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Drowsiness Detection for Online Courses

Sanskriti Jain[1], Mili Tyagi[2],Rajat Jain[3] , Kashish Makkar[4] and Dr. Pooja Gupta[5]
[1] Maharaja Agrasen Institute of Technology, Delhi, India
Email: jsanskriti01@gmail.com
[2-5] Maharaja Agrasen Institute of Technology, Delhi, India
milityagi98@gmail.com, rajat06jain47@gmail.com, kashishmakkar99@gmail.com, poojagupta@mait.ac.in

***Abstract*—Online learning has become more centric in people's lives today with COVID-19 acting as a catalyst for the growth of this industry. It is believed that this will bring about an educational revolution in the way knowledge is disseminated and become an integral component of the education system. But one should not forget the challenges it brings along with it. The monotony of staring at our screens for so long crepts in disengagement in the form of drowsiness and results in decrease of attention or vigilance on part of the learners. Therefore, with the power vested in our hands through the capabilities of Machine Learning algorithms, we propose an algorithm to detect drowsiness in an individual measured during the online courses using Eye Aspect Ratio (EAR), Mouth Aspect Ratio (MAR), PERCLOS (Percentage of Eyelid Closure over Pupil). Proposed algorithm produces very good results as detailed in this research. It produces an accuracy of approximately 94% and outperforms various other algorithms on the given dataset. Comparative study has also been done in which we have compared proposed algorithm accuracy to other machine learning algorithms' accuracy.**

***Index Terms*— Online classes, Drowsiness Detection, OpenCV, Dlib, Natural Language Processing, Eye Aspect Ratio, Mouth Aspect Ratio, PERCLOS.**

I. INTRODUCTION

For a long time, learning has been the passageway supporting survival of the fittest. With it comes the dire need for attention as an accomplice. The wheel of time turned, we are now advancing towards the technological era of miracles where everything seems effortless. E-learning one of the flag bearers of 21st century has taken over all the traditional ways of teaching and learning. Online courses have paved the way for the great minds of today being able to access aplethora of courses from many esteemed universities, e-learning sites like Udemy, Byju's, Coursera etc. These sites and universities offer a gamut of courses in multiple languages and diverse topics which have millions of learners sitting at the other end.

A 2017 report on Online Education in India by KPMG and Google projected this industry would grow to $ 1.96 billion, have 9.6 million users and Primary and Secondary supplemental education becoming the largest category by 2021. Key players like Byju's have recorded tremendous growth in the last 4 years - from 108.96 crores in FY 16 to 1281.9 crores in FY 19. Professional learning platforms like Upgrad have grown at a scorching pace too – from 55 lakhs in FY 16 to 85.14 crores in FY 19. Clearly there were signs that Online Education is the next big thing. While the entire economy has come to a standstill due to COVID-19; online education seems to have benefited more from the lockdown. Between Jan to March 2020, Byju's is estimated to get an average of 14.45

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million monthly website visitors and while Vedantu has been getting 10.60 million visitors during the same period. The number of users signing up has increased as well. Vedantu has witnessed 36 folds growth in the number of users signing up for free live online classes. Toppr has seen a 100 per cent increase in enrolments since launching free classes. Expectedly, observers see COVID-19 as a tipping point for the industry and projecting a higher growth citing the "new normal". Some are even going to the extent of declaring online classes as the default model for education.

With great power comes great responsibility. What many have seen to ignore is the possible fatigue that might have crept in for the students from these online classes. Sitting in one position for long periods of time might sap the energy of the learners. The body equates this stillness with sleep. Also, staring at the computer screen for a long time causes eyestrain which results in the mood for shut-eye. If the courses are not interactive or interesting enough and are in the form of some recorded, dull videos full of content then they arouse disengagement in the form of drowsiness or sluggish behaviour from the side of the learners who had trusted enough over the credibility of the course. Drowsiness occurs when not being engaged in an active task and that monotony of monitoring leads to decrease of vigilance. This affects and hinders learning and indicates problem in delivery of the instruction which urges the need for an update in the pedagogy of the course to make some reasonable adjustments.

