Efficient Car Alarming System for Fatigue Detection during Driving

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***Abstract*—Driver inattention is one of the main causes of traffic accidents. Monitoring a driver to detect inattention is a complex problem that involves physiological and behavioral elements. Different approaches have been made, and among them Computer Vision has the potential of monitoring the person behind the wheel without interfering with his driving.**

A computer vision system for driving monitoring uses face location and tracking as the first processing stage. On the next stage the different facial features are extracted and tracked for monitoring the driver's vigilance. In this thesis I have developed a system that can monitor the alertness of drivers in order to prevent people from falling asleep at the wheel. The other main aim of this algorithm is to have efficient performance on low quality webcam and without the use of infrared light which is harmful for the human eye. Motor vehicle accidents cause injury and death, and this system will help to decrease the amount of crashes due to fatigued drivers. The proposed algorithm will work in three main stages. In first stage the face of the driver is detected and tracked. In the second stage the facial features are extracted for further processing. In last stage the most crucial parameter is monitored which is eye's status. In this last stage it is determined that whether the eyes are closed or open. On the basis of this result the warning is issued to the driver to take a break.

***Index Terms*—Digital image processing, video analytics, computer vision.**

I. Introduction

Driving is a complex task where the driver is responsible of watching the road, taking the correct decisions on time and finally responding to other drivers' actions and different road conditions. Vigilance is the state of wakefulness and ability to effectively respond to external stimuli. It is crucial for safe driving. Among all fatigue related accidents, crashes caused by fell-asleep-drivers are common and serious in terms of injury severity.

According to recent statistics driver fatigue or vigilance degradation is the main cause of 17.9% of fatalities and 26.4% of injuries on roads [1]. Vigilance levels degrade mainly because of sleep deprivation, long monotonous driving on highways and other medical conditions and brain disorders such as narcolepsy. Majority of the road accidents are mainly due to the driver fatigue. Driving for a long period of time causes excessive fatigue and tiredness which in turn makes the driver sleepy or loose awareness. The study states that the cause of an accident falls into one of the following main categories: (1) human, (2) vehicular, and (3) environmental. The driver's error accounted for 93% of the crashes. The other two categories of causative factors were cited as 13% for the vehicle factor and 34% for environmental factors. It is important to note that in some cases; more than one factor was assigned as a causal factor.

The three main categories (human, vehicular, and environmental) are related among each other, and human error can be caused by improper vehicle or highway design characteristics. The recognized three major types of errors within the human error category: (1) recognition, (2) decision, and (3) performance [2]. Decision errors refer to those that occur as a result of a driver's improper course of action or failure to take action. A recognition error may occur if the driver does not properly perceive or comprehend a situation. To perform all these activities in time and accurately its necessary that driver must be vigilant.

In Pakistan 10,125 crashes were reported to police including 4193 fatal cases in 2006. According to a study conducted by the Aga Khan University in Karachi, government statistics included only 56% of deaths and 4% of serious injuries and concluded that traffic fatalities are a much more serious health problem than is reported by the official statistics which show a death rate of 11.2 per 100,000[3].

The aim of this paper is to develop a computer vision method able to detect and track the face of a driver in a robust fashion, also determine the status of the eyes, and with the highest precision possible. It is to serve as the bases of an automatic driver fatigue monitoring system.

II. Existing Systems and Approaches.

Many researchers have worked in recent years on systems for driver inattention detection, focused mainly in drowsiness, with a broad range of techniques. Sleep has a long history of research in the fields of psychology and medicine, where accurate measurements and indicators have been developed [4]. Electroencephalograms (EEG) [5] represent the electrical changes in the brain, measured with a series of electrodes placed in the scalp. The electrodes detect small voltages produced in the brain cortex. These potentials form waves at several frequencies, known as delta, theta, alpha, beta and gamma waves, which are linked to different cognitive and motor processes, including drowsiness and the different sleep stages, as shown in figure 1. Brain studies couple EEG with electrooculography (EOG), which detects eye movements, and electromyogram (EMG) that monitors muscular tone. These measurements provide the best data for detection of drowsiness, and as such have been used by several drowsiness detection systems, usually in conjunction with heart rate and breathing rate. The problem of these techniques is that they

Manuscript received May 3, 2012; revised June 17, 2012.

