The Vehicle Speed Control & Alert System based on the Drowsiness of the Driver

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Abstract

Safety is the first priority while travelling or driving. One mistake of the driver can lead to severe physical injuries, deaths and significant economic losses. According to the National Highway Traffic Safety Association more than 4,000 people died due to drowsy driving from 2013 to 2017 and this number is increasing yearly. So it is necessary to come up with an efficient technique to detect drowsiness as soon as the driver feels sleepy, thereby it could prevent a large number of accidents. In this paper the authors propose a visual based hybrid model for drowsiness detection and based on the threshold value of drowsiness, an alert is generated to make driver alert and further controls the speed of the vehicle if the driver is detected as drowsy.

Keywords: *Drowsiness Detection, micro sleep, Eye Aspect Ratio(EAR), CNN, OpenCV.*

1. Introduction

In today's world the increasing numbers of road accidents are resulting from driver's in-alertness i.e. from sleep deprivation or sleep disorders. The Drowsy Driver Warning System can possibly prevent or reduce the accident which may happen due to the in-alertness or drowsiness of the driver. There are different techniques in detecting drowsiness. These techniques are the Image Processing and artificial neural network based techniques which are non-intrusive techniques or computer vision based techniques, Electroencephalograph based techniques which are intrusive techniques, and Vocal-based techniques, Vehicular-based techniques. Although intrusive techniques yield better detection accuracy, these are not accepted widely because of less practicality and the need to attach the measuring equipment must to the driver. Thus, computer vision based techniques are particularly effective, because the drowsiness can be detected by observing the facial features such as the position of the head, eye openness and eyelid movement. In this paper the authors propose a visual based hybrid model for the detection of the drowsiness which is based on the extracted visual features by continuously monitoring the driver using the camera.

2. Related Work

Significant studies have been carried out on the drowsiness detection and fatigue monitoring by various researchers. Based on various visual cues and observed facial features, several computer vision based schemes have been developed for non-intrusive and real-time detection of driver drowsiness [3]. A person's fatigue and vigilance levels can be reflected by observing the movement of eyes, head and facial expression patterns. Some of the typical features of high fatigue and drowsiness of a person are head movement, eye closure, eyelid movement, eyebrow shape, jaw drop etc. Usually a remote camera is being fixed on dashboard of the vehicle to monitor various visual cues. These cues together with extracted facial features analyses the driver's physical condition and classify his/her current state of drowsiness [4].

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The drowsiness detection models developed in the past are generally based on eye blink rate, eye closure, eye brow shape, yawning and other hand engineered facial features. Kartik Dwivedi et al. [1] proposed a novel algorithm for Driver Drowsiness Detection based on analogic cellular neural network (CNN). Their work uses features learnt from CNN to find various latent facial features and non-linear feature interactions. To classify the driver as drowsy or not-drowsy a softmax layer is used. Their work starts with the detection of heads in colour images using variations in colour and structure of the human face and that of the background. By normalizing the reference point's distance and position, all faces should transform into same size and position. For normalization, eyes serve as reference points. For grayscale image the CNN algorithms detects eyes based on characteristic features of the eyes and eye sockets.

The main disadvantage of CNNs is they perform poorly when provided with fewer amounts of data. CNNs have millions of parameters, with small dataset, would result in an over-fitting problem. So CNNs need huge amount of data for better performance. CNNs also require high computational power for training.

Rajneesh et al. [2] proposed an algorithm for Drivers Drowsiness Detection based on live monitoring of EAR (Eye aspect Ratio). Their work decomposes HD live video into continuous frames and detects facial landmarks using Dlib functions of pre trained Neural Network. HAAR Cascade algorithm is used to train Dlib functions. EAR is calculated by computing the Euclidean distance between measured eye coordinates. By monitoring EAR against a threshold value Blink and micro sleep are detected. A graph is plotted with EAR on the y-axi, time on x-axis and based on width of the dip in the graph Blinks and drowsiness is differentiated. The main focus is on blinks detection throughout the video sequence by continuously monitoring the eyes of the driver. An IR camera will be used for capturing live video of driver eyes in all light conditions and frames are extracted from the video for the purpose of image processing.

