Instant Warning System to Detect Drivers in Fatigue

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Abstract: *This paper presents a non intrusive prototype computer vision system for monitoring a driver's vigilance in real time. It is based on a hardware system for the real-time acquisition of a driver's images using an active video camera and the software implementation for monitoring some visual behaviors that characterize a driver's level of vigilance. two parameters are used. one is the head position and the second is the percentage of eye that is closed while running. These parameters are combined using a fuzzy classifier to infer the level of inattentiveness of the driver. The use of multiple visual parameters and the fusion of these parameters yield a more robust and accurate inattention characterization than by using a single parameter. The system has been tested with different sequences recorded in night and day driving conditions in a motorway and with different users. Some experimental results and conclusions about the performance of the system are presented.*

Keywords: Facial features, Head position, Concealment of the eyes, region of interest, boundary box

1. Introduction

The increasing number of traffic accidents due to a drivers diminished vigilance level has become a serious problem for the society. In order to decrease traffic accidents many countries have started to pay attention for their safety. Driver fatigue has been acknowledged as the most significant safety hazard in the transport industry. A recent comprehensive analysis of the world's literature shows the emphasis is moving from investigations of causes to studies of counter measures.

Fatigue and sleeplessness are typically reflected in a person's facial expression and effect eye-lid movements, gaze orientations and head-movement. Such visual clues can be exploited by the computer vision techniques for the detection of the fatigue and vigilance level of the driver. This class of technique offers a promising, no-invasive and low cost alternative to, electrode-based measures of fatigue such as those described by Hietmann et al in[1].

In Europe, statistics show that between 10% to 20% of all the traffic accidents are due to drivers with a diminished vigilance level caused by fatigue. In the trucking industry, about 60% of the fatal truck accidents are related to driver fatigue. It is the main cause of heavy truck crashes.[2]. According to U.S National Highway Traffic Safety Administration (NHTSA), falling asleep while driving is responsible for at least 100 000 automobile crashes annually. An annual average of roughly 40,000 nonfatal injuries and 1550 fatalities resulted from this crashes.[3]. These figures underestimate the true level of involvement of drowsiness because they do not include crashes during day-time hours involving multiple vehicles, alcohol, passengers or evasive maneuvers. These statistics do not deal with driver having distraction which is believed to be a larger problem.

The majority of computer vision approaches for monitoring fatigue driving relay on special hardware. For instance, Ji and Yang monitor driver vigilance with a custom designed hardware system for real-time image acquisition and illumination control; the system is coupled with various computer vision algorithms for eye and facial expression tracking system. The work proposed in this paper is related to driver fatigue monitoring. The novelty of this approach is that the measurement is taken based on the eye-lid movement and changes in facial expression such as yawning and nodding of the head. The whole project can be converted

2. Literature Survey

Many of the leading companies have promised a system which will detect fatigue or drowsiness in drivers. But most of them are either very expensive or not real-time based. This idea of fatigue detection was put forward from as early as year 2005. From that time onwards the real issue was the exact time the warning must be given and for what duration.

A driver's state of vigilance can also be characterized by indirect vehicle behaviors' such as lateral position, steering wheel movements and time-to-time crossing. Although these techniques are not intrusive, they are subject to several limitations such as vehicle type, driver experience, geometric characteristics, condition of the road, etc. On the other hand, these procedures require a considerable amount of time to analyze user behaviours and therefore, they do not work with the so called micro-sleeps—when a drowsy driver falls asleep for a few seconds on a very straight road section without changing the lateral position of the vehicle

In this line different experimental prototypes can be found, but at this moment none of them has been commercialized. Toyota [4] uses steering wheel sensors (steering wheel variability) and a pulse sensor to record the heart rate, as explained above. Mitsubishi has reported the use of steering wheel sensors and measures of vehicle behaviour (such as the lateral position of the car) to detect the driver's drowsiness in their ASV system.

