A Fuzzy Based Method for Driver Drowsiness Detection

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***Abstract*—This paper describes a novel approach for an intelligent driver drowsiness detection system using visual behavior of the driver. The estimation of driver's vigilance is successfully made by combining facial and eye symptoms using fuzzy logic controller. Experimental result using fuzzy-logic simulation in Matlab show the performance of the developed approach in term of robustness and reliability.**

***Keywords*—intelligent system, driver's vigilance, drowsiness, fuzzy controller, Classification, Neural Network**

I. Introduction

Driver drowsiness is a huge traffic safety issue and widely regarded as one of the most contributing of deaths and serious injuries today. According to the National Association of toll roads companies, sleep related vehicle accident is between 20% and 25% in European road.

The development of new technologies for monitoring driver vigilance is a major challenge in the field of accident avoidance system.

There are many method for driver drowsiness detection that can be divided into three categories: First category is related to vehicle based method, by measuring steering wheel movement [1], standard deviation of line (SDLP), pressure on the acceleration this type of measure is usually affected by external factor such as lighting conditions. The second one is a physiological based measure, by measuring EEG [2], ECG [3], EOG [4], EMG [5], skin conductivity [6], despite the accuracy of this method their intrusive nature remains a challenge. The last category deals with the behavioral based method, by continuously monitoring driver's face through a camera and extracting symptoms.

Driver face monitoring system can be divided into four subcategories:

- Symptom related to eye region including eye closure [7], distance between eyelid [8], gaze direction [9], Eye blink speed and eye blink rate [10].
- Symptom related to mouth region such as Yawing [11].
- symptoms related head like head nodding [12] and head orientation [13].
- Symptom related to face using facial expression recognition [14].

These measures can be merged to increase the performance of driver drowsiness system.

In [15], many facial expressions were recognized using Dynamic Bayesian Network (DBN) for drowsiness detection.

In [16], a model based on Dempster-Shafer Evidence theory Evidence is used for driver drowsiness detection with the fusion of contextual, visual and non visual information.

In [17], a Finite State Machine (FSM) was used to estimate driver alertness based on eye closure, Eye blink rate and Head orientation.

Q.Liu and Z.Li [18] provides a feasible method for the evolution on ship driving fatigue using Backpropagation Neural Network.

I.Tayeb and O.Jemai [13] used Head posture estimation and eyes recognition system based on Wavelet Network for driver's vigilance determination.

In this paper we used a new method based on monitoring driver's face by combining fuzzy information from face and eye behavior.

The remainder of this paper is organized as follows. Section II presents the overall of the proposed system. Methodology will be presented in section III. Section IV presents experimental result. Finally, section V ends with a conclusion.

II. Overall of the proposed system

The overall architecture of the proposed system can be described as follows: .

In each frame of the video,we continuously detect face using Haar feature-based cascade classifiers which is an effective object detection method proposed by Paul Viola and Michael Jones [19].

By localizing driver's face, face related behavior are extracted and eyes are localized by Viola and Jones method. One of the main component of our system lies in the classification of eye state .

Through this process, we used a fuzzy system to combine these symptoms and motoring driver's vigilance.

Figure 1 shows the flowchart of the proposed system.

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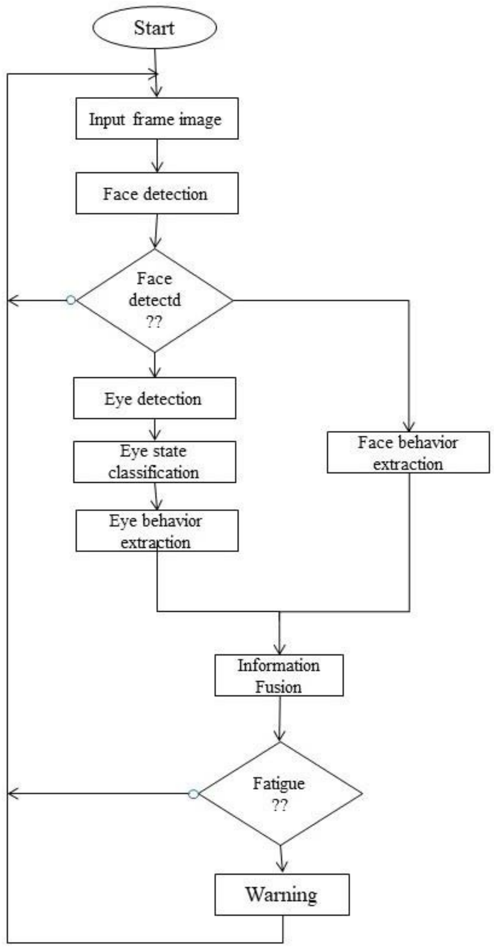