The main advantage of EAR model based drowsiness detection is, this model doesn't require large training data as it is geometrical model that mainly depends on the coordinates of the face and the eye. As it is under user control to allow number of frames that is processed per second which makes it more flexible and manageable, at the same time it doesn't require high computation power like Graphic processing units for training and implementation of model.

EAR model can run in basic CPU with minimum configuration which make it most compatible model of usage. One of the main drawback that is observed in EAR method is, there are some false alarm found when relative position of camera changes with respect to eye position of the driver as model mainly depends on the coordinates of the eye lids even if the person stare at angle less than -300 with respect to x-axis(horizontal), it look like that the person is closing their eyes to the camera as it is placed in parallel to position of the eye.

In the current work, the authors proposed a model that overcomes the observed disadvantage in the EAR model i.e. change of relative position of the camera with respect to the eye position of the driver by combining both the EAR based model and CNN model, that results in effective hybrid model.

3. Methodology

In this paper the authors have proposed a hybrid model that contains both EAR model and CNN model for the drowsiness detection. The main intention of using this hybrid model is to overcome some of the disadvantages of both the model and the same time considering the hardware requirement of the system.

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3.1 Design of the Proposed Hybrid Model

Design of the proposed hybrid model and the flow of steps in the proposed solution is shown in fig.1.Authors mainly focus on both eye blink in EAR method and facial expression which is detected by the features extracted by CNN model. The Hybrid Model starts with capturing video by pi camera which is configured with a raspberry pi. Initially frames are acquired from the video, and for each frame facial landmark detection is done which represent the eye boundaries using 2-D coordinates as shown in Fig.2. By extracting the geometrical coordinates of the eye, EAR value is computed as:

EAR (Eye aspect Ratio) = (|p2-p6| + |p3-p5|) / 2|p1-p4|

As EAR for blink and microsleep is different, this EAR value is continuously monitored for each frame to differentiate between these two situations. Microsleep period is estimated between the blink based on the width of the dip in graph which is plotted with EAR value on y-axis and time on x-axis. Microsleep period is detected by estimating the time between blinks and appropriate alert is made to make driver alert. After getting EAR value of the each frame if the value is less than threshold (taken as 0.2)[2] for 3 seconds then driver is said to be in drowsy state, at this point of time when EAR model detects that the person is drowsy then, we observe the output of the CNN model. As the same frames are given as input to CNN model which extracts only facial expression features to detect the state of drowsiness of driver, if CNN model detects that the person is drowsy in about 90% of the frames then the hybrid model labels the final state of the driver as drowsy otherwise if CNN model detects it as not drowsy in same percentage of frames then final state is labelled as not drowsy the hybrid model. On the other hand if the EAR model itself detects that person is not in drowsy state then labels the hybrid model the gives final label as driver is not in drowsy state.

