Real-Time Computer Vision System for Continuous Face Detection and Tracking

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ABSTRACT
The ever-increasing number of traffic accidents due to a diminished driver's vigilance level has become a problem of serious concern to society. With the ever growing traffic conditions, this problem will further deteriorate. For this issue, development of system which can actively monitors driver vigilance level and alert the driver for any insecure driving condition is essential. So this paper gives detailed information about driver vigilance level monitoring system. The ultimate goal of the system is to detect and alert the driver from insecure sleepy or low concentration driving condition. The system consists of two main modules including drivers face and eye detection module and drivers face tracking module. Viola Jones face detection with AdaBoost (Adaptive-Boosting) method and Circular Hough Transform technique are integrated in the drivers face and eye detection module. In the drivers face tracking module, CAMSHIFT (Continuously Adaptive Mean Shift) algorithm has been used for continuous face tracking of driver. The main components of the system consist of a video camera, a specially designed hardware system based on Raspberry Pi for real-time image processing and controlling the alarm system. In the proposed system, only one video camera is used in practice yet an achievement of fast and accurate detection results are obtained.

General Terms
Vigilance level, Face Detection, Face Tracking, Image processing.

Keywords
Viola Jones Face detection, CAMSHIFT, Raspberry Pi, AdaBoost, Circular Hough Transform.

1. INTRODUCTION
Driver Monitoring System is a process where a system can continuously monitor drivers face in a vehicle and detects more than one parameter at a time like face detection, eye detection, face orientation, eye blinking, etc. The technical brilliance and development in different fields has led to a drastic change in our lives, one among them is embedded systems and telecommunications. Telecommunications has the potential to provide a solution to avoid accident on road. The advances in information and communication technologies enable technically, the continuous monitoring of driver in any vehicle regardless of module of vehicle or company. Proposed system provides valuable real time information enabling the drivers to be alert and keep attention on road continuously. The analysis of driver attention is a most popular field of research for safety improvements.

In the system presented in this paper, a real-time non-intrusive approach for driver fatigue monitoring is adopted, exploiting the driver's facial expression using computer vision techniques and an Adaptive boosting classifier for classification purposes. Then cascading of classifiers is used to increase the face detection accuracy. By going through different stages of week classifiers a strong classifier is made and face will be identified at the final strong classifier stage. As per different testing studies performing the face detection for all frames is computationally complex method. So after face detection in the first frame, face tracking algorithms are used to track driver face in the next frames [1].

The rest of this paper is organized as follows: in Sections 2 and 3, the concepts behind the face detection and face tracking are demonstrated. Section 4 discusses about the design process of the system. And Section 5 presents the results obtained by the system. Finally section 6 concludes the paper.

2. VIOLA JONES FACE DETECTION
Viola Jones algorithm [2] uses following concepts in its algorithm. It uses the concept of Haar-like features, Integral image formation, AdaBoosting and cascading of classifiers.

Haar-Like Feature representation was used to select simple features based on pixel intensities rather than pixels values. Haar-like feature is a scalar product between the image and some Haar-like [4] templates.

Integral image formation is used for features calculation, by considering only four corners of the image. Adaptive boosting is used for aggressive feature selection. It leads to a major reduction in the required computational time for processing of algorithm. Here RGB to grayscale conversion of image frame is takes place first.

AdaBoost learning algorithm is used to select only critical features from around 160000 features obtained from one single image frame. By using Adaptive boosting classifiers [2] the speed of detection is increased further.

Cascading of number of classifiers was applied in the algorithm, for development of a strong classifier chain.

The Open Source Computer Vision Library (OpenCV), which is developed by Intel Corporation [5], provides a command prompt training utility called haartraining which generates a classifier in XML format when given positive and negative examples of the object to be detected [6].

3. CAMSHIFT
CAMSHIFT is a continuously adaptive mean shift algorithm which is used for tracking purpose. The CamShift tracking algorithm is a modification of Mean Shift algorithm which is very fast and simple method of tracking. The main goal of tracking is to find the driver face object between the consecutive frames in image sequences. Algorithm for the

tracking object is necessary when the driver is detected in the previous frame but lost in current frame.

A general idea to accomplish this task is to adopt CamShift algorithm with color histogram as the characteristic of the target object. The difference between the two algorithms is that CamShift continuously used adaptive probability distribution (dynamically changing distribution), while Mean Shift [3] is based on static distribution. The CamShift tracking algorithm works well as long as the color probability distribution of object is discriminative enough from the background. The tracking procedure can be divided into 3 parts as given below.

1. Back projection: is a process in which capturing color histogram of target object conversion of image to a color probability distribution takes place.

