

Driver Eye State Detection using Minimum Intensity Projection - An Application to Driver Fatigue Alertness

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Abstract

The growing number of traffic accident due to driver's drowsiness has become a serious problem for society. Hence there is a need to address this problem to avoid accidents by alerting the driver so that road safety can be improved. Invasive techniques that assess physiological conditions, like brain waves, heart rythm rate of the driver and vehicle behavior techniques, including speed, turning angle, lateral position are used in driver fatigue monitoring. In this work, a non-invasive technique that monitors the eye state is used to detect the drowsiness of the driver. A novel feature called minimum intensity projection is proposed to detect the eye state of the driver and Support Vector Machine (SVM) is used to classify the eye state as open or closed. After detecting the eye status, drowsiness level is measured by calculating the duration of eye closeness and if the eyes are found to be closed over some consecutive frames then it is concluded that the person is falling asleep or having a state of drowsiness and hence an alarm is raised. Our approach for fatigue detection is non-intrusive which makes use of only the video from a camera mounted in front of the driver. This work yields a overall fatigue recognition accuracy of 97.4%.

Keywords: Eye State Detection, Fatigue Alertness, Minimum Intensity Projection, SVM

1. Introduction

The development of technologies for detecting or preventing drowsiness at the wheel is a major challenge in the field of accident avoidance systems. By observing the eyes, the symptoms of driver fatigue can be detected early enough to avoid a vehicle accident. Hence the focus of this paper is to design a system that will precisely discriminate the open or closed state of the person's eyes that can be applied to detect driver's drowsiness.

A review on driver face monitoring system for fatigue and distraction detection is seen in¹. A method using synthesized gray projection in an image is used to detect closed eye, is presented in². In³, eyes closeness detection

from still images with multi-scale histograms of principal oriented gradients is presented. A robust real-time computer vision-based system to detect the eye state for driver alertness monitoring is presented in⁴. In paper⁵ a robust and efficient eye state detection method based on an improved algorithm called LBP+SVM mode is proposed. An approach based on optical flow for fatigue detection is presented in⁶. Spatio-temporal features and multi scale dynamic feature based driver fatigue alertness is proposed in^{7,8}. In^{9,10}, a visual based approach for fatigue detection is presented. In¹¹ Haar classifiers are used to detect and alert fatigue. The authors of¹² assesed driver fatigue based on heart rate variability using neural network.

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2. Overall Architecture of the Proposed Work

The overall architecture of the proposed eye state detection is given in Figure 1. The approach uses Viola-Jones face cascade of classifiers for the detection of face. Further the eye region is determined heuristically with respect to the width and height of the detected face. The rowwise minimum intensity and columnwise minimum intensity projection of the histogram equalized eye image is used as a feature and is fed to support vector machine to discriminate the open and closed state of the eye.

2.1 Face and Eye Localization

Human face localization and detection is often the first step in applications such as video surveillance, human computer interface, face recognition and facial expressions analysis. The rapid object detection method presented in¹³

forms the basis of the face detection approach considered in this work. Viola - Jones object detection procedure based on cascade of classifier is used to locate the face within each frame of the video. After identifying the location of the face region, successive processing takes place within that region of interest and in particular, the eyes are estimated with respect to the width and height of the detected face. The following [Equation 1-Equation 4] are used to draw the eye rectangle.

$$\text{left.x} = (r.x+r.width/6) \quad (1)$$

$$\text{left.y} = (r.y +r.height/4) \quad (2)$$

$$\text{right.x} = (r.x+r.width*5/6) \quad (3)$$

$$\text{right.y} = (r.y +r.height/2) \quad (4)$$

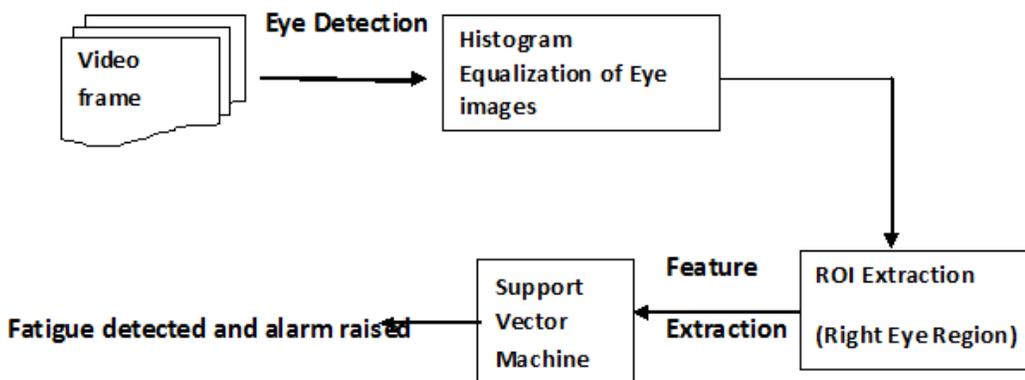


Figure 1. Work Flow of the Fatigue Detection Approach.