Fig. 1. Flowchart for driver drowsiness detection system

III. Methodology of the proposed system

In this section, the methodology of the proposed system is discussed in details. The eye state are classified. It follows by symptoms extraction includes face and eye behaviors. Then driver drowsiness level is estimated.

A. Eye state classification

The proposed system uses the histogram of oriented gradients (HOG) features, prposed by N.Dalal and B.Triggs [20], for eye feature extraction. The choice of this method is justified by its performance against skin color, illumination and scale changes. The key feature of this algorithm is that local object appearance and shape within an image can be described by the distribution of intensity gradients or edge directions.

Then, a feed-forward backpropagation Neural network is applied to the feature vector for the classification task and gives a score of '0' to opened eye and '1' to closed eye. Figure 2 shows the flowchart of eye state classification.

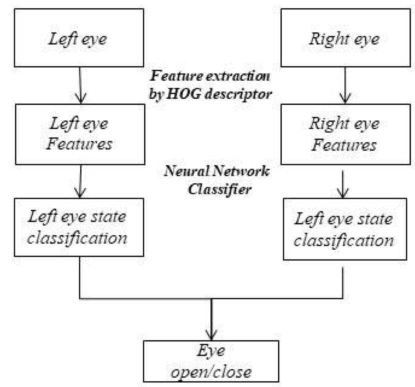

Fig. 2. Flowchart of eye state classification

The NN classifier is used over SVM classifier due to real time consideration, as seen in Table I.

TABLE I
Comparaison between Svm and NN classifier

	Occuracy	Time
SVM	94.7%	312 ms
NN	94.2%	15 ms

The classifiers of this method are trained using a large database composed of 3600 samples (2400 samples of opened eyes and 1200 samples of closed eyes).

B. symptom extraction

Once eyes are classified to open /close state, three symptoms related to visual behavior were extracted :

1) Percentage of Eye Closure: The first symptom is Percentage of eye closure (PERCLOS) which is a significant measure of a alertness [21].

$$PERCLOS[k] \sum_{i=k-n+1}^{k} (\frac{C[i]}{n}) \tag{1}$$

PERCLOS can be obtained by the equation 1 where PERCLOS(k) is the percentage of eye closure in the Kth frame, n is the number of frames through a period of time, c(i)=0 correspondent to opened eye and c(i)=1 correspondent to closed eye on each frame.

2) Eye Closure Duration: Eye Closure Duration (ECD) is used too as a real time drowsiness indicator [22].

$$ECD[k] \sum_{i=k-n+1}^{k} (\frac{Cl[i]}{t[i]}) \tag{2}$$

ECD can be obtained by the equation 2 where ECD(k) is the eye closure duration in the Kth frame, Cl(i) is the number of cluster of closed eye and t[i] is the total frame of closed eye in a period of measurement of n frame.

3) Percentage of oriented head: Percentage of oriented head (PEROH) is one of the symptom related to head orientation which is an effective measure of driver distraction, when the number of face detected in accepted region over a long time mean that the driver drwosiness level is high.

$$PEROH[i] \sum_{i=k-n+1}^{k} (\frac{FD[i]}{n}) \tag{3}$$

PEROH can be obtained by the equation 3 where PEROH(k) is Percentage of oriented head in the Kth frame and FD(i) is the number of detected faces in a period of measurement of n frame.

