Drowsiness State Detection of Driver Using Eyelid Movement

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Abstract -- Drowsiness detection system is regarded as an effective tool to reduce the number of road accidents. This project proposes a non-intrusive approach for detecting drowsiness in drivers, using Computer Vision. The algorithm is coded on OpenCV platform in Linux environment. The parameters considered to detect drowsiness are face and eye detection, blinking, eye closure and gaze. Input is recorded and live fed from a camera that supports night vision as well. The algorithm is Haar, trained to detect the face and the eye from the incoming frame. Once the eye is detected, further coding is done to track the eye and automatically set a dynamic threshold value. Depending on the values obtained from each of the incoming frames and deviations from the threshold values, eyelid closure/blink/gaze is detected. Warning system is designed to alert the driver. This system renders an efficient solution to road accidents and the cost of developing it into a real time system is also feasible when compared to the cost involved in the manufacture of car.

Index Terms- OpenCV, Linux, Haar Classifiers, Eye detection

I. INTRODUCTION

Drowsiness is defined as a decreased level of awareness or feeling abnormally sleepy or tired during the day. It might be caused by an absence of rest, medicine, substance misuse, or a cerebral issue. Drowsiness may lead to additional symptoms, such as forgetfulness or falling asleep at inappropriate times. Mental exhaustion has additionally been appeared to diminish physical performance. It can show as sleepiness, dormancy, or coordinated consideration weakness. Some of the most common causes of drowsiness include the following:

- Inadequate, interrupted or fragmented sleep.
- A work schedule that affects amount of sleep.
- Driving for too long without a sufficient rest period.
- Consumption of alcohol or narcotics.

Drowsiness is one of the major causes for road accidents. A driver who falls asleep is in an edge of losing control over the vehicle prompting crash with other vehicle or stationary bodies.

- Studies have suggested that around 20% of all road accidents are due to fatigue.
- Roughly 168 million American drivers – or 60% of the population – claim to have operated a vehicle while drowsy in the recent years.
- Between 1999 and 2008, drowsy driving is playing an important role in 7% of collisions in which a vehicle was towed from the accident scene, 13% of crashes involving at least one hospitalized person and 17% of vehicular fatalities.
- Between 2005 and 2009, it is estimated that drowsy driving caused roughly 4,400 vehicle collisions and more than 5,000 fatalities.
- Over the last decade, more than 7,000 people have been killed in drowsy-driving-related crashes.
- According to new research from the AAA Foundation for Traffic Safety, the risk of getting into accidents is higher during night time hours. The researchers monitored 3,500 individuals in six locations across the U.S. between October 2010 and December 2013. Over that period, the drivers were involved in more than 700 crashes, with drowsiness a factor in 8.8% to 9.5% of them. More than 10% of the accidents that resulted in property damage, airbag deployment, or injury were associated with sleepy drivers.

Using eye related parameters is one of the apposite ways to detect drowsiness. In fact, repeatedly simulated experiments show that the most valid measure of loss of alertness among drivers is the percentage of eyelid closure over the pupil over times. Blink detection by analyzing the bright pupils have also come up in the past. Driver drowsiness detection is a car safety technology which helps prevent accidents caused by the driver getting drowsy. Time taken for eyelid closure is one of the chosen parameters to detect drowsiness in a driver. Driver drowsiness detection system is one of the applications of Computer Vision, a field of image processing where decisions are made by the system based on the analysis of the images. Computer vision-based driver monitoring approach has become prominent due to its predictive validity of detecting drowsiness. Attempts to detect drowsiness using Open CV has been carried out mostly under normal illumination. Using Open CV to implement eye tracking algorithms produces optimum results. Haar Classifiers based on Viola Jones algorithm is one of the best ways to detect various objects.

Existing Method

Physiological and brain related activities help us understand how to provide useful feedback and alert signals to the drivers for avoiding car accidents. Previously, EEG based attempts to detect drowsiness have been made. ECG and EMG have also been parallel to detect multiple features in a subject. A lot of template based and feature based matching methods had been developed in the past. A number of parameters can be used to detect drowsiness. Head is one of those parameters that have been utilized to study drowsiness in the past. A neural based drowsiness detection system developed in the past however, could not guarantee efficiency enough much to apply to actual systems.