Drowsiness detection is the only crumb of comfort these instructors could salvage from this entire window. Apropos the revolutionizing of the world by Machine learning, drowsiness detection can be achieved by the powerful capabilities of the Machine Learning algorithms which have the answer to all the questions involving analytics. In online courses prevailing over the market today, there is no provision for such detection using facial recognition. To overcome this, we propose a Drowsiness detection algorithm. Unlike a number of previous approaches which used electroencephalography, monitoring of heart rate and temperature levels to detect drowsiness which is not feasible for thousands of learners or attendees to have or engage in at their homes, our algorithm takes into account a number of visible parameters or indicators. This lays a hand on research on drowsiness detection based on facial and behavioural parameters and at the same time on the improvement of conventional teaching methods. To detect whether a person is drowsy or not, our algorithm focuses on various facial and behavioural indicators like the Eye Aspect Ratio (EAR), Percentage of eye closure (PERCLOS) calculation, Mouth Aspect Ratio (MAR) or Yawn detection. It also takes into account the number of frames for which a learner is detected drowsy as a parameter to be able to differentiate between blinking and micronapping.

II. Literature Review

With the help of information gained from various sources like books which are an indispensable resource for researchers and provide a gamut of existing products and guidance in developing a new solution to a problem[18] and after re- ferring to lots of papers we have been able to get a correct view on the existing systems and methodologies. Many researchers have been working on drowsiness detection for car drivers to avoid fatal car accidents and have proposed various physiological or the non-image and action or the image-based methods for the same.

Drowsy people manifest their fatigue in the form of - changes in heart rate, oxygen level, brain waves, blood pressure (biological or physiological indicators) - head and eye movement and task performance(action-based indicators)[17]. Different methods are there to resolve different needs. Electroencephalography (EEG) and electromyography are the most reliable and accurate sensor based physiological techniques for drowsiness detection. These non-image methods analyse eye movements by capturing electrical signals of the muscles around the eyes using sensors [6, 7, 9]. EEG signal recorder has also been used to get the electrical activity of the brain to later perform processing of data to establish communication between brain and external devices [11, 13] These are the most predictive, expensive and intrusive techniques since they meddle with the user and cause discomfort. It is not a feasible approach for drowsiness detection of thousands of users of online courses. Therefore, the camera-based approach is the most promising technology for detecting drowsiness for online courses.

Physiological methods may be more reliable but video-based assessment has gathered popularity for practicability and feasibility. It is a non-invasive method and uses facial features or visible parameters for drowsiness detection [12,16].

U Ghole's approach monitors status of the subject using USB camera, Raspberry Pi, Computer vision using OpenCV and alerts the subject through an alarm in case of an anomaly(drowsiness detection)[2,6]. Lahoti and Umang have designed a 97% accurate system to detect drowsiness for online course users which uses Eye

Aspect Ratio(EAR) and Mouth Aspect Ratio(MAR) validated using ResNet50 pre-trained model. In order to increase the user engagement when drowsiness is detected, they propose to make the course interactive by making questions appear on the screen [8]. Eye blinking based techniques are also used to check drowsiness [5,10]. The use of IR sensor to detect eye blink computation doesn't work for a person wearing sunglasses. This challenge is resolved by using facial expressions instead of conventional eye states alone [1,3]. To improve implementation and to further optimize the solution, behavioural or visible parameters like face tilt or head pose estimation are also used which calculate the orientation of head relative to the camera view [7, 24]. Yugo Sato considers face change such as cheek's loosening and variation of edge intensity to address deep wrinkles some subjects have in their drowsy states[23].

The image captured from the subject can also be processed in Matlab[15] and after processing sensitively alarm the subject upon drowsiness detection. Many hardware-based approaches are also prevalent. Gabhane, Jyotsna create a buzzer and a goggle application[19] whereas [22] carries out a simulator-based experiment whose process includes data collection on the basis of questionnaires, attachment of physiological instruments to the body and self-rating of the drowsiness level by the subject. Built on microprocessor board that connects to external cameras, IR LEDs, GPS [20] allows to transmit site warnings to the monitoring centre while focusing on the problem of poor lighting and training the machine according to the characteristics of the driver(face shape, nose, ears, blink time). Since blink related events and not blink related events(micronapping) bear resemblance[21] it is important to have a threshold number of frames to remove any discrepancies or anomalies[2,6].

