Implementation of Computer Vision to Detect Driver Fatigue or Drowsiness to Reduce the Chances of Vehicle Accident

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Abstract— **Fatigue or drowsiness is one of the main reasons of inattention of drivers. Now a day Computer Vision is a very active field to detect specific human physiology and behavior during driving to detect driver's drowsiness. This paper proposes a design of detection system which can detect fatigue in drivers based on computer vision. The system approaches to detect fatigued drivers by first, detecting the face from a video sequence of driver's frontal face followed by locating the eye from the extracted face. Secondly, system finds the existence of eye pupil from detected eye and measures the blink rate simultaneously and by analyzing these parameters, system measures the loss of awareness before driver completely loss his/her attention. The proposed system aims to be more cost effective than industrial installments and therefore all parameters have been analyzed under laboratory environment and frames have been captured with a low cost webcam.**

Keywords— Computer Vision; Fatigue Detection; Face Detection; Blink Rate

I. INTRODUCTION

Human error causes traffic accident more than machine error. One of the main reasons of this human error is driver's inattention. At maximum time driver's inattention comes from fatigued state or drowsiness. Fatigue is a subjective feeling of tiredness which is distinct from weakness, and has a gradual onset. Physical fatigue is a transient inability of a muscle to maintain optional physical performance. A simple model of driver fatigue was proposed by Hattori, Matsuura, Narumiya, Araki and Ohnaka (1987), who demonstrated the three stages of driver performance in extending driving [1]. The driver began in stage One, characterized by alertness. In Stage Two (drowsy driving) drivers appeared to be sleepy, and had a tendency to decrease their close attention to safety and to drive gazing vacantly at one unspecified point. The car speed was kept fairly constant but there was often a delay changing speed in response to change of gradients of the road. This type of driving had been referred to as highway hypnosis. In stage three (dim driving) the consciousness level of the driver seemed to become even lower and blinking were extremely reduced. The steering operation becomes pronounced. During this repeated zigzag driving the car sometimes crossed the centre line of ran off the side of road. In Stage three a high level of fatigue is present and vehicle control is difficult to maintain.

A survey done in the U.S.A. by The national Highway Traffic Safety Administration (NHTSA) estimated that in 1996 there were 56,000 sleep related road crashes in the U.S.A. [2]. Another survey done it 2007 says that 18% of fatal accidents involved fatigue as the main factor. In Great Britain up to 20% of serious road accidents is caused due to fatigue [3]. Similarly, a survey done by the Road and Traffic Authority (Australia) states that in the year 2007, fatigue contributed to 20% of fatalities caused on road [4]. Again a 100-car "naturalistic" driving study conducted by the Virginia Tech Transportation Institute says that fatigue is a cause of 20% of car crashes, rather than the two of three percent previously estimated based on surveys, simulator studies and test tracks [5]. As road accident due to drowsiness is increasing at an alarming rate, we need to increase public awareness as well as technological advancements to reduce vehicle accidents. There are many well established technologies on fatigue detection and predictions, like fitness for duty technologies, ambulatory alertness prediction technologies, and vehicle based performance technologies, behavioral studies using physiological signals and behavioral studies using Computer Vision systems.

This paper proposed a fatigue detection system based on Behavioral Studies using Computer Vision and aims to present a fast and simple method of detection technique. The system is designed based on face detection followed by eye detection algorithm to locate and analyze eye pupil existence to measure blink rate. Then analyzing these parameters system decides a fatigue level for the driver.

978-1-4799-4819-2/14/$31.00

II. RELATED WOEKS

Recently, many countries have begun to pay great attention to the safety of drivers. Technological improvements are enhancing day by day. Detection of driver's drowsiness is now a very active field for researchers. Developing vision based warning systems for drivers is an increasing field of interest.

Computer Vision is gaining a lot of attention in the area of face detection, face tracking, eye detection etc for various applications like security, fatigue detection and biometrics due to its non-intensive nature and convenient technique to monitor driver's vigilance. As the accuracy of the entire method relies on the accuracy of face detection, proper face detection is one of the most important criteria in a vision based fatigue detection system.

In 2000, Margrit and William developed a driver monitoring system using edge detection and template matching technique [6]. The detection system was based on statistical decision theory and used Bayes decision rule to estimate from the color of the pixel if it images a face. Though, the system had many drawbacks. Template matching algorithm requires a lot processing power which can't be provided frequently in a car with low cost installments. Also, this method minimized the average loss due to the classification decision by using the likelihood ratio. As a result the algorithm showed noticeable errors. In the same year Nikolaos P. used front view and side view images to precisely locate eyes [7].

In 2004, Wen-Bing developed a face detection and eye tracking technique by converting images from RGB (Red, Green and Blue) color space to HSI (Hue, Saturation and Intensity) color space and came up with an accuracy of 88.9% [8].