Proposed System

The implementation of the drowsiness detection system architecture consists of hardware and software layers. The hardware used is Raspberry Pi 3.RPI runs in Linux environment and the operating system is Raspbian Stretch OS. Many OS based on various platforms are available. Among them Linux has better performance and execution speed is high when compared to other platforms. Linux is an interface between computer/server hardware, and the programs which run on it. The detection mechanism is carried out with the help of OpenCV Library. Mid portion of the chapter described how the entire process of drowsiness detection occurs in low level. For conducting this OpenCV is used. Computer Vision (OpenCV) is a library of programming functions that is exclusively used for applications based on computer vision. Open CV was generally developed by Intel for their processors to obtain high graphics processing. Earlier it was developed by using C language. Later on it became the cross platform for all languages. The libraries are made to convert in desired language in which users opt to work. OpenCV is quick when it comes to speed of execution. Different .xml files of OpenCV are operated on the input and provide the required result. The interfacing of RPI and OpenCV which executes better in their respective fields create a new awareness technology.

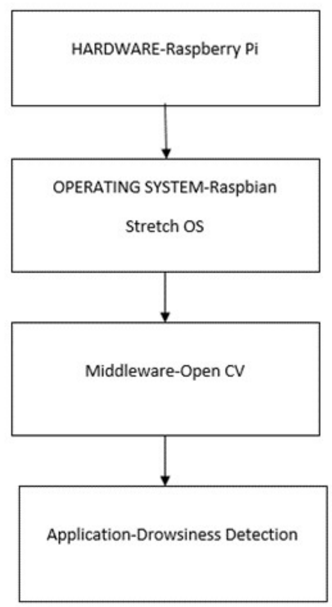

Fig 1: System Overview

II. LITERATURE SURVEY

1. Joon Park, Ling Xu, Vishnu Sridhar, Mike Chi, Gert Cauwenberghs [1] has proposed drowsiness detectors using EEG technology. The large number of standard EEG channels requires

extensive wiring, while the conventional wet electrodes cause discomfort in long-term monitoring. They propose drowsiness detection technology suitable for detecting drowsiness in a variety of environments. Their design incorporates pronged dry-AgCl electrodes in a headband harness, which eliminates the discomfort of gel electrodes while obtaining strong signals from hair covered areas of the scalp. The electrodes send signals to a wireless base unit which then transfers the signal to a computer where it is analyzed using a unique algorithm. With solely this one-channel system, they obtained strong EEG signals from which alpha, beta and theta waves can be observed. Their one channel wireless EEG system was able to provide simple drowsiness detection. The pronged dry electrodes allowed for contact with scalp through hair without need for uncomfortable gels. While signal processing and analysis were performed on collected data sets, these can be easily programmed onto a microprocessor and run in real time. Additionally, further engineering can reduce the size of the PCB wireless base unit as well as its power consumption.

2. Divya Chandan [2] published on International Journal of Scientific & Engineering Research on Development of drowsiness detection is due to the use/help of machine vision-based concepts. In order to detect fatigue or drowsiness, small camera has been used which points directly towards the driver's face and detects the eye ball movement of the driver. An image here is processed with the help of Viola Jones Algorithm. In the first step, the face is detected and then the eyes are sectioned and are processed to detect drowsiness/ fatigue. With the help of rectangular ( ) function, it measures the length and width of an eye. The position, length and width can be obtained with the help of Vision class. 'Cascade Object Detector' which is an inbuilt object detector in MATLAB is used to detect eye. The obtained image is then cropped using 'imcrop( )' command in MATLAB. Colored image is converted into grey scale image using 'rgb2grey ( )' function. In order to create box, they used 'bbox( )' function. 'immadjust( )' help in adjusting the level of contrast. Accuracy of the project depends on the quality of Web-Camera. The processing time is increased with the 'getsnapshot( )' function in MATLAB. By defining the region of interest for detection is done by using Viola Jones Algorithm in order to reduce computational requirements of the system. Using MATLAB Image processing, sleep detection system can be explained. If the driver is using sunglasses, then the computation doesn't work. If there is the striking light directly on the web-camera then the system doesn't work. It is required to make the speed of vehicle slow or slow down the speed of vehicle in real time drowsiness detection. In order to create continuous monitoring, threshold drowsiness detection should be kept aside. While monitoring the drowsiness continuously, when the level exceeds certain value a signal is generated which directly controls the braking of vehicle.

