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Driver's Drowsiness Detecting and Alarming System

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Abstract: **Drowsiness of the drivers is the main cause of accidents in the world as well as Sri Lanka. Due to lack of sleep and tiredness, drowsiness can occur while driving. The best way to avoid accidents caused by drivers' drowsiness is to detect drowsiness of the driver and warn him before fall into sleep. To detect drowsiness many techniques like eye retina detection, facial feature recognition has been used. Here in this paper, we propose a method of detecting driver drowsiness using eye retina detection and pulse rate detection of the driver. In this report, we propose a more accurate drowsiness detection method which is a hybrid approach of eye retina detection and pulse pattern detection.**

Keywords: **Drowsiness, Driver, Detection.**

I. INTRODUCTION

Driver exhaustion is a significant variable in an expansive number of vehicle accidents. Late insights, assess that yearly 1,200 deaths and 76,000 injuries can be credited to weariness related accidents. Road Accidents in Sri Lanka cause financial losses worth around Rs.9.34 billion every year. It can be seen there are around 2,400 road accidents consistently which is one death per every four hours. It has been figured around 20% of car crashes with driver fatalities are due to driver's drowsiness. It was uncovered that driving execution quickly drop with expanded tiredness which result in making more than 20% of all vehicle accidents. Less attention heads the driver to being distracted and the likelihood of street accident goes high. Drowsiness related accidents have all the earmarks of being more serious, because of the higher speeds involved distraction and the driver being not able to take any avoiding activity, or even brake, before the accident.

The improvement of innovations for recognizing or preventing tiredness of the driver is a significant test in the field of accident preventing systems. Because of the danger that that drowsiness presents on the road, strategies need to be created for checking its influences. Loss of the awareness because of the tiredness causes a few changes in the human's body and activities. These side effects and parameters empower us to effectively measure the drowsiness level. Different strategies for drowsiness identification can be partitioned into two general classifications. The techniques in the first gathering recognize the level of the tiredness focused around the physiological changes in the body. Eye status, speech properties, time interval between two yawning, head position, sitting carriage, heart rate, and brain signals are simply a couple of illustrations of the strategies in the first classification. Drowsiness additionally brings about some changes in the driving style. Techniques in the second category estimate the driver's drowsiness level by following these progressions. Steering angle, distance from the following vehicle, lateral position of the vehicle, longitudinal speed, longitudinal speeding up, and lane departure are utilized as a part of the technique of the second classification.

II. LITERATURE REVIEW

What is Drowsiness

The term "drowsy" is substitutable with sleepy, that merely means that an inclination to fall asleep. The stage of sleep is often classified as awake, non-rapid eye movement sleep(NREM), and rapid eye movement sleep(REM). The second stage, NREM, is often divided into the subsequent 3 stages.

- Stage I : Transition from awake to asleep(drowsy)

- Stage II : Light- Weight sleep
- Stage III: Deep sleep

Features, which Drowsiness Depends On

One of the challenges in developing an economical drowsiness detection system is a way to acquire proper drowsiness information. Because of safety reasons, drowsiness cannot be manipulated during a real environment, Therefore the drowsiness detection system needs to be developed and tested in a laboratory setting. However, in a laboratory setting, the foremost reliable and informative information that pertains to driver drowsiness depends only on the approach in which the driver falls into the drowsy state. Driver drowsiness principally depends on the quality of the last sleep, the biological time (time of day) and the rise within the period of the driving task. In some analysis experiments, the subjects were totally deprived of sleep, whereas they were only part deprived of sleep in others. Additionally, some researchers recruited night shift staff as their subjects, in this case, the subjects were entirely deprived of sleep as results of the experiments were conducted within the morning. Kokonozi, et al. Conducted an experiment during which they monitored the participants for twenty four before the experiment began to make sure that they were utterly sleep deprived [1]. In certain experiments, researches partly deprived the subjects of sleep by permitting them to sleep for less than a half dozen. Peters, et al. Studies an equivalent subject throughout four consecutive days and regarded the results of no sleep deprivation , partial sleep deprivation and total sleep deprivation on their drowsiness level [2]. They discovered that, even within the case of partial sleep deprivation, the subjects tend to urge drowsy after a while. Hence, the standard of the last sleep is a crucial criterion that influences drowsiness. Otamani, et al. Found that sleep deprivation alone doesn't directly influence the brain signals that control, drowsiness, whereas the period of the task includes a strong influence [3]. Researchers have additionally inferred that prolonged driving on a boring setting stimulates drowsiness. In fact, it has been discovered that the subjects will become drowsy at intervals twenty to twenty five min of diving.

Researchers on Drowsiness Detection Using Behavioral Measures

Template matching

Template matching is a method for discovering zones of a picture that match to a format picture. There are two picture classifications the source picture the picture in which we hope to discover a match to the format picture and the Template picture the patch picture which will be contrasted with the format picture. To recognize the matching territory, must be contrasting the format picture against the picture by sliding. Sliding is moving the patch one pixel at once (left to right, up to down). At every area, a metric is computed. So it represents how "Great" or "Terrible" the match at that area is (or how comparable the patch is in that specific territory of the source picture). The brightest areas indicate the highest matches[4].

