Bachelor of Science in Computer Science & Engineering

Vision-Based Drowsiness Detection System for Night Time Driving

by

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Submitted in partial fulfilment of the requirements for
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in Computer Science & Engineering

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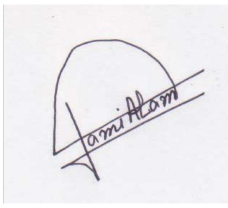

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Abstract

In this project, we have designed and implemented a vision based drivers drowsiness detection system for night time driving. Materialising the system is complicated as it includes face detection, facial outline detection, extracting information of the state of eye etc. in different lighting condition. The system should work in real time. For this we use openCv and dlib library. We calculate the EAR of eye to decide if the driver is drowsy or not . our system can detect drivers drowsiness and alert him.

Keywords— openCv; numpy; dlib;EAR

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Chapter 1

Introduction

1.1 Introduction

Sleepiness during driving is one of the main causes of traffic accidents and it has been proved.

In particular, in [1] Klauer et al. have shown that the risk of an accident increases between four and six times when the driver is sleepy when compared to driving when the user is awake. Again, the chance of an accident is higher at night or when sleep deprivation is present. In fact, at least 15-20 percent of all car accidents are thought to be caused by sleepiness [2].

1.2 Framework/Design Overview

This work presents a method to monitor driver drowsiness based on the technology of computer vision installed on the vehicle. In front of the driver, a camera is placed on the dashboard to get EAR. It has therefore proved to be the best outdoor parameter. The system is bound to restrictions on real time and robustness. Our work requires a separate process of calibration and includes techniques for solving the typical image processing algorithms problems like light changes, user appearance and rapid movements in the head. No calibrations are required for computer vision algorithms to determine the closure of the eye. However, a standard EAR eye closure value is required. This value depends on driver's eye constraints and the camera lens selected. Although in a first manual process, it is estimated for flexible installation of this system in any vehicle. The system developed is robust against high light variations and meets the requirements of real-time computing. In both simulation and actual operating scenarios, the implemented system is user-independent and can evaluate the EAR indicator in real time. Our system is meant to be flexible and open source.

1.3 Difficulties

The major difficulties for implementing the system are given below:

1. **Real time face detection:**

   Frame in a video changes 60 times per second and the position of face changes almost every time. so it is a big challenge to detect the face in real time

2. **Face outline extraction:**

   Extracting the face outline from every frame is also difficult

3. **EAR calculation:**

   As EAR is the basis for drowsiness detection in our project, we are needed to be very precise to calculate the EAR and taking the threshold for the comparison with our real time calculated EAR.

1.4 Applications

Drivers drowsiness detection system can form the basis of a system to potentially reduce the number of crashes of vehicles related to drowsy driving. The video processing technique to calculate EAR scientifically validates the measurement of drowsiness. Every driver can use it as an assistant for their driving. This system can potentially save many lives.

1.5 Motivation

Developing a system which monitors the attention state of the driver will be convenient for the drivers and for others as well. It will alert at the critical moment when the driver is getting drowsy, thus it will prevent accidents. This system will save lives of many people.

Therefore, we intent to do this project.

1.6 Contribution of the thesis

The major contributions of this project are listed as follows:

- We have developed a system to detect drowsiness of drivers.
- We have used an efficient method to calculate the EAR of eye.
- We effectively alert the driver when he is drowsy.

1.7 Thesis Organization

The rest of the paper is organized as follows.

- In Chapter 2 a brief discussion on the previous work related to drowsiness detection system is provided.
- In Chapter 3 we provide our methodology, describe our data set in detail, introduce the performance metrics, and then, show the selection procedure to find influential people.
- In Chapter 4 the experimental results and performance evaluations are presented.
- Finally, in Chapter 5 we conclude the paper and outline future work directions.

1.8 Conclusion

In this chapter, the overview of our work has been discussed. The difficulties, applications, and motivation of our work have also been discussed throughout this chapter. We also mentioned the contributions of our work. This chapter gives a summary of our work.

Chapter 2

Literature Review

2.1 Introduction

Several ways have been developed to detect drowsiness of drivers. Some important methods for detecting drowsiness are summarized in this section.

2.2 Related Literature Review

Lamia Alam et al. [3] developed a system which estimates the attention level of the driver. It also classifies the attention states of drivers on the basis of eyelid closure percentage (PERCLOS) in real time , the yawning frequency and the detection of gaze.

Malla et al. [4] developed a light-insensitive system. They used Haar Algorithm for objects detection [5] and implemented face classification by [6] OpenCV [7] libraries. Eye regions come from the face region with factors anthropometric. Then we will find the Eyelid for eye closure measurement.

Rateb et al. [8] used deep neural networks to detect real-time driver drowsiness. They have also developed an Android application.

Tereza Soukupova et al. [9] calculated drowsiness of drivers using EAR(Eye Aspect Ratio) as a standard measure. The types of systems used for drowsiness detection of drive were also detailed.

