Study and Determination of Eye Aspect Ratio using Data Mining

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Abstract—**This research paper studies the landmarks of the eye and analyses the value for Eye Aspect Ratio, which is the ratio of the average of Euclidean distance between pairs of landmarks in vertical position and the Euclidean distance between the horizontal landmarks of the eyes. This ratio has a value lying in a particular range. This ratio is of crucial importance in the blink detection using computer vision. Also this value will be used for other computer vision related tasks like behavior and facial expression detection. Our aim is to find the range of EAR value using which the results of detection will have optimal error in accuracy. An exploratory data analysis on data collected from real world and for various scenarios is conducted. A supervised machine learning model will also be trained and deployed for frame to frame prediction. Their combined result is demonstrated with visualization.**

Index Terms- Eye Aspect Ratio, Computer Vision, Advanced Driver Assistance System, Mediapipe, Facial Landmarks, Exploratory Data Analysis, Eye Landmark Detection.

IV. Introduction

Human vision enables humans to see and computer vision enables machines to see the world. Humans have a brain trained throughout their life time to detect any object giving us a head start. In contrast, machines have to be trained rather in very limited time. Which is why we continuously research and develop new methods, faster and efficient than before, to solve this modern problem. Unlike humans, computers get the raw video as an input, from which it analyses each frame and it's pixel data to understand the structure of this image.

Existing methods are either active or passive. Active methods are reliable but use special hardware, often expensive and intrusive, e.g. infrared cameras and illuminators [2], wearable devices, glasses with a special close-up cameras observing the eyes [10]. While the passive systems rely on a standard remote camera only.

There are some difficulties in eye detection, tracking and eye blink estimation: Eye patterns have large variation in appearance due to various factors, such as size, pose, rotation, the closed and open eyes, illumination conditions, the reflection of glasses and the occlusion by hairs etc. Given the complexity of the task, most approaches in the past have made a number of contributions.

Due to the high need for robust and efficient computer vision solutions which can operate and provide real time results, there is always a need for new algorithms and techniques apart from the present. Such needs include use in Advanced Driver Assistance Systems [3], in systems that warn a computer user staring at the screen without blinking for a long time to prevent the dry eye and the computer vision syndromes [4, 8, 9], in human computer interfaces that ease communication for disabled people [5], or for anti-spoofing protection in face recognition systems [6].

This research study was done while working on drowsiness detection system for an ADAS [12]. After determination of the range for which EAR deviates, the results were used in the drowsiness detection system to calculate accuracy. The model after resulting in acceptable accuracy was used on real dash cam video footage to determine whether the model detects the drowsy driver or not.

II. Eye Aspect Ratio

To build our blink detector, we'll be computing a metric called the eye aspect ratio (EAR), introduced by T. Soukupová and J. Čech in their 2016 paper, Real-Time Eye Blink Detection Using Facial Landmarks [1, 13]. The eye aspect ratio is instead a much more elegant solution that involves a very simple calculation based on the ratio of distances between facial landmarks of the eyes. This method for eye blink detection is fast, efficient, and easy to implement.

The blinking of eye is a fast closing and reopening of eyelids. Each individual has a little bit different pattern of blinks. The pattern differs in the speed of closing and opening, degree of squeezing the eye and in blink duration. The eye blink lasts approximately 100-400 ms [7]. We propose to exploit state-of-the-art facial landmark detectors to localize the eyes and eyelid contours. From the landmarks detected in the image, we derive the eye aspect ratio (EAR) that is used as an estimate of the eye opening state. Since the per frame EAR may not necessarily recognize the eye blinks correctly, a classifier that takes a larger temporal window of a frame into account is trained. Description of features for every video frame and the eye landmarks are detected. The eye aspect ratio (EAR) between height and width of the eye is computed.

The calculation initiates when their is availability of frame and landmark data of the image or video. The data is normalized using the below formulae

x = x coordinate * frame width
y = y coordinate * frame height
z = z coordinate

Normalized data is used to calculate the euclidean distances between certain pairs of landmarks which is in this case shown in the below image.

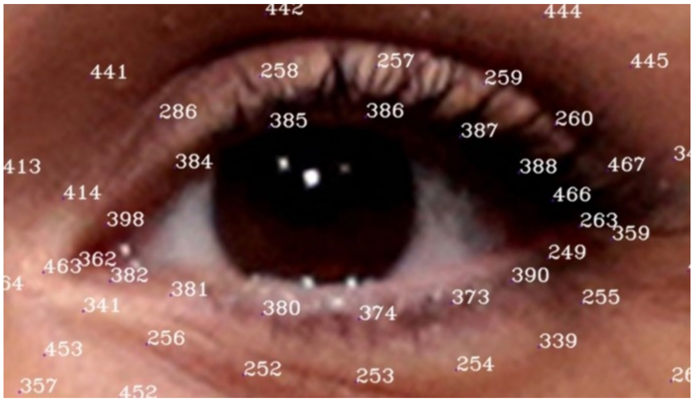

Fig. 1: Eye Landmarks

Formulae to calculate the euclidean distances

$$Euclidian\,Distance=\sqrt{(x_2-x_1)^2+(y_2-y_1{}^2)+(z_2-z_1{}^2)} \qquad ...(1)$$

