# Drowsiness Detection for Drivers Using Computer Vision

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*Abstract:* - Drowsiness detection system is regarded as an effective tool to reduce the number of road accidents. This project proposes a non-intrusive approach for detecting drowsiness in drivers, using Computer Vision. The algorithm is coded on OpenCV platform in Linux environment. The parameters considered to detect drowsiness are face and eye detection, blinking, eye closure and gaze. Input is captured and live fed from a camera that supports night vision as well. The algorithm is Haar trained to detect the face and the eye from the incoming frame. Once the eye is detected, further coding is done to track the eye and automatically set a dynamic threshold value. Depending on the values obtained from each of the incoming frames and deviations from the threshold values, eyelid closure/blink/gaze is detected. Warning system is designed to alert the driver. This system renders an efficient solution to road accidents and the cost of developing it into a real time system is also feasible when compared to the cost involved in the manufacture of car.

*Key-Words:* - OpenCV, Linux, Haar Classifiers

## 1 Introduction

Drowsiness is one of the major causes for road accidents [1]. It becomes substantial to combat accidents due to drowsiness and hence, develop a system to avert such fatalities. Physiological and brain related activities help us understand how to provide useful feedback and alert signals to the drivers for avoiding car accidents. Previously, EEG based attempts to detect drowsiness have been made [2], [3], [4]. ECG and EMG have also been parallely to detect multiple features in a subject [5]. A lot of template based and feature based matching methods had been developed in the past. A number of parameters can be used to detect drowsiness. Head is one of those parameters that has been utilized to study drowsiness in the past [6]. A neural based drowsiness detection system developed in the past however, could not guarantee efficiency enough much to apply to actual systems [7], [8]. Using eye related parameters is one of the apposite ways to detect drowsiness. In fact, repeatedly simulated experiments show that the most valid measure of loss of alertness among drivers is the percentage of eyelid closure over the pupil over times [9]. Blink detection by analyzing the bright pupils have also come up in the past [10]. Percentage of eyelid closure is one of the chosen parameters to detect drowsiness in a driver [11]. Driver drowsiness detection system is one of the applications of Computer Vision, a field of image processing where decisions are made by the system based on the analysis of the images. Computer vision based driver monitoring approach has become prominent due to its predictive validity of detecting drowsiness. Attempts to detect drowsiness using OpenCV has been carried out mostly under normal illumination before [12]. There have been several attempts in introducing a drowsiness detection system in car; however, nothing turned out practically well enough to run on roads. Among those, photoplethysmography is one such method [13]. The various states of drowsiness have been detected by Support Vector Machine (SVM) in the past [14], [15], [16]. Using OpenCV to implement computer vision algorithms produces optimum results. Haar Classifiers based on Viola Jones algorithm is one of the popular way to detect various objects [17]. Multilayer Perceptron based algorithms were popularly used in a number of detection methods for various entities [18]. Gathering from all the past works, eye related parameters are most sought after [19].Though there has been spectacular research in this area, there is no specific measure to determine drowsiness in a real time automobile industry yet. Driver drowsiness detection is a car safety technology based on identifying suitable driver-related variables that are correlated to the driver’s level of drowsiness [20].

The proposed system takes input from camera. An algorithm is developed to detect the face and eyes and subsequently track the eyes and perform calculations to determine if the driver is drowsy. The warning system issues an alarm to the driver if the above condition is true. Drowsiness during driving is a very serious problem without a doubt. The increasing numbers of deaths due to road accidents have shown drowsiness as one of the topmost reasons for the same. It thus becomes a substantial motivation to combat drowsiness among drivers, reduce accidents and save lives. There can be numerous causes to drowsiness. In this paper, we consider four parameters namely face and eye detection, blinking, eyelid closure and gaze.

## 2 System Overview

This paper delivers a drowsiness detection mechanism along the following lines shown in Fig. 1.