Figure 2. Face and Eye Localization.

where (1) and (2) are the top left corner co-ordinates and (3) and (4) are the bottom right co-ordinates of the eye rectangle and r.x, r.y are the top left co-ordinates and r.width, r.height are the bottom right co-ordinates of the face rectangle respectively. Figure 2 shows the sample image with face and eye localized.

2.2 Feature Extraction from the Eye Region

Feature is an informative portion extracted from an image or a video stream. Visual data exhibit numerous types of features that could be used to recognize or represent the information it reveals. Since the left eye and the right eye open or close synchronously, their states are the same. So it is reasonable to consider only one eye for

feature extraction and hence redundant computation can be eliminated.

The size of the eye image is 100 x 40 and the portion of right eye used for feature extraction is of size 36 x 28 (width x height) respectively. Histogram Equalization is a useful pre processing technique for image analysis. The eye images are histogram equalized to improve the visual important features and the enhanced eye images show details better for further analysis. Each eye image is scanned horizontally to find the pixel with minimum intensity value. Since the eye image height is 28, a total of 28 values are obtained which is the row minor pixel feature vector. Similarly the eye image is scanned vertically for the pixel with minimum intensity and a total of 36 values are obtained which is the column minor pixel feature

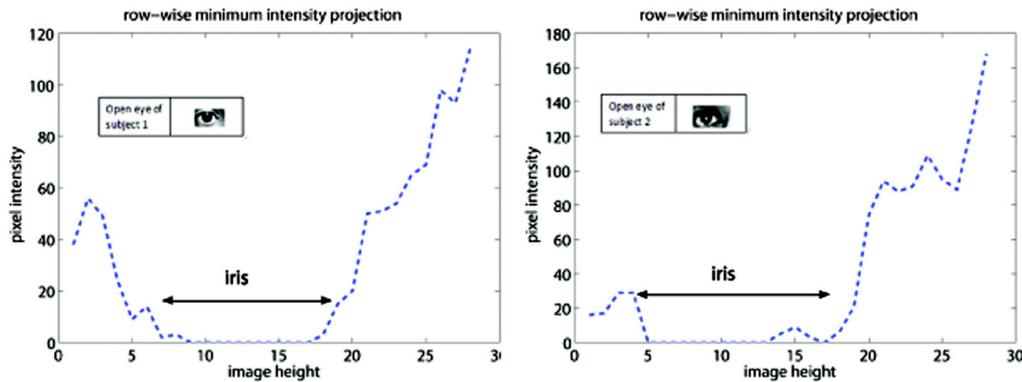


Figure 3. Rowwise Minimum Intensity Projection of Open Eye.

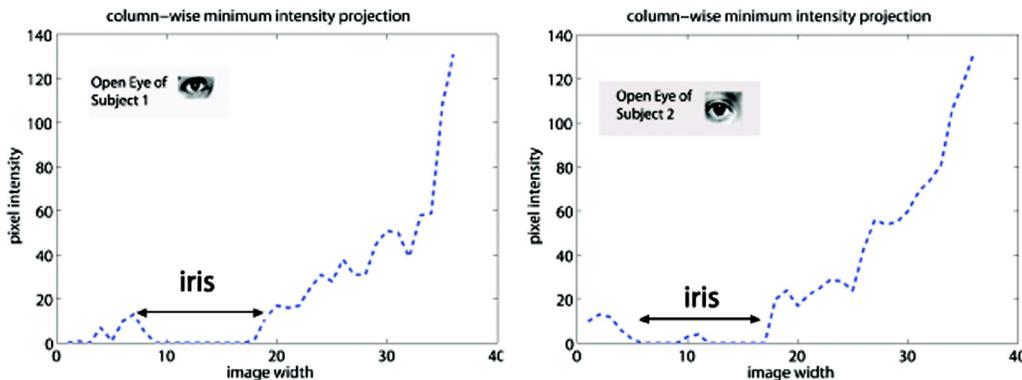


Figure 4. Columnwise Minimum Intensity Projection of Open Eye.