Principal Component Analysis (PCA) and Linear Discriminate Analysis (LDA) for Blink Detection

J. Lee, H. Jung, K.R. Park and J. Kimpropose another driver checking system considering driver tiredness and diversion [5]. In the event that the driver is looking ahead, tiredness identification is performed. If not diversion discovery is performed. Besides, another eye recognition, calculation is presented. It joins versatile boosting, versatile layout matching, and blob discovery with eye acceptance. Those calculations diminish the eye discovery lapse and handling time essentially, by accomplished the said calculations. Third, they have used principal component analysis (PCA), and linear discriminate analysis (LDA) with a specific end goal to attain exact eye identification. Fourth, they have proposed a novel eye state detection calculation that joins appearances gimmicks got utilizing PCA and LDA, with measurable peculiarities.

Harr cascade Classifier

J. Suryaprasad classifies the method for face/eye detection methods utilizing image processing in real time [5]. In this project, it further clarifies the method for utilizing the harr cascade tests and the separation of eye blink and drowsiness identification. This paper acquaints a vision based strategy with distinguishing the drowsiness. The significant difficulties are face recognition, Iris location under different conditions and creating the real time system.

Researches on Drowsiness Detection Using Physiological Measures

Many researchers consider the subsequent physiological signals to observe drowsiness, electrocardiogram (ECG), electro encephalogram (EEG). The heart rate (HR) additionally varies considerably between the different stage of drowsiness, like alertness and fatigue. Therefore, heart rate, which may be simply determined by the ECG signal, can even be used to observe drowsiness. Others have measured drowsiness using heart rate variability (HRV), within which the low (LF) and high (HF) frequencies fall within the range of 0.04-0.15 Hertz and 0.14-0.4 Hertz respectively, shows a physiological signal sensing system that may be integrated into vehicles to observe driver drowsiness. But still, compared to the drowsiness detection using behavioral measures, numbers of researches on physiological measures to detect drowsiness are low.

Real time Nonintrusive Detection of Driver Drowsiness [6] project has done by Xun Yu, University of Minnesota Duluth. In this research they have mainly concern on the detection of the drowsiness using heart rate of the driver. This system aims to develop a real time; nonintrusive driver drowsiness detection system to cut back drowsiness caused accidents. Biosensor is built on the vehicle steering wheel to read driver's heartbeat signals. Heart rate variability (HRV), a physiological signal that has established links to waking/ Sleeping stages, Therefore can be analyzed from the pulse signals for the detection of driver drowsiness.

III. METHODOLOGY

Prior to proposing a new hybrid method for the drowsiness detection, a thorough study is carried out on the existing methods of drowsiness driver detection mechanisms and they are listed at. A better hybrid version of drowsiness detection mechanism is expected to be proposed using the specifications, observations and calculations figured out in the theoretical study. Standard face detection techniques and heart rate variability analysis results were studied and they have been used to create a new fuzzy based hybrid drowsiness detection mechanism. In fulfilling this task EMGU CV (A cross platform .Net wrapper to the OpenCV image processing library), fuzzynet1.2.0 (Fuzzy Logic Library for Microsoft .Net), "Kubios HRV Analysis" software and MATLAB fuzzy tool box has been used.

General Flow of the Study and Implementation

The general flow of the research can be mainly divided into several parts. In here drowsiness detection model is proposed with the physiological and behavioral measurements of the subject. According to that the study varies mainly on these two sectors. Basic steps of the behavioral measurements are as follows,

- Study of behavioral techniques used to detect drowsiness.
- Video Acquisition.
- Extracting features to detect drowsiness.
- Monitoring features with time.
- Providing output based on the detected features.

Basic steps of the physiological measures are as follows,

- Study on physiological measures used to detect drowsiness.
- Selecting HRV analysis to detect drowsiness.
- Analyzing LF/HF ratio for test samples.
- Selecting a suitable range of LF/HF for the implementation.

Using the two input variables finally a fuzzy model has been designed to predict the driver's drowsiness level.

Eye Shut Duration as Behavioral Measurement for Drowsiness Detection.

After the thorough study of behavioral measurements to detect drowsiness, we selected eye shot duration of the driver as the behavioral measurement to detect drowsiness. To calculate the blink duration, the first thing we did was face detection. To do the face detection we use "harr cascade face detection mechanism". To detect eye in the face we use "harr eye tracking algorithm". To detect the eye shut duration we use the Hough circle detection mechanism. The basic flow is shown in Figure 1.