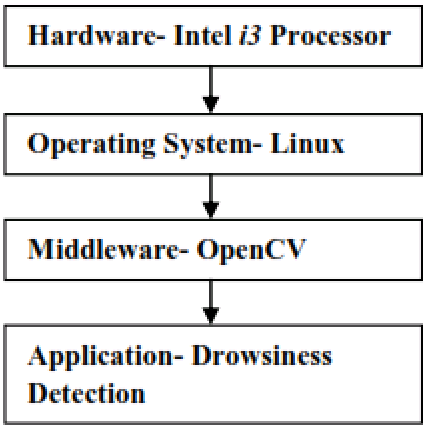


**Fig. 1. System Architecture**

As indicated, the whole system can be delivered in an ARM environment or an Intel environment. The processor is left to the choice of the users' feasibility and viability. The operating system employed is Linux. Linux is popularly used open source operating system and can be reliably used. The entire detection mechanism consists of various image processing functions. The evaluation is laid on the OpenCV Library. The proposed system is executed as shown in the block diagram below.

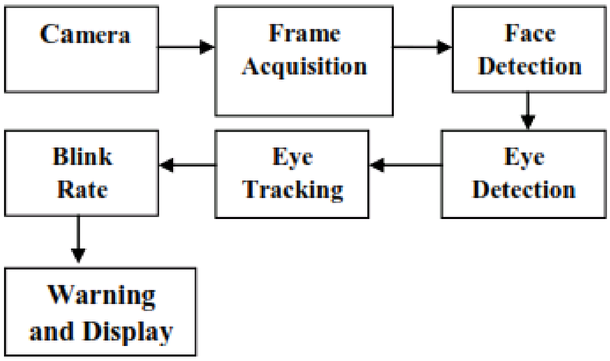


**Fig. 2. Block Diagram for Drowsiness Detection**

## 3 Experimental Protocol

The system proposed is built on Linux Operating system and the detection mechanism is carried out with the help of OpenCV Library. Linux is an interface between computer/server hardware, and the programs which run on it. The most obvious advantage of using Linux is that it is free to obtain. A Linux distribution can be installed on any number of computers free of cost. In line with the costs, the security aspect of Linux is much stronger than that of other OS. Hence, no extra money has to be spent on virus protection software. Open source Computer Vision Library (OpenCV) is a library of programming functions that is exclusively used for applications based on computer vision. It has C++, C and Java interfaces and supports Linux easily. OpenCV is quick when it comes to speed of execution. OpenCV programs only require around 70MB of RAM to run in real-time. Any device that can run C, can, in all probability, run OpenCV. The detection algorithm is implemented using features of the Haar Classifiers for object detection. The core basis for Haar classifier object detection is the Haar-like features. These features use the change in contrast values between adjacent rectangular groups of pixels instead of the intensity values of a pixel. The entire system for detecting drowsiness is implemented using these Haar Classifiers.

The different phases of the algorithm are driven by:

- Face Detection
- Eye Detection
- Eye Closure Characterization
- Yawn Detection

Following sections elaborate the entire algorithm.

# 4 Algorithm

The different phases involved in detecting drowsiness are as described below.

## 4.1 Smoothening the input image

The live feed is continuously fed into the camera placed in front of the driver. The video that is captured is then converted into frames. The illumination changes in the input should be corrected. This is done by smoothening the image. An average filter is used for the same. Consider the Fig. 3;

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 5 | 6 |
| 7 | 8 | 9 |

**Fig. 3. Pixel Grid**

It takes the average of all neighboring pixels and sum is computed. This is then divided by the number of pixels in the window. One such window can be seen in Figure 3.

$$(p) = \frac{\sum_{i=1}^{9} p}{9} \quad (1)$$

Where, *(p)* is the filtered pixel. The average filter thus smoothens out the input images. The filter used is of 3*3 size. The average filter lessens the changes in illumination from the images drawn.

## 4.2 Face Detection

The face is detected using Viola Jones based Haar Classifiers. The classifier is trained for a set of positive and negative images. The training algorithm includes the region of interest, here; the face as positive samples of images and the negative images become the images that do not comprise face. A sample of pixel values is generated by an input of numerous face images. Thus, the face is detected herewith. OpenCV thus acts as the trainer and the associated pixel values characterize an input feature as a face or a non-face. If it is detected as a face, it is carried forward to detect the eyes, otherwise it is discarded from any further detection mechanism. This identification is done with the help of cascading a number of classifiers.

