An Efficient System to Identify User Attentiveness Based on Fatigue Detection

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Abstract— **This paper presents a user alertness identification system based on fatigue detection. The user may be a person like computer operator, operating critical operations on distant machines, hands free interaction with computational devices/machines, controlling heavy machineries like cranes or performing time critical operations like air traffic controlling etc. Same system can also be employed to detect and notifying the driver vigilance level and hence to avoid possibility of road accidents. The proposed system uses the time–efficient image processing techniques to measure eyes closer count, blinking rate of eye and user yawning as the parameters to conclude user's fatigue. The proposed system continuously captures the image of the subject on site using web camera and detects face region, then focuses on eyes and lips using efficient image processing techniques to monitor their behavior. If abnormality either in behavior of eyes or mouth is detected, it indicates that the subject is falling asleep or having state of drowsiness therefore fatigue is detected and a warning alarm is generated.**

Keywords— face detection, eye blinking rate, eye closer count, yawning, edge density, threshold value.

I.   INTRODUCTION

Many efforts have been reported in the literature for developing an active safety system for reducing the number of accidents due to reduced vigilance level. Fatigue detection in the user can be generally divided into the following categories:
1. Sensing of physiological characteristics of the user,
2. Sensing of user operation,
3. Sensing of machine response,
4. Monitoring the response of the user.
Among these methods, the best techniques in terms of accuracy are the ones that are based on Human physiological phenomena [3].
They are implemented in two ways:
a.) measuring changes in physiological signals, such as brain waves, heart rate, and eye blinking and
b.) measuring physical changes such as sagging posture, leaning of the user's head and the open/closed states of the eyes [3].

The first technique, while most accurate, is not realistic, since sensing electrodes would have to be attached directly onto the user's body, and hence be annoying and distracting to the user. In addition, long time usage would result in perspiration on the sensors, diminishing their ability to sense accurately. The second technique is well suited for real world conditions since it could be non-intrusive by using optical sensors of video cameras to detect changes.

User operation and machine behavior is good indicator of detecting alertness level of user. These are non intrusive ways of detecting drowsiness, but unfortunately are limited to machine type and user conditions. The final technique for detecting drowsiness is by monitoring the response of the user. This involves periodically requesting the user to send a response to the system to indicate alertness. The problem with this technique is that it will eventually become tiresome and annoying to the user.

The proposed system is altogether different from discussed techniques. It is based on eyes closer count (blinking rate), duration of eye closure (nap detection) and yawning detection of the user. By monitoring the eyes and mouth, it is believed that the symptoms of user fatigue can be detected early enough to avoid an accident. Blinking rate of normal eye is 4-5 times per minute. In drowsiness state, eye blinking rate either increases or decreases by normal rate. Similarly duration of eye closure is also a significant parameter in detecting somnolence because in drowsiness state eye closure duration increases to 3-4 seconds (micro sleeps). But it is difficult to predict alertness level based only on eyes functioning because previous researches have proven that eye detection has several limitations like if user is wearing eyeglasses then eye detection becomes a problem[1],[2],[3]. Also, eye detection is difficult for users having smaller eyes.

Moreover, if we only look at the number of consecutive frames where the eyes are closed, then at that point it may be too late to issue the warning. To overcome this, proposed system also considers yawning detection as a second parameter to detect somnolence. Yawning is a very good indicator to detect drowsiness state [3] and if yawning is detected then warning signal may be issued early enough to avoid accident.

This system has been designed to be deployed in real time environment at very less cost because it does not require additional hardware. Previous works requires extra hardware

like frame grabbers [1], infra red camera [2] to detect drowsiness which increases the cost of system to a great extent. Also, it does not require additional surrounding light sources as required by previous research [1]. Proposed system works efficiently even in the presence of different illumination sources in the background, unlike the previous research [1] which requires that there should be dark background behind the user.

In addition to these qualities, proposed application is very light weight (space and time efficient), does not eat up much CPU execution time.