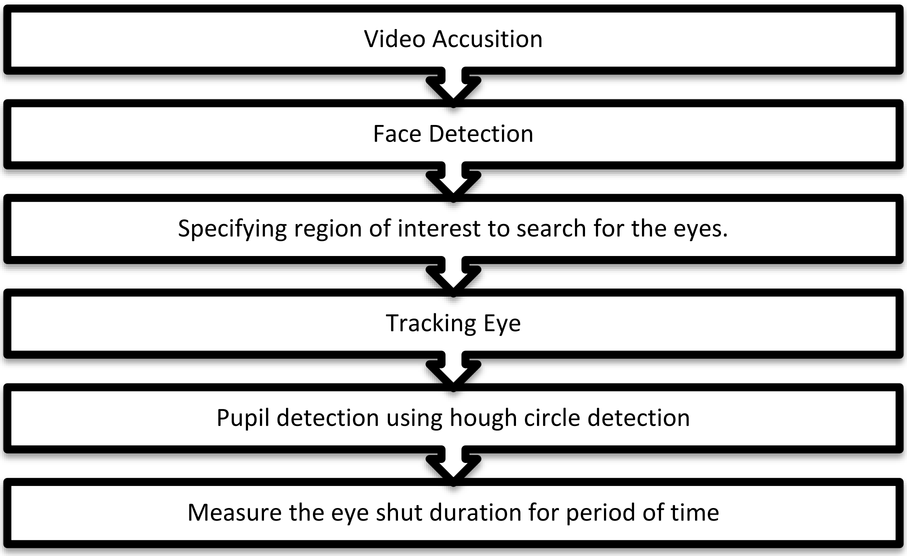


Fig. 1: Basic Flow of Behavioral Measure

Here the "haar face detection" and "haar eye tracking algorithm" were built in EmguCv library, and they were used to detect the face and the eye. To improve the eye searching mechanism, we give eye searching area the region of interest to search for the eyes as heuristics. This region of interest was selected by studying the normal human facial geometry.

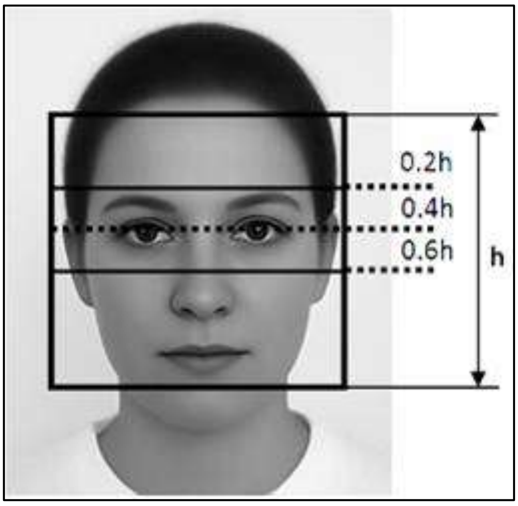


Fig. 2: Rules of Human Face Proportions

As shown in Figure 2 the human eyes are located in 0.2h to 0.6h heights from the top border of the facial area (When the total height of the face is h). This feature was used and given as an input to the eye detection algorithm [7]. After detection of the eye, to detect the eyes open or shut the Hough circle detection was used. When the eye is in the open state iris can be detected by Hough circle detection. To improve the detection mechanism canny filters were used.

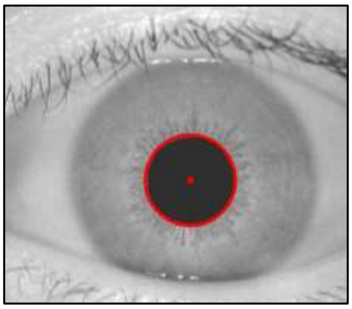


Fig. 3: Iris Detection Using Hough circles

When the eye lids are closed no iris is detected and this is used to calculate the eye shut duration. For every 50 frames of the input video, number of frames which eye lid is closed is recorded and it was taken as the input to create the fuzzy input for the system.

Heart Rate Variability (HRV) as Physiological Measurement for Drowsiness Detection

After thorough study on physiological measurements for drowsiness detection, Heart Rate Variability was selected to detect to detect drowsiness of the driver. Heart rate variability (HRV) is the physiological phenomenon of variation in the time interval between heartbeats. It is measured by the variation in the beat-to-beat interval. Other terms used include: "cycle length variability", "RR variability" (where R is a point corresponding to the peak of the QRS complex of the ECG wave; and RR is the interval between successive Rs), and "heart period variability". Methods used to detect beats include: ECG, blood pressure, ballistocardiograms, and the pulse wave signal derived from a photo plethysmograph (PPG). ECG is considered superior because it provides a clear waveform, which makes it easier to exclude heartbeats not originating in the senatorial node. The term "NN" is used in place of RR to emphasize the fact that the processed beats are "normal" beats. When analyzing HRV there are mainly three methods of analyzing.

Time Domain Analysis

These are based on the beat-to-beat or NN intervals, which are analyzed to give variables such as:

- SDNN, the standard deviation of NN intervals. Often calculated over a 24-hour period.
- SDANN, the standard deviation of the average NN intervals calculated over short periods, usually 5 minutes.
- RMSSD ("root mean square of successive differences"), the square root of the mean of the squares of the successive differences between adjacent NNs.
- SDSD ("standard deviation of successive differences"), the standard deviation of the successive differences between adjacent NNs.
- NN50, the number of pairs of successive NNs that differ by more than 50 ms.
- pNN50, the proportion of NN50 divided by total number of NNs.
- NN20, the number of pairs of successive NNs that differ by more than 20 ms
- pNN20, the proportion of NN20 divided by total number of NNs.

