A Method of Driver's Eyes Closure and Yawning Detection for Drowsiness Analysis by Infrared Camera

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***Abstract*— A challenge of research in area of the driver drowsiness detection is to detect the drowsiness in low light condition. In this paper, we proposed a method to detect driver's eyes closure and yawning for drowsiness analysis by infrared camera. This method consists of four steps, namely, face detection, eye detection, mouth detection, and eyes closure and yawning detection. 3,760 images were used to test the performance of the proposed method. The accuracy rate of eyes closure detection, and yawning detection were 98%, and 92.5%, respectively. The experimental resulted show that the proposed method performed effectively. The advantage of this work is that this method can detect eye closure and yawning in low light condition.**

Keywords—Drowsiness, Yawning detection, Eyes closure detection

I. INTRODUCTION

Currently, the most popular vehicle is car. For long range travel, the driver can be fatigue or drowsiness, these factors are causes of car accidents. The deaths rate from car accident about 2.2 percent of worldwide deaths rate [1]. Ramathibodi Foundation reported that there is thirteen percentages of car accident in Thailand was happened from driver drowsiness [2]. Thai people who use vehicle on the road around 28-53 percent have accepted that they had sleep during driving a car. Driver drowsiness or force sleep is known as 'Microsleep' [3]. This symptom is body's phenomenon when body confuse between awaken or sleep. And you get force sleep for 2 second. Before getting microsleep body will have symptoms like yawn a lot, blink too much and feel sleepy.

Car accidents are a majority problem for society, and driver drowsiness is one of main reasons of accident. When the driver is sleeping, the car will continue drive with speedy around four second and car will go for 100 meters without control, so it is very dangerous. Driver could be seriously injured or death immediately. Road statistic show around 12 p.m. to 8 a.m. is the most popular duration to have car accident cause of driver drowsiness [4], So it means in cockpit has low light situation

Existing technologies of driver's drowsiness detection and warning can be separated in two types: 1) using images processing [5,6,7,8,9] and 2) using signal processing [10,11]. Which methods are present about different type of input data for example image from normal camera or image from infrared camera and using bio-signal. In first case they use eyes closure detection and yawning detection for descript are a driver sleeping begin with face detect to find driver's eyes and mouths then processing percent of driver could be drowsiness by set camera in front of a driver [5], or using one eye detection method to indicate driver drowsiness [6]. This work can detect driver drowsiness in left side or right side. In real-time drowsiness detection B. Reddy and et al present method for detecting driver drowsiness by face recognize deep learning from neural network, in this paper they use normal camera to get input data [7]. About hardware O. Khunpisuth and et al. [8] use Raspberry pi3 with extension camera for detecting eyes closure and calculate rate of drowsiness the driver cloud be, and alarm when variable get too high. Accordingly, these works cannot be used in low light situation and some works do not use another drowsiness symptoms except eyes closure to define driver drowsiness. There are few researches used infrared camera. One of this use histogram for detecting driver's face and eyes, and separate group for eyes closure as fully opened, half opened and close, by setup camera in front of driver [9]. This work used infrared camera to get input image, but this work only used eyes closure to define driver drowsiness.

For signal processing technique, C. Lin and et al [10] present method that used Electroencephalogram (EEG) to measure signal from brain and process that signal to estimate driver drowsiness. Electrooculogram (EOG) can be used for detecting driver drowsiness [11]. The method is using EOG signal and image from high frame rate camera for calculating. As mentioned these works have to attach to driver's body that may make diver feels uncomfortable while driving.

From the above there are few researches which use infrared camera. So normal camera cannot be use in low light situation, and many researches use camera set up in front of

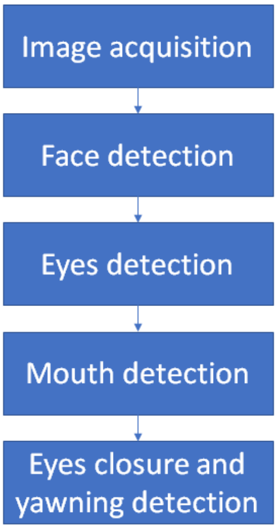


Fig. 1. flow chart of the proposed method.