C. Drowsiness detection

Based on selected symptoms, the combinaison of these three measures is accomplished using fuzzy logic to estimate driver's vigilance.

The main structure of the fuzzy controller is composed of three main blocks as shown in Figure 3. Scalar variables are converted into fuzzy variable: fuzzification, then, fuzzzy input are excuted with applicable rule in the rulebase to compute fuzzy output functions and finally, output function are defuzzified to generate the crisp output .

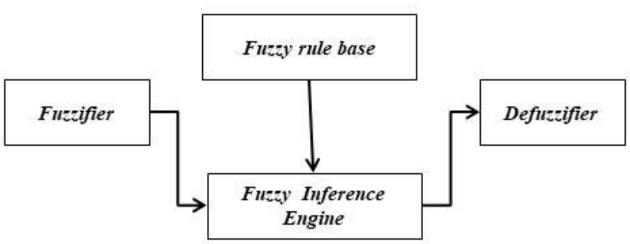

Fig. 3. The structure of fuzzy system

The proposed system has 3 three inputs (PERCLOS,ECD,PEROH) and 3 levels for each input, figure 4, 5, 6 illustrate the fuzzy membership of these parameters.

Figure 7 presents the output of the developed fuzzy controller of the driver drowsiness (Normal,Drowsy,dangerous) .

The fuzzy expert system is established using IF-Then rules (27 rules), some fuzzy rules are shown in the following:

(1)-If (PERCLOS is PER_H) and (ECD is ECD_H) and (PEROH is PEROH_H) then (output1 is dangerous).

(6)-If (PERCLOS is PER_M) and (ECD is ECD_L) and (PEROH is PEROH_H) then (output1 is drowsy).

(20)-If (PERCLOS is PER_L) and (ECD is ECD_M) and (PEROH is PEROH_L) then (output1 is drowsy).

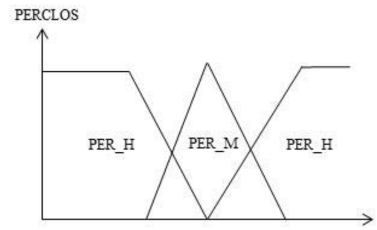

Fig. 4. Fuzzy membership functions of PERCLOS

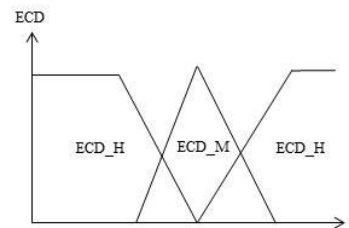

Fig. 5. Fuzzy membership functions of ECD

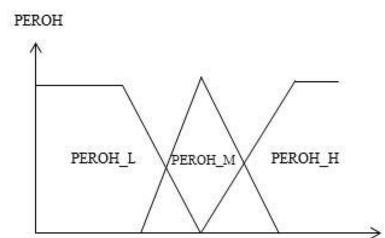

Fig. 6. Fuzzy membership functions of PEROH

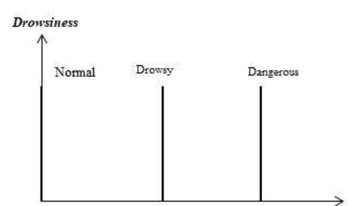

Fig. 7. Fuzzy membership functions of drowsiness estimation

IV. Experimental Results

The proposed system was implemented in Matlab 2016a on personal computer (intel i5/ 6GB RAM) and was performed various test under various conditions. Figure 8 shows the simulation results .

The curvature of PERCLOS, ECD, and PEROH related to face and eye behaviors are extracted as shown in figure 9, 10 and 11.