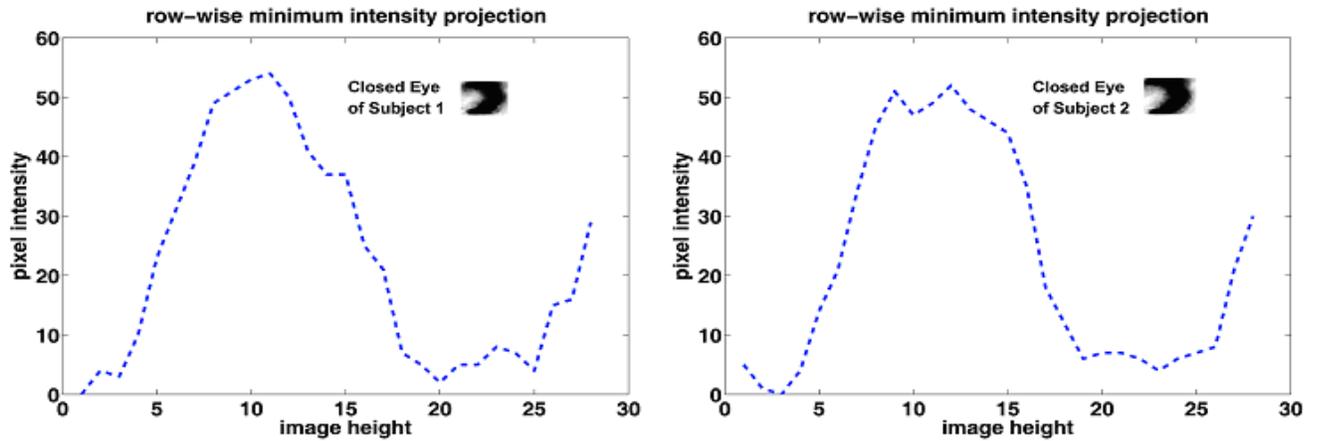


Figure 5. Rowwise Minimum Intensity Projection of Closed Eye..

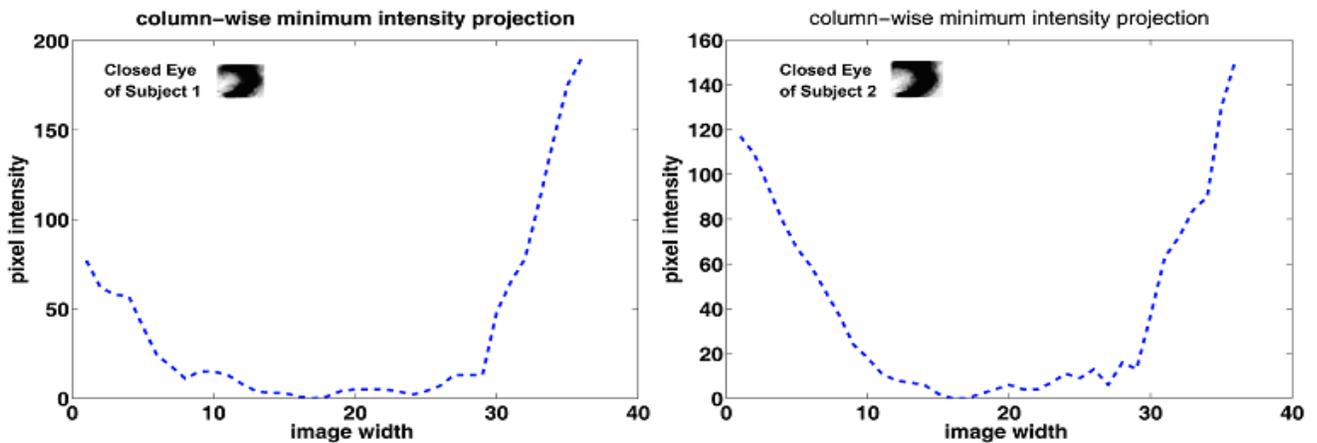


Figure 6. Columnwise Minimum Intensity Projection of Closed Eye.

vector. These row minor and column minor feature vector are combined and is of size 64 is fed as input to support vector machine to detect the open/closed state of the eye.