Fig. 2. Input image from infrared camera

driver. That may obscure vision of the driver, and few works used another factor to detect driver drowsiness except eyes closure such as few researches do not detect yawing although it is one of main reasons cause drowsiness symptom. This paper will be present method to detection eyes closure and yawning in low light situation by using infrared camera. This work setup the camera by side of driver to prevent interference driver's vision, and use yawning detection with eyes closure detection to define driver drowsiness.

II. THE PROPOSED METHOD

The main concept is detecting the driver's face, and set it to region of interest (ROI). Next use ROI to find targets as eyes and mouth. This process starts from get input from infrared 2D camera and processing by MATLAB R2015a. Flow chart has five steps, namely, image acquisition, face detection, eye detection, mouth detection, and eyes closure and yawning detection, shown in Fig. 1.

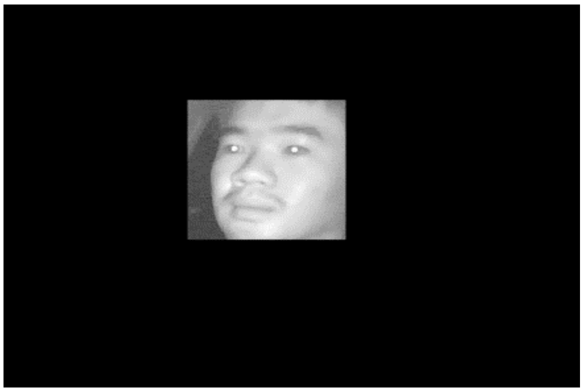


Fig. 3. Driver's face detection and set it to ROI

A. *Input image from infrared*

Record driver video from driver's seat. Install camera at the middle of car's console. Facing approximate 15 degrees to driver's face. Frame rate set as 25 frame per second and input scale is 200×200 pixel. Made of infrared camera is MD-tech series 02 it used 850nm light range. Show in Fig 2.

B. *Face detection*

Haar-like feature is one of methods that has ability to detect face. This method is invented by Paul Viola and Michael Jones [12]. This step use to make region of interest (ROI) for finding driver's face. Harr-like feature is the method classify dominate of face by determine differential of shading rectangle and normal rectangle, and compare it with threshold and polarity. Equation (1) is determine sum of rectangle area.

$$i_s(x_1, x_2, y_1, y_2) = \sum_{x=x_1}^{x_2} \sum_{y=y_1}^{y_2} i(x, y) \qquad (1)$$

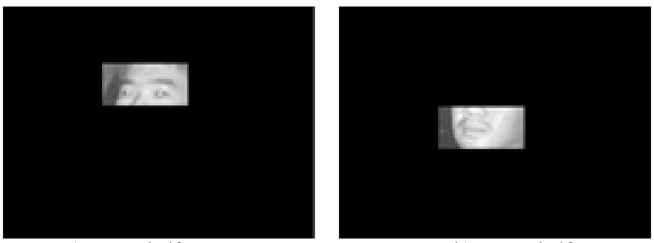
Which $i(x, y)$ means strength of shading. x and y mean sum of shading value. x_1, x_2, y_1 *and* y_2 is position of rectangle's corner. In this method after detect driver's face author will set it to ROI, and another area will set to black show in Fig 3.

C. *Split image to upper-half and lower-half*

Author have to separated face image to halves. This method for limit scope to detect driver's eyes and mouth. Fig 4a and 4b are showed upper and lower half.

D. *Detecting driver's eyes and mouth*

This step use to detect driver's eyes and mouth by using Haar-like feature, by the camera settings the driver's image will be little tilted, so this step will rotate image approximate3 degrees to the left and right. Fig 5a and 5b are showed images have rotated.

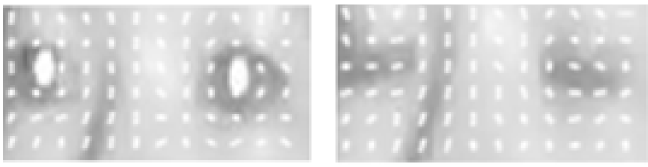


a) Upper half b) Lower half

Fig. 4. Images after split two half

c) Upper half d) Lower half

Fig. 5. Images after split two half



a) Eyes-opening's HOG b) Eyes-closing's HOG

Fig. 6. HOG images of eyes

E. *Detecting eyes closure and yawning*

About classify data author use Support vector machine (SVM). Before train data to SVM normal images have to be turn into vector data by extracting Histogram of oriented (HOG). HOG is method separate images to many cells and collecting histogram from every single gradient, and calculate scale and vector of that cell [13]. HOG is vector of each pixel. Fig 6a and 6b show HOG of eyes-opening and eyes-closing.