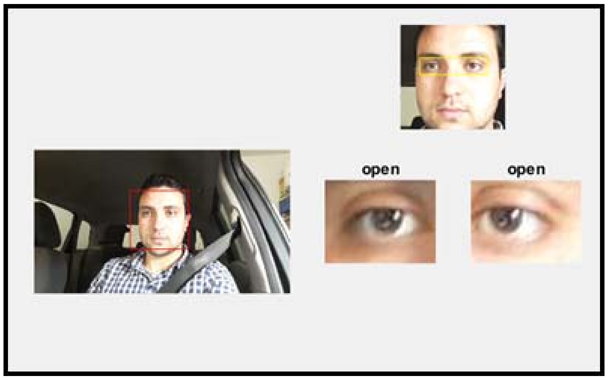

Fig. 8. Simulation Result

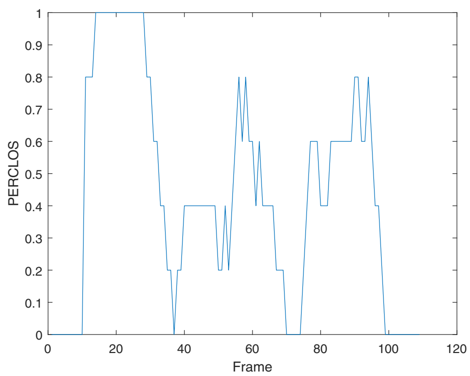

Fig. 9. Curvature of PERCLOS

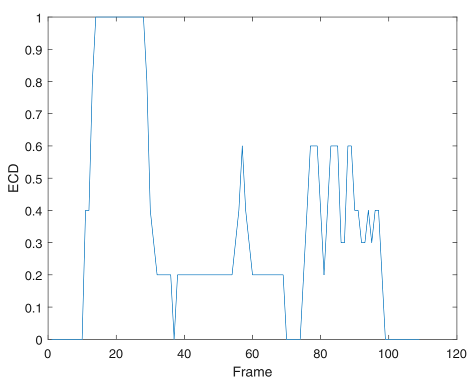

Fig. 10. Curvature of ECD

After analyzing these parameters, driver's vigilance was estimated with the proposed approach. Figure 12 illustrate the curvature of the estimated level of drowsiness.

For example in the interval of frame between [0 40]. Initially, the driver was in normal state. When PERCLOS increases and ECD increases and the number of detected face in accepted region is high the curvature of drowsiness estimation increases, the drives is in dangerous state.

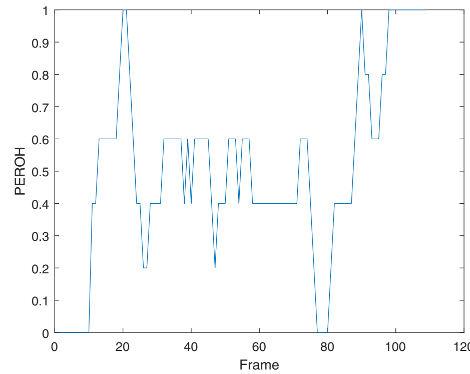

Fig. 11. Curvature of of PEROH

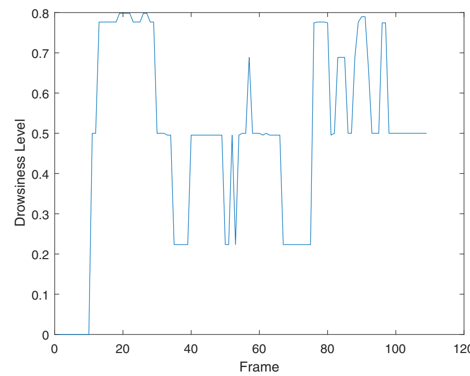

Fig. 12. Curvature of Driver drowsiness estimation

However, when ECD and PERCLOS decrease and PEROH is medium, the driver drowsiness level decrease and the driver become on Normal state.

V. Conclusion

The paper presents the design and simulation of a fuzzy based drowsiness detector. Three parameters were extracted, two symptoms related to eye behavior after the classification of the eye state and one symptom related to face behavior. The system has shown his accuracy under various conditions.

Future work are related with other measures which can be integrated to increase the performance of the developed system and real time constraints will be considered.

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