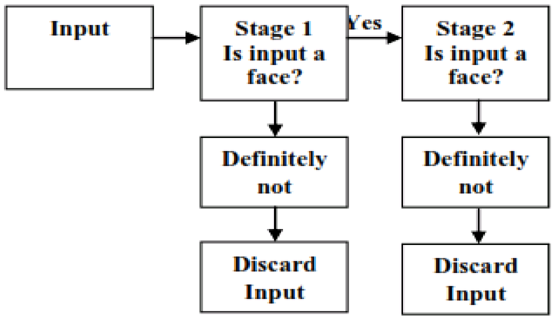


**Fig. 4. Cascade Classifiers to detect face**

## 4.3 Eye Detection

Once the cascade classifiers detect and pass an image detected as face, the eyes are searched for. Using the Haar Classifiers, feature points are analyzed and pixel values are determined from the passed image. A sample of Haar feature types are passed and the filter gradient calculates the pixel values of the region of interest which are the eyes here. Some of the Haar types used in searching and locating the eyes are shown in Fig. 5.

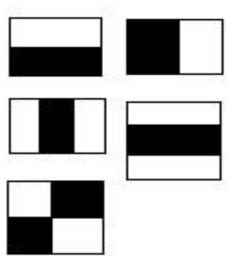

**Fig. 5. Haar Types used to detect eyes**

## 4.4 Characterizing the integral image

Rectangle features that characterize the pixel values of the regions of interests are computed using an intermediate representation for the image called the integral image. The integral image at location x, y contains the sum of the pixels above and to the left of x, y, inclusive:

$$ii(x,y) = \sum_{x' \leq x, y' \leq y} i(x',y') \qquad (2)$$

Where, *ii(x, y)* is the integral image and *i(x, y)* is the original image. Using the following pair of recurrences:

$$s(x,y) = s(x,y-1) + i(x,y) \qquad (3)$$

$$ii(x,y) = ii(x-1,y) + s(x,y) \qquad (4)$$

Where, *s(x, y)* is the cumulative row sum, *s(x, −1) =0*, and *ii(−1, y) = 0)* the integral image can be computed in one pass over the original image [21].

## 4.5 Eye Closure Evaluation

The eye related parameters used to detect drowsiness in the proposed system are namely eyelid closure, gaze detection and blink rate monitoring. A square wave has been used to recognize the different states of the eye. A logical 1 and 0 are respectively used to signify input of frames and otherwise. The following block diagram briefly depicts the algorithm involved.

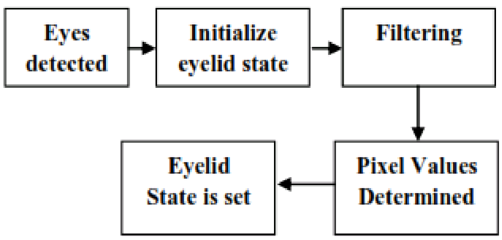


**Fig. 6. Eyelid State Detection**

### 4.5.1 Eyelid Closure

When the driver becomes drowsy, the mean amplitude of the eyes decreases and the frequency increases significantly. The fully awake states are characterized by low frequency. So, when the eyelid closes completely, eye movements decrease even further with long eye closures. This detection of closure is recognized by mean time period of the acquisition of frames. In a period of 1 second around 25 frames are acquired into the camera such that;

Or 1000 ms correspond to 25 frames;

Or 40 ms correspond to 1 frame.

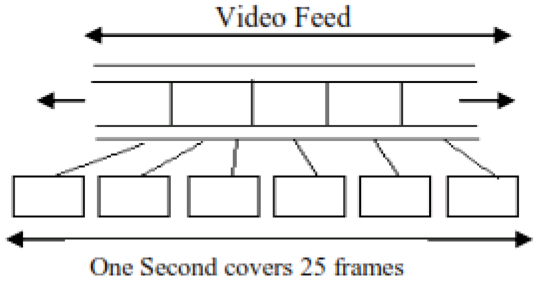


**Fig. 7. Speed of Acquisition**

From the above calculation, the closed state of eye is illustrated below:

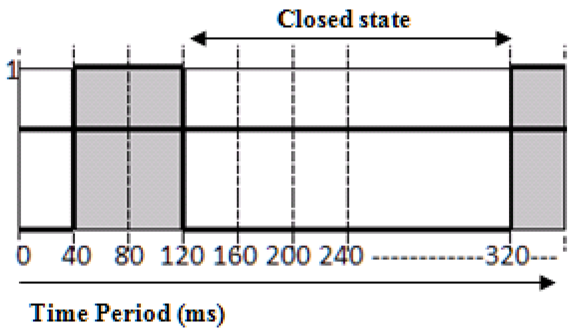


**Fig. 8. Eyelid Closed**

### 4.5.2 Gaze

Gaze is the phenomenon which synonymously indicates complete open state of eyes. For a period of time, if the input frames acquired records a continuous and close to constant pixel intensity for a few integral multiple of time period, a gaze is detected. The same is depicted below:

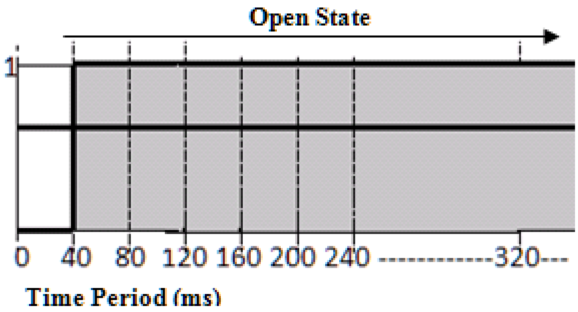


**Fig. 9. Gaze detected**

### 4.5.3 Blink Detection

When continuous frames of either a steady intensity or steady dip is not detected and rather, an alternate change of pixel intensity is observed over a period of time, it is detected as blink.

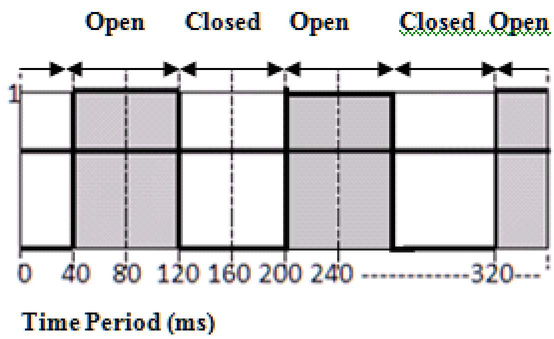


**Fig. 10. Blink Detected**

## 5 Design of Camera

A daylight camera is an ambient option for areas that have a constant source of light. However, in order to accommodate the conditions of poor light conditions, the proposed drowsiness driver detection system consists of a night vision camera that takes images of the driver's face even under low light conditions or no light. An infrared-sensitive camera is employed to generate the eye images. Here a USB camera has been efficiently modified to capture images in the near infrared wavelength. This is because the infrared light source illuminates the driver's face in low light to no light conditions. The steps involved in doing the same are:

- USB cam case is unscrewed.

- The lens assembly from the circuit board is then unscrewed.

- On unscrewing, the CCD (the Charge Coupled Device is an array of photosensors on the green PC board) will be exposed.

- The IR filter is then carefully removed.

- An infrared LED ring is mounted around the outer lens for illumination under dark environment.

**Fig. 11. Night Vision Camera**

The camera designed works on the principle of active illumination. Active illumination works on the principle of coupling imaging intensification with an active source of illumination in the near infrared band. Infrared is used in night vision when there is insufficient visible light to see. Active illumination involves conversion of ambient light photons into electrons which are then amplified by an electrochemical process and then converted back into visible light. Active infrared night vision combines infrared illumination in spectral range 0.7–1 µm, due to which the scene, which appears dark to a human observer now appears as a monochrome image on a normal display device.

## 6 Experimental Results

The whole detection mechanism for drowsiness is ported in a Linux environment. The proposed system hence, is built on Ubuntu 13.04. The algorithm is implemented using the OpenCV library. According to the proposed system, the live feed is first converted into frames, the average face and eye detection time of which is computed to be around 79 ms as shown below.