Typical visual characteristics observable from the images of a person with a reduced alertness level include a longer blink

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duration, slow eyelid movement, smaller degree of eye opening (or even closed), frequent nodding, yawning, gaze (narrowness in the line of sight), sluggish facial expression, and drooping posture. Computer vision can be a natural and nonintrusive technique for extracting visual characteristics that typically characterize a driver's vigilance from the images taken by a camera placed in front of the user. Many studies on developing image-based driver alertness using computer vision techniques have been reported in the literature. Some of them focus primarily on head and eye tracking techniques using two cameras. The method presented in [5] estimates the head pose and gaze direction. It relies on a two-dimensional (2-D) template searching and then a three dimensional (3-D) stereo matching of the facial features. A 3-D model is then fit and minimized using virtual springs, instead of the least-squares fit approach for determining the head pose. In [6], a method is presented based on a stereo template matching system to determine some specific facial features. A least squares optimization is done to determine the exact pose of the head. Two eye trackers calculate the eye-gaze vector for each eye; these vectors are combined with the head pose to determine the gaze direction. In [7], a system called FaceLAB developed by a company called Seeing Machines is presented. This is an evolution of the two previous studies. The 3-D pose of the head and the eye-gaze direction are calculated in an exact way. FaceLAB also monitors the eyelids to determine eye opening and blink rates. With this information, the system estimates the driver's fatigue level. All the above mentioned systems rely on a manual initialization of the feature points. The systems appear to be robust, but manual initialization is a limitation, although it makes the whole problem of tracking and poses estimation trivial.

Another attempt that was tried to discover the fatigue was to introduce an EEG system [8] which monitors the drivers throughout the drive. This apparatus must be connected to the driver which had sensors attached to the driver. Whenever the driver is feeling fatigue the reading changes and from graph it plots, the fatigue can be detected. Other two mentionable projects are AWAKE and NAVTECH. These combined both the technology of the facial features such as eye-lid motion and difference in the grip of the steering wheel as well as lane tracking sensor and steering wheel positioning. Exhaustive pilot testing was done and finally report was that it cannot be used outdoor because it worked only in well constructed highway. The remainder of this paper is organized as follows. Section III describes the problem statement, IV the proposed approach or the methodology. Section V shows results and discussion, while section VI draws conclusions and VII future work

3. Problem Definition

Detect fatigue in drivers from the onset of it and to alert him at the right time using the right method. Monitor the driver's features such as facial expression and head position.

4. Methodology

This paper presents a way to detect the fatigue in a person by checking his facial conditions such as rubbing of eyes and nodding of head. These two factors contribute for finding the

