, brake pedal, gear position) and fatigue driving detection based on the fusion of multi-sources information[2].

Now, many countries have achieved some research results.Wierwille Walt established the PERCLOS theory, which judges the degree of fatigue by means of the degree of eye closure for more than 80% of the unit time [3]. The University of Tokyo developed a Wrist tester based on physiological signals, by measuring the Alcohol, ammonia and lactic acid content in driver's sweat, determined the driver's fatigue level, when fatigue driving occurs, gave an effective warning[4]. Murphy etc developed a six degree of freedom tracking system for driver's head position and rotation angle,to detect the driver's attention state [5]. Australian International University developed the DAS4 driver detection system and applied it in real life. It detects the driver's state through the eye tracking system [6]. Suzuki etc extracted eyes blink frequency, percentage of eye movement parameters and set up multiple regression models for each driver to detect the driver fatigue level [7]. Tang etc proposed fatigue detection method based on Omni-directional vision sensor, using multiple sensors to get images from different angles and finally improve the accuracy of observation [8].

However, much fatigue driving detection methodsare mainly to make a conclusion basedon the imagesgot from kinds of sensors or cameras, while image acquisition is affected by light conditions greatly and especially is difficult to get enough effective images under the dim light[14].To get a better image, it is an alternative to choose infrared sensor .But long-term use of infrared sensors has a defect; it may bring damage to the driver's eye [9]. Therefore, thispaper proposes a solution that uses different kinds of sensors to obtain information and through the fuzzy neural network semantic learningto fuse and determine the heterogeneous information, which can effectively improve the reliability and accuracy of fatigue driving detection.

2 Fatigue driving characteristics

Fatigue drivingmeans after driving long hours, the driver shows a status of physiological and mental disorders, and the driving skills decline obviously [10]. Fatigue driving affects the driver's attention, feeling, judgment and decisions etc emotions. It causes the driver only has a narrow vision focus, decreased judgment and attention, sometimes even makes the driver toappear hallucinations. When fatigue driving, the driver directly or indirectly presents kinds of characteristicschange. Thesecharacteristics include eye tracking, bodyposition, facial expression and body temperatureetc [11].

By measuring the above state value of the driver, the current behavior and attention of the driver can be analyzed.When the driver driving for a long time, the eyes closure time increased, heart rate increased; when the driver in a different mood, facial expressions and body temperature will be in a different state; when the driver is not in good condition, the posture of the head will also show some changes. Using the neural network semantic learning method gets the driver's stateoutput and makes fatigue driving assessment.

2.1 Eye tracking detection

Eye fatigue test is a good method to detect fatigue. PERCLOS (Average Eye Closure Speed) is defined as the percentage of eye closure time at a certain time[3]. PERCLOS is recognized as a parameter for fatigue detection, which is established by Wierwille according to the experiments on the driving simulator in 1994. It is defined as the proportion of eye closure time in 1 minute.Eyes closure has three kinds of standards, that are 70%, 80% and completely closed,the best effect is the 80% standard. The research resultsindicate that the PERCLOS represents the slow blink of an eye, rather than the quick blink of an eye. It can be viewed as a strong reaction to the mental state of fatigue. Figure shows the diagram of the PERCLOS detection, as long as the T1 value is got, the value of PERCLOS must be calculated. Figure 2 is the result chart of eye tracking with the Asus eyeX Tobii eye tracker.