In the past decade many researchers have given their own mathematical model to make vision based detection system more accurate and sophisticated. Wenhui Dong proposed a method to detect the distance of eyelid, and then judge the driver's status by this kind of information [9]. Zutao Zhang located the face by using Haar algorithm and proposed an eye tracking method based on Unscented Kalman Filter [10]. Abdelfattah Fawky presented a combination of algorithms, namely wavelets transform, edge detection and YCrCb transform in the eye detection [11].

In 2007, David and Lim developed an eye tracking system by combining the color segmentation and Hough transform technique [12]. In this system unwanted face features were filtered using masking which makes the system faster and accurate than previous works.
This paper presents a model of detection system which is also based on Hough transform, but with some preprocessing and post processing to make the algorithm strong and accurate even with the low cost instruments. Gaussian model have been used with canny edge detection to blur frames and to avoid false detections

III. PROPOSED METHOD FOR FATIGUE DETECTION

The design that has been proposed in this paper aims for both simplicity and effectiveness. The system has been tested via a low cost webcam to capture frames. A video recording device, in this case which is a webcam is placed in front of the driver to capture frames from driver's frontal face and sent to the system to analyze. The method, first build up using Matlab (R2013a) to design the appropriate algorithm and then finally implemented using OpenCV 2.1 (by Intel Corp.), an open source C++ library aimed for Computer Vision [13], as in real-time applications OpenCV consumes less time and less processing power than Matlab. The system first searches and detects face from every captured frame and localizes the eyes. After first detection of eye, system sets an image ROI (Region of Interest) to make next searches faster. Then the system localizes eye pupils and checks the time interval between appearance and disappearance of the eye pupils. If the time interval is longer than usual for a specific time than the system detects the driver as fatigued. Gaussian blur have been used with adaptive threshold to reduce noise and false detection. Fig. 1 shows roughly how the algorithm works.

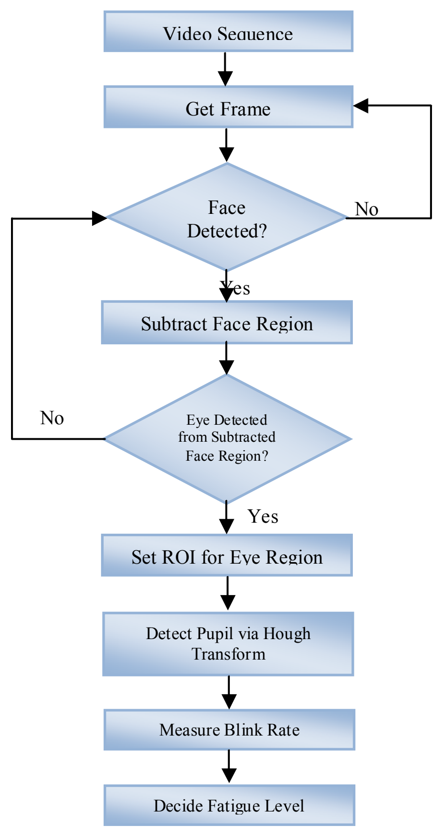

Fig.1. Overview of the proposed algorithm.

A. Face Detection

In this method, face detection comes as the first requirement to approach its aim. There are many well established methods to detect face from a frame quickly and accurately such as, face detection using PCA, face detection using Edge-Orientation Matching [14], robust face detection using Hausdorff Distance [15]. However, this paper approaches to face detection using Viola-Jones object detection framework [16]. This algorithm is based on weak classifier cascade which is simple and efficient for face detection. The method uses rectangular features like Edge features, Line features and Center-surround features and which are known as 'Haar-like features', due to the similarity of analysis of complex waveforms of Haar wavelets. Viola-Jones algorithm works in 'YCbCr' color space. Haar-like features consist of a class of local features that are calculated by subtracting the sum of a sub region of the feature from the sum of the remaining region of the feature. Fortunately, OpenCV has a very efficient object detection function based on Viola-Jones's Haar classifier cascades to detect frontal face from an image. In this paper, OpenCV's default frontal face classifier cascades have been used to detect face from an image. Fig 2 shows how OpenCV's face detection detects face from a frame.

Fig.2. (a) Detected face from a captured frame; (b) Detected face region; (c) Face region with canny edge detector

But it is important to make sure that the system detects only one face which should be driver's face. As the cam is installed just in front of driver, a scale variation measure has been used by calculating total area of the detected face region to find out the largest face.

B. Eye Localization

The system deals with eye detection and localization with simple solution. The goal is to find eye pupil from the detected face region using circular shape detection and to make it simple and fast an edge detection algorithm has been applied.

Hough transform is a well established technique to find imperfect instance of objects within a certain class of shapes [17]. The classical Hough transform was concerned with the identification of lines in the image, but later the Hough transform has been extended to identify positions of arbitrary shapes, most commonly circles or ellipses. OpenCV's Hough circle detection function is well suited with the purpose of this paper. But, as most of commercially low cost video devices give poor video sequences, the Hough circle detection may come out with lots of false detection. That's why a popular edge detection known as Canny Edge detection have been used before the Hough transform [18]. It helps Hough circle function to find circles with very low false detection.