Vitabile et al. [10] developed a system that uses an infrared camera. It detects the symptoms of driver drowsiness. They have developed an algorithm to detect and track eyes of the driver. It uses the bright pupils arteries phenomenon of the eyes. The system warns the driver by blowing an alarm when drowsiness of the driver is detected.

Bhowmick and Kumar [11] detects the face region using the Otsu thresholding method [12]. They located the facial landmarks like the eye brow and possible face center and accomplished the localization of the eyes. They also used morphological operations and Kmeans to get accurate eye segmentation. Following that, they calculated a set of shape features and then trained the fratures using non-linear SVM. Finally, it determined the eye's status.

A real time eye state detection system is defined by Hong et coll.[13] to detect driver drowsiness state. They detected the face region using the optimized Jones and Viola method [5]. The area around the eyes is obtained by a horizontal projection. Finally, a new complexity function was introduced by them that uses a dynamic threshold with a view to identifying the state of eye.

Tian et Qin [14] create a technique to monitor the driver's eye conditions. The Cb and Cr components of the YCbCr color space are used in their system. This system locates the face with a horizontally projected eye and a vertical projected eye function. The system calculates the eye conditions based on a function of complexity When the eyes are located.

2.3 Conclusion

In view of the foregoing, the detection of the driver's drowsy state provided by the PERCLOS is commonly processed through the following stages:

- Detecting face,
- Eyes Location,
- Face and eyes tracking,
- Eyes states Identification,
- PERCLOS calculation and identification of driver status.

2.3.1 Implementation Challenges

The major challenges for implementing the system are : Frame in a video changes 60 times per second for 60fps and the position of face changes almost every time. so it is a big challenge to detect the face in real time. Extracting the face out outline from every frame is also difficult. As EAR is the basis for drowsiness detection in our project, we are needed to be very precise to calculate the EAR and taking the threshold for the comparison with our real time calculated EAR.

Chapter 3

Methodology

3.1 Introduction

In Figure 3.1 the general architecture for drowsiness detection system for night time driving is shown. It consists of four major modules: Pre-processing stage, Eyelids detection and tracking, EAR estimation and Evaluation of the drowsiness detection system. A low-cost micro camera supports the video acquisition. For image processing the facial detection and tracking stage is responsible. We track the Eyelids in real time robustly. During the visual behavior phase, we will compute certain picture parameters, in order to detect visual behaviors that can easily be observed in people who suffer from fatigue.The parameters are slow eyelid movement, smaller degree of eye opening, blink time etc. Finally, we combine the various parameters obtained in the previous phase with the Boolean logic during the driver's drowsiness ground truth signal generation stage, thus giving the driver a threshold inattention. If this level is above a certain threshold, an alarm is activated.