Since the open eye has iris region, horizontal and vertical projection of open eye has lower intensity values than the closed eye. This forms the basis for choosing the row and column minor pixel as feature in this work and the chosen features are well able to discriminate the open eye from the closed one. Figure 3 and Figure 4 shows the projection of row wise and column wise minimum intensity feature vector of open eye of two different subjects and Figure 5 and Figure 6 shows the projection of row wise and column wise minimum intensity feature vector of closed eye of two different subjects and it is observed that the plot of the feature vector of open eye has more

zero gray values that corresponds to the iris region in the open eye.

2.3 Drowsiness and Distraction Detection

After detecting the eye status (OPEN/CLOSED), driver drowsiness level is measured using the duration of eye closeness. It is defined as the period of time the eye is closed and in this work the threshold is set as 15 frames and if the eyes are closed above the threshold then it is fatigue and an alarm is raised. The algorithm does not generate an alarm if the eye closeness is less than 5 frames i.e., during the eye blink. Driver distraction is detected if the driver head is rotated and the driver does not look at the road ahead for a certain period of time. This is

achieved by simply tracking the video frames for driver's frontalface and distraction is detected if no eyes are being detected over a period of time. The threshold is set as 20 frames and if the number of frames is greater than the threshold, then the driver is alerted.

3. Support Vector Machine

Feature classification is performed in the last stage of an automatic fatigue detection system. Support Vector Machine is a learning method for pattern recognition problem introduced by Vapnik et al.¹⁴. Support Vector Machines classify data through determination of a set of support vectors, through minimization of the structural risk. The support vectors are members of the set of training in-puts that outline a hyperplane in feature space. This k-dimensional hyperplane, where k is the number of features of the input vectors, defines the boundary between the different classes Figure 7.

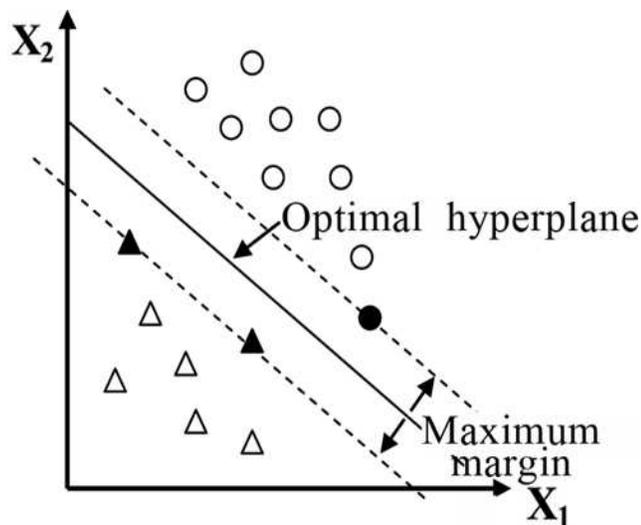


Figure 7. Optimal Separating Hyperplane.

The classification task is simply to determine which side of the hyperplane the testing vectors reside in. Minimizing the structural risk reduces the average error of the inputs and their target vectors. The support vector algorithm approximately performs Structural Risk Minimization. Given a set of training examples $(x_1, y_1), (x_2, y_2), \dots, (x_l, y_l)$, if there is a hyperplane that separates the positive and negative examples, then the points x which lie on the hyperplane satisfy $w \cdot x + b = 0$, where w is normal to the hyperplane and b is the distance from the

origin. The margin of a separating hyperplane is defined as the shortest distance to the closest positive or negative example. The support vector algorithm looks for the separating hyperplane with the largest margin.

By applying what is known as the kernel trick, a non-linear mapping function maps the original data points onto a higher dimensional feature space in which linear separability could be attained. The SVM then linearly classifies the transformed data points in the new feature space, even though the input space may not be linearly separable. The mapping function is known as the kernel function, and it is defined in terms of a transform ϕ , where the dot product between two vectors in the input space is being considered. This work exploits polynomial and Radial Basis Function (RBF) kernel models.

4. Experimental Results

In this section, the experimental results obtained on Eye State detection system are presented. The experiments are conducted in Matlab 2013a on a computer with Intel Xeon X3430 Processor 2.40 GHz with 4 GB RAM. The sample videos are captured using Logitech Quick cam Pro5000.