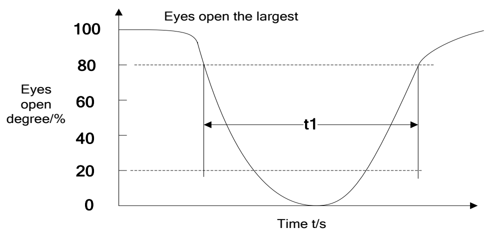

Figure 1Eye closure detection

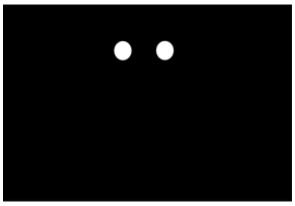

Figure 2Eyeball tracking

2.2 Attitude feature detection

Measuring the driver's attitudemainly in order to judge the driver's head, hands and other body state.When the driver feelsfatigue, the swing frequency of the head will increase. When the driver's head position is too low, the system will alarm. Meanwhile, the attitude itself isan expression of emotional information channels.There are two kinds of attitude recognition methods:①analysis of daily behavior;②analysis of the characteristics of the gesture action (such as the behavior of the way, intensity, frequency, etc).This paper presentsan attitude feature detection method using interactive sensor, whose main work principleis sending out the laser speckle, which is reflected back to the sensor. The method can effectively measure the target in the same plane. Figure 7 shows somatic recognition result.

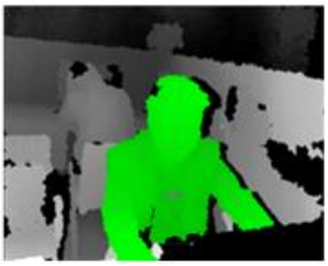

Figure 3somatic recognition

The headposture is a very import aspect in the process of Attitude feature detection. The position of the head is defined as $Head(\mathrm{x,y,z})$ and the position of the neck is defined as $Neck(\mathrm{x,y,z})$, so the head's horizontal attitude could be got from the formula (1):

$$\alpha_H = a\tan((Neck_x - Head_x)/(Neck_y - Head_y)) \ (1)$$

The head's pitch attitude could be got from the formula (2):

$$\beta_H = a\tan((Neck_z - Head_z)/(Neck_y - Head_y)) \quad (2)$$

When detection result meets the following formula, means the driver is not in the center of the field of view.

$$Head_{\min}(\mathrm{x,y,z}) < Head(\mathrm{x,y,z}) < Head_{\max}(\mathrm{x,y,z}) \ (3)$$

If $\beta_H > T_{\max}$ or $\beta_H < T_{\min}$, then it shows that the driver may bow or rise too much, and now is in the state of very fatigue.

2.3 Facial expressions detection

In the process of facial expression detection, extractcharacteristics from human facial expression got from sensordevice and making corresponding analysis. According to the human cognitive method, classifies different facial expression and ultimatelyunderstands thedriver's mood [12].

Figure 4Facial expressions detection

Commonly used mooddetection methods include: ①according to the geometric characteristics of facial expression, such as the mutual position changes between the five senses. Positioning and measuring the detailed information about the shape, size and spacing, the proportion of the geometriccharacteristics to identify the driver's mood;②through the overall analysis,making a certain transformation to the whole or some special areas of the face, to get different expression characteristics and carrying out the mood recognition;③through the establishment of suitable physical model, extracting key characteristics using the knowledge of anatomy etc,comparing the characteristics of the changes of facial key characteristics and completing the mood recognition.

2.4 Heart rate detection

ECG signals are mainly used in the physiological measurement of driving load.Compared with other signals, ECG signals are easierto be detected [16].Derivatives as ECG signals, Heart rate variability (HRV) is a small fluctuation in the continuous sinus heart rate (instantaneous heart rate) or small differences in the beat R wave interval of heart rate (HR).A large number of studies show that the indicators HR and HRV can reliably reflect the driver's load and psychological changes [17].Figure 12 (a) is the value of the original heart rate, (b) the ratio of low frequency and high frequency, the ratio of low frequency and high frequency ratio can be seen, this ratio increased with the increase of driving time.

(a) Original heart rate

(b) Low frequency and high frequency ratio of heart rate

Figure 5Heart rate detection

2.5 Temperature characteristics detection

Body temperature detection mainly reflects people's emotions state.A research group from Finland conducts experiments to 700 volunteers; theymeasure the temperature of the human body under different mood control, and then use the heat image to show it. Figure 6 shows a temperature maps under differentemotions [13].