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are intrusive to the subject. They require electrodes and other sensors to be placed on the head, face and chest as in figure 2, which may annoy the driver. They also need to be carefully placed: installing the electrodes to obtain an EEG requires external help and takes a few minutes, and medical equipment is always expensive. Recent research has introduced some contact-less readings, but no remarkable results have been achieved so far. Nonetheless, physiological measures such as EEG have been used in some projects [6], and are frequently used as the ground-truth for testing other, less invasive methods.

A driver's state of attention can also be characterized using indirect measurements and contact-less sensors. Lateral position of the vehicle inside the lane, steering wheel movements and time-to-line crossing are commonly used, and some commercial systems have been developed. These systems do not monitor the driver's condition, but its driving. Volvo Cars introduced its Driver Alert Control system [Volvo Car Corp. 08] in 2008, which is available on its high-end models. This system uses a camera, a number of sensors and a central unit to monitor the movements of the car within the road lane, to assess whether the driver is drowsy (see figure 3). Mercedes-Benz has introduced a similar system (ATTENTION ASSIST) [DaimerAG 09] in its newest E-Class vehicles

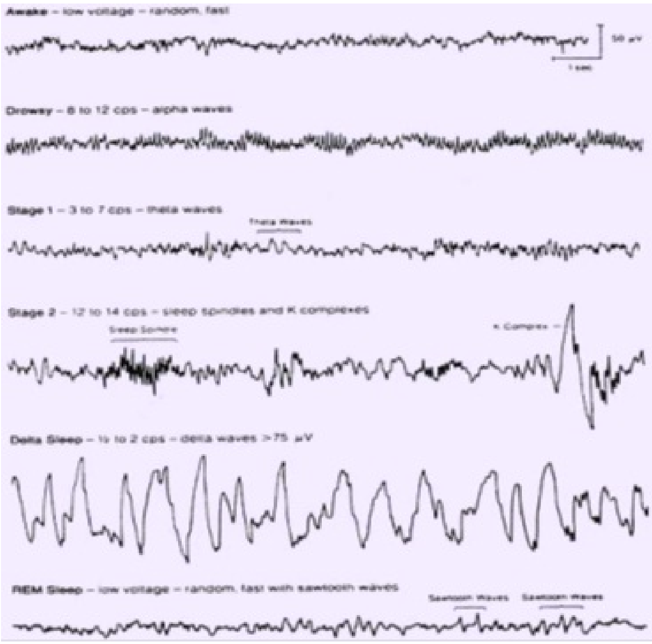


Fig. 1. An example of brain wave activity for different sleep stages. *(Source:www.sleephomepages.org)*

(shown in figure 4). Daimler AG, owner of Mercedes-Benz, was in 2001 one of the first to develop a system based on vehicle speed, steering angle and vehicle position relative to road delimitation (recorded by a camera) to detect if the vehicle is about to leave the road [7]. Other manufactures have conducted research and presented prototypes. Toyota [5] used steering wheel movement sensors and pulse sensor to record the heart rate. Mitsubishi has reported the use of steering wheel sensors and measures of vehicle (such as lateral position of the car) to detect driver drowsiness in their advanced safety vehicle system [6].

Fig. 2. A driver wearing a helmet with electrodes for EEG.