Ideally any software proposed to help us should not affect our normal course of interaction with the system otherwise the usability and acceptability gets hampered adversely like some antivirus software make the system responding too slow to the user and even some times disturb the user with their annoying pop ups sometimes disturbs our normal functioning. This system has been proposed by keeping this point into consideration.

Therefore, proposed system identify fatigue accurately and efficiently while incurring minimized time complexity, space complexity, cost and overheads of using it.

II.   PROPOSED METHODOLOGY

2.1 System Overview

The flow chart of the functionality of proposed system is shown in Fig. 1

After capturing the image (RGB image), it is converted into grayscale image. Then image is blurred so as to erase pixels of irrelevant information and edges of the blurred image are detected by applying Sobel filters.

Assuming the face of the user at the center of the image, the image is divided into two halves horizontally which results in two independent images, image of eyes and mouth independently.

Edge density in image of mouth is calculated independently to detect yawning. Image of eye is again partitioned into two from center vertically so as to get images of both the eyes separately and edge density in each eye is calculated to find eye closure. More density of edges were recorded when eyes or mouth are open as compared to that when they are closed.

Blinking rate is measured over a specific period of time, say 1 minute. If more than 6-7 or less than 2 image of closed eyes are observed per minute , it indicates the abnormal blinking rate.
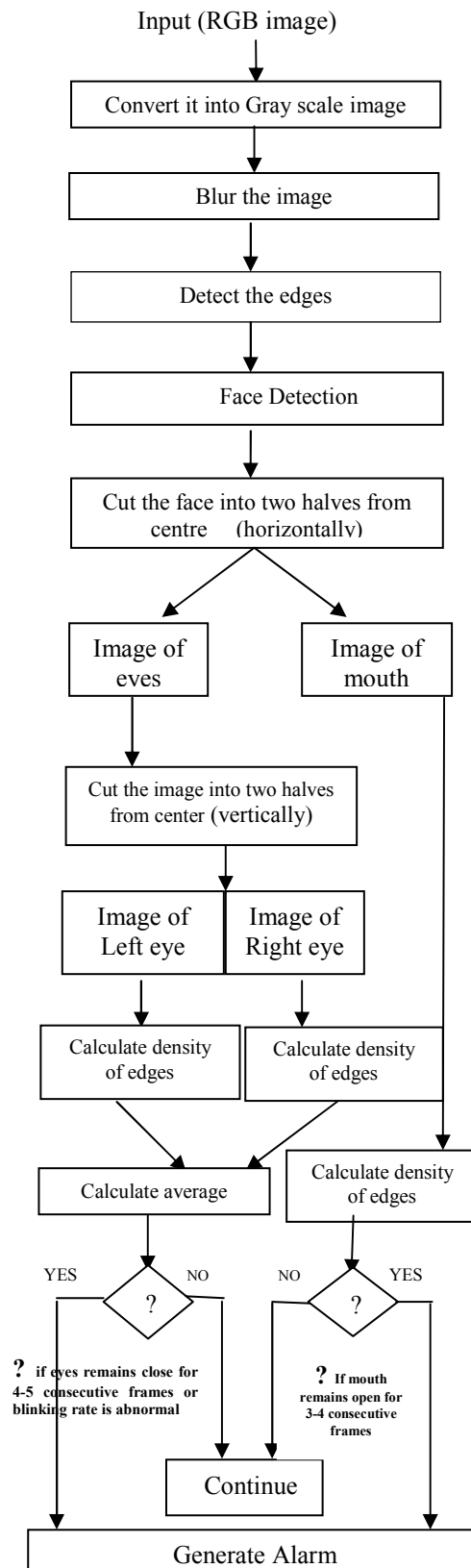