Next step, there are 2 groups of data like eyes opened and eyes closed. SVM is many types of it. In this paper SVM is suitable. Principles of SVM are learning models to analyze data. Given the data example at least for 2 groups [14].

III. EXPERIMENT RESULT

A. *Experiment setup*

This work has four experiments such as 1) face detection 2) eyes detection 3) mouth detection 4) eyes closure and yawning detection. First step author will set the infrared camera at top of car console approximate 15 degrees facing to driver, and the driver would random action symptoms of driver drowsiness for example blink a lot, close driver eyes and yawn randomly. These experiments do at low light situation with 4 volunteers. When the program can detect driver's eyes or mouth, the program will print green rectangle around eyes and mouth area show in fig 7a and 7b. When the program can detect symptoms of driver drowsiness program will print red rectangle at symptom area such as yawning will be printed with red rectangle around driver's mouth and eyes closure will be printed with red rectangle around driver's eyes area show in fig 7c and 7d.

a) Output when driver is normal

b) Output when driver is normal

c) Output when driver is Drowsy (yawning)

d) Output when driver is Drowsy (eyes closure)

Fig. 7. Program's output images

B. *Accuracy Rate*

There are four experiments such as 1) face detection 2) eyes detection 3) mouth detection 4) eyes closure and yawning detection. Show in table I-IV.

TABLE I. Face detection accuracy

Subject	**Total frame**	**Correct frame**	**Error frame**	**Miss frame**	**Accuracy**
1	865	865	0	0	100 %
2	1041	1025	2	14	98.46 %
3	1047	1043	1	3	99.61 %
4	825	825	0	0	100 %
Total	3778	3758	3	17	99.47 %

TABLE II. Eyes detection accuracy

Subject	**Total frame**	**Correct frame**	**Error frame**	**Miss frame**	**Accuracy**
1	865	733	33	99	84.73 %
2	1027	1004	16	7	97.76 %
3	1044	986	40	18	94.44 %
4	825	825	0	0	100 %
Total	3761	3548	89	124	94.33 %

TABLE III. Mouth detection accuracy

Subject	**Total frame**	**Correct frame**	**Error frame**	**Miss frame**	**Accuracy**
1	865	829	36	0	95.83 %
2	1027	1016	11	0	98.92 %
3	1044	1003	41	0	96.07 %
4	825	816	9	0	98.90 %
Total	3761	3664	97	0	99.80 %

TABLE IV. Accuracy of eyes closure and yawning detection

Subject	**True Positive Rate (Eye)**	**True Negative Rate (Eye)**	**False Positive Rate (Mouth)**	**False Negative Rate (Mouth)**
1	32.4 %	96.7 %	51.0 %	64.1 %
2	92.8 %	98.6 %	97.4 %	96.2 %
3	75.4 %	96.5 %	77.2 %	70.5 %
4	99.5 %	98.9 %	97.7 %	98.0 %
Validation	98.0 %	96.0 %	92.5 %	92.5 %

Fig. 8. Driver are opening mouth too much, so the program can't detect mouth correctly.

C. *Discussion*

From experiments accuracy table found that error of 7.5% of yawning detection that cause from driver mouth is open too much show in fig 8, so the program can't detection are driver yawning. And error of ROI detection that come from the camera is setup side of driver, so camera can't capture full driver's face is straight way.

IV. CONCLUSION

This paper presented a method to detect driver's eyes closure and yawning for drowsiness analysis by infrared camera. This method consists of four steps, namely, face detection, eye detection, mouth detection, and eyes closure and yawning detection. Four experiments, namely 1) face detection, 2) eyes detection, 3) mouth detection, and 4) eyes closure and yawning detection, were used to test the performance of the system. The accuracy rate of 1) face detection, 2) eyes detection, 3) mouth detection, and 4) eyes closure and yawning detection were 99.47%, 94.33%, 99.80%, and 92.5%, respectively. Errors occurred when a face is occluded such as hand. For future work, the method should be performed effectively, although capture angle of camera is varied in width range.

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