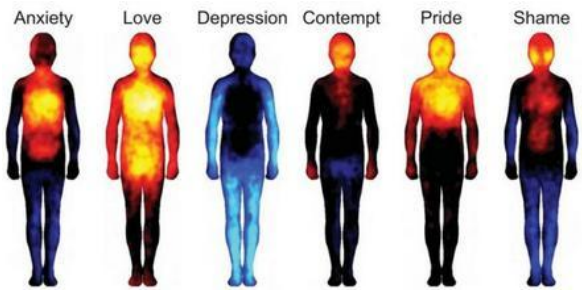

Figure 7 Body temperatures in different emotions

The results show that emotions can cause chemical changes in the human body, resulting in a different heat distribution. When angry, for example, the temperature of the head and chest increases; when the emotion is depressed, the whole body is cool; when feel shy, "hot" will focus on the face. In short, emotions changes affect the distribution of body heat, which is equivalent to get a map of the emotional body.

3 Neural network semantic learning method for multi sources fusion

The state characteristics informationextracted from the driver mainly include temperature, heart rate, body movement, posture, facial expressions and eye tracking. In order to Understand the driver's current status and make areasonable assessment, Constructing the multidimensional characteristics space sample library using extracted characteristics information,establishing the mapping relationship between the characteristics and the semantic based on the neural network semantic learningfunction. According to the assessmentresult,to judge whether the driver is in a state of fatigue and whether can continue to drive, even give warning prompt information.The whole process is shown as Figure 8.

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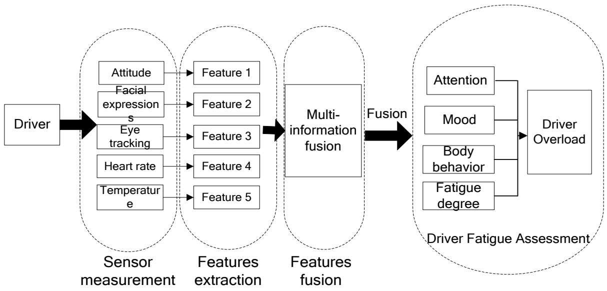


Figure 8Fatigue driving detection flow chart

3.1 Model establishment of the driver's states

The establishment of driver's various state models mainly consists of two steps: one is the semantic quantification of the state model; the two is the establishment of the state space. Choose more adjectives to build the adjective set of driver's state model, which is shown in the Table 1.

Table 1Adjective set

1、excited | peaceful	6、stressful | relaxed
2、happy | sad	7、overloaded | easygoing
3、Fatigue | not fatigue	8、Fatigue |peaceful
4、relaxed| depressing.	9、anxious | neutral
5、nervous |relaxed	10、Angry | happy

According to the adjective set inTable 1, such as "excited | peaceful",it is divided into five grades, including severe fatigue, slight fatigue, general fatigue ,good, very good.

To establish the state space, first to obtain the evaluation quantized value of thenth adjective in state m from the test users, And then calculate the average value of the evaluation quantized value to get a matrix $Y = [y_{m1}, y_{m2}, ..., y_{mn}]$,And according to the following formula for standardization, get the matrix X .

$$x_{mn} = \frac{y_{mn} - \bar{y}_n}{s_n} \quad (3)$$

$$\text{st: } \bar{y}_n = \frac{1}{M}\sum_{m=1}^{M} y_{mn} \ , \quad S^2{}_n = \sum_{m=1}^{M} (y_{mn} - \bar{y}_n)^2$$

Through the above steps, the mapping of the adjective, the feature space and the vector of the driver is established, which is a component of the semantic learning neural network as shown in the Figure 9.