3.2 Diagram/Overview of Framework

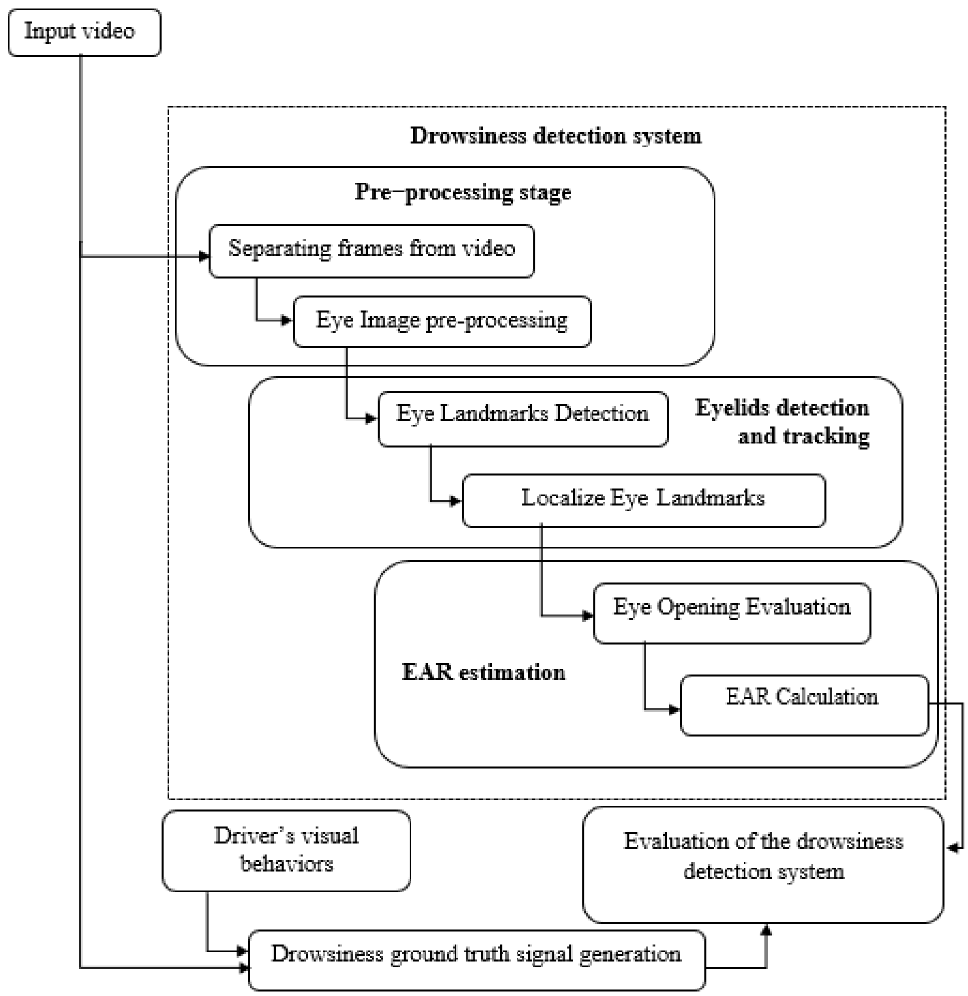

Figure 3.1: Drowsiness detection system methodology

In our system we will first take video input in real time then extract each frames. As we know the picture will be in BGR form. We convert it into gray scale image. Then run our face detection and facial landmark extraction process. Once the face is detected the we search for our eyelid.Then we calculate the distance between our eyelids using EAR formula. Comparing the value of EAR with the threshold value of EAR, we generate a drowsiness ground truth signal. When this signal is true it will blow an alarm.

3.3 Pre-processing stage:

In the entire video frame, in this step eye location will be located. The different facial colours, appearance, poses, relatively large sizes and very uneven lighting conditions make it a very complicated challenge. The search for the eye is performed in two steps. The first is to search for the face. The eye detector is applied to it as soon as the area of face is found. We'll turn it into a gray scale picture in this step. Between consecutive images, we will trim detection failures. When facing quick face motions, it gives solidity to the EAR measurement.

3.3.1 Separating Frames from video:

Video is nothing but the continuous flow of picture. Our camera can capture 60 frames per second. Each frames capture one picture. These pictures are saved in our memory as a numpy [15] array like fig. 3.2.

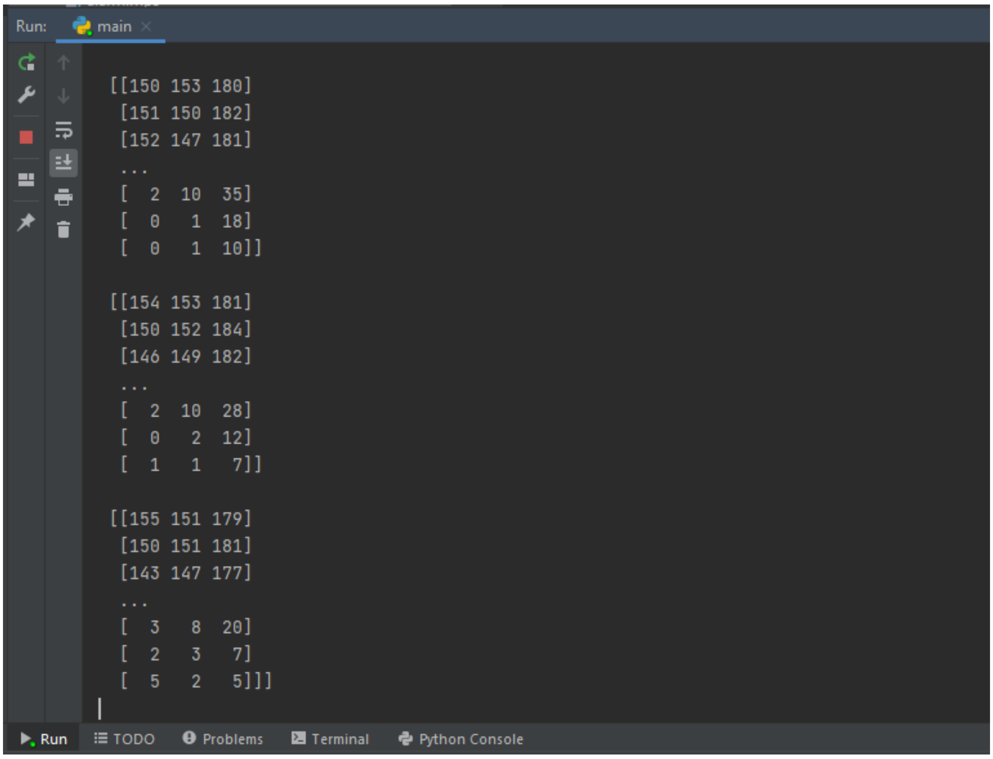

Figure 3.2: Numpy array of original image.

3.3.2 Eye Image Pre-processing:

The fig. 3.3 shows the function of this step. Here each frame extracted from the video is converted from BGR to gray scale image. After gray scale conversion the image looks like black and white image. This image is now ready for the face detection process.