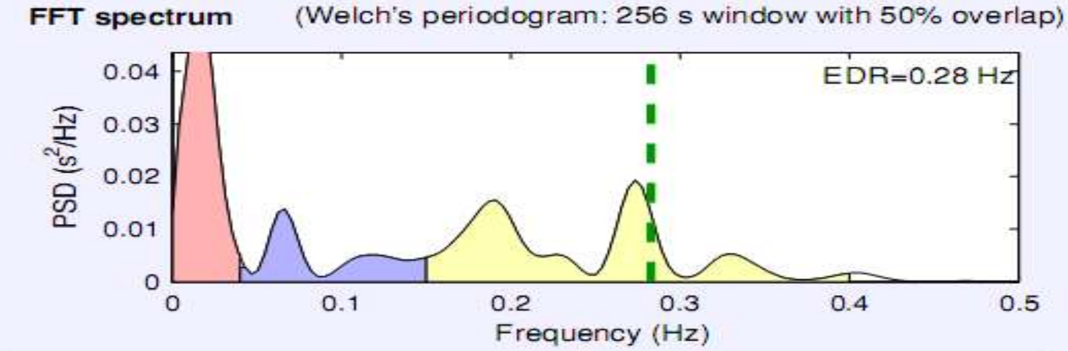
Frequency Domain Analysis

Frequency domain methods assign bands of frequency and then count the number of NN intervals that match each band. The bands are typically high frequency (HF) from 0.15 to 0.4 Hz, low frequency (LF) from 0.04 to 0.15 Hz, and the very low frequency (VLF) from 0.0033 to 0.04 Hz. Several methods of analysis are available. Power spectral density (PSD), using parametric or nonparametric methods, provides basic information on the power distribution across frequencies. One of the most commonly used PSD methods is the discrete Fourier transform. Methods for the calculation of PSD may be generally classified as nonparametric and parametric. In most instances, both methods provide comparable results. The advantages of the nonparametric methods are the simplicity of the algorithm used (Fast Fourier Transform [FFT] in most of the cases) and the high processing speed, while the advantages of parametric methods are smoother spectral components that can be distinguished independent of preselected frequency bands, easy post processing of the spectrum with an automatic calculation of low- and high-frequency power components with an easy identification of the central frequency of each component, and an accurate estimation of PSD even on a small number of samples on which the signal is supposed to maintain stationary. The basic disadvantage of parametric methods is the need of verification of the suitability of the chosen model and of its complexity.

Non Linear Analysis

Applying HRV analysis based on methods of nonlinear dynamics will yield valuable information. Although chaotic behavior has been assumed, more rigorous testing has shown that heart rate variability cannot be described as a chaotic process. The most commonly used non-linear methods of analyzing heart rate variability are the Poincare plot. Each data point represents a pair of successive beats; the x-axis is the current RR interval, while the y-axis is the previous RR interval. HRV is quantified by fitting mathematically defined geometric shapes to the data. Other methods used are the correlation dimension, nonlinear predictability, point wise correlation dimension and approximate entropy. Here in this research, we use Frequency domain analysis to detect the features drowsiness. There we acquire the results of HRV analysis done previously and also analyze some ECG measurements of sleeping subjects. (ECG data were obtained from physionet.org) [8].

When doing the analysis "Kubios HRV Analysis" software was used and the method of analyzing was Fast Fourier Transform mechanism. The Low frequency band power (LF) (Represent parasympathetic nerve system of the human body) and High Frequency band power (HF) was analyzed and found out the range of the ratio of LF/HF which relevant to the drowsiness states. Figure 4 shows the analysis window of kubios HRV software for a sleeping subjects ECG.



Frequency Band	Peak (Hz)	Power (ms^2)	Power (%)	Power (n.u.)
VLF (0–0.04 Hz)	0.0156	1268	38.8	
LF (0.04–0.15 Hz)	0.0664	542	16.6	27.1
HF (0.15–0.4 Hz)	0.2734	1456	44.5	72.7
Total		3269		
LF/HF		0.373		

Fig. 4: HRV Frequency Domain Analysis on "Kubios HRV"

This LF/HF ratio range has been used as a fuzzy input to the fuzzy model that we prepare for the system.

Fuzzy Based Model for Drowsiness Detection

Fuzzy model prepared for the drowsiness detection system has two input variables and an output. The details of the input and outputs are as follows, we proposed a fuzzy based model for the drowsiness detection system because mainly the inputs that we use for this system are from two different measurement mechanisms. Due to that the relationship between them is not exact. Also, when considering the output, which is drowsiness levels, it's also a fuzzy value, that is we can't either Seymour have a fine line between drowsiness and wakefulness. Due to these reasons we proposed fuzzy model to detect drowsiness

Fuzzy Inputs

Eye shut duration was measured using the frames of the video. For every 50 frames of the video, number of frames which have not detected Iris has been monitored and the count has been used as an input. According to the range this inputs has been categorize into three fuzzy sets.

1. Normal
2. Average
3. Danger

The membership function for input eye shut duration is shown in Figure 5.