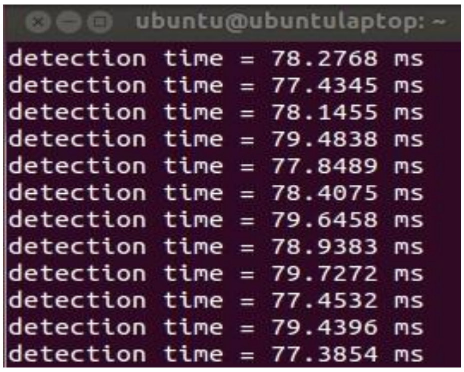


**Fig. 12. Detection Time on the console**

The input frame is then laid across the face detection algorithm using the Haar Cascade Classifiers. After the detection of the face, the eyes are tracked and identified. The algorithm is able to detect the eyes even in the presence of glasses.


**Fig. 13. Face and Eye Detection**

Once the face is detected and the eyes are tracked, the drowsiness detection starts. The states of eyes are checked for and accordingly the driver is prompted with an alert or warning. The results of the same are illustrated below.

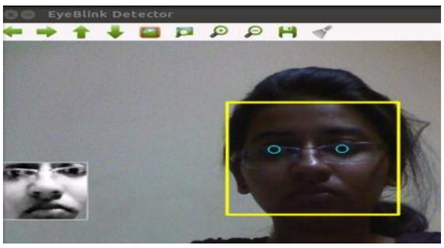


**Fig. 14. Blink Detection**

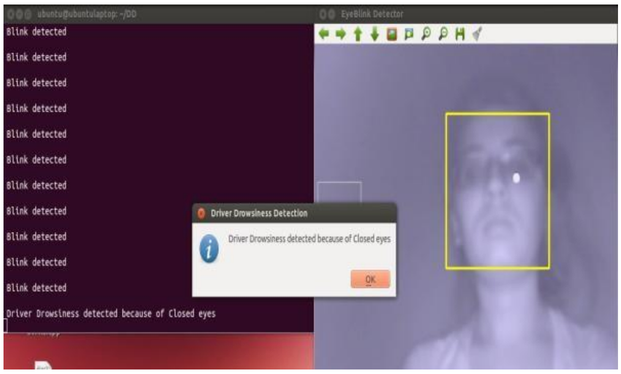


**Fig. 15. Indication of Drowsiness**

## 7 Conclusion

In this paper, we have devised a novel drowsiness detection system for drivers using OpenCV computer vision library. The system so developed is efficiently able to detect drowsiness based on eye-related parameters by monitoring the blink rate. Till date, there has not been a stable real time product incorporated in cars running on roads. The proposed system can suitably be ported onto a high speed automotive board and be used in cars. The camera used to capture the feed is also designed specially to cater to the dim or no light conditions around the driver. The economics involved in building a real time product will also be reasonable considering the car manufacturing costs. Our paper can be absolutely used to detect drowsiness and thus help reducing the number of road accidents drastically. The hit rate for the proposed work was compared to previous experiments conducted on different platforms. The following table illustrates that this paper could achieve a hit rate with efficient algorithm.

| DETECTOR | PLATFORM | HIT RATE(%) |
|---|---|---|
| Proposed Work | Intel *i3* Processor | 95.0 |
| Betke and Mullaly | GPP | 83.0 |
| D’Orazio et al | GPP | 93.7 |
| Veeraraghavan et al | SPARC | 70.9 |

**Table.1 Performance Comparison**

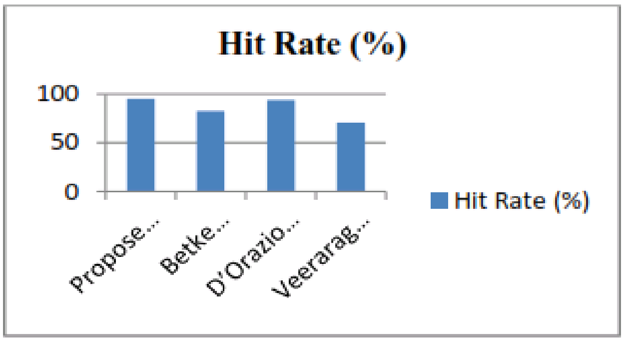


**Fig. 17. Graphical Depiction of Performance**

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