3. Matthew Sacco, Reuben A. Farigaig [3] published on Researchgate about the presented approach adopts the Viola-Jones classifier to detect the driver's facial features. The correlation coefficient template matching method is then applied to derive the state of each feature on a frame by frame basis. A Support Vector Machine (SVM) is finally integrated within the system to classify the facial appearance as either fatigued or otherwise. Using this simple and cheap implementation, the overall system achieved an accuracy of 95.2%, outperforming other developed systems employing expensive hardware to reach the same objective. Support Vector Machines (SVMs) are very often used for the classification of data in a wide variety of machine learning applications Support Vector Machines (SVMs) are very often used for the classification of data in a wide variety of machine learning application. A number of techniques were used in the development process, including histogram equalization and median filtering for image pre-processing. The Viola-Jones object detection framework was then used to detect the face, eyes and mouth in successive frames, together with correlation

coefficient template matching to determine feature states. Support Vector Machine classification based on a combination of three fatigue features was then used to detect the overall fatigue level of the driver being captured by the camera in real-time at 15 frames per second with a 640×480 resolution. They used SVM (support vector machine) to classify the components in the input video. While cropping the region of interest components in the video is not accurate. Sometimes it will show regions wrong. To sense the eyes first they have to create boundary boxes for that and a classification algorithm. The algorithm of SVM will not support.

4. Deepu Kurian, Johnson Joseph P. L., Krishnaja Radhakrishnan, Arun A. Balakrishnan[5] published on Researchgate about this study presents an innovative approach to detect drowsiness by using Photoplethysmography signals which is easily acquirable with non-invasive techniques. Drowsiness detection based on biological signals is being employed in precautionary personal safety. Autonomous Nervous System (ANS) activity can be measured non-invasively from the Pulse Rate Variability (PRV) signal obtained from photo plethysmography signal (PPG) that comprises alterations during, relaxation, extreme fatigue and drowsiness episodes. Their hypothesis is that these variations manifest on PRV. They develop an on-line detector of drowsiness based on PRV analysis. The databases have been collected with the aid of an external observer who decides upon each minute of the recordings as drowsy or awake, and constitutes their data base. A novel method for detecting drowsiness by making use of easily obtainable PPG signal is proposed. This signals were very much affected by motion artifacts, and wavelet based methods are used for denoising. The peaks are detected with 100% accuracy. Even though there is ambiguity in deciding the point of drowsiness a drowsiness period can be easily identified. The major application of this algorithm will be in workers safety gadgets like a watch or glove which can detect the sleepy worker for overnight working shifts. This can be also employed for drowsy driver detection to prevent accidents on road. In future PPG technique can also be used as a tool for detecting sleep and sleep stages for various medical applications. Autonomic Nervous System (ANS) activity presents variations during relaxation, extreme fatigue and drowsiness episodes. Wakefulness states are characterized with an increase of sympathetic activity or a decrease of parasympathetic activity, while extreme relaxation states are characterized with an increase of parasympathetic activity and a decrease of sympathetic activity. The ANS activity can be measured non-invasively from the Pulse Rate Variability (PRV) signal obtained from photoplethysmography signal (PPG). Photo plethysmography (PPG) is a non-invasive technique that detects changes in peripheral blood circulation. Even though different measuring metrics perform various waveform analysis, PPG signals make use of the information obtained from the peak and valley.