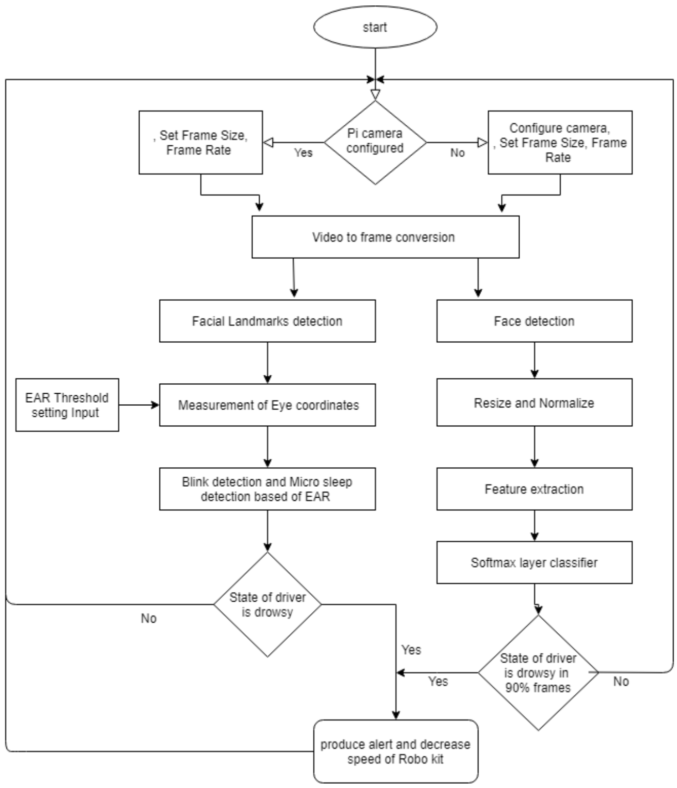

Fig.1. Design of the proposed hybrid model

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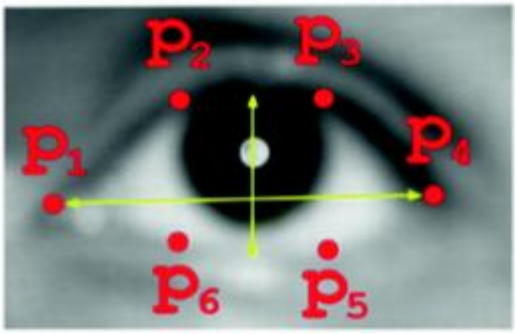

Fig.2. Eye represented by 2-D coordinates

The authors used a robokit shown in the Fig.3, which is an IOT kit(equipped with 4 DC motors) to demonstrate speed control based on the drowsiness of driver. Major components that required to build robokit includes Wide Angle Raspberry Pi Camera, DC motors, DC-DC 5V/2A Voltage Converter, H Bridge which is an electronic circuit that switches the polarity of a voltage applied to a load. All other accessories like Wires and screws to build the Car.

Robokit receives command from the raspberry pi whenever the person is drowsy and based on the period of the micro sleep, speed of the DC motor is mapped to safety level and if the person continuous to persists in the same drowsy state then gradually the speed of the robokit is brought to zero.

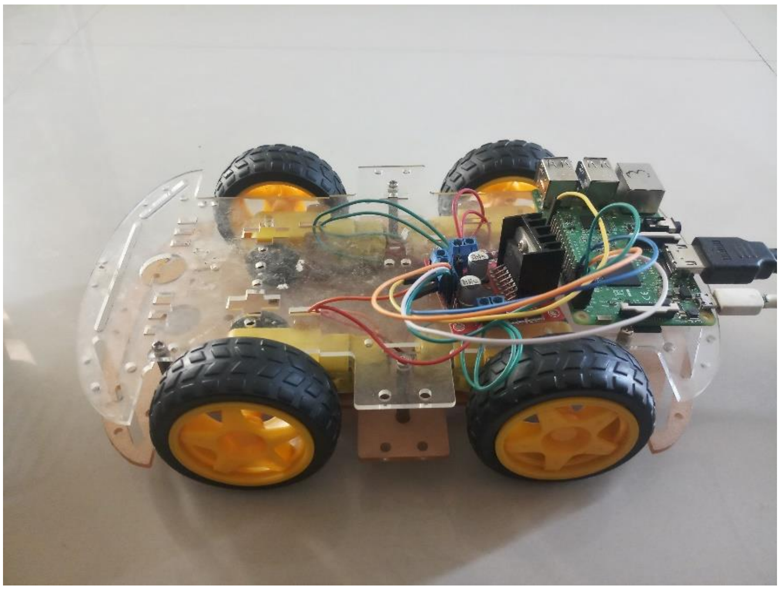

Fig.3. RoboKit

3.2 Tools and Libraries

Authors have used various libraries for building the model which include, OpenCV - a huge open-source library for machine learning, computer vision and image processing, Imutils - a series of functions to perform basic image processing operations such as resizing, translation, rotation, skeletonization, Dlib - general purpose cross platform software library written in C++ and both Python 2.7 and Python 3. The authors have used PWM technique to control the speed of the robokit, if the driver is detected as the drowsy. PWM is a technique for generating a

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signal that has characteristics of analogue signal using digital equipment and digital voltage levels (on or off e.g. 3.3v or 0.0v) and varying the time that the voltage level is high or on and the time the voltage level is low or off.

4. Results Analysis

The entire model testing was performed in raspberry pi with 16 GB (Main storage + Secondary storage) along with latest (release date 2020-02-05) Raspbian buster lite software. The authors evaluated the model under different circumstances include both normal and exceptional conditions.