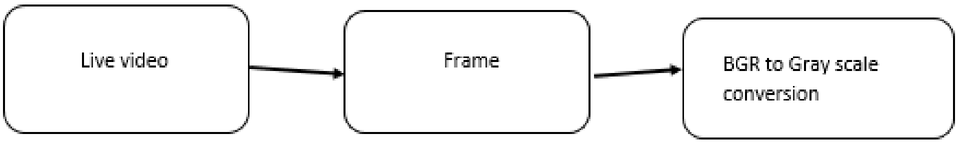

Figure 3.3: Image pre-processing stage.

3.4 Eyelids detection and tracking:

In order to achieve ocular measurements, the eyelids of the subject are continuously monitored, and the algebraic distance algorithm is altered to fit two ellipses in each of them, as implemented in OpensCV . The level of opening of the eye is marked by the shape of the Eyelid. As the eyes close, the muscles of the eyelids begin to come closer and their forms become more elliptical. We can use the eyelids ellipse to describe the eyelid opening status with the Eye Aspect Ratio.

3.4.1 Facial Landmarks Detection:

After gray scale conversion we run our dlib,s [16] facial landmark detection process in the image.The next step is to apply facial landmark detection to localize each of the important regions of the face. This process finds the different 68 points [17] like fig. 3.4. The facial landmarks which are produced by dlib are an indexable list.

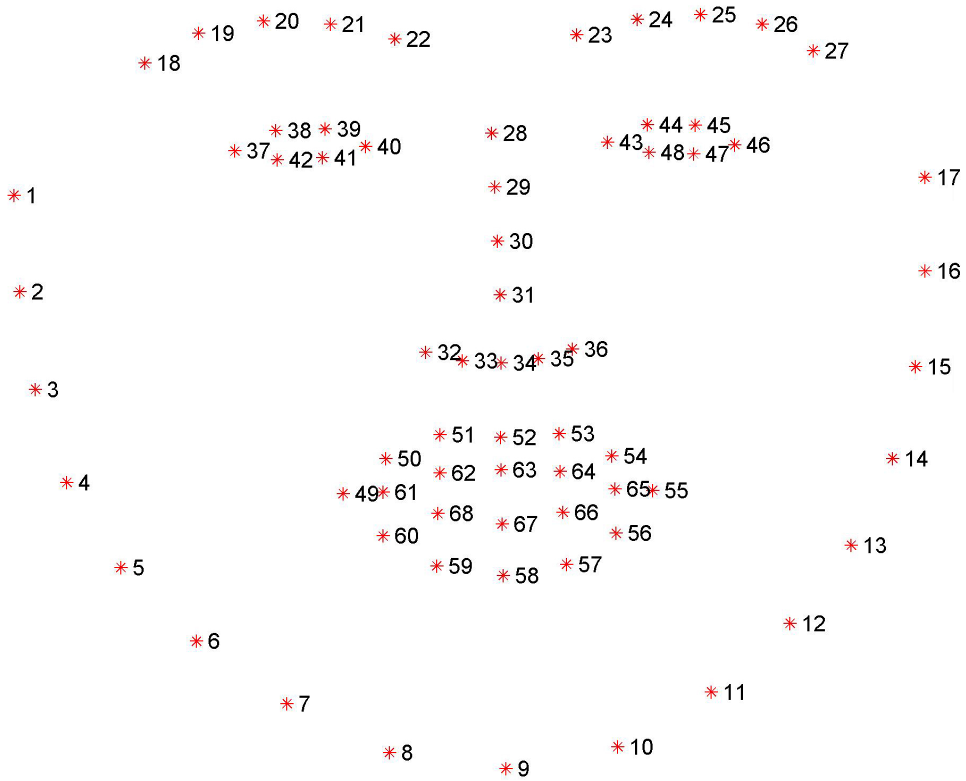

Figure 3.4: 68 different points of face.

3.4.2 Localize Eye Landmarks:

We will run dlib's facial landmark detector For each of the detected faces.Then it will be converted to a NumPy array. From the converted array, we will be using NumPy array slicing. From this array slicing method we can extract the (x, y)-coordinates of the left and right eye.These figures fig. 3.5 and fig. 3.6 the convex hull of the eyes when they are open and close respectively.

Figure 3.5: Convex hull of the open eyes.

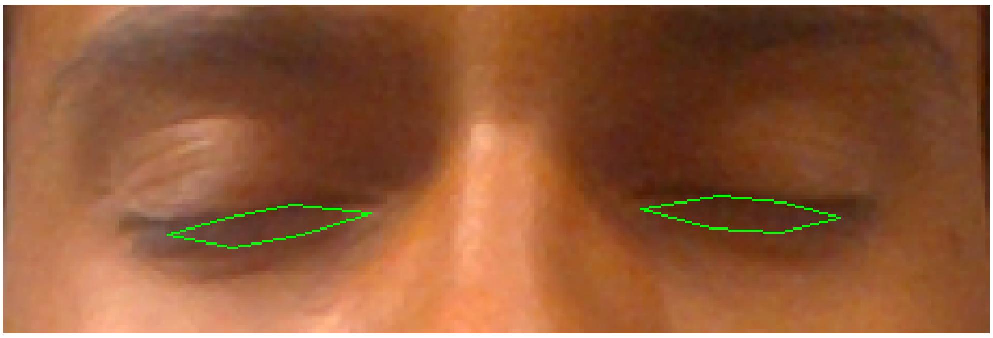

Figure 3.6: Convex hull of the closed eyes.