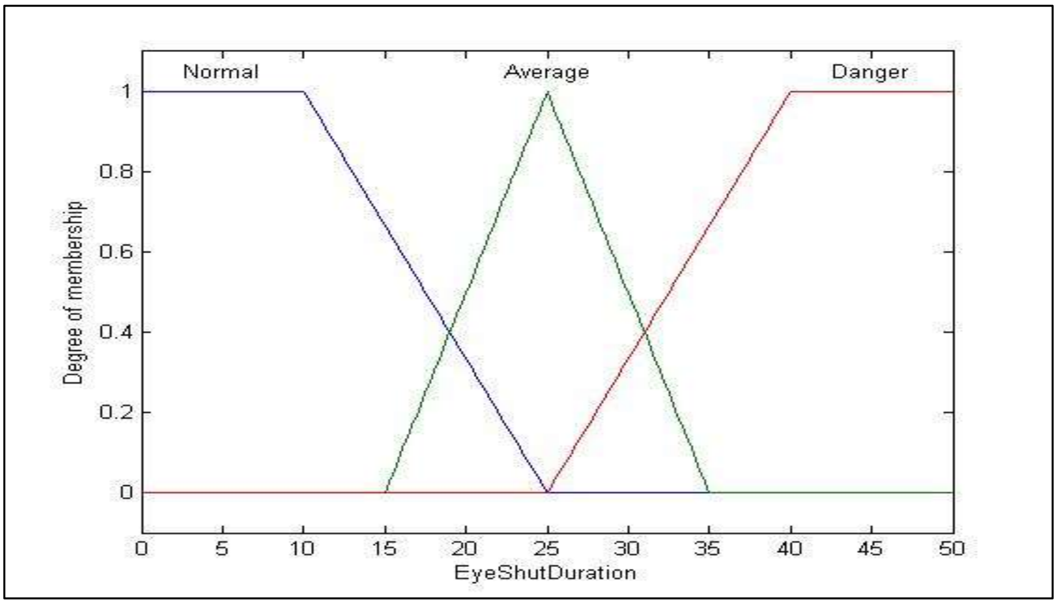


Fig. 5: Input Membership Function- Eye Shut Duration

HRV Analysis (LF/HF Ratio)

After the study on LF/HF ratio we obtain a range from 0.2 to 1.2 as the range which drowsiness could happen. Here the LF band is in range (0.04 - 0.15) Hz and HF band is in range (0.15 – 0.40) Hz The second fuzzy input was prepared according to this range. This input rang was mainly divided into three parts as follows,

1. Low
2. Mid
3. High

The membership function for input LF/HF Ration is shown in Figure 6.

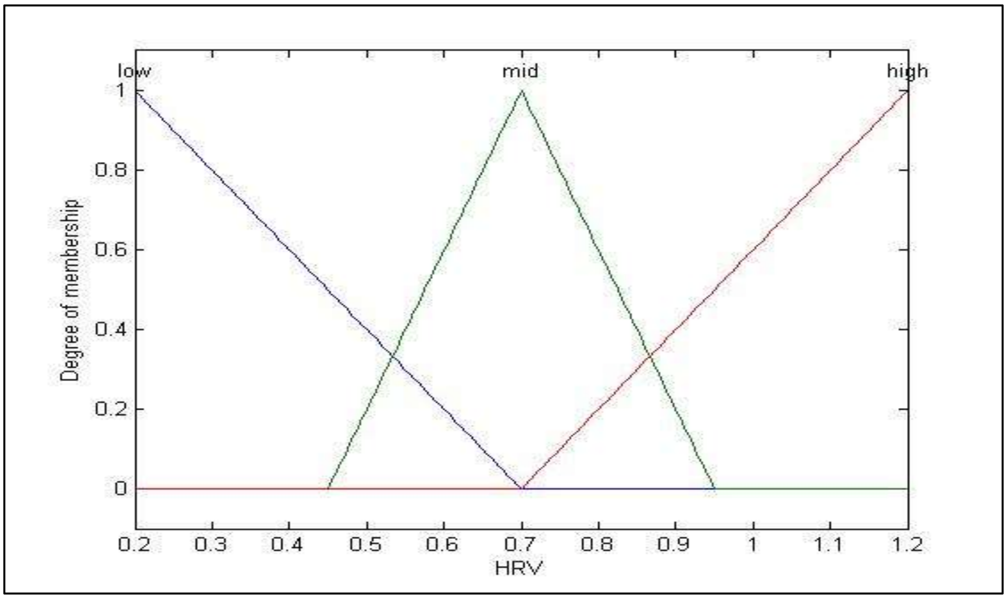


Fig. 6: Input Membership Function- LF/HF Ratio

Fuzzy Output

The output of the system is drowsiness level. We proposed three main stages of drowsiness levels to observe. The outputs are given from range of indexes from 0 to 1. They are as follows,