Fig. 4. Normal state detected by hybrid model

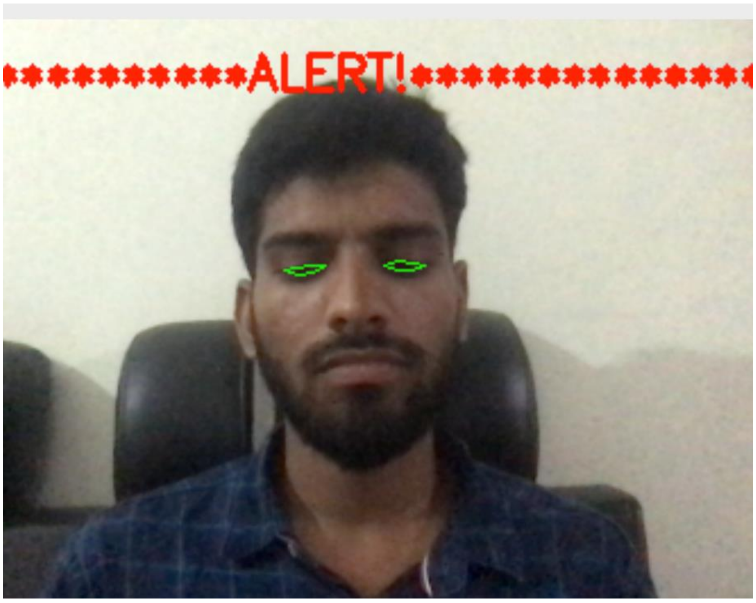

Fig. 5. Drowsy state detected by hybrid model

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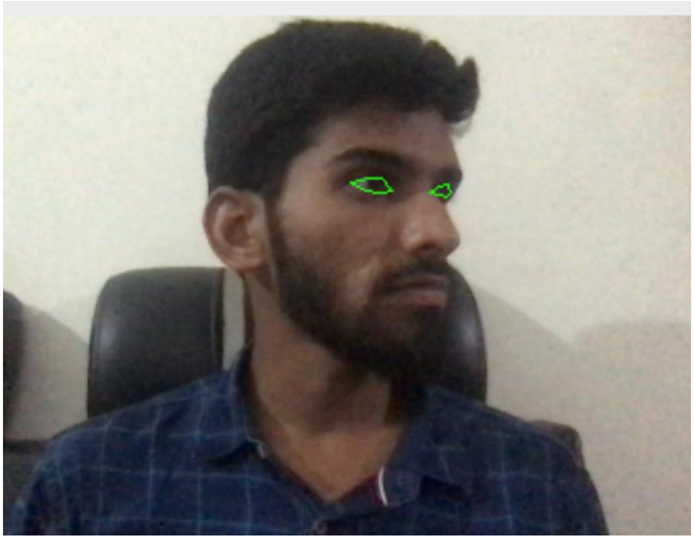