amount of vigilance the driver is currently having. The general architecture can be given with the aid of a flow chart (fig: 1).The flow is as follows. First step is to acquire the video. Here it is done using normal web cam since an on road experiment cannot be done. From the video the head position is identified. By pointing out the midpoint of the face the eyes can be spotted. This is one of the conditions that are to be checked. When the eye is detected the concealment of it can be detected. While the eye is being rubbed, it is hidden under a finger or palm. As a result it won't be visible and can be monitored. The second condition to be checked is the position of the head. If the head is in an inclined angle than the usual then it can be detected. All these steps should be repeated if the image acquisition is not proper. Each time when there is a failure then the steps are repeated until a good image is obtained. The alert is produced in the end if fatigue is detected.
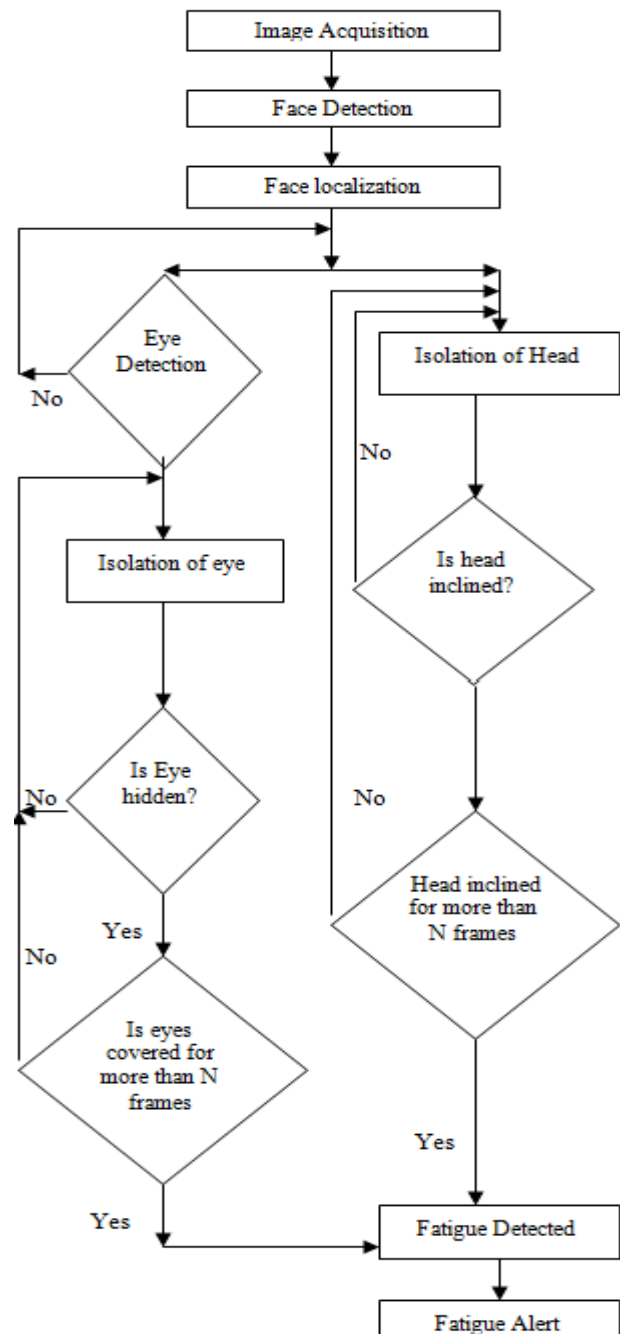

Figure 1: Flow chart of the proposed System

This section can be further divided into two segments
A. Technique for visual based fatigue detection in drivers
B. Face Detection
C. Rubbing of the Eyes
D. Head inclination detection

A. Technique for visual based fatigue detection in drivers
In this paper a built-in library in MATLAB is used which is known as the *Vision,Cascade.Object Detector System* is used. This detects objects using the Viola-Jones algorithm. Here framing of an object is done. Framing of an image allows to specify the ROI(Region of Interest). The ROI defines location of the object which is used to train the object.

Viola-Jones is the one of the best face detection algorithm because they are robust- very high detection rate and very low false positive, real-time- for best result at least two frames must be used and finally its face detection not recognition, the basic idea is to identify face from non face area. The algorithm has mainly 4 stages –
1) Creating Integral Image
2) Haar Features Se lection
3) AdaBoost Training algorithm
4) Cascaded Classifiers

1. Creating Integral Image
The first step of the Viola-Jones face detection algorithm is to turn the input image into an integral image. This is done by making each pixel equal to the entire sum of all pixels above and to the left of the concerned pixel. This is demonstrated in figure 2
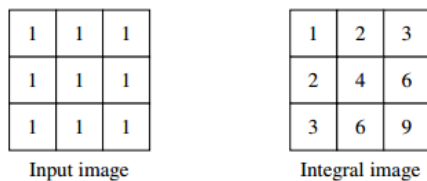

Figure 2: The integrated image

This allows the calculation of the sum of the pixel can be done based on the four values. These values are the pixels in the integral image that coincide with the corners of the rectangle in the input image. This is demonstrated in Figure 3
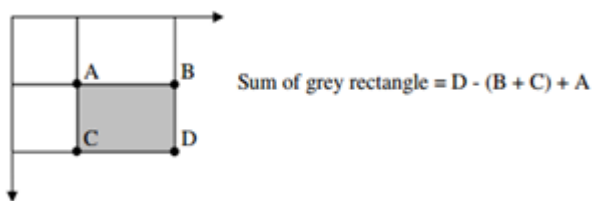