4.1 Dataset

The experiments are conducted with 12 subjects and the subject being captured by the camera in real-time at 15 frames per second with a 640 x 480 resolution. From the captured images, eye region is extracted for state detection. The Figure 8 shows the sample histogram equalized eye images and Figure 9 shows the portion of eye region used for feature extraction.

For eye state detection, 200 images of each subject showing open and closed eye states are used for experimental purpose. The features extracted from the eye region are input to SVM for training. The features are labelled -1 and +1 for open and closed eye respectively. The system is evaluated with Polynomial and RBF kernel and it has been observed that SVM with RBF (gaussian) kernel yields good recognition accuracy when compared to Polynomial kernel as seen in Table 1. This designates that RBF kernel best fit the data for fatigue recognition. The approach using this kernel gives an accuracy of 97.04%. Also the efficacy of the feature is evaluated by testing videos collected from different persons, where the video duration is of 60 secs. The Table 2 shows a few samples of fatigue and distraction detection results and

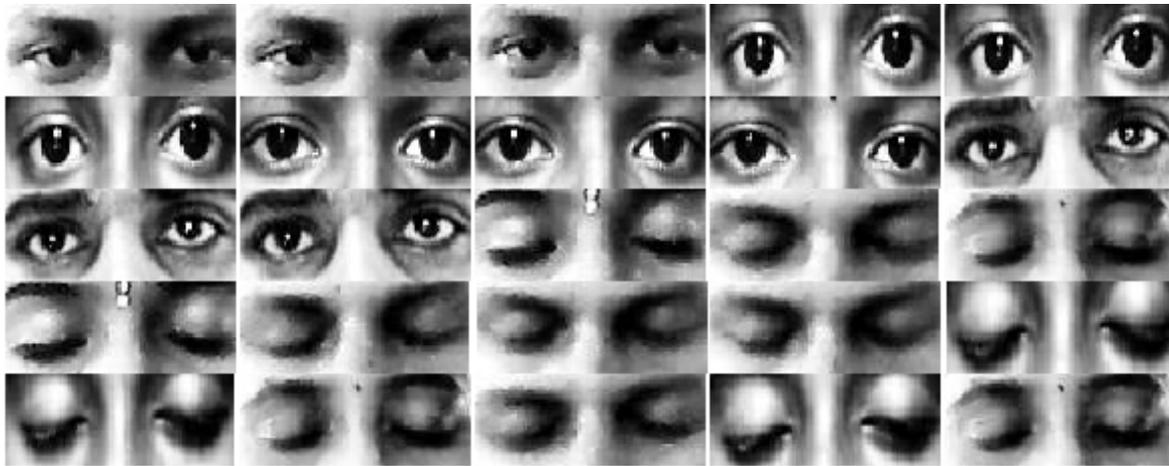


Figure 8. Histogram Equalised Eye Images.

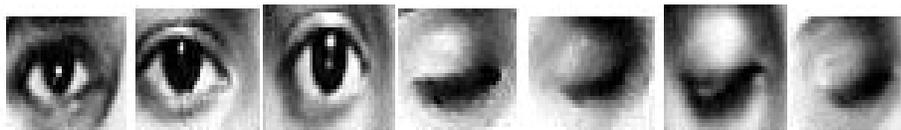


Figure 9. Portion of Eye Image used for Feature Extraction.

alarm generation part of the proposed work. The graphical user interface of this work is shown in Figure 10, 11, 12 respectively.

4.2 Evaluation Metric

A systematic study of performance measure for classification tasks is presented in 15. Precision (P) and Recall (R) are the commonly used evaluation metrics and these measures are used to evaluate the performance of the

proposed system. These measures provide the best perspective on a classifier’s performance for classification. The measures are defined as follows:

$$\text{Precision}(P) = \frac{\text{No. of True Positives}}{\text{No. of True Positives} + \text{False Positives}}$$

$$\text{Recall}(R) = \frac{\text{No. of True Positives}}{\text{No. of True Positives} + \text{False Negatives}}$$

Table 1. Eye State Detection Results

SvmKernel	Class	Precision(%)	Recall(%)	F-Score(%)
RBF	openeye	97.4	98.2	97.79
	closedeye	96.2	95.7	96.30
Polynomial	openeye	94.8	92.4	93.5
	closedeye	91.7	89.3	90.48