The two key parameters of the Canny Edge algorithm are an upper threshold and a lower threshold. The upper threshold is used to mark edges that are definitely edges. The lower threshold is to find faint pixels that are actually a part of an edge. Thresholds have been chosen in a range that can make the algorithm fast yet accurate enough. But it is hugely dependent on environmental parameters. This edge detection method is also prone to noise. A bit smoothing should be done to reduce noises. Unfortunately, OpenCV 2.1 doesn't do this automatically. So, manually a noise reduction method should be applied, in this case which is Gaussian Blur. It is widely used smoothing operation.

After, smoothing with Gaussian Blur the next steps of canny edge detector are to calculating gradient magnitude and direction. The magnitude of the gradient at a point determines if it possibly lies on an edge or not. A high gradient magnitude means the colors are changing rapidly, implying an edge. A low gradient implies no substantial changes and so it's not an edge. The direction of the gradient shows how the edge is oriented. The last step of canny edge detector is non maximum suppression, which means if a pixel is not a maximum, it is suppressed. In fig 1(c) it is clear that with the help of Gaussian blur the canny edge detector works good enough and the eye pupils has appeared clearly circular.

With smoothing operation when OpenCV's canny edge detector successfully detects edges of the frame, system hands over the frame to Hough circle detection to find circular shape around the face region. As the only pure circular shape on a face region is the pupil of each eye, system detects them. Fig 3(a) (b) shows the results of the proposed pupil detection. When, system successfully detects the eye pupils for the first time, it sets an image ROI to make the later search faster. The ROI have been chosen as a rectangular area wide 2cm from the centre on each side of the detected circular pupil, fig 3(c). Next time when system searches for the pupil it searches only on the ROI area and can takes less time to find the target. This method even reduces the chances of false detection.

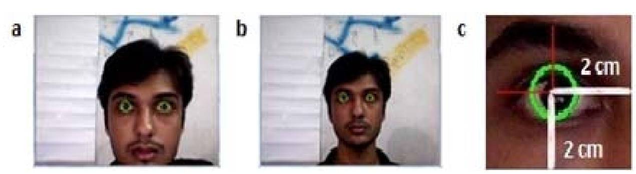

Fig.3. (a) (b) the proposed system has detected the eye pupils; (c) ROI of detected pupil area.

C. Blink Rate Measurement and Fatigue Detection

High blink rate is a symptom of a fatigued driver that has been used as the main concern to help decide the driver is fatigued or not. Generally, for adults between each blink there is an interval of 2-10 seconds [19]. However, when the eyes are focused on an object or in a direction for an extended period of time, blink rate decreases. After the system detects eye pupil, it waits for its disappearance and calculates the time interval between disappearance and next appearance of the pupils in the frame. Normally, blinking of eyes is so fast that a low cost video may easily miss some blinks. So the system averages the time intervals for a specific time (in this case which is 10 minutes). If the time interval is increasing gradually though out that specific time, system may detect the driver as fatigued. But that specific time should be adjustable as the blink of eye may differ from individual to individual.

IV. EXPERIMENTAL RESULTS

The proposed system was tested under laboratory conditions with 4 volunteer participants. The video sequence was recorded using an A4TECH 2 megapixel webcam which has a low frame rate of 15. The algorithm was developed on a 3.2 GHz Intel quad core pc with 2 GB ram.

In the experiment, every volunteer has been tested for 5 minutes. Table 1 shows the detection numbers counted in every minute. From average detection rate it is clear that volunteer No. 3 will be detected as relatively fatigued. System reached its decision by finding the minimum pupil detection time which represents low pupil existence on the frame and detected as a fatigued subject. The major drawback of the system is the chances of false detection. Also the system must be given an experimental time range for pupil existence for every particular subject below which the subject will be detected as fatigued. Another factor which affected the accuracy was the eye lids. If the eyes were partially open then the system had problem detecting the eye pupil as circular shape. Although the system is not error free, accuracy will be improved further in future.

TABLE I. Number of pupil detections of 4 volunteers for 5 minutes.

Volunteers	**1st min**	**2nd min**	**3rd min**	**4th min**	**5th min**	**Average detection per min per volunteer**
Volunteer 1	28	32	17	27	15	23.8
Volunteer 2	33	26	37	35	29	32
Volunteer 3	19	17	27	13	26	20.4
Volunteer 4	34	25	14	41	39	30.6

V. FUTURE WORK

When it is about a life of a human being, a decision should not be taken which is not 100% reliable. The system is still in development and experimentation. In this stage, it can only be used as a driving companion. Also, the method itself is still time consuming to reach its decision and sometimes can give a false decision (concerning the experiments which can happen in rare case) as it depends only one physical symptom. Further developments of the system with other physical signs of drowsiness (i.e. skin tone analyze, grip pressure measurement etc.) has already begun and a hopeful outcome can be expected.

ACKNOWLEDGMENT

The authors would like to acknowledge Himadri Dev who have sponsored this project and gave inspiration. And thanks to OpenCV developer's community who have been working so hard to enrich the OpenCV library.

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