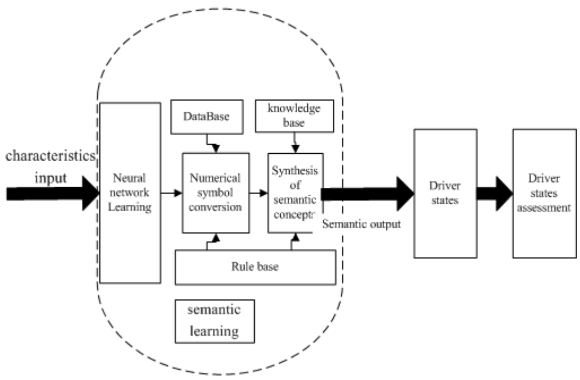


Figure 9　Driver state assessment based on neural network semantic learning

3.2 Semantic learning based on neural network

The semantic combination construction requires the use of combination of semantic expression between different components of the text. Therefore, firstly analyze the data obtained from kinds of sensors, thentransform the analyzed data in accordance with the sequence of dependencies defined by the parser, and finally get the combination relationship hierarchy tree of the whole sentence, as shown in Figure 10.

According to the node level relationship of tree structure shown in Figure 10, began to orderly combine layer by layerfrom the bottom leaf node, finally get the semantic representation of the whole sentence.

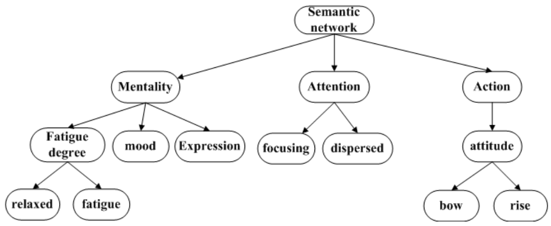


Figure 10Sentence combination relation tree hierarchical graph

In this paper, we combine the two sub nodes in the tree. Then, according to the tree structure constructed by the semantic combination, the results of neural network learning are used to fill the different types of semantic words. At last, the driver's condition assessment is given to estimate whether the driver is suitable to continue driving at present.

4 Fatigue detection systems simulation experiment

Firstly, the paper introduces the function of each hardware device and using them to get the multi information from the driver, then completes the driver state monitor with got information based on the semantic learning method of neural network.

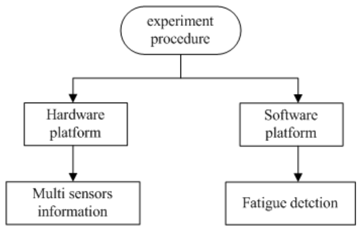
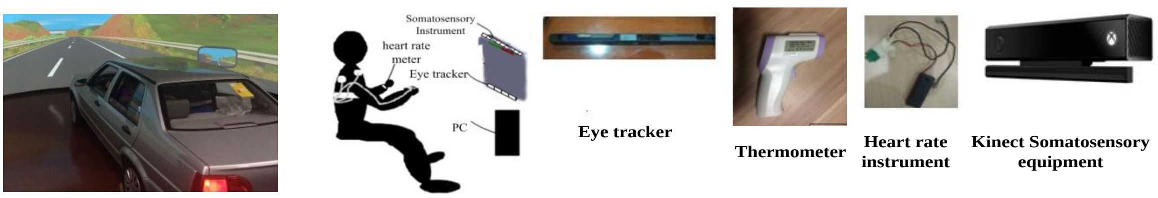


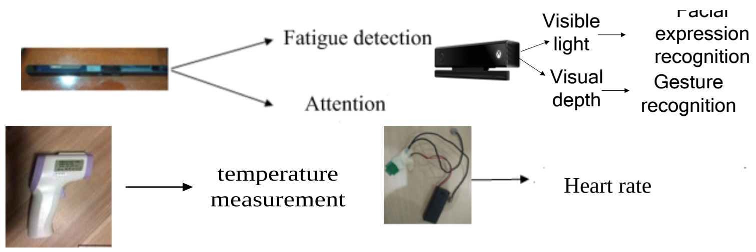
Figure 11 Fatigue detection experiment procedure

4.1 Experimental device

The sensor used in experiment includes measuring gesture sensor,somatosensory sensor, facial expressions, eye tracking or eye fatigue detection tracking sensor, and temperature sensor.