Sum of grey rectangle = D - (B + C) + A

Figure 3: Sum calculation

2. HAAR like Features
According to Viola-Jones, all human faces share some similar properties. This knowledge is used to construct certain features known as Haar Features. The properties that are similar for a human face are:- The eyes region is darker than the upper-cheeks, the nose bridge region is brighter than the eyes, location - size: eyes & nose bridge region. This detection is done based on a set of rectangles which

forms the features. These are also known as sub-windows. The different types of features are shown in Figure 4.
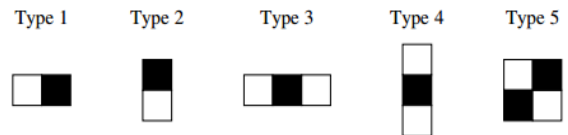

Figure 4: Different types of features

Each feature results in a single value which is calculated by subtracting the sum of the white rectangle(s) from the sum of the black rectangle(s).

3. AdaBoost Training Algorithm
AdaBoost is a machine learning boosting algorithm capable of constructing a strong classifier through a weighted combination of weak classifiers. To match this terminology to the presented theory each feature is considered to be a potential weak classifier. A weak classifier is mathematically described as:

$$h(x,f,p,\theta) = \begin{cases} 1 & \text{if } pf(x) > p\theta \\ 0 & \text{otherwise} \end{cases}$$

Where x is a 24*24 pixel sub-window, f is the applied feature, p the polarity and θ the threshold that decides whether x should be classified as a positive (a face) or a negative (a non-face).

4. Cascaded Classifiers
The basic principle of the Viola-Jones face detection algorithm is to scan the detector many times through the same image – each time with a new size. Even if an image should contain one or more faces it is obvious that an excessive large amount of the evaluated sub-windows would still be negatives (non-faces). This realization leads to a different formulation of the problem:

Instead of finding faces, the algorithm should discard non-faces.

The thought behind this statement is that it is faster to discard a non-face than to find a face. With this in mind a detector consisting of only one (strong) classifier suddenly seems inefficient since the evaluation time is constant no matter the input. Hence the need for a cascaded classifier arises.

B. Face and Eye Detection

The initialization of the video sequencing is done by connecting the video cam (laptop cam for this study) and positioned in such a way that maximum face area can be focused. Therefore it is assumed that the eye plane is orthogonal to the optical axis of the camera. This approach tolerates some vulnerability in distance, since it can detect objects that are close and considerably far.

The segmentation of the face area is calculated based on the boundary box function provided by the vision library. This will help to separate the face area from the background. When the video sequencing is turned on, first the bbox will form a boundary around the face. The face area is detected

based on the HAAR like objects. Same way the eye region is also detected (fig 5) .the detected region of the eye is marked with another box known as the eye box. The eye region when detected can be used for fatigue detection.

Figure 5: Face and eyes detection

C. Rubbing of the Eyes

Rubbing of the eyes is one of the symptoms of fatigue. Usually a person never realizes how many times he is actually rubbing his eye when they are tired. They will not take it seriously. Tired eyes always have an itching sensation which will make the driver to rub his eyes. This also might be because of several reasons such as sleep deprivation or long drive. When the driver rubs his eye, the eye portion is covered by his hand or fingers(fig 6). The video sequencing cannot detect the eyes because of this. If the rubbing is continued in more than the predefined set of frames that is if the frequency of rubbing is more, then an alert must be produced to alert the driver.
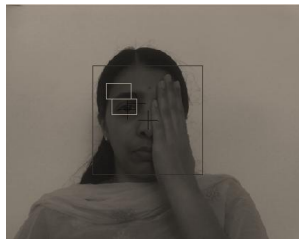