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1. Good
2. Observe
3. Alarm

The membership function for the output is shown in Figure 7

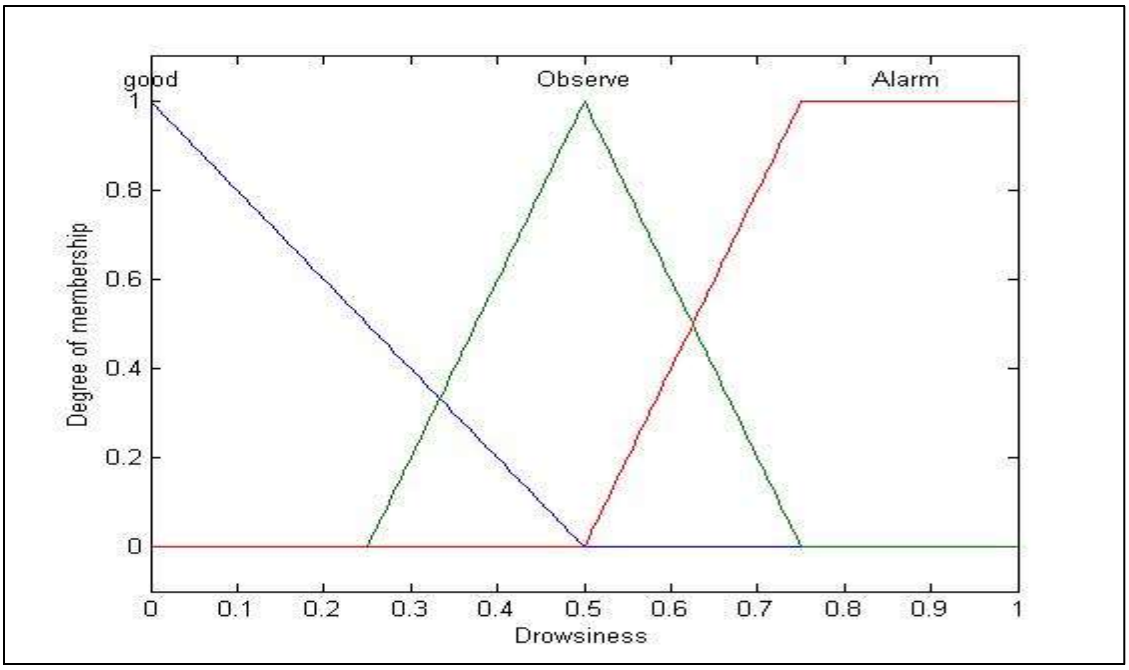

Fig. 7: Output Membership Function - Drowsiness Level

Defining Fuzzy Rules

After testing the fuzzy system for couple of subjects we came up with seven fuzzy rules to the fuzzy system. When defining the rules most concern was given to the eye shut duration since when eye shut duration is high there is a high probability of drowsiness. The seven rules are as follows,

1. If Eye Shut Duration is danger then Drowsiness is Alarm.
2. If Eye Shut Duration is average and LF/HF is low then Drowsiness is Alarm.
3. If Eye Shut Duration is normal and LF/HF is mid then Drowsiness is good.
4. If Eye Shut Duration is normal and LF/HF is high then Drowsiness is good.
5. If Eye Shut Duration is average and LF/HF is high then Drowsiness is good.
6. If Eye Shut Duration is average and LF/HF is mid then Drowsiness is observe.
7. If Eye Shut Duration is normal and LF/HF is low then Drowsiness is observe.

The rules are in more understandable format in Table 1

Table 1: Fuzzy Rules

		Eye Shut Duration		
		Normal	***Average***	***Danger***
LF/HF Ratio	***Low***	Observe	Alarm	Alarm
	Mid	Good	Observe	Alarm
	High	Good	Good	Alarm

The surface of the fuzzy system is shown in figure 8

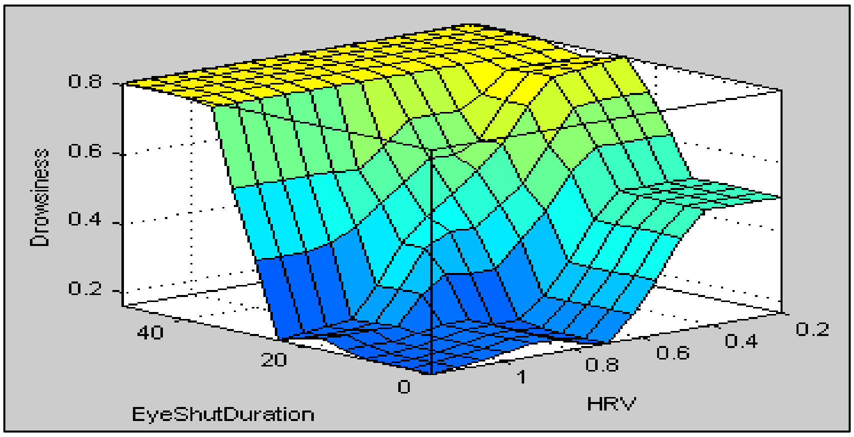

Fig. 8: Surface of the Fuzzy System

Defuzzification Process and Taking the Final Decision

To take a final decision defuzzification is needed, in here we used centroid method for defuzzification and based on the crisp output the final decision was given. Final output also has three categories they are as follows when crisp output is "X",

1. Good (When X <0.33)
2. Observe (When 0.33 <= X < 0.66)
3. Alarm (When 0.66 <= X)

IV. RESULT AND DISCUSSION

The results of this experiment can be mainly divided into three subcategories, which are results from the physiological measurements, results from the behavioral measurements and result from the overall system.