3.5 EAR estimation:

A complete horizontal and vertical projection from the sensitive area of the eye is included in the eye closure assessment algorithm. The integrated projections seemed to have some points from the empirical experience. For both directions, the variance is estimated, and the vertical one is equal to the eye height used to achieve the EAR. An earlier calibration process is necessary to evaluate EAR. At the beginning of the workout, the calibration process is done manually. When awake, the driver has to look at the road in a relaxed position and calculate the normal EAR value by the algorithm. The instantaneous EAR will be evaluated with this normal value. The distance from the upper to the lower eyelids is calculated. The methodology does not identify any eyes when the driver's head is turned.

3.5.1 Eye Opening Evaluation:

The fig. 3.7 and fig. 3.8 shows the localized points of eye when it is opened and closed. When the eye is open the distance between p2, p6 and p3, p5 will be maximum. But when the eye is closed the distance between p2, p6 and p3, p5 will be minimum. These differences gives us a basis to mathematically differentiate between the two states of our eye. Taking this into consideration we will calculation our EAR. It will also help us to determine the threshold for differentiating two different states of eye

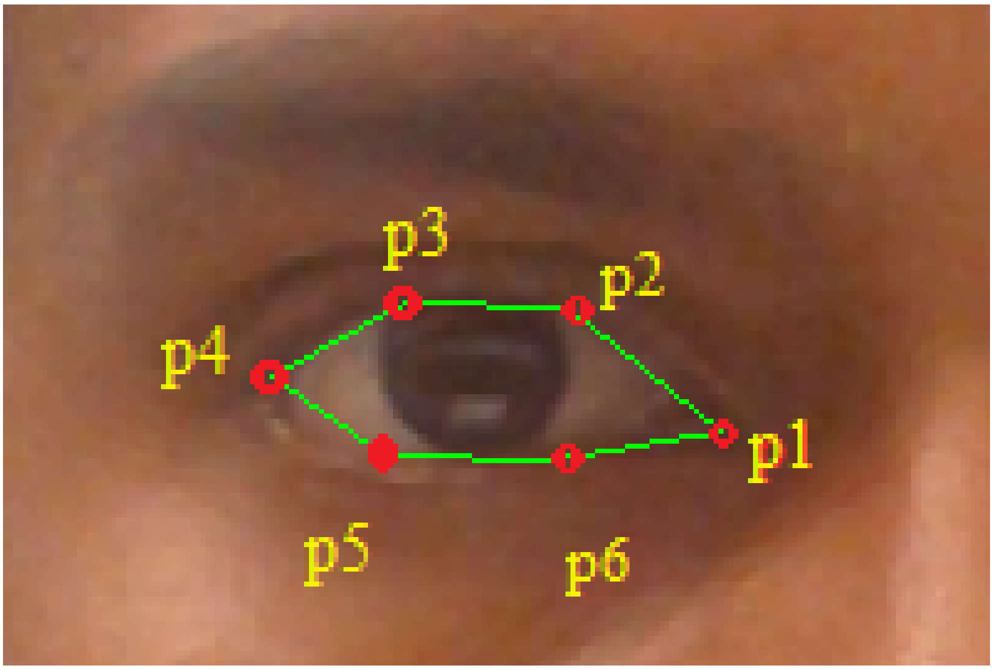

Figure 3.7: Six different points of open eye.