III. COMPONENTS USED

A. Raspberry pi 3

RPI is a credit-card sized computer (dimension-85 x 56 x17mm). A monitor or TV has to be connected with it externally to visualize its operating system and it operates on Linux environment. Its OS is commonly known as Raspbian Stretch, we can use a keyboard and a mouse to provide input to it. An external memory has to be used to load its operating system. We can program it with several languages. Its components include the following:

- 700 MHz processor.
- 512 MB RAM.
- USB ports for external devices.
- Micro SD card slots.
- Ethernet port.
- HDMI port.
- 40 GPIO pins.
- Camera interface.
- Display interface.
- Power supply port.

Fig 2: Raspberry Pi 3

B. Night vision camera

A daylight camera is a good for areas that have a constant source of light. However, in order to accommodate the conditions of poor light conditions, the night vision cameras are used. An infrared LED ring is mounted around the outer lens for illumination under dark environment. The camera designed works on the principle of active illumination. Active illumination involves conversion of ambient light photons into electrons which are then amplified by an electrochemical process and then converted back into visible light, due to which the scene, which appears dark to a human observer now appears as a monochrome image.

Fig 3: Night Vision Camera

C. Buzzer

A passive buzzer emits a tone when a voltage is applied across it. It also requires a specific signal to generate a variety of tones. A buzzer can be connected to RPI just like an LED, but as they are a little more robust, you won't need a resistor to protect them. There is an audio jack provided in RPI from which audio input and output can be obtained.

D. Software

The software needed for implementing and applying image processing is OpenCV. OpenCV (Open Source Computer Vision) is software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. The library has more than 2500 optimized algorithms, which includes a comprehensive set of both classic and state-of-the-art computer vision algorithms. These algorithms can be used to detect and recognize faces, identify objects, classify human actions in videos, track camera movements, track moving objects, extract 3D models of objects, produce 3D point clouds from stereo cameras, stitch images together to produce a high resolution image of an entire scene, find similar images from an image database, remove red eyes from images taken using flash, follow eye movements, recognize scenery and establish markers to overlay it with augmented reality, etc. There are certain packages used by OpenCV in image processing, commonly known as Dependencies. There are many dependencies used for image processing in OpenCV.

IV. BLOCK DIAGRAM

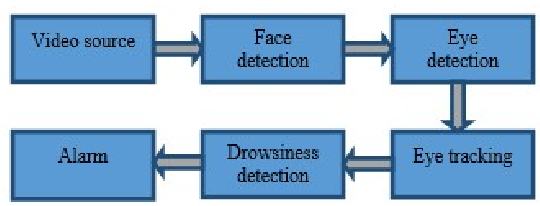

Fig 4: Block Diagram

A. Video source

Night vision camera has the capacity to find images in dull light (night). Night vision technologies are divided into three main categories:

- Image intensification
- Active illumination
- Thermal imaging

The image intensifier is a vacuum-tube based gadget that imperceptible light from a picture to unmistakable light with the goal that an item oblivious can be seen by a camera or the exposed eye. At the point when light strikes a charged photocathode plate, electrons are produced through a vacuum tube that strike the smaller scale station plate that reason the picture screen to enlighten with a photo in an indistinguishable example from the light that strikes the photocathode, this is much similar to a CRT TV, however rather than shading weapons the photocathode does the transmitting. The strengthened picture is, normally, seen on a phosphor screen that makes a monochrome, video-like picture, on the client's eyepieces. Active illumination involves conversion of ambient light photons into electrons which are then amplified by an electrochemical process and then converted back into visible light, due to which the scene, which appears dark to a human observer now appears as a monochrome image. The monochrome image is then made to appear on the screen by Thermal Imaging process. Heat signatures are impregnated on the plate and are converted into human understandable images.