Results from Physiological Measurements

Before developing a model to detect the drowsiness, to select the suitable values for the LF/HF ratio relevant to drowsiness previous researches was studied and from the results of those researches we acquire a range of LF/HFratio for the drowsiness. There the selected range of LF/HF ratio to observe was 0.1 to 1.0 [9]. According to the pilot range we observed ECG records of sleeping subjects using Kubios HRV analysis software. These ECG records were obtained from "physionet.org". [7] There we analyze the ten different ECG signals taken while sleeping. From the analysis, we obtain that most drowsy subjects show LF/HF ratio between 0.3 and 0.5. According to the results we modeled the fuzzy input membership function varies from 0.2 to 1.2 LF/HF ratios. Figure 15 shows the basic analyzing window of the Kubios HRV analysis software.

Fig. 9: Kubios HRV Analysis Interface

Results from Behavioral Measurements

The basic face detection was done using haar face detection mechanism and Figure 10 show the basic detection of the face and facial features when eyes are open.

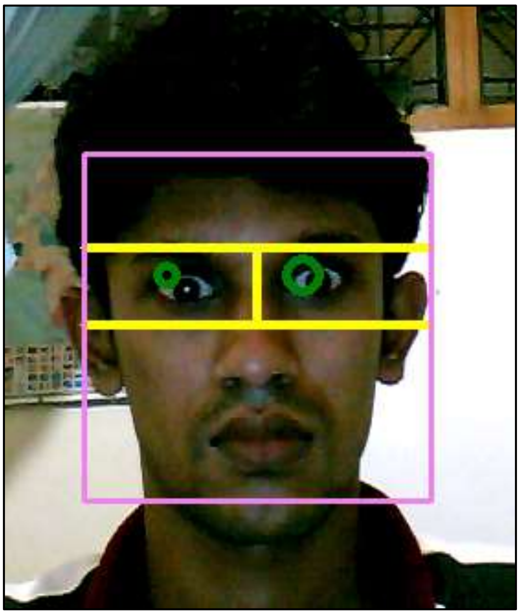

Fig.10: Basic Feature Detection (Open Eyes)

Here in Figure 10, the basic face detection is shown by pink color squire. Then the region of interest to search for the eyes, that obtain from the basic rules on human face proportions are shown in yellow frames. Also in green the detected iris using Hough circle detection mechanism are shown.

The Figure 11 shows the feature detection when the eyes are close which imply the drowsiness. There face is detected but iris is not detected. Frames in this stage are used as the data frames for the system. That is video frames which didn't detect iris are counted and given as the inputs to the system.

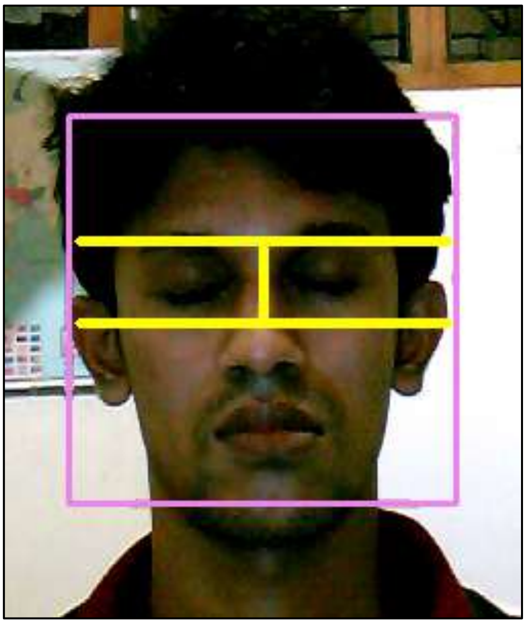

Fig.11: Basic Feature Detection (Close Eyes)

The detection was tested on subjects from various ages both male and female and achieved 100% success results in detecting facial features. Couples of test results are shown Table 2

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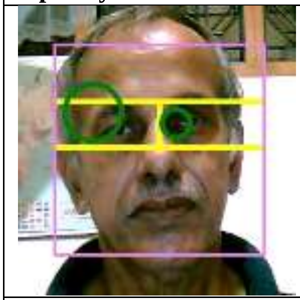
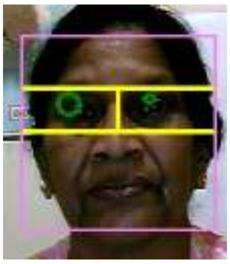
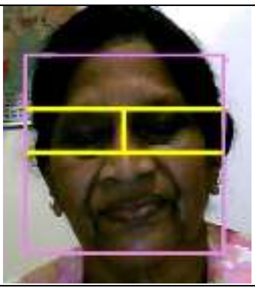
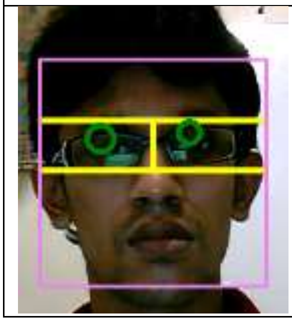
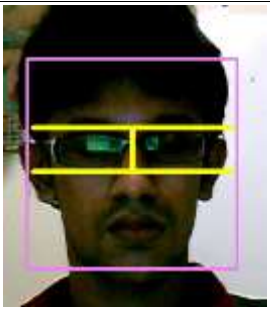
Table 2: Test Results for Facial Recognition

Open eyes	Close eyes
	
	
	

Also the testing was done with the subjects with spectacles. The results were not as good as the subjects without spectacles. The system was unable to detect eyes in most of the cases with spectacles. The main reason for this is reflections on the surface of the spectacles.