(a)Experimental platform(b)state monitoring schematic diagram(c) kind of sensors



(d) sensor function

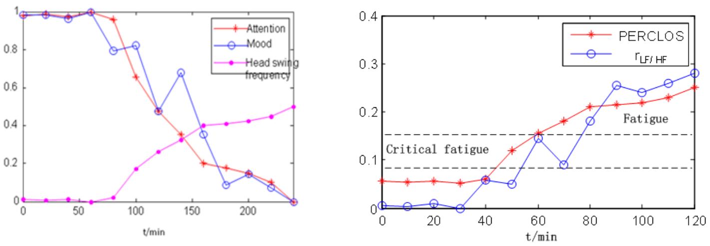
Figure 12 Experiment devices and their functions

After driving for a long time, it can be inferred whether the driver is in a state of fatigue based on the collected information from the sensors, such as the eyes closed time increases, heart rate changes etc. All processing information is performed in the computer. As shown in Figure 12for the system experimental device.

In order to reduce the interference of equipment to the driver,This paper uses the Tobii eyeX eye tracker, mainly used for eye fatigue detection and target attention detection, using Microsoft Kinect2 or ASUS Xtion attentionsense device for expression recognition or gesture recognition, the heart rate is used for fatigue detection.

4.2 Driver state monitoring based on multi sensor information

Synthesizing the measured value that got from multi sensors and, Estimating the driver's fatigue, mood, load, body behavior and eye's attention. The curve of driver's mood, attention, and the frequency of head movement frequency is shown in Figure 13(a).



(a) The curve of the change of mood, attention(b) The curve of PERCLOS value of eye closure and the heart rate r_{LF} / r_{HF}

Figure 13The trend chart of driver's state with time

It could be seen from the eye closure PERCLOS value and heart rate r_{LF} / r_{HF} value shown in Figure 13(b) that along with the time lapse, the driver's fatigue degree increases sharply, the mood also changes the disgust and the anger, the movement frequency of the head also correspondingly increases.

In this paper, the RPE scale chart is used to quantify the degree of fatigue of the driver. RPE scale chart is a quantitative form of fatigue, which is proposed by the Swedish scientist Borg in 1962, it is also known as the Borg scale, it has been proved to be a scientific, simple and practical method [15].

Table 2 shows the body condition of the driver at different time, according to the different condition of the driver, the corresponding judgment of fatigue driving and driving operation advice is put forward. In the case of continuous driving, the status of the driver will be reduced with the change of time; the best driving hours of the driver is 1~2 hours.If driving more than 4 hours, then the driver is in a more serious fatigue driving state.

Table 2The human body state at different times of the driver and driving advices

Testing time/min	Driver state	RPE score	Driving Advice
30	Fatigue detection：no fatigue(very good) mood：very good attention: very high action: look straightly	7	Can be very good to complete the driving task, no advice or warning
60	Fatigue detection： no fatigue(good) mood：good attention: high action: look straightly	9	Can be good to complete the driving task, no advice or warning
120	Fatigue detection： slight fatigue mood：general attention: general action: look straightly	11	Be able to complete the driving task, suggest keeping attention
180	Fatigue detection：general fatigue mood：hate attention: low occasionally action: bow	15	Showing a slight fatigue driving symptoms, suggesta rest later.
240	Fatigue detection： severe fatigue mood：Irritability attention: very low action: look straightly	19	Showing a fatigue driving condition, suggest to have a rest immediately and giving warning

5 Conclusions

In order to effectively detect the driver's driving status, a kind of fatigue detection method based on multi sensor measurement and input is proposed. Provide a variety of sensor state supervision for the driver, including sensors for measuring gesture, posture, facial expressions, eye tracking sensor, heart rate sensor and temperature sensor.Make fatigue driving judgment based on neural network semantic learning using collected multi-sources information. It can improve the reliability of driving fatigue detection and the adaptability of different environments, which can provide some reference for the research of related fields.