Fig. 6. Eye coordinates detected by hybrid model with left view

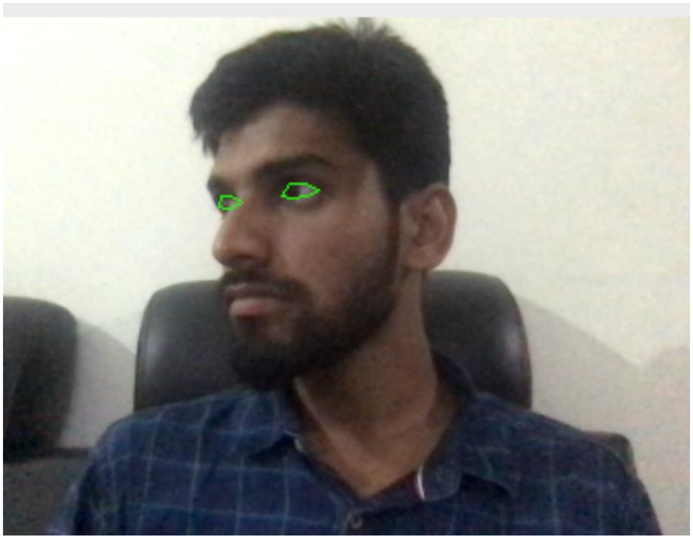

Fig. 7. Eye coordinates detected by hybrid model with a right view

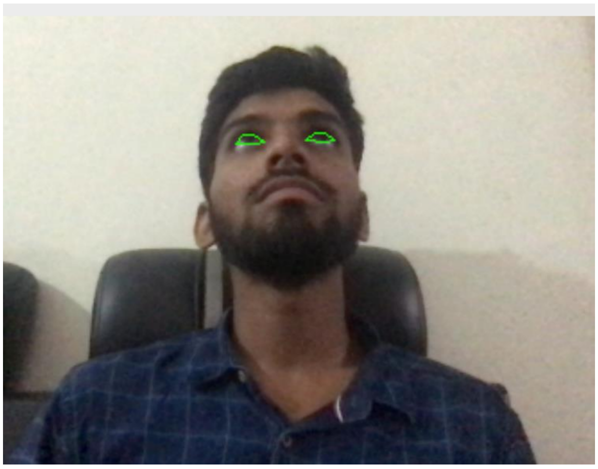

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Fig. 8. Eye coordinates detected by hybrid model with upward view

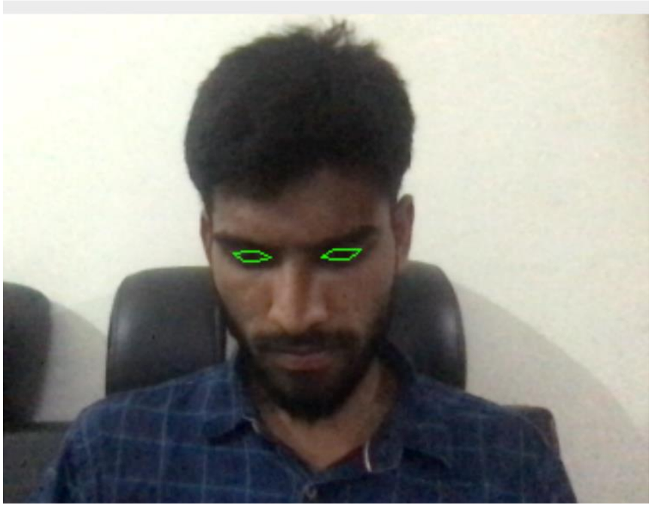

Fig. 9. Eye coordinates detected by hybrid model with a downward view

The proposed hybrid model is also tested on a female under different circumstances.

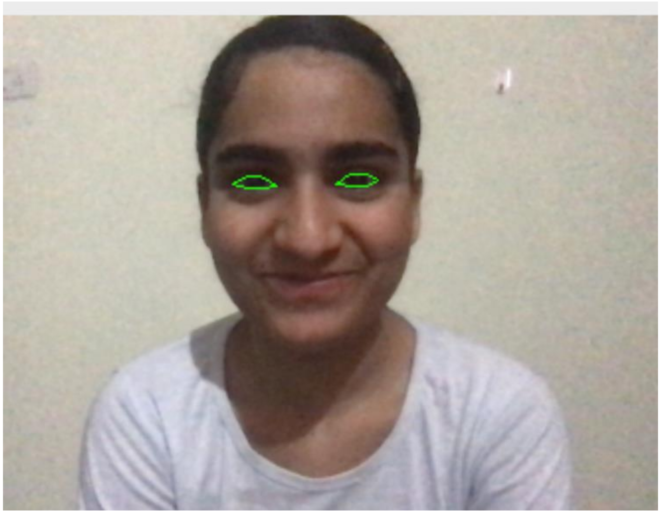

Fig. 10. Detection of Normal state by hybrid model on female face

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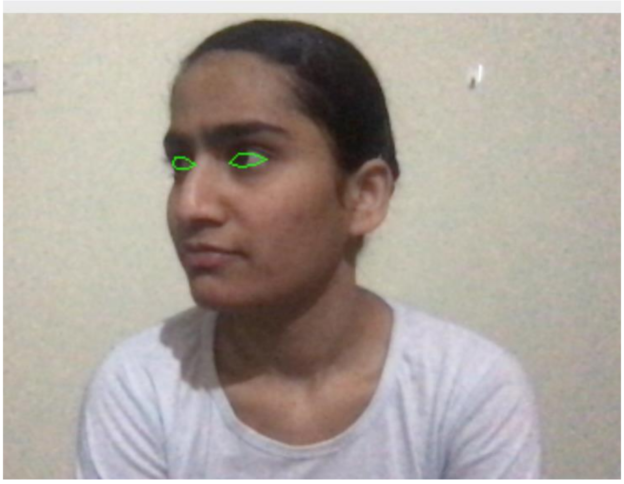