Table 2. Fatigue and Distraction Detection Results of Sample Videos

Dataset	Actual Dozing, Distraction	Alarm Raised	False Positive Alarms	False Negative Alarms	Correct Alarms
Video1	8	12	2	4	6
Video2	5	6	1	0	5
Video3	10	12	2	2	8
Video 4	7	8	1	0	7

The work used F1-measure (F1) as the combined measure of Precision (P) and recall (R) for calculating accuracy which is defined as follows:

$$F1 - measure = \frac{2 \cdot Precision \cdot Recall}{Precision + Recall}$$

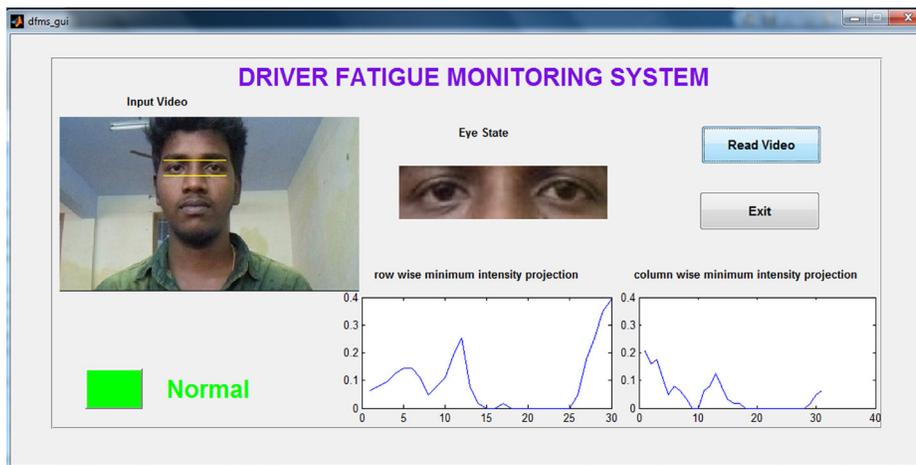


Figure 10. Driver in Normal State.

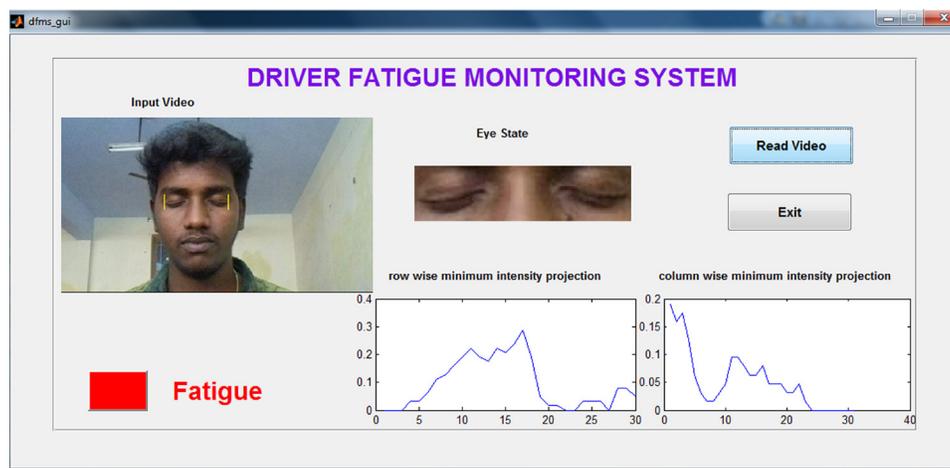


Figure 11. Driver in Drowsy State - Alarm Raised.

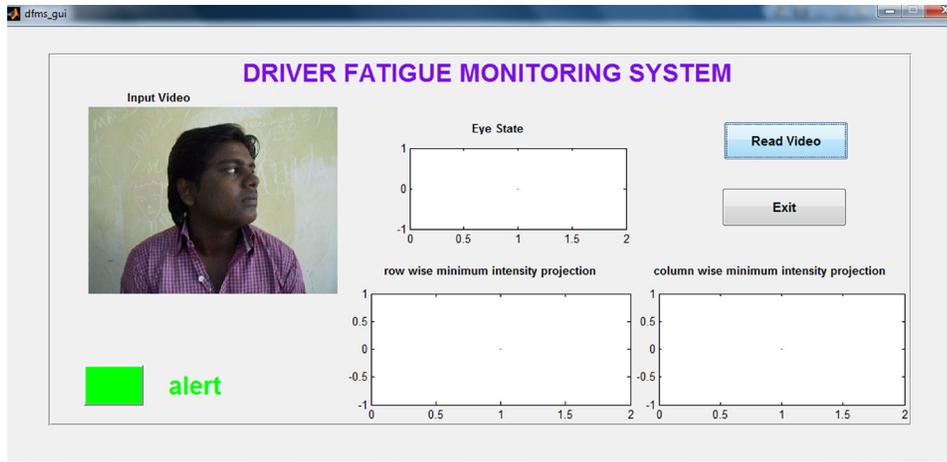


Figure 12. Driver Distraction- No Frontal Face Found.