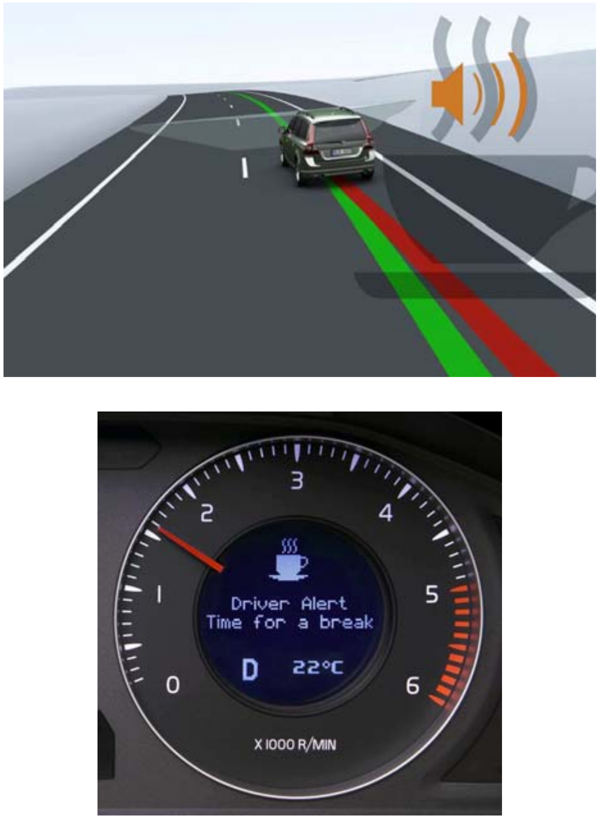


Fig. 3. Volvo's driver alert control. *images from volvo cars*

These techniques are not invasive, and to date they obtain the most reliable results with the least number of false positives, a critical problem in this type of systems. However, they face several limitations such as geometric characteristics and state of the road, and driver experience. They also require a training period for each person, during which the driving style of the user is learned and modeled, and thus are not applicable to the

Fig. 4. Mercedes-benz's attention assist. *Images from emercedesbenz.com*

occasional driver. Despite the high number of parameters involved, these systems are basic in that the behaviors they are able to detect are few: the measurements may not reflect user behaviors such as the so-called micro-sleeps: if a drowsy driver falls asleep for few seconds, the lateral position may not change in a straight road [8]. Response time of these systems may compromise their effectiveness.

In *ASV (Advanced Safety Vehicle)* project, held by Toyota [9], the driver must wear a wristband in order to measure his heart rate. Others techniques monitor eyes and gaze movements using a helmet or special contact lens [10]. These techniques, though less intrusive, are still not acceptable in practice. There is a "***Driver Fatigue Monitor System***" by Attention Technologies, Inc. It is based on the PERCLOS (PERcent of the Time Eyelids are CLOSed) measure of driver fatigue. They have discovered that the PERCLOS-based system does work but has some flaws.

Drivers in fatigue exhibit changes in the way their eyes perform some actions, like moving or blinking. These actions are known as *visual behaviors*, and are readily observable in drowsy drivers, and also in distracted ones. More precisely, typical characteristics include longer blink duration, modified blinking frequency, slow eyelid

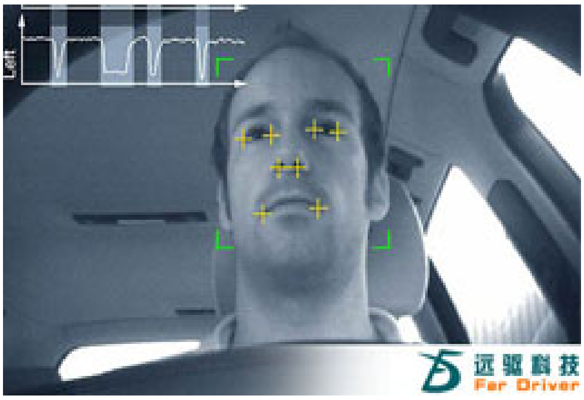


Fig. 5. System by attention technologies. images from attention technologies.

movement, a smaller degree of eye opening and gaze (narrowed field of view, with reduced response to objects in the peripheral areas of vision). Although not purely *visual*, other characteristics that are included in this group are yawning, nodding, sluggish facial expression (due to relaxed muscular tone) and dropping posture. Of all of them, the percent of eye closure (PERCLOS) has been found to be the most reliable indicator of drowsiness [11].Computer vision has been the tool of choice for many researchers to be used to monitor visual behaviors, as is non-intrusive. Most systems use one or two cameras to track the head and eyes of the subject [12]. Commercial products are available for general applications not focused on driving problems. A few companies commercialize systems as accessories for installation in vehicles, but are not part of the car manufacturers' developments: reliability is not high enough for car companies to take on the responsibility of its production and possible liability in case of malfunctioning. By installing the system themselves, the owners take the responsibility instead. Seeing Machines sells the FaceLAB software that uses two cameras to track the face in 3D. They have also presented the Driver State Sensor (DSS), which calculates PERCLOS. The Swedish company SmartEye AG [13] offers mono- and multi-camera systems that detect eye movements, gaze fixation and blink detection. Mono-camera systems have been a major focus on late years, because integration in industrial production is much easier and less costly.As it can be seen, some systems have indeed entered the market, but in the literature there are very few details available regarding the methods and parameters of those systems.