Fig. 1 Flowchart of the proposed system

2.2 Working

2.2.1 Converting the input RGB image into Gray image.

Since RGB image takes 24 bits (8 x 3) while gray scale image takes only 8 bits to store and we are interested in developing a time efficient system, therefore after capturing the image (RGB image) it is converted into gray scale image. Intensity of an image is the average of the three color elements, so the gray scale image that represent the original color image can be computed as:

$$I_0 = (Ri + Gi + Bi)/3 \qquad (1)$$

Io is the output intensity; Ri, Gi, and Bi are the red, green, and the blue element intensity. The formula for more realistic result is by adding different weight for each R,G, and B element. We normally percept green color brighter that red color, and red color brighter than blue color. That's why we usually set the weight higher for red and higher for green.

$$I_0 = (0.299Ri + 0.587Gi + 0.144Bi)/3 \qquad (2)$$

Actually there is no absolute reference for each weight values because it depends on the display technology that might change in the future. The above formula is standardized by NTSC (National Television System Committee), and its usage is common in computer imaging [8].

2.2.2 Blurring the Gray scale image

In order to blur the image, erosion /dilation image processing techniques have been applied.

Erosion
It turns off pixels which were near pixels that were off originally, thereby eating away at the edges of the items in the image
Erosion generally shrinks image objects. Erosion decreases the sizes of objects and removes small anomalies by subtracting objects with a radius smaller than the structuring element [11] [19].
With grayscale images, erosion reduces the brightness (and therefore the size) of bright objects on a dark background by taking the neighborhood minimum when passing the structuring element over the image.

Dilation
It turns on pixels which were near pixels that were on originally, thereby thickening the items in the image. Dilation generally expands image objects. Dilation generally increases the sizes of objects, filling in holes and broken areas, and connecting areas that are separated by spaces smaller than the size of the structuring element.
With grayscale images, dilation increases the brightness of objects by taking the neighborhood maximum when passing the structuring element over the image [11][19].

Fig. 2.1 shows a blurred image obtained from gray scale image by applying erosion and dilation.

a.) Gray image   b.) Blurred image

Fig. 2.1

2.2.3 Finding the edges of blurred image
To find the edges of blurred image , Sobel filter method have been used.
Sobel edge detection filter algorithm
Two 3x3 convolution masks are applied to each pixel, one color at a time - one with a horizontal trend and one with a vertical trend. The result of the each convolution is treated a vector representing the edge through the current pixel. If the magnitude of the sum of these two orthogonal vectors is greater than some user-specified threshold, the pixel is marked in black as an edge. Otherwise, the pixel is set to white [5].

Vertical Kernel				Horizontal Kernel		
-1	0	+1		-1	-2	-1
-2	0	+2		0	0	0
-1	0	+1		+1	+2	+1

Fig. 2.2 shows the edges of image taken after applying Sobel Filter method

Fig. 2.2 edge detection

2.2.4   Face Detection
From the edges of the image ,next step is to find face among edges.For finding the face, start scannig the image from both ends left as well as right end and marking great intensity changes along y coordinates or vertical direction .
Great intensity changes denotes left and right corner of face. Fig. 2.3 shows the graph showing the intensity changes of the image. Face region is found between two highest peaks.
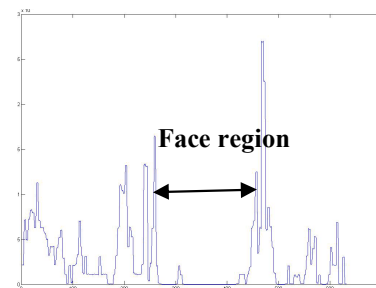

Fig. 2.3 Face detection

2.2.5 Cutting the image of face into two halves

By cutting the image of face into two halves horizontally from the centre,gives the images of eyes and mouth separately.

Now eyes movement and yawning can be monitered independently as the system has two independent images to process as shown in Fig. 2.4
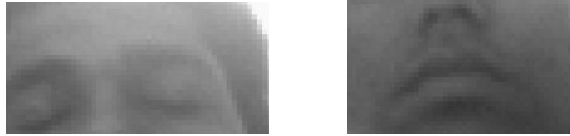

Fig.2.4

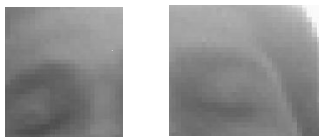### 2.2.6 Cutting the image of eye into two halves vertically.