5. Conclusion

This paper presents a novel approach to recognize open/closed eye states using projection of row wise minimum intensity and column wise minimum intensity. The performance of the proposed feature is evaluated with Polynomial and RBF kernel of support vector machine. The support vector machine with RBF kernel yields the best performance with an overall accuracy rate of 97.04% in fatigue recognition. The proposed method effectively detect the drowsiness of driver by calculating the duration of eye closeness and if the eyes are found to be closed over some consecutive frames then it is concluded that the person is falling asleep or having condition of drowsiness and hence an alarm is generated.

6. References

1. Sigari MH, Pourshahabi MR, Soryani M, Fathy M. A Review on Driver Face Monitoring Systems for Fatigue and Distraction Detection. *International Journal of Advanced Science and Technology*. 2014; 64(3):73–100.
2. Lu L, Ning X, Qian M, Zhao Y. Close eye detected based on synthesized gray projection. In: *Advances in Multimedia, Software Engineering and Computing*. 2012; 2:345–51. DOI:10.1007/978-3-642-25986-9_53.
3. Song F, Tan X, Liu X, Chen S. Eyes closeness detection from still images with multi-scale histograms of principal oriented gradients. *Pattern Recognition*. 2014 Mar 23. 47(9):2825–38.
4. Gonzalez-Ortega D, Daz-Pernas FJ, Anton-Rodríguez M, Martínez-Zarzuola M, Dez-Higuera JF. Real-time vision-based eye state detection for driver alertness monitoring. *Pattern Analysis Applications*. 2013;16(3):285–306.
5. Sun R, Zheng ma. Robust and efficient eye location and its state detection. *Advances in Computation and Intelligence*. LNCS. 2009; 5821: 318–326. DOI: 10.1007/978-3-642-04843-2_34
6. Senaratne, Jap R, Lal B, Hsu S, Halgamuge A, Fischer S. Comparing two video-based techniques for driver fatigue detection-classification versus optical flow approach. *Machine Vision Applications*. 2011; 22(4):597–618.
7. Akrouf B, Mahdi W. Spatio-temporal features for the automatic control of driver drowsiness state and lack of concentration. *Machine Vision and Applications*. 2015; 26(1):1–13.
8. Yin B, Fan X, Sun YF. Multiscale dynamic features based driver fatigue detection. *Int Journal Pattern Recogn Artif Intell*. 2009; 23(3):575–89.
9. Akrouf B, Mahdi W. A visual based approach for drowsiness detection. *IEEE Intelligent Vehicles Symposium*; 2013 Jun 23–26; Gold Coast, QLD: IEEE Conference Publications; p. 1324–29.
10. Flores MJ, Armingol JM, de la Escalera A. Real-Time Warning System for Driver Drowsiness Detection Using Visual Information. *Journal of Intell Robot Syst*. 2010; 59(2):103–25.
11. Ibrahim LF, Abulkhair M, AlShomrani AD, AL-Garni M, AL-Mutiry A, AL-Gamdi F, Roa'aKalenen. Using Haar classifiers to detect driver fatigue and provide alerts. *Multimedia Tools Appl*. 2014; 71(3):1857–77.
12. Patel M, Lal SKL, Kavanagh D, Rossiter P. Applying neural network analysis on heart rate variability data to

- assess driver fatigue. *Expert System Applications*. 2011; 38(6):7235–42.
13. Viola P, Jones M. Rapid object detection using a boosted cascade of simple features. *IEEE Conference on Computer Vision and Pattern Recognition*; 2001. p. 511–18.
 14. Vapnik V. *Statistical Learning Theory*. Wiley, NY; 1998. ISBN: 978-0-471-03003-4.
 15. Sokolova M, Lapalme G. A systematic analysis of performance measures for classification tasks. *Information Processing and Management*. 2009 Jul; 45(4):427–37.