Computer vision systems use natural light, infra-red (IR) or both to illuminate the face of the driver. This is an important problem of system that must work 24/7 and day and night scenarios are very different. Usually daytime algorithms need to be adapted to work during nighttime. [14] presented a system using 3D techniques to estimate and track the line of sight of a person using multiple cameras. In [15] a system with active IR illumination and a camera is implemented. In addition to providing illumination, IR light reflects on the eye's cornea and produces the *red-eye effect*, similar to the one appearing in photography when flash light is used. This reflection can be detected and used for locating and tracking the rest of the face. They propose to estimate the local gaze direction based on pupil location. In [16] a system based on natural light was presented.Systems relying on a single visual cue may fail when the required features can not be detected accurately or reliably. Also, people's visual behaviors under fatigue or distraction change from person to person, and a single indicator may not be representative of the overall cognitive state [15]. Relaying on multiple visual cues reduces the uncertainty and the ambiguity compared to that of relaying on only one source. Recent research points in this direction. In [17], another multi-sensor system was presented. The authors tested two decision making methods, fuzzy inference system (FIS) and artificial neural networks (ANN) to fuse the data and obtain an estimation of the drowsiness state of the driver. The AWAKE European project proposed a multisensory system that integrated multiple visual cues with information from the vehicle and the environment. This system must be configured explicitly for each driver, requiring a learning stage. Another European initiative, SENSATION, carried on with this line of research. A non-intrusive system fusing driver's condition information with data from his/her driving, with minimal to no per-person customization would be the best candidate for mainstream adoption, and thus research has concentrated on this option lately.

III. Proposed System

The algorithm proposed is a computer vision algorithm that aids in the detection of the current driver state of vigilance. It detects the current state of the driver eyes in every frame (open or closed). Applying this algorithm on consecutive video frames may aid in the calculation of eye closure period. Eye closure periods for drowsy drivers are longer than normal blinking, a fact that can be exploited to monitor a driver state of vigilance. It is also a very critical parameter because the closure of eyes for a little longer time could result in serve crash. So we will warn the driver as soon as closed eye is detected. The flow chart of the algorithm is represented in Figure 7.

A. Algorithm Stages

The major stages of algorithm are as:

1) Image Capture

The image is captured from the video, where image is a numeric representation (normally binary) of a two-dimensional image. The video is acquired by using a low cost web camera. The camera provides 30 frames per second at VGA mode. The web camera is shown in figure 6.

Fig. 6. The web camera used. Image from http://www.a4tech.com.

Then the recorded video is opened in MATLAB and the frames are grabbed, then the algorithm is run on every frame detecting the driver's vigilance.

2) Face Detection

In every given frame the face is detected using an specified algorithm. Face detection is a computer technology that determines the locations and sizes of human faces in arbitrary (digital) images. It detects facial features and ignores anything else, such as buildings, trees and bodies. Face detection can be regarded as a specific case of object-class detection. In object-class detection, the task is to find the locations and sizes of all objects in an image that belong to a given class. Early face-detection algorithms focused on the detection of frontal human faces, whereas newer algorithms attempt to solve the more general and difficult problem of multi-view face detection. That is, the detection of faces that are either rotated along the axis from the face to the observer (in-plane rotation), or rotated along the vertical or left-right axis (out-of-plane rotation), or both. The newer algorithms take into account variations in the image or video by factors such as face appearance, lighting, and pose.Many algorithms implement the face-detection task as a binary pattern-classification task. That is, the content of a given part of an image is transformed into features, after which a classifier trained on example faces decides whether that particular region of the image is a face, or not.If the result of face detection comes positive then the algorithm proceeds to the next, otherwise the flow of algorithm goes back to the image capture stage. The different face detection algorithms are explained in detail in later chapters.