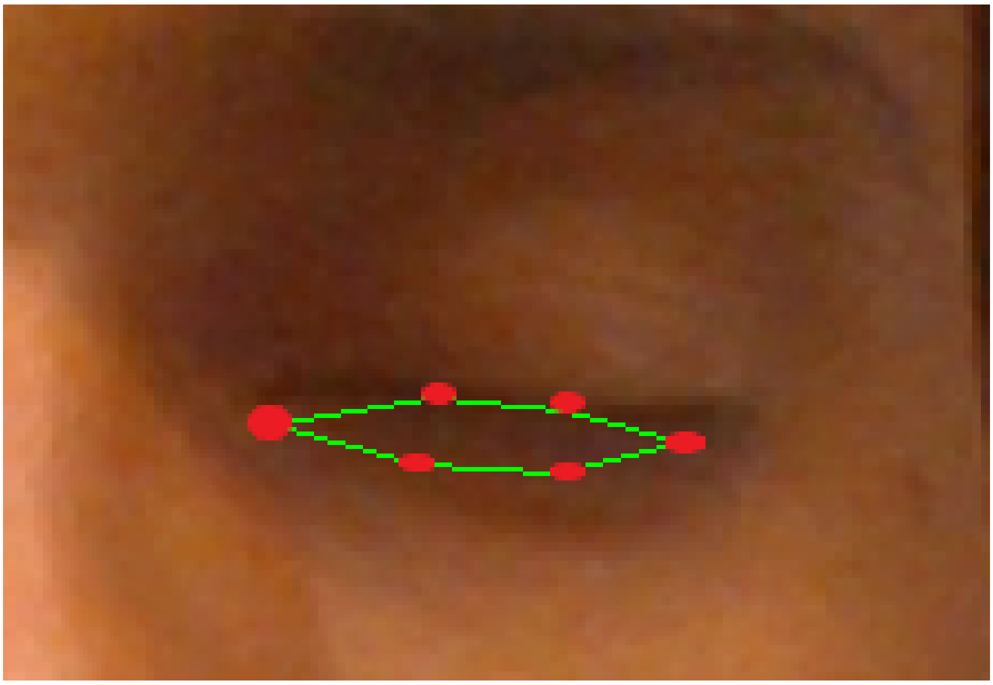

Figure 3.8: Six different points of closed eye.

3.5.2 EAR Calculation:

We have defined the eye aspect ratio function used to calculate the distances of the vertical eye signs from their horizontal eye signs.The euclidean distance between vertical eye signs (x, y)-coordinates is calculated.

$$A = dist.euclidean(eye[p2], eye[p6]) \tag{3.1}$$

$$B = dist.euclidean(eye[p3], eye[p5]) \tag{3.2}$$

The euclidean distance between the horizontal eye landmarks (x, y)-coordinates is calculated

$$C = dist.euclidean(eye[p1], eye[p4]) \tag{3.3}$$

Then we calculate the eye aspect ratio

$$ear = (A + B)/(2.0 * C) \tag{3.4}$$

3.6 Drowsiness ground truth signal generation

We have to determine a threshold for our Ear to generate a drowsiness truth signal. This depends on the distance between the camera and the driver, characteristics of eye of the driver. In our case distance between camera and me was 2 to 3 feet. For this distance we have taken a threshold 3.0. When the EAR is below 3.0 for 48 consecutive frames then it will generate a drowsiness ground truth signal. When the drowsiness ground truth signal is true it will blow the alarm. The fig. 3.9 shows the EAR value when the eye is open and closed. Here we can see a rapid drop in the value of Ear when the eye is closed.

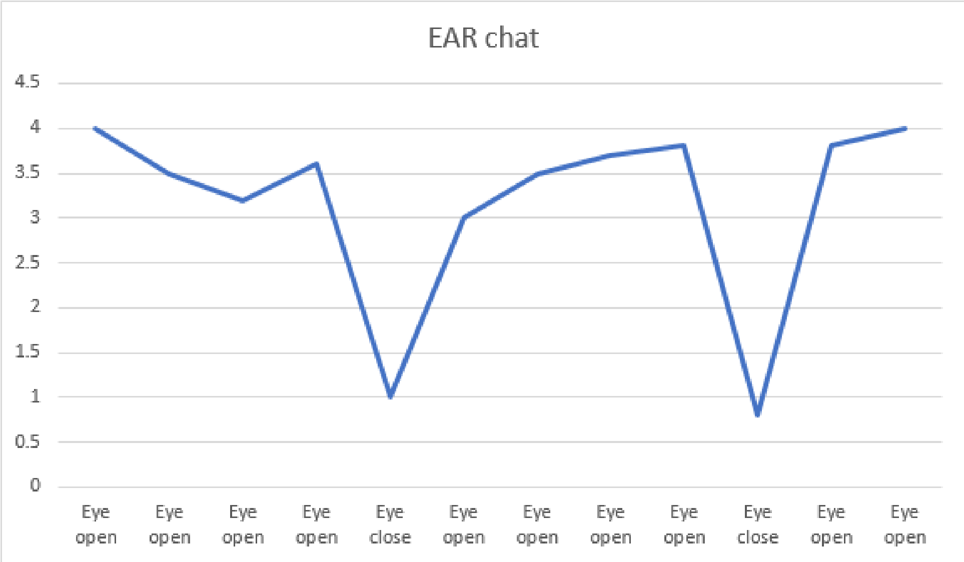

Figure 3.9: EAR vs Eye state

3.7 Conclusion

In this section we have discussed the methodology of our project in details using relevant images and equations. Our methodology has four basic blocks named: Pre-processing stage where we detect the face and eye, Eyelid detection and tracking where we track the eyelid, EAR estimation where we calculate the eye aspect ratio and Drowsiness ground truth signal generation where we generate a truth signal if it satisfies some condition. This signal then blow the alarm.

Chapter 4

Results and Discussions

4.1 Introduction

In the previous chapter, the methodology for driver drowsiness detection system using Eye Aspect Ratio has been discussed in details. In this chapter, we will evaluate the results and performance of our proposed system.

4.2 Dataset Description

Here we have used dlib's pre-trained facial landmark detector [18]. Using the classic Histogram of Oriented Gradients (HOG) feature the face detector is developed. To make the system more precise it was combined with a sliding window detection scheme, linear classifier and an image pyramid. The paper One Millisecond Face Alignment with an Ensemble of Regression Trees [19] was implemented in dlib to develop the pose estimator. The pose estimator was trained on the iBUG 300-W face landmark dataset [20].