2. Mean shift: Mean shift is a nonparametric, iterative procedure to detect the mode in a probability distribution image. Here first selection of the search window size and initial location will takes place. Then computation of mean location (centroid) within the search window has been taking place.

3. CamShift: The basic idea of algorithm is based on Mean Shift, which iteratively detect the mode in the probability distribution image until it convergence. CamShift allows the probability distribution of tracked object being changed in size and location in image sequences. The last known location of tracked object is set as initial search location in the current frame.

The detail steps of the implementation are as below.

First, set the calculation region of the probability distribution to the whole image. Second, initialize the position and size of the search window. Third, compute the color distribution within search window slightly larger than the mean shift window size. Fourth, apply Mean Shift and obtain a search window center. Store the zeroth moment (area of size) and center location. Fifth, for the next frame, use the value obtained by fourth step to initialize the location and size of search window. Repeat step 3 until the object is tracked.

4. DESIGN PROCESS

1. Preprocessing of image: By acquiring the image frame first segmentation of image frame will be takes place. Then conversion of original image frame to grey scale is there. Due to which we can analyze single pixel intensity values of the image frame, and processing speed of the system gets increased. Then histogram equalization of image has been performed to equalize all intensity values of the image. This method usually increases the global contrast of images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.

2. Viola Jones face detection algorithm has been applied on acquired frame of image. When face gets detected region of interest of face is cropped from image frame. On that face ROI image eye detector has been applied and after eye detection. ROI of eye is cropped. On detected eye ROI image different image processing functions has been applied. First histogram equalization is applied, and then threshold operation is applied to convert the eye ROI image into binary image. After that Gaussian filtering is applied on eye ROI image for blurring purpose. Then Circular Hough Transform is used for pupil detection along with canny edge detection algorithm.

By pupil detection if detected number of circles are greater than zero then eye open count will increase. Else if detected numbers of circles are equal to zero then eye close count will increase. When eye open count will be equal to five, driver alert condition will be display on screen. When eye close count will be equal to five, driver drowsiness condition will be display on screen and alarm will be generated to alert driver.

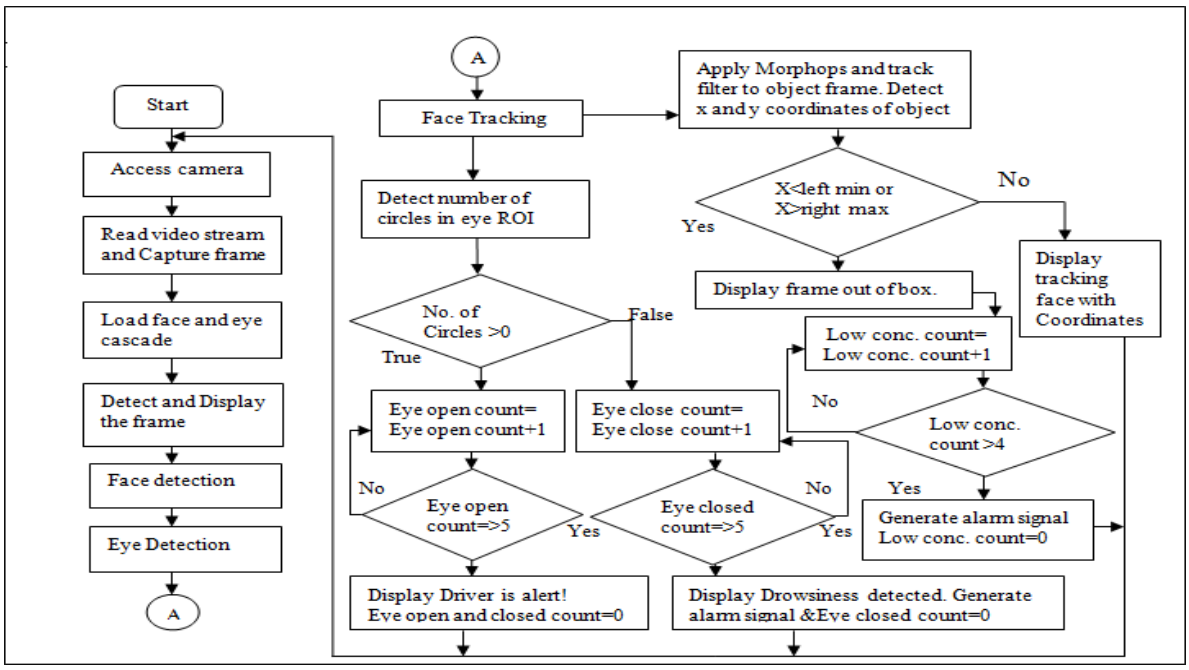

Fig 1: Total flow of the system

3. CAMSHIFT (Continuously Adaptive Mean Shift) algorithm has been applied on input color image frame. Here search window adjust itself in size of input image. In well segmented distribution (for example face image), this algorithm automatically adjust itself for the size of face as the person moves closer to and further from the camera. For every detected face image, recording of his color histogram has been takes place. Each image of the sequence is converted into a probability distribution image relatively to the histogram of the object to be tracked. From this image, the centre and the size of the object are measured. These new centre and size are employed to place the search window in the next image. This process is then repeated for a continuous target tracking in the video stream accessed by camera. Here conversion of image from BGR to HSV color space has been takes place first. Then InRange function will be applied on image frame to find largest white block (group of pixels or binary linked objects) and its location in the input image.