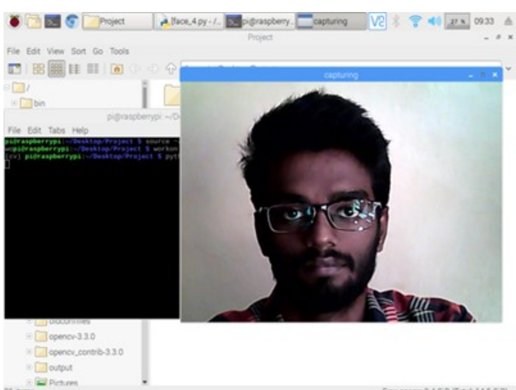

Fig 5: Input from Night Vision Camera - Day time

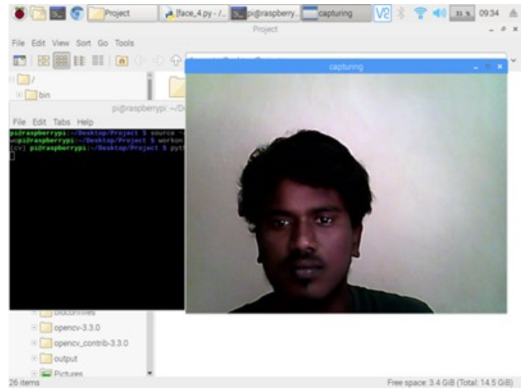

Fig 5a: Input from Night Vision Camera- Night time

B. Face detection

Face detection is a technique that identifies or locates human faces in digital images. Face is a type of object. So, consider detection of face as a particular case of object detection. In this type of class detection, we try to know where the objects in the interest image are located and what is their size which may belongs to a particular class. The work of algorithm that is made for face detection is mostly concentrated on finding the front side of the face. For our case it may be face in the tilted position or any other portion of the faces and also it finds the possibility of multiple faces. The amount of light may also affect. Also the position of the input may vary the output. Many calculations actualize the face-detection assignment as a two way pattern-differentiation task. It means the contextual features present in the interest image is repeatedly change into features and this results in preparing the respective classifier on the reference faces which decides if the specified area is a face or any other objects. If we obtain a positive response for the detecting a face then the process goes for next stage continuation otherwise the algorithm is designed in such manner to go for capturing of image till any hint of face is found. The main algorithm used for this process is Viola Jones algorithm. For getting particular output the utilization of cascade part of OpenCV is made. Cascade file of OpenCV contains 24 stages and has got 2913 weak classifiers. The classifier used for face detection is Haar Cascade. Haar are digital image features used in object recognition. They owe their name to their intuitive similarity with Haar wavelets and were used in the first real-time face detector. The Haar Cascade wavelets are predefined in an .xml file.

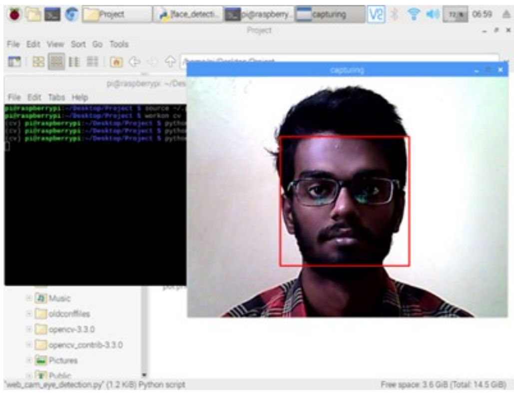

Fig 6: Face Detection Sample 1 - Day time

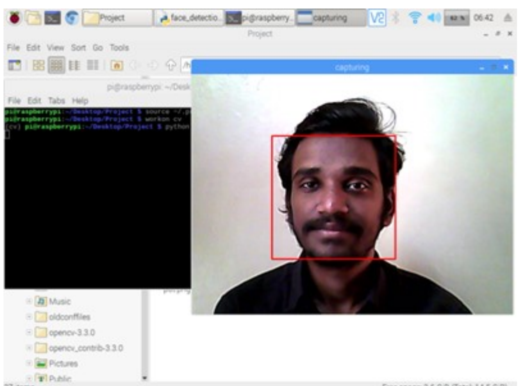

Fig 6a: Face Detection Sample 2 - Night time

C. Eye detection

After successful detection of face eye needs to be detected for further processing. In our method eye is the decision parameter for finding the state of driver. In this case it performs the detection of eye in the specified region with the use of feature detection.Generally, Eigen approach is used for this process. It is a time taking process. Eye detection is divided into two categories:

1. Eye contour detection
2. Eye position detection

Basically, eyes are detected based on the assumption that they are darker than other part of the face. The Haar features vary with different patterns, sizes and positions; they can only represent the regular rectangular shapes. But for our case of eye detection eye and iris is of round shape. Hence eyes can be represented by learning discriminate features to characterize eye patterns. So an approach towards probabilistic classifier to separate eyes and non-eyes are much better option for better accuracy and for robustness.

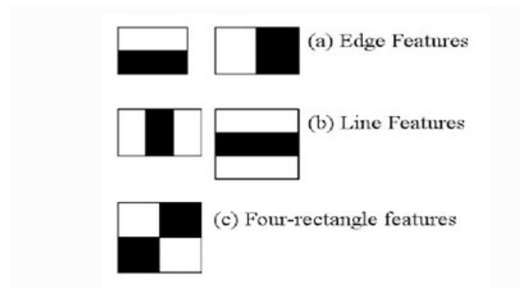

Fig 7: Haar like Feature

These Haar Features are like windows and are placed upon images to compute a single feature. The feature is essentially a single value obtained by subtracting the sum of the pixels under the white region and that under the black. The process can be easily visualized in the example below.

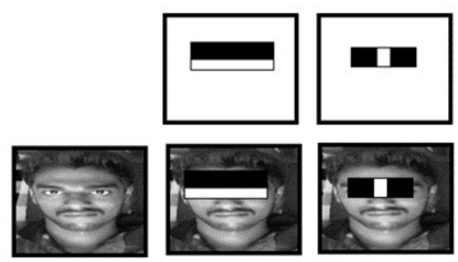

Fig 8: Haar Cascade Implementation

We are only extracting two features; hence we have only two windows here. The first feature relies on the point that the eye region is darker than the adjacent cheeks and nose region. The second feature focuses on the fact that eyes are kind of darker as compared to the bridge of the nose. Thus, when the feature window moves over the eyes, it will calculate a single value. This value will then be compared to some threshold and if it passes that it will conclude that there is an edge here or some positive feature.