4.3 Impact Analysis

The importance of impact analysis in the implementation of any new system cannot be overstated. It is vital to consider whether it will benefit or harm society and human ethics. The impact analysis is broken down into two sections, which are explained below:

4.3.1 Social and Environmental Impact

This proposed framework helps people to ensure safe driving and decreases the number of accidents. This system will also help to reduce the number of drop dead. It helps preventing preventing people from driving when they are drowsy.So, it will do good for society.

4.3.2 Ethical Impact

This proposed System is completely ethical. It gives a safe driving experience for the drivers. It does nothing bad to any user as well as their surroundings.On the contrary, it keeps people's mind stable while driving by ensuring their consciousness during driving. .

4.4 Evaluation of Framework

Our system can detect eyes and calculate the EAR even if the angle between the user and the camera is 60°. Here fig. 4.1, fig. 4.2, fig. 4.3 shows the Ear when the angle is 0°, 45° and 60° respectively.

Figure 4.1: 0° with the camera

Figure 4.2: 45° with the camera

Figure 4.3: 60° with the camera

Our system can also detect eyes and calculate the EAR when the user use glasses, mask, cap etc. Here fig. 4.4, fig. 4.5, fig. 4.6,fig. 4.7, fig. 4.8, fig. 4.9 respectively shows the Ear when the user is wearing glasses, mask, cap, both glasses and mask, both cap and mask, all three of them at a time.

Figure 4.4: User wearing glasses.

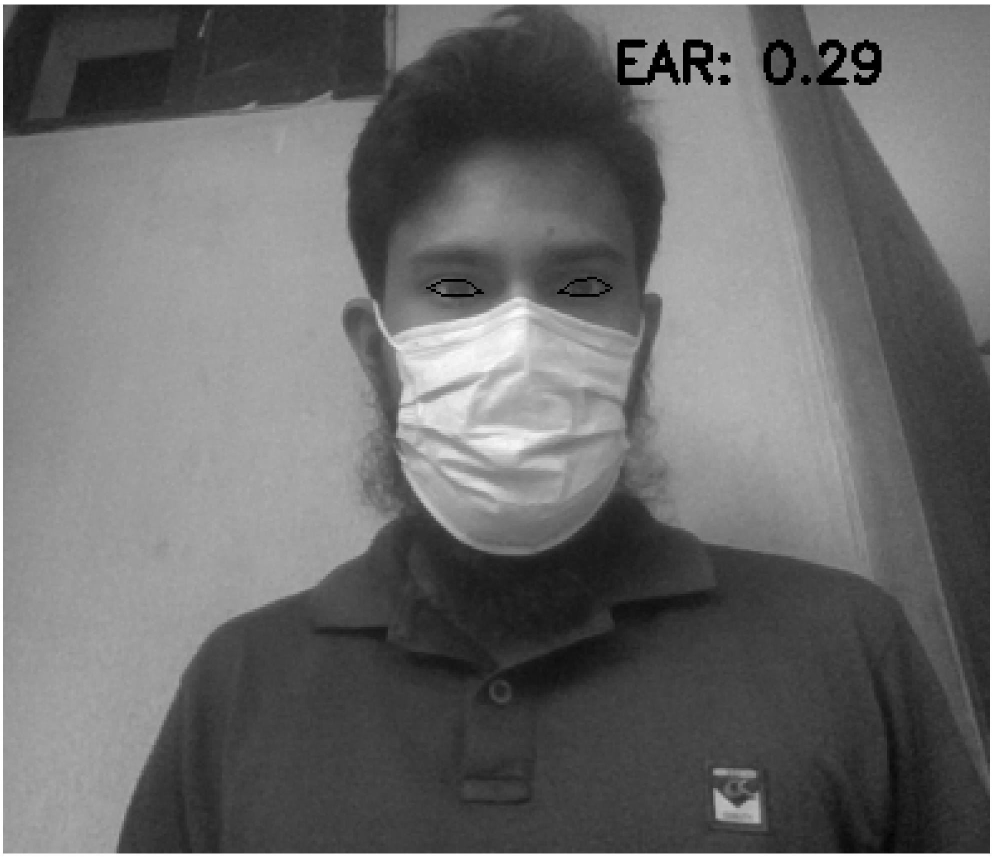

Figure 4.5: User wearing mask.

Figure 4.6: User wearing cap.

Figure 4.7: User wearing mask and glasses.

Figure 4.8: User wearing mask and cap.

Figure 4.9: User wearing mask, cap and glasses.

We test several drivers on the car in real driving conditions in order to validate our system. We use a camera with an automatic low-lighting system in reduced luminosity and night conditions. The view from our camera placed in the dashboard is shown in the fig. 4.10.

Figure 4.10: View from camera placed on the dash-board.

After Applying our system we get the eye landmarks and EAR. fig. 4.11 shows the EAR when the driver is awake.

Figure 4.11: View from camera placed in the dash-board.

fig. 4.12 shows the EAR when the driver is drowsy.