EAR is the ratio between average of vertical euclidean displacement and the horizontal displacement of eye landmark pairs respectively. The formulae is given below

$$EAR=\frac{|p_2-p_9|+|p_3-p_{10}|+|p_4-p_{11}|}{3|p_1-p_{16}|} \qquad ...(2)$$

Value of EAR [1] is always greater than 0, usually in decimal but constant. Hence we ca propose that there must be a range for EAR for eyes at a particular instance, let's say for an open eye. There is a research paper on the similar topic but lacks accuracy due to inclusion of less landmarks, technological limitations at that time and unavailability of the depth related data of the image, which is possible now using mediapipe's algorithms. Here the landmarks available for each eye are more than 16, although for this paper only 16 are being used. EAR has a range for open eyes and it can be used for blink detection with the help of state of the art algorithms.

III. Methodology Used

We propose an algorithm to detect facial landmarks using state of the art mediapipe and computer vision libraries. An exploratory data analysis was conducted on EAR values that were extracted using the algorithm and then collected to analyze for a preferable range of EAR. Real videos were recorded using the same camera for every subject and subjects were chosen in way to have maximum diversity in the dataset. This diversity is due to the inclusion of people from various ethnicity, gender and people with spectacles.

First the videos were recorded and edited frame to frame for the following four scenarios:

1. Closed eyes without spectacles
2. Closed eyes with spectacles
3. Open eyes without spectacles
4. Open eyes with spectacles

All videos were then run through the algorithm and the coordinates of eye landmarks extracted and saved after normalization. These data were then collected for exploratory data analysis and underlying are the results.

A scatter plot and bar graph were drawn for an approximate range of the EAR value.

Features	Left Eyes	Right Eyes
Count	31218.000000	31218.000000
Mean	0.127787	0.130422
Std	0.023227	0.023295
Min	0.032663	0.028558
25%	0.113178	0.116434
50%	0.126243	0.129286
75%	0.144572	0.147417
Max	0.234871	0.224482

Table 1: Data Features

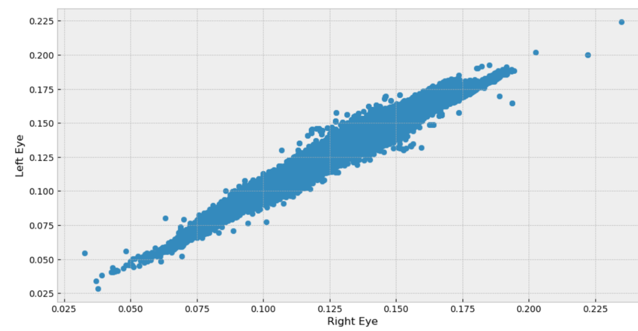

Fig. 2: Scatter plot using EAR values for range estimation

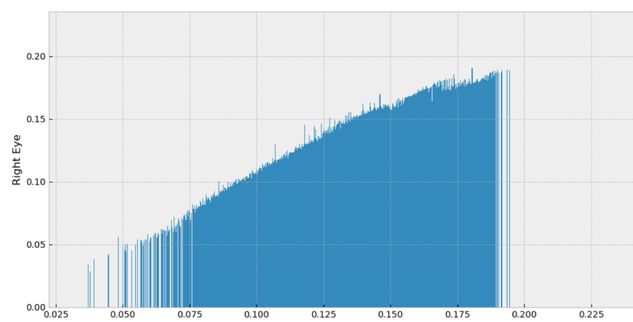

Fig. 3: Bar Graph using EAR values for range estimation

From plots, we can derive an important insight. The value of EAR lies between 0.050 and 0.200 for both eyes with and without spectacles. So EAR below 0.200 could be considered an eye blink. After analysis of data with open eyes, the EAR was found to have a range starting from 0.210 clearly above 0.200.

This study suggests the successful applicability of the range in the algorithms. The result was tested using real time video capturing and also tested on real life dash cam video clips of drowsy drivers before accident.

IV. Result

The range was used in the drowsiness detection algorithm to detect whether the detection's were accurate as expected or not. The below screenshots demonstrate the prediction of the drivers conditions.