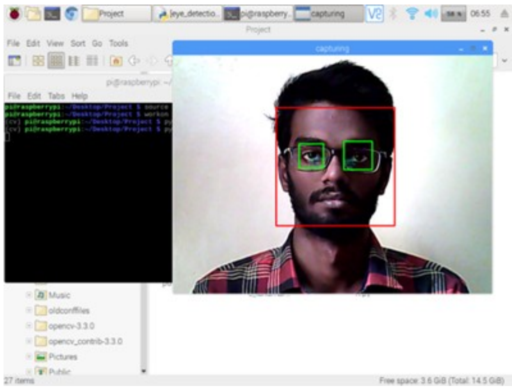

Fig 9: Eye Detection Sample 1 - Day time

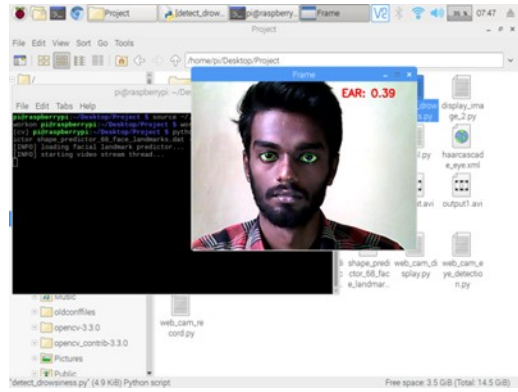

Fig 10: Eye Tracking Sample 1 - Day time

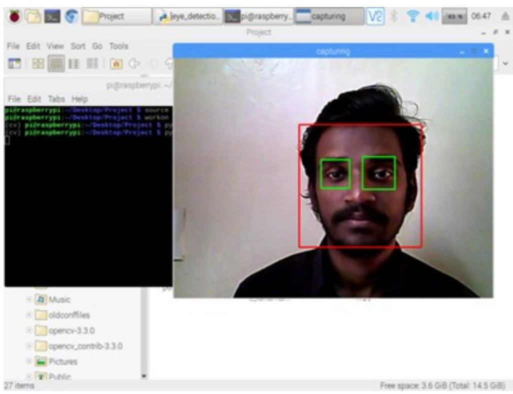

Fig 9a: Eye Detection Sample 2 - Night time

D. Eye tracking

After the successful detection of eye, the eye should be continuously monitored i.e. tracking. Eye tracking is the process of measuring either the point of gaze (where one is looking) or the motion of an eye relative to the head. The eye position is extracted from video images. Using eye features, different measures can be calculated with percentage of eyelid closure, maximum closure duration, blink frequency, average opening level of the eyes, opening velocity of the eyes, and closing velocity of the eye and an effective driver drowsiness detection model can be created which can work under varying unconstraint and luminance conditions.

E. Drowsiness detection

The state of the eyes (whether it is open or closed) is determined by time of closure of eyelid. When the eyes are closed, the distance between the y – coordinates of the intensity changes is larger if compared to when the eyes are open. The amount of time of closure tells the drowsiness. Because the blink rates differ from the fatigue state. The time taken for closing of eyelid for blinking is very less when compared to sleeping or in drowsy state. When there are 5 consecutive frames find the eye closed, then the alarm is activated, and a driver is alerted to wake up.

F. Alarm

Based on the values provided, the alarm will do the rest. A threshold value will be set as drowsy state. If the time taken for closing the eyes is beyond the threshold value means the driver is in drowsy state. The alarm turns on if the obtained value is less than threshold value. Then the driver will be able to wake up after external stimuli. The accidents can be avoided before it happens. Many lives can be saved by a single alarm.