3) Facial Feature Detection

Facial Feature Detection (FFD) is to find the exact location of facial features, such as mouth and eyes corners, lip contour, jaw contour, and the shape of the entire face. Face and facial feature detection are difficult problems, due to the large variations a face can have in a scene caused by factors such as intra-subject variations in pose, scale, expression, color, illumination, background clutter, presence of accessories, occlusions, hair, hats, eyeglasses, beard etc.

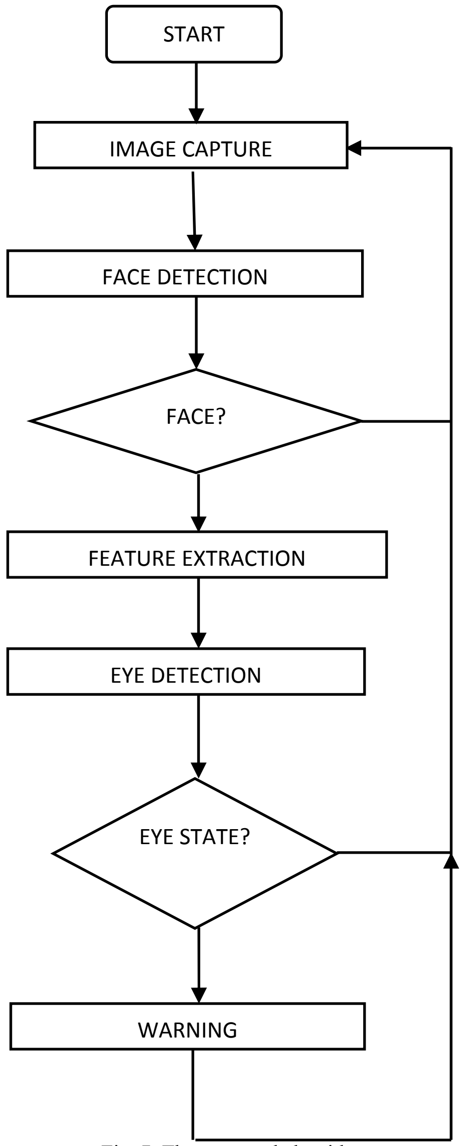


Fig. 7. The proposed algorithm.

The easiest case considers a single frontal face and divides it into region of interest like for mouth, eye and nose etc.The feature detection is used to determine the region of eyes so that their status can be determined easily and quickly. It is performed by segmenting the face that has been detected. This segmentation is based on the experimental results obtained from the different research papers.

4) Eye Detection

Eye detection is the essence of eye tracking and iris recognition – without it, there's no way to identify the eye itself. It sounds simple, but it's really quite complicated. In this stage the eyes are detected in the specified region by the feature detection. In the beginning it looks for the Eigen eye. This process is time taking and it is done just once. After the detection of Eigen eye it is just matched in the other frames for the same candidate. The eye detection process is explained in detail in later chapters.

5) Eyes State

In this stage, it is determined that whether the eyes are closed or open. The detection of eyes status is very important. It is done by an algorithm which will be explained in the later chapters. If the eyes are detected to be closed then the warning is sounded. If the eyes are open then the algorithm goes to the first step of the image capture. The same pattern repeats to check the status of the eyes.

IV. Experimental Results

A. Image Capturing

As mentioned earlier, the video is recorded by web camera for testing the system. The recorded video is used in MATLAB by using "mmreader" command. The algorithm is performed on the each frame of the video.