Implemented System

The system was implemented using C# language, EmguCv framework and fuzzynet 1.2.0 library. The system acquires real time video using a web camera. The system provides an input field to insert the LF/HF ratio as the input. This input is given manually because the system is not design to take ECG data real time. The user interface of the system is shown in Figure 12

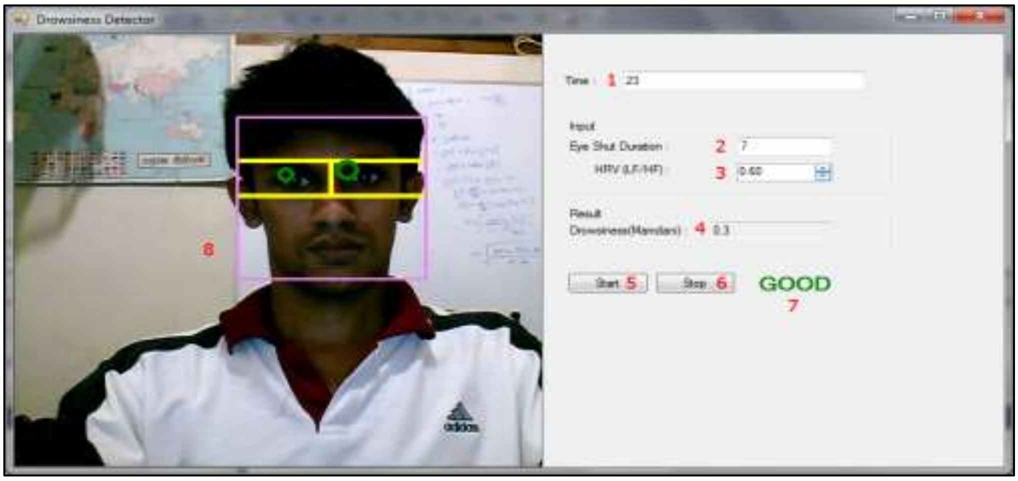


Fig.12: User Interface of the System

The function of the each element in Figure 12 is as follows

1. **Timer:** Show video captured time in seconds
2. **Eye Shut duration :** Number of frames that eye has been shut in previous 50 frames is shown
3. **LF/HF Ratio :** Data input area for the LF/HF values
4. **Crisp output :** Crisp output value from the fuzzy system
5. **Start Button :** Push to Start the drowsiness detection
6. **Stop Button :** Push to stop the drowsiness detection
7. **Output :** A label that show the State of the driver
8. **Video :** The input video and detected components are shown in this

Basic Functionality

- This implemented system acquire real time video input from the web cam and detect the eye closed time in every 50 frames and save it in "2" text field.
- LF/HF ratio need to be entered to the in Numeric up down field "3".
- To start monitoring start button need to be pressed and from then onwards system calculate inputs and output the condition of the driver in label "7" and the crisp output from the fuzzy model is displayed in "4" text field.
- To stop the detection stop button need to be pressed

The implemented system detects drowsiness in real time and gives the output. This implementation is only to demonstrate the functionality of the fuzzy model that we proposed. The implemented system also tested with subjects from various age levels and the also the system has tested on various lighting conditions.

The systems works perfectly in day light, but in the night conditions performance is lacking due to the limitations of acquisition of behavioral data from the webcam. But since this model is a hybrid model using the physiological measurements the system could still function. This has not been tested real time because this system is not implemented to take real time inputs on HRV data.

Discussion

The fuzzy based model for drowsiness detection which we proposed works remarkably fine with the webcam and the external input of LF/HF ratio. One of the key objectives of this study is to provide more cheap but effective drowsiness detection system and with the model that we provided it can be achieved. Also these results prove that hybrid method to detect drowsiness is robust to the environmental issues such as lighting conditions. However this project does not provide any hardware implementation other than the web cam due to that the exact cost for implementation this system cannot be estimated.

V. CONCLUSIONS

Considered the facts that mentioned in Discussion in IV Section it is concluded that the hybrid method that we proposed for drowsiness detection is more suitable than the detection techniques which consider only one category of measurements such as physiological, behavioral or vehicle based methods. Also the fuzzy based model proposed in this research assures high accuracy in detecting drowsiness and it provides exceptional results compared to the other models which is only taken crisp levels in predicting the drowsiness. As recommendation we can improve the system by providing a night time video acquisition camera. Also providing a real time input mechanism for HRV analysis data can make this proposed system a real time application.

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