5. RESULTS

5.1 Face Detection Results

First application of Viola Jones face detection algorithm has been taking place on input image frame accessed by camera. By this algorithm rapid face detection is achieved. Processing of Viola Jones algorithm is basically in three steps. First internal image gets formed from original image frame, due to this conversion storage memory requirement gets decreased and processing speed will be fast. Then AdaBoost classifier is applied on image frame for adaptive boosting purpose and then application of cascade of classifiers has been takes place to increase the face and eye detection accuracy of an algorithm. Then application of Circular Hough Transform [8] along with canny edge detection [7] is there by which pupils of eyes are gets detected. If we detect one or two circles of pupil in five consecutive frames then we can say driver is in alert condition. Else drowsiness condition will be detected. Here two cases are occurred open eye condition and closed eye condition. Step by step results are discussed and presented as below.

5.1.1 Open Eye Condition

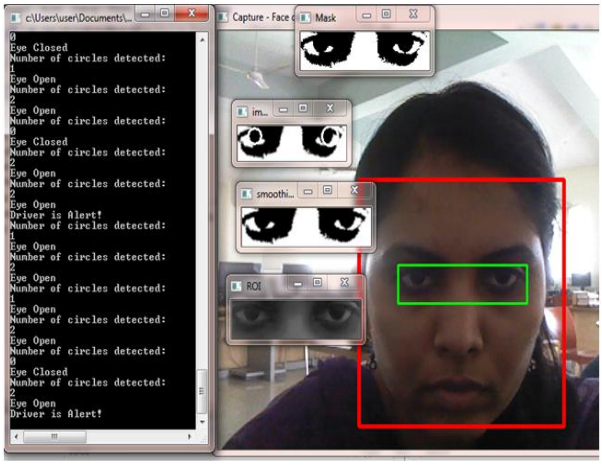

Fig 2 open eye condition

After face detection, eyes are detected. Then region of interest (ROI) of eyes has been selected for further processing. On eye ROI smoothing is applied to make their edges more clear. Then masking on image is applied for filtering purpose. Finally for pupil detection application of circular Hough transform has been applied. For continuous five frames if one or two circles (Pupils of eyes) have been detected then the eye open condition will occur. And it display result as 'driver is alert'.

5.1.2 Closed Eye Condition

For closed eye condition all the steps has been followed like open eye condition. And as eyes are closed number of circles detected (Pupils of eyes) will be zero. So pupil detection case is false, hence eyes are declared as closed. For continuous five frames eyes condition has been checked and then result of drowsiness detection is generate by alarm sound, displayed on screen as drowsiness is detected.

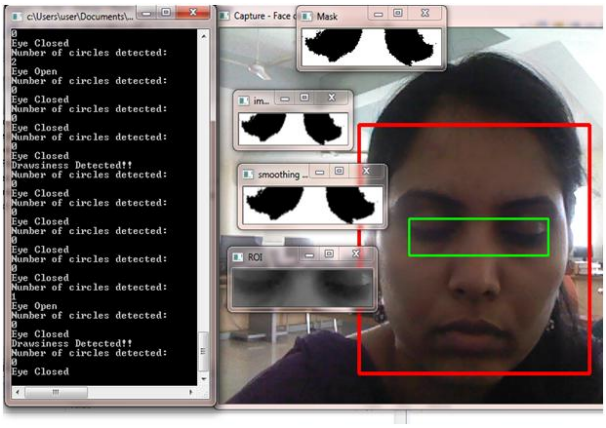

Fig 3 Closed Eye Condition

5.2 Face Tracking Results

Face detection along with face tracking module works at a same time. The only difference in these two modules is that in face tracking it takes colored frame to process and in face detection module it takes converted grey frame of original image frame.

Once face and eyes gets detected tracking module will continuously detect the centre of face for detection of proper on road attention and position of face and eyes of driver. Here results are obtained for three different cases as tracking face with driver alert condition; tracking face with drowsiness condition and tracking face with out of box condition for no proper central position of drivers towards the camera and on road. The results for these three cases are demonstrated as below.