Fig.2.5

Now the edge densty in each image is calculated and then their average is taken to find if eyes are open or closed. If the number of edges are less than the threshold value ,it indicates eyes are closed else eyes are open.This is shown in Fig2.6

Fig. 2.6

If eyes are found to be close for 4-5 consecutive frames then snap is detected and hence warning signal is generated.

Similarly , we calculate edge density in image of mouth to detect yawning .If the number of edges are less than the treshold value,it indicates mouth is closed else it is open.This is shown in fig 2.7
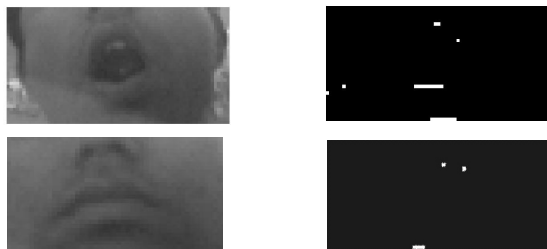

Fig. 2.7

If mouth is found to be open for 3-4 consecutive frames then yawning is detected ,hence warning signal is generated.

III. RESULTS

The Proposed system is implemented in real time and work successfully.It was experimented on 6 different people and gave high accuracy (more than 90%).

All the pictures and results used in this paper are obtained from actual implementation of system.

3.1
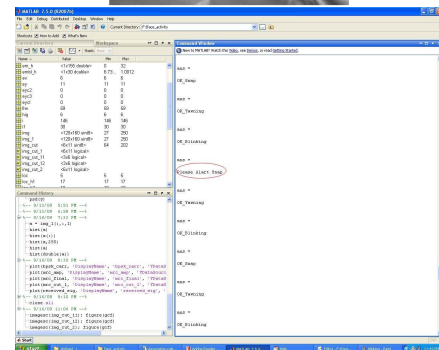#### Case I : When Nap is detected

Fig. 2.8 Nap Detection
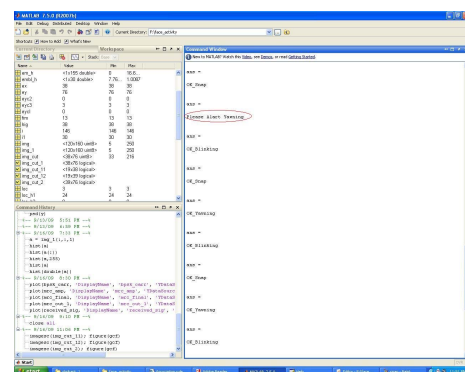
Case 2: When yawning is detected

Fig. 2.9 Yawning detection

Case 3: When Blinking Rate is Abnormal

Fig. 2.10 Blinking rate detection

IV. CONCLUSION

In this paper, a user alertness detection system has been proposed based on fatigue detection. The proposed system is based on eyes closer, blinking rate of eye & yawning detection of the user. The system continuously captures the image of the subject on site and detects face region , then eyes and lips are detected in the face under consideration to determine if eyes are closed or open ,if eyes found to be closed for 4-5 consecutive frames or blinking rate of is found to be abnormal or lips are found to be open for long duration (yawning) ,for 3-4 consecutive frames then it is concluded that the subject is falling asleep or having state of drowsiness therefore fatigue is detected and a warning alarm issued.

The proposed system can be applied to large number of applications like in vehicles to detect drowsiness level of user, in software industries where developers works continuously for 14-15 hours to detect their vigilance level, for computer operators, operating critical operations on distant machines, hands free interaction with computational devices/machines, controlling heavy machineries like cranes etc.

The proposed system has following advantages

1. Works in real time without requiring any extra hardware, thus reducing the cost of system to a great extent.
2. Works with users wearing eyeglasses or having smaller eyes also
3. Works even when background is not uniform.
4. Computations are very easy and it is a very lightweight system, does not irritate user while using it and does not disturb user in doing his regular work unlike antivirus software.

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