Fig 11: Alarm On

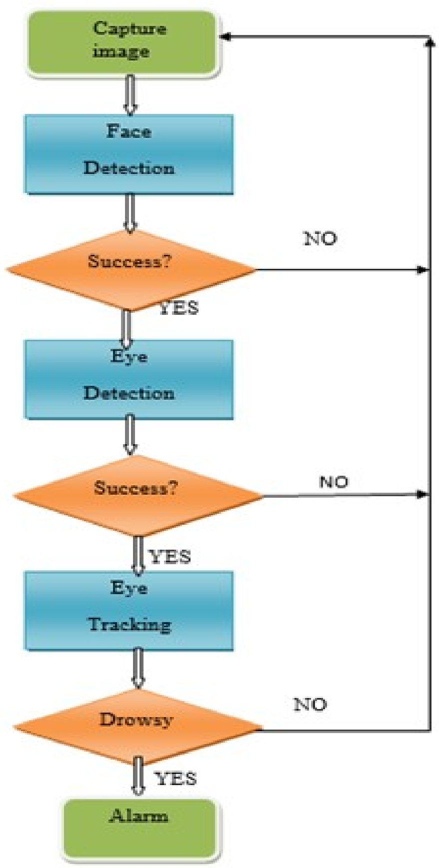

Fig 12: Flow Chart

V. DESCRIPTION

The entire system is implemented using Raspberry Pi 3.The algorithm is coded on Open CV platform in Linux environment. This system is a real time system which captures video continuously. Input is live fed from a camera in that supports night vision as well. The video source fed the input to RPI by frames. The frame rate is set and each frame is passed one after another continuously. The entire system for detecting drowsiness is implemented using these Haar Classifiers. The core basis for Haar Classifiers the Haar-like features. These features use the change in contrast values between adjacent rectangular groups of pixels instead of the intensity values of a pixel. The Cascade Classifier used for face detection is 'haarcascade_frontalface_default.xml'. This is an .xml file where all the features for faces are predefined. The input frame is converted into gray image and then the matrix form of the gray image is compared with the feature set of 'haarcascade_frontalface_default.xml' file. If there is any positive feature then the rectangular box is drawn for the face. After the successful detection of face the ROI should be created for eye because eye is mainly used to detect the state of the driver. The Cascade Classifier used for eye detection is 'haarcascade_eye.xml'. As told above the eye cascade classifiers contain predefined libraries for the features of eye. The detected face is compared with the eye cascade classifier and marks the eyes in rectangular form. We need to track eye to find the state. It is not possible to track the rectangular box since eye is in oval shape. So we need to extract the eye in its shape. So the detected face and eye are converted into facial landmarks using dlib library. The Euclidean distance is found out between the two eyes and the shape of the eye is extracted. For detection of drowsiness the time taken for closing value of eye is considered. The eye shape that is extracted is continuously monitored and is compared with the threshold value. So when the closure of eye exceeds threshold value then the driver is identified to be sleepy. The moment when the value exceeds the threshold value a signal is sent to buzzer which alerts the driver and avoid accidents before it happens and will save many lives.

VI. RESULTS

Prototype of drowsiness detection system was designed using Raspberry Pi 3 hardware and coded in python language. It was tested with different subjects and different condition like straight and tilted head and photo copy of the output was shown below. The result is obtained by taking several positions of head like straight, tilted (Right), tilted (Left) etc. We can observe that when the eyes are open circles appears around eye indicating open state of eye. When eyes are closed circle disappears indicating closed state of eye. In both the cases face detection occurs which is shown by a pink colored circle. In the side window the output parallels with one and zero according to the fact that eye is opened or closed respectively.

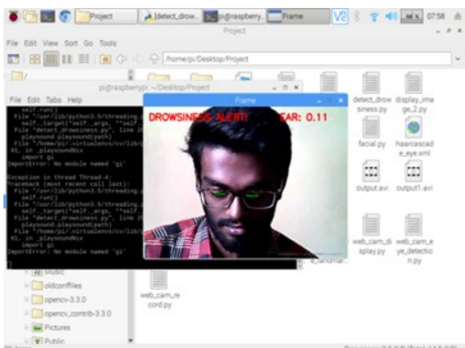

Fig 13: Drowsiness Alert Sample 1 - Day time

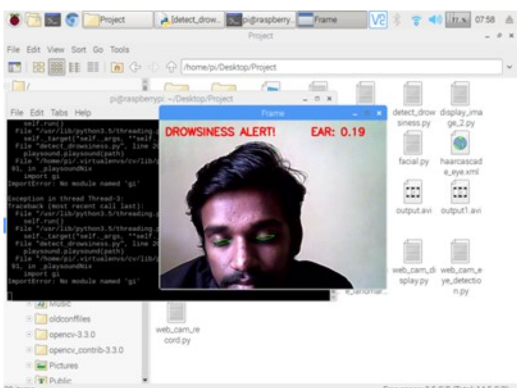

Fig 13a: Drowsiness Alert Sample 2 - Day time

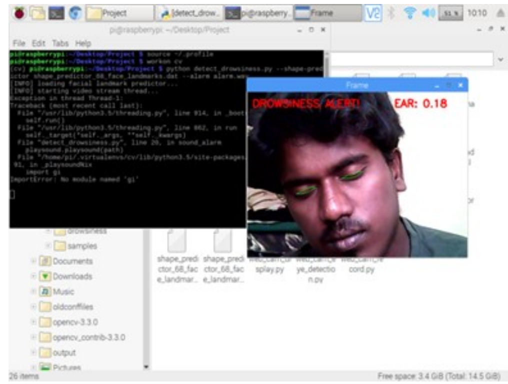

Fig 13b: Drowsiness Alert- Night time

VII. CONCLUSION

Implementation of drowsiness detection with Raspberry Pi 3 was done successfully. The face is recorded lively with camera. Captured video was divided into frames and each frame were analyzed. Successful detection of face followed by detection of eye. If closure of eye for successive frames were detected, then it is classified as drowsy condition else it is considered as normal blink and the loop of capturing image and analyzing the state of driver is carried out again and again. In this implementation during the drowsy state the eye is detected by circle to track continuously.

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