5.2.1 Tracking Face with Driver Alert Condition

In face tracking for five consecutive frames number of eyes detected should be at least one, to detect driver alert condition. Here low concentration count should be zero or less than four. If it is equal to or greater than four then alarm will be generated for out of frame result. For continuous five frames if one or two circles (formed on pupils of eyes) have been detected, position of face centroid is at centre and low concentration count is zero or less than four then tracking face with driver alert condition will occur.

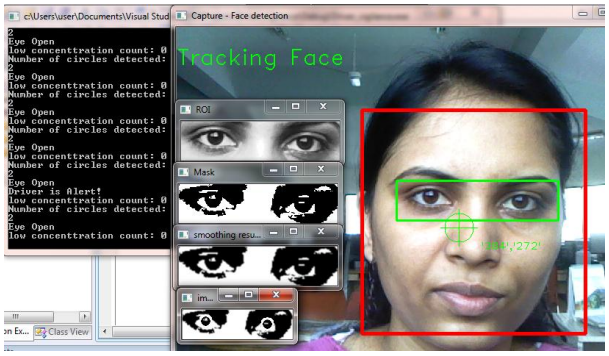

Fig 4 Tracking Face with Driver Alert Condition

5.2.2 Tracking face with drowsiness condition

In face tracking for five consecutive frames number of eyes detected should be zero, to detect driver drowsiness condition. Here low concentration count should be zero or less than four. If it is equal to or greater than four then alarm will be generated for out of frame result. For continuous five frames number of circles detected are zero(formed on pupils of eyes), position of face centroid is at centre and low concentration count is zero or less than four then tracking face with driver drowsiness condition will occur and alarm is generated.

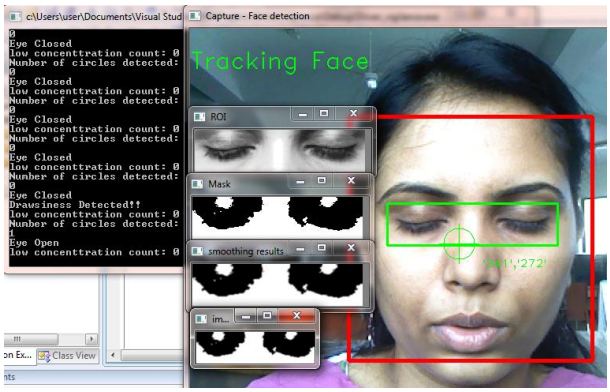

Fig 5 Tracking face with Drowsiness condition

5.2.3 Tracking face with out of box condition

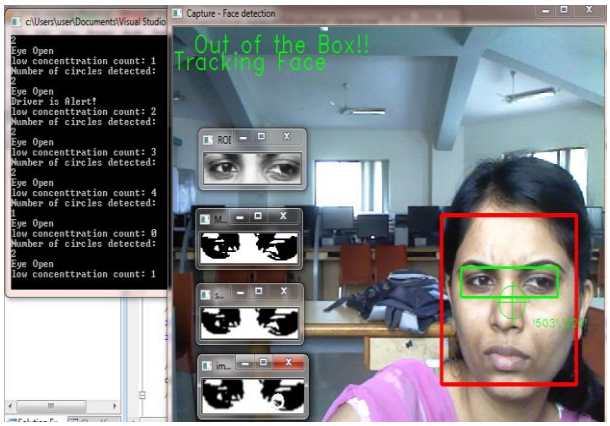

Fig 6 Tracking face with out of box condition

Here low concentration count is increasing continuously and alarm will generate after the count of four. For interval of low concentration of four alarms will be generated continuously. When driver face centroid position is become at centre again then the low concentration count becomes zero again. Tracking face with normal detection condition will occur again.

6. CONCLUSION

A driver vigilance monitoring system based on computer vision has been developed and demonstrated in this paper. The ultimate goal of the system is to detect drowsiness condition of driver. By using Viola Jones algorithm rapid face detection with feature extraction has been achieved. In this method integral image is formed and then AdaBoost classifier is applied on this image, and by cascading of classifiers face detection accuracy is further increased. And as continuously adaptive mean shift algorithm (CAMSHIFT) is implemented in which window size is adaptive means variable as per the input image for tracking, so accuracy of tracking is increased. So by implementing this system on raspberry pi a compact and low cost application is designed and tested.

The future works may focus on the utilization of outer factors such as vehicle states, sleeping hours, weather conditions, mechanical data, etc. for fatigue measurement. It can be implemented as a standalone product, which can be installed in an automobile for monitoring the automobile driver. It can be implemented as a smart phone application, which can be installed on smart phones. And the automobile driver can start the application after placing it at a position where the camera is focused on the driver. Signals changes for person in different conditions such as illness will be studied and considered in future works as well.

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