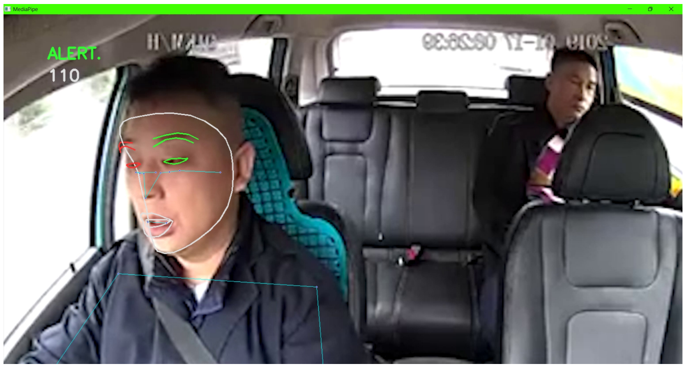

Fig. 4: Algorithm Detecting Alertness in Driver

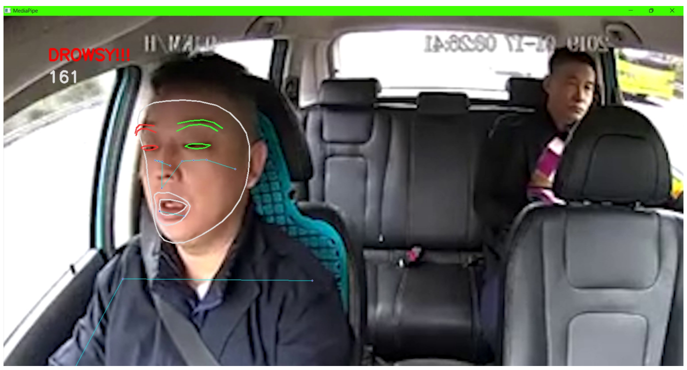

Fig. 5: Drowsy Driver before Accident

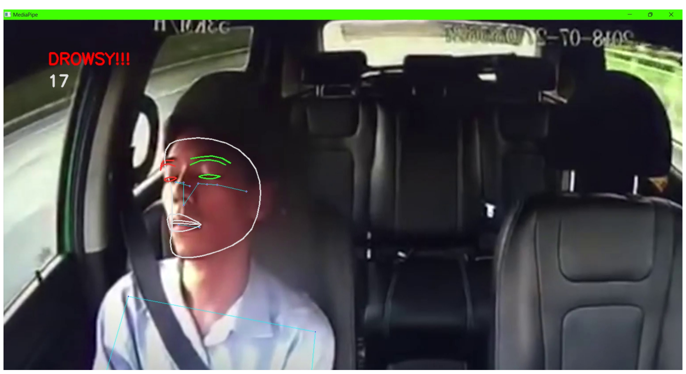

Fig. 6: Sleeping Driver

V. CONCLUSION

This research was done with the sole purpose of determination of EAR range for which a drowsiness detection system works with high accuracy. Although this technique for detection of drowsiness or blinking of eye is very robust, we can always introduce new methodologies. One such method could be the detection of irises and using it to determine the state of eye at a particular instance of time.

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REFERENCES

[1] T. Soukupová and J. Čech. Real-Time Eye Blink Detection using Facial Landmarks, 21st computer vision winter workshop, Luka Čehovin, Rok Mandeljc, Vitomir Štruc(eds.), Rimske Toplice, Slovenia, February 3–5, 2016.

[2] L. M. Bergasa, J. Nuevo, M. A. Sotelo, and M. Vazquez. Real-time system for monitoring driver vigilance. In IEEE Intelligent Vehicles Symposium, 2004.

[3] V. K. Kukkala, J. Tunnell, S. Pasricha and T. Bradley. Advanced Driver-Assistance Systems: A Path Toward Autonomous Vehicles. IEEE Consumer Electronics Magazine, Digital Object Identifier 10.1109/MCE.2018.2828440, 9 August 2018. https://ieeexplore.ieee.org/document/8429957

[4] Z. Yan, L. Hu, H. Chen, and F. Lu. Computer vision syndrome: A widely spreading but largely unknown epidemic among computer users. Computers in Human Behaviour, (24):2026–2042, 2008.

[5] D. Torricelli, M. Goffredo, S. Conforto, and M. Schmid. An adaptive blink detector to initialize and update a view-based remote eye gaze tracking system in a natural scenario. Pattern Recogn. Lett., 30(12):1144–1150, Sept. 2009.

[6] G. Pan, L. Sun, Z. Wu, and S. Lao. Eyeblink based anti-spoofing in face recognition from a generic web camera. In ICCV, 2007.

[7] K. A. Kwon, R. J. Shipley, M. Edirisinghe, D. G. Ezra, G. Rose, S. M. Best, and R. E. Cameron. High-speed camera characterization of voluntary eye blinking kinematics. J R Soc Interface. 2013 Aug 6; 10(85): 20130227.

[8] M. Chau and M. Betke. Real time eye tracking and blink detection with USB cameras. Technical Report 2005-12, Boston University Computer Science, May 2005.

[9] T. Danisman, I. Bilasco, C. Djeraba, and N. Ihaddadene. Drowsy driver detection system using eye blink patterns. In Machine and Web Intelligence (ICMWI), Oct 2010.

[10] Medicton group. The system I4Control. http://www.i4tracking.cz/.

[11] L. Wang, X. Ding, C. Fang, C. Liu, K. Wang. Eye blink detection based on eye contour extraction. Proceedings of SPIE- The International Society for Optical Engineering, February 2009.

[12] https://github.com/MUHAMMED-RIZWAN-P-S/Driver_Drowsiness_Detection_System

[13] https://pyimagesearch.com/2017/04/24/eye-blink-detection-opencv-python-dlib/

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