B. Face Detection

The face detection is done by the Viola and Jones algorithm. For the accurate setup we used the cascade which is part of the OpenCV library. This cascade contains 24 stages and has a total of 2913 weak classifiers. Its starting window size is 24 × 24 pixels. The starting scale was set to 1.0, the scale step size was set to 1.1 and the position step size Δ was set to 1.0. In total 32 different scales were checked, yielding a total of more than 1.8 million possible detection windows. The OpenCV has the trained cascade so its easy to use. On the other hand the processing speed in OpenCV is very fast as compared in MATLAB because OpenCV is basic programming language as compared to MATLAB which is high level programming language. The results of face detector are as:

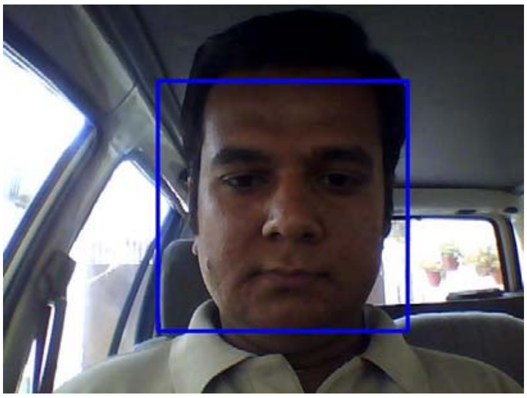


Fig. 8. Input and output of face detector.

C. Facial Feature Extraction

For the facial feature extraction firstly the search areas are defined according to the geometry of the face. Then in these search areas specific content is found by its own algorithm.

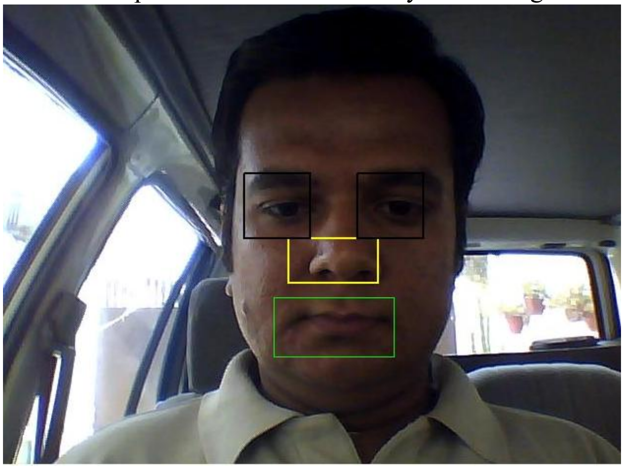


Fig. 9. The highlighted search areas for mouth, nose and eyes.

1) Nose holes

Finding nose holes in an area given from face's geometry depends on the angle between camera and face. If there isn't a direct line of sight between nose holes and camera, it is obviously not possible to track them.Nose holes colors have a significant saturation, depending on its color black. The threshold must be defined and over geometry or clustering two centers of saturation can be found.

2) Mouth

Detecting the middle of the mouth isn't as simple as it is thought. There are a lot of possibilities, going over gradient horizontal and/or vertical decent, hue or saturation. At the moment it is implemented utilizing the distinct hue of lips. Light reflects on lips and this point is fetched by a defined hue value. In contrast to the methods, this method is not light independent, thus intensity and direction of the light can influence results. A better method should be included in the future.

3) Eyes and pupils

A lot of ways can be developed to find pupils in the given area surrounding the eyes. It can also be done using hue or saturation, which leads – controlled conditions given - to good results, but it highly depends on the current light situation. Different pupils where used for testing and the best results were gained by pupils directly from the tester, which was not really surprising. Obtaining them is not that simple though. An algorithm from Anirudh S.K. called "Integrodifferential operator" [7] was used, which requires too much calculation time to be used in real-time environments, but is fast enough for getting the first pupils, so it takes time only first time for finding the Eigen pupil. Once the Eigen pupil is there the rest is very simple. But sometimes due the lack of lighting conditions it takes a little longer time to find the pupil. Still this algorithm is very accurate and the it perform incredibly well under very low lighting condition. This feature of operating under low lighting conditions is very useful in our system.

Then for tracking the Eigen pupil found by the Integrodifferential operator, there are few steps:

- The face is detected from the image.
- In the detected face the geometric region of the eye is defined.

- The Eigen pupil is resized according to the size of the newly found eye region.
- Then Eigen pupil is run as mask on the whole eye region and the men difference is found at every point.
- The point which gives the minimum mean difference is defined as the pupil of the eye.