It still exist some deficiencies in this paper. (1) It is just a design method of driving fatigue monitoring based on multi-sources information, lack of verification of actual driving under the actual highway environment ;(2) There are many characteristics of driving fatigue, and how to combine the complementary effect of multi-source feature information is still to be further studied.

References

[1] Sun Wei,Zhang Weigong,Zhang Xiaorui,etc. Development of Fatigue Driving Detection Method Research [J].Automotive Technology, 2009(2):1-5.

[2] Shen Yongzeng, Hu Lifang, Feng Jimiao.Multi-Source Information Fusion Application to Driving Fatigue Detection [J].Computer Applications and Software,2012, 29(2):272-274.

[3] Wierwille, Ellsworth, Wreggit,etc. Research on vehicle Based driver status/performance monitoring: development, validation, and refinement of algorithms for detection of driver. drowsiness[R].National Highway Traffic Safety Administration Final Report. DOT HS 808 247,1994.

[4] Liu ChunSheng.Research on face feature detection and fatigue state recognition [D].ShanDong University, 2012.

[5] Murphy-Chutorian E. Trivedi M M. Head pose estimation and augmented reality tracking: An integrated system and evaluation for monitoring driver awareness [J]. IEEE Transactions on Intelligent Transportation Systems, 2010, 11(2):300-311.

[6] FLETCHER L, APOSTOLOFFN, PETERSSON L, etc. Vision in and out of vehicles[J]. IEEE Trans on Intelligent Transportation Systems, 2003, 18(3):12-17.

[7] Suzuki M, Yamamoto N, Yananoto O, etc. Measurement of driver’s consciousness by image processing-A method for presuming driver’s drowsiness by eye-blinks coping with individual differences[C]. IEEE International Conference on Systems, Man and Cybernetics, 2006, 4:2891-2896.

[8] Tang Yiping , Lou Yongpan , Zhou Zongsi. Design of Drowsy Driving Video Detecting Device Based on Omni - directional Vision Sensor [J].ComputerMeasurement&.Control, 2008,16(9): 1233-1236.

[9] Xue Zhuqing.Infrared protection[J].Occupation and Health, 1990(5) : 12.

[10] BOVERIS S. Driver fatigue monitoring technologies and future ideas[C]. Proc of A WAKE Road Safety Workshop, 2004.

[11] Chen Bo,Feng Ruijia,Zhang We,etc.Driver Drowsiness Detection and Warning System Based on Multi-source Information Fusion[J].Journal of Highway and Transportation Research and Development,2009,26(12):13-18.

[12] Matre G N, Shah S K. Facial expression detection[C]. IEEE International Conference on Computational Intelligence and Computing Research. 2013:1-3..

[13] The temperature of the passions betray you[EB/OL]. http://health.qq.com/a/20140109/006006.htm.

[14] Liu X, XU F L, Fujimura. Real-time Eye Detection and Tracking for Driver Observation under Various Light Conditions[C]. Proceedings of Intelligent Vehicle Symposium. Versailles, France, 2002: 344- 351.

[15] Abadie B R. Effect of viewing the RPE scale on the ability to make ratings of perceived exertion.[J].Perceptual & Motor Skills, 1996, 83(1):317-318.

[16] Lai S. K. L,Creg A. Driver Fatigue, Electroencephalography and psychological assessment[J], Psychophysiology, 2002,39 (3): 313?321.

[17] Wang Rao-fen,Zhang Jian-hua,Wang Xingyu. Heart rate variability analysis of process control operator based on wavelet packet transforms [J].Journal of Nanjing University of Science and Technology, 2009, 33(9)