Figure 6: Rubbing of the eye

D. Head Inclination Detection

One of symptoms related to drowsiness is head nodding resulted from dozing. During drowsiness, head is gradually bent Head pose estimation is a key element of human behavior analysis. Many applications would benefit from automatic and robust head pose estimation systems such as driver drowsiness detection, it gives the vital information. Many methods are there to estimate the head pose from monocular images. One method of detection is to view the head angle by 3D orientation (fig 7). Determination of head orientation is an effective symptom for detection of driver distraction and prediction of driver intent to lane change.
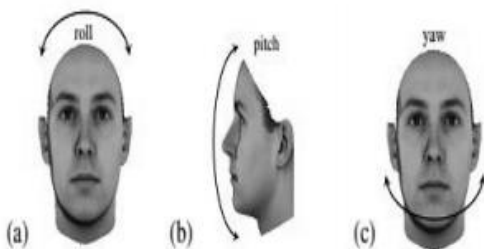

Figure 7: 3D view of the head

Another simpler yet efficient method is to view the image as a 2D form where the threshold can be set accordingly. Here

the sensor will sense the lightness and the darkness accordingly. If '0'represents darkness and if '1'represents white then the alarm can be set accordingly.

$$Alarm = \begin{cases} 1 & HDP \le Thr \\ 0 & HDP \ge Thr \end{cases}$$

Figure 8: Nodding of head

5. Results and Discussion

The hardware used in the current implementation of the proposed approach consists of a laptop with attached webcam. Inexpensive hardware was deliberately chosen in order to demonstrate that the prototype system can function with low cost components and therefore could be affordable to a large segment of the driving population.

Experimental results were acquired using DELL XPS L501X laptop with 2.53GHZ i5 processor with 4.00 GB RAM and 64-bit Operating System. The videos were taken as 24 frames per second. The experiment was conducted using MATLAB version 2013a on WINDOWS 7 platform.

The following table (fig 9) was acquired by combining all the symptoms. Here the frame threshold is set as three. If three consecutive frames show warning then the fourth frame will be taken as a critical. All through the warning frames a low pitched short alarm is played in the background which would help the driver to come back to the alert state if it is the starting state of the drowsiness. If the driver is not responding in all the three frames then during the fourth frame a high pitched and long alarm is blared. In the table zero represents non severe warning and one represents severe warning.

	Year	Month	Date	Hour	Min	Warning Level	
1	2015	1	30	10	36	0	Driver Error Table
2	2015	1	30	10	36	0	
3	2015	1	30	10	36	0	
4	2015	1	30	10	36	1	

Figure 9: Table showing driver statistics

6. Conclusion

A nonintrusive prototype computer vision system for the real-time monitoring of a driver's vigilance was constructed. This system tries to look at the emerging technologies and determine the best approaches in trying to prevent the number one cause of fatal vehicle crashes. It is based on the capturing system which will process the data online. Here only two parameters were used, such as rubbing of eye and nodding of the head. The system is fully autonomous. It was tested under different illumination condition with different

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users. The system works accurately under proper light and if the person is not wearing dark goggles or sun glasses. The performance of the system decreases as the light falling on the face increases. This system provides an accurate technique for fatigue detection in drivers. The proposed system is considerably more reliable than the existing system. Another benefit is the diminished false rate by judging the conventional approach.

7. Future Scope

The accuracy of this method can be further increased in this future by adding more parameters. Other parameters such as blinking of the eye and the yawing frequency can increase the accuracy up to 100%. In future studies, we intend to test the system with more users for longer periods of time in order to obtain real fatigue behaviours. With this information, we will be able to generalize our fuzzy knowledge base. Then, we would like to enhance our vision system in order to solve the problems for daytime operation and to improve the system for use with drivers wearing glasses. Finally, this system could be easily extended to other types of vehicles, such as aircraft, trains, subways, etc., consequently improving safety in transportation systems.

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