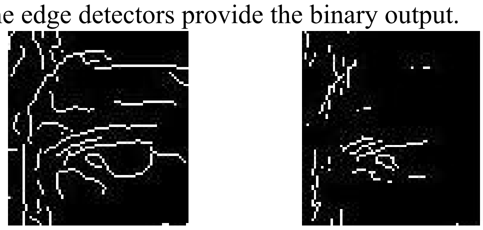
This method of finding the pupil is very quick and easy. It takes very less time as compared to the Integrodifferential operator.

D. Detection of Eyes Status

To detect the eyes are whether open or close was a quite challenging task. Many different approaches were implemented for the detection of the status of the eyes. Some of them are listed below:

1) Status Determination using edge detection

In this novel and simple approach, the eye region from the detected face is subjected to the edge detector. The advantage of using MATLAB is that it has built in edge detector. so I applied “Canny Edge detector” and “Sobel Edge detector”. The results of both the edge detectors are presented below. The Canny Edge detector ha lot of noise and it makes some extra edge. On the other hand the Sobel Edge detector gives better results in case of the noisy image. Both the edge detectors provide the binary output.



a) b)

Fig. 10. Eye edge diagram using a) canny edge detector and b) sobel edge detector.

The eye status detection is performed by calculating the sum of the binary image. As the sum of the image will be higher in case of open eyes, because there are more edges than the closed eye. The problem arises when the lighting conditions and the background interfere with the image. It results in the change in number of edges.

2) Eye status detection using correlation

The in correlation approach the eye region is correlated with the previous eye region. The result will be different in the case of change of status of eye. It was implemented with the built-in function of 2D correlation in MATLAB. But the positioning of eye in each frame and the external factors affect the correlation results. The experimental results show that this system is also not very good for the implementation.

3) Proposed Method for Eye Status Detection

In this technique, the first step is to calculate the average intensity for each x – coordinate. These average values are found for both the eyes separately. When the plot of these average values was observed it was found that there are two significant intensity changes. The first intensity change is the eyebrow, and the next change is the upper edge of the eye, as shown in the figure. Thus with the knowledge of the two valleys the position of the eyes in the face was found. The state of the eyes (whether it is open or closed) is determined by distance between the first two intensity changes (valleys) found in the above step. When the eyes are closed, the distance between the x – coordinates of the intensity changes is larger if compared to when the eyes are open as shown in Figure.

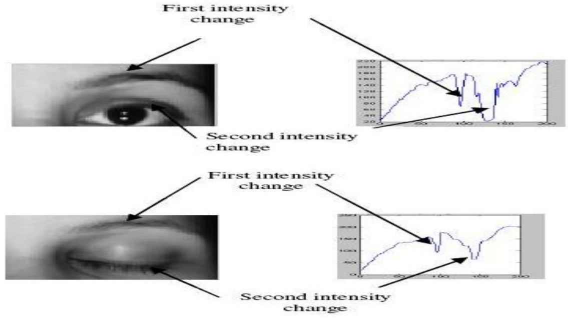


Fig.11. Average intensity variation on the face when eyes are open and close.

E. Drowsiness Detection

The eye status defines the drowsiness state of the driver. If the eyes are closed then the driver is fatigued and need to take some rest. Some of the systems don’t warn the driver on the first closed eye is detected, but for a vehicle moving at a high speed the closed eye even for a moment can be very crucial. Because if the vehicle is moving on 100 Miles/Hour, which means its 44.7 Meters/Second. So if we waste a second or so that could prove to be lethal.

F. Results

The result of the tracking is as:

Fig. 12. Tracking for eyes open.

Fig. 13. Tracking for eyes closed.

For the Figure 12 and 13 we can see that incase of eyes closed the pointer does not exactly points to the eyes. This is because the use of matching algorithm for the eyes tracking. It will match it to the eye brows, because they also high concentration of dark pixels.For drowsiness detection the results of the eyes status algorithm is very accurate.

V. Future Recommendations

System can be improved in many dimensions some of which are discussed including the other parameters of the driver like yawning etc. should be included to get the better vigilance status of the driver. The algorithm should be made at night with low lighting, as the light from the inside light unit of the car. The warning system should be modified to either stop the car slowly or make some vibrations to wake up the driver.

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