Figure 4.12: View from camera placed in the dash-board.

After successfully completing the pre-processing stage the each frame is converted into gray scale image. fig. 4.13 shows a portion of the numpy array after gray scale conversion.

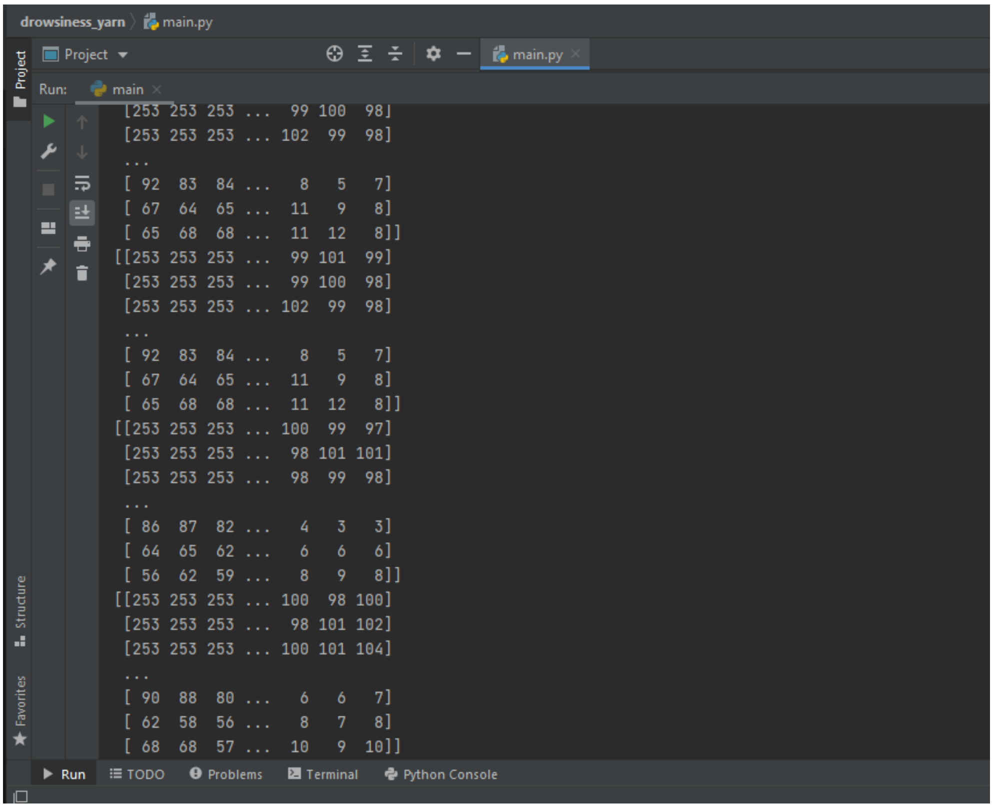

Figure 4.13: Numpy array of gray scale image.

fig. 4.14 shows the findings of the face region, where the percentage of inaccuracy is calculated by dividing the number of frames with a false state of face by the total number of frames multiplied by 100.

Driver	Frames Number	Could not detect face	False face detection	False rate
Day1	600	21	1	3.66%
Day2	730	18	0	2.47%
Day3	540	11	0	2.04%
Day4	950	25	2	2.84%
Day5	800	27	3	3.75%

Figure 4.14: Accuracy of face detection.

4.5 Evaluation of Performance

We test several drivers in the vehicle with real driving conditions to validate our system . In the case of reduced luminosity and night conditions, we use a camera placed in the dashboard of the vehicle with a low lighting systems.

Driver	Frames Number	False Eyes sates		False Rate
		Open	Close	
Day1	750	35	3	5%
Day2	630	27	2	4.6%
Day3	950	28	5	3.47%
Day4	500	40	0	8%
Day5	430	20	1	4.8%
Day6	600	31	2	5.5%

Figure 4.15: Accuracy of eye state detection.

4.6 Conclusion

We developed a vision base drowsiness detection system in this project. Evaluation shows that the proposed system is working well with high percentage of accuracy in real time driving scenarios. our system can be installed in the vehicle in real life driving condition. This will hopefully save many lives reducing the road accidents related to sleepiness.

Chapter 5

Conclusion

5.1 Conclusion

In this project, we presented a design and implementation of a vision-based driver drowsiness detection system that warns the driver if he or she is sleepy. In real-life day and night conditions it is possible to determine the driver state using the IR camera. Symmetry is used to detect the face and eyes. For the decision of the eye states Hough Transform for Circles is used. The results are satisfactory, with the possibility of improving face detection using other symmetry calculation techniques.

5.2 Future Work

Due to Covid-19 It was not possible to test the system for every weather condition. We could not find proper financial support to buy very good quality night vision camera. Also here we have used our laptop to run the system which is not very good for real life use. In future we will try to run our system using raspberry pi. We will also use very good quality night vision camera. We will also take other parameter like yawn, pupil tracking , blink frequency etc. under consideration. Hopefully, these will make our system more precise and user friendly for real life use.

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