Fig. 11. Eye coordinates detected by hybrid model with a right view on female face

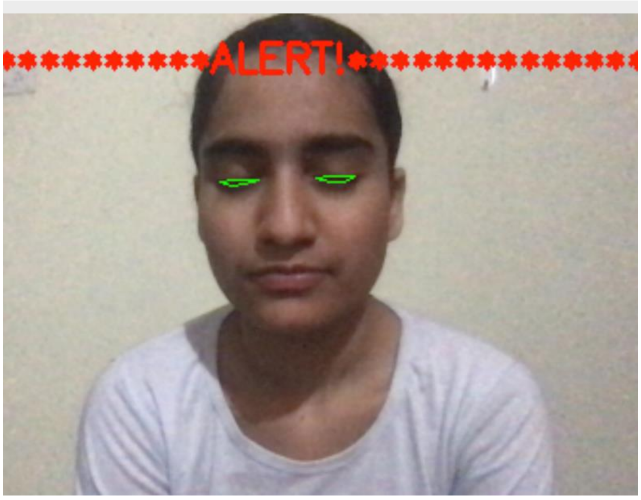

Fig. 12 Drowsy state detected by hybrid model on female face

The authors have experimented the proposed hybrid model on 4 males and 3 females for a number of microsleep observed in each person and results are compared with the basic EAR Model

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Table 1. Comparison of accuracy between the EAR model and Hybrid model under normal condition.

EAR model					Hybrid model			
Gender	Total Experimented microsleeps	True detection	False detection	% Accuracy	Total Experimented microsleeps	True detection	False detection	%Accuracy
Male-1	51	49	2	96.07	51	48	3	94.11
Male-2	50	47	3	94	50	49	1	98
Male-3	52	51	1	98.1	52	52	0	100
Male-4	60	55	5	91.66	60	55	5	91.66
Female-1	55	53	2	96.36	55	55	0	100
Female-2	53	50	3	94.33	53	49	4	92.45
Female-3	54	54	0	100	54	52	2	96.29
Total	375	359	16	95.78	375	360	15	95.98

The table 1 shows the experiments excluding exceptional case in EAR model (taking threshold value as 0.2) i.e, if the person stare at an angle less than -300 with respect to x-axis(position of the camera is horizontal), it looks like that the person is closing their eyes to the camera position. This experiment is separately done considering both the model and experimented on the same people as in the above experiment. The table 2 shows the experimental results under exceptional cases in both the basic EAR model and the proposed Hybrid model. From the experimental results it is very clear that the proposed hybrid model is very efficient in drowsiness detection even in exceptional cases.

Table 2 Comparison of accuracy between EAR model and Hybrid model under exceptional condition.

EAR model					Hybrid model			
Gender	Total Experimented microsleeps	True detection	False detection	% Accuracy	Total Experimented microsleeps	True detection	False detection	%Accuracy
Male-1	22	10	12	45.45	22	18	4	81.81
Male-2	21	11	10	52.38	21	16	5	76.19
Male-3	24	13	11	54.16	24	18	6	75
Male-4	23	10	13	43.47	23	17	6	73.91
Female-1	19	9	10	47.36	19	11	8	57.89
Female-2	25	11	14	44	25	16	9	64
Female-3	18	9	9	50	18	10	8	55
Total	152	73	79	48.02	152	106	46	69.73

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5. Conclusion

In this work, the authors have demonstrated a vision based hybrid model to detect drowsiness of the driver using and a raspberry pi configured with Pi camera and a robokit is used for the demonstration speed control of the experiment. It starts with monitoring the driver where each and every frame of the live video is observed to label whether the driver is drowsy or not. The model developed by the authors is a hybrid model which is the combination of both the EAR model and CNN model. It is evaluated under different circumstances along with the exceptional cases to improve the efficiency.

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