To detect whether a person is drowsy or not, our application focuses on various facial and behavioural indicators like the Eye Aspect Ratio (EAR), Percentage of eye closure (PERCLOS) calculation as an additive feature, Mouth Aspect Ratio(MAR) or Yawn detection. It also includes Micronapping (not blink related event) as a parameter to distinguish it from blink detection by measuring the number of frames for which a subject is detected drowsy to compensate for the unpredictable responses or anomalies.

III. METHODOLOGY

We have proposed an idea in which drowsiness of an individual is categorized by three main parameters as given below: 1. Eye Aspect Ratio Calculation (EAR)

2. Yawn Detection or Mouth Aspect Ratio Calculation (MAR)
3. PERCLOS (PERcentage of eyelid CLOSure over pupil)

Eye Aspect Ratio Calculation: It is a parameter which estimates the degree of eye openness. As a result of which it is an important indicator in measuring the drowsiness level. It has been formulated using 8 reference points as shown in Figure (1) to improve the accuracy of the results obtained. 2 of these points(P1,P2) are used to measure the width and 6 reference points (P3-P5, P4-P6, P7-P8) are used for measuring the height.

The formula is designed in such a way that its numerator helps to calculate the average distance between the vertical reference points and the denominator compute the distance between the horizontal reference points. The value of EAR helps to detect eye openness in such a way that its value comes out to be greater than 0.25 when the eyes are open fully and gradually decreases to 0 when the eyes are closed.

The formula for calculating Eye Aspect Ratio (EAR) has been given by the following Equation (1)

$$\text{Eye Aspect Ratio (EAR)} = \frac{|P3-P5| + |P4-P6| + |P7-P8|}{3*|P1-P2|}$$

Mouth Aspect Ratio Calculation or Yawn Detection: This parameter helps in yawn detection which is an important indicator of the drowsiness level. When a person is drowsy, he usually yawns and this is where this parameter comes into play. It is measured using 8 reference points as shown in Figure (2). 2 of these points (A, B) are used to measure the width of the mouth and 6 reference points (C-D, E-F, G-H) are used for measuring the height. The formula used for calculating Mouth Aspect Ratio (MAR) has been given by the following Equation (2).

$$\text{Mouth Aspect Ratio (MAR)} = \frac{|C-D| + |E-F| + |G-H|}{3*|A-B|} \quad (2)$$

This formula is similar to the way in which Eye Aspect Ratio (EAR) is calculated. It gives a constant value greater than 0 when a person yawns and remains 0 otherwise.

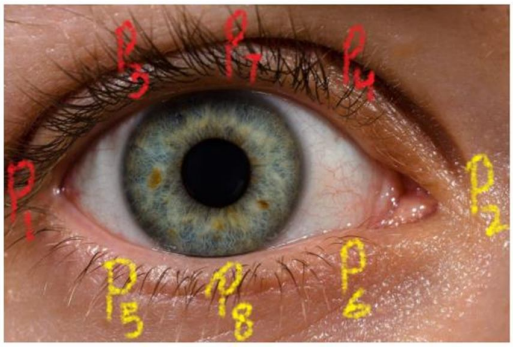

Figure 1: Eye aspect ratio

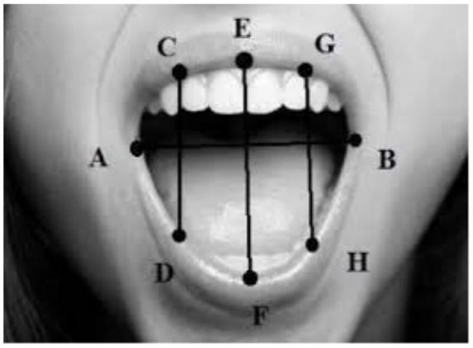

Figure 2: Mouth Aspect Ratio Calculation

PERCLOS (PERcentage of eyelid CLOSure over pupil): It is a reliable parameter which helps to distinguish between normal blinking and napping which makes it an important metric in drowsiness detection. It takes into account the time for which the eye remains open and closed. PERCLOS calculation has been given by the Equation (3) below:

$$\text{PERCLOS} = \frac{\text{Closed eyes time}}{(\text{Closed eyes time} + \text{Open eyes time}) * 100} \quad (3)$$

In this formula, we are measuring the percentage of the time for which the eyes remain closed.

Steps to be Followed in implementation

1. Facial Recognition using OpenCV: OpenCV library of python is used to detect facial expressions of an individual
   during online classes. Webcam keeps recording state of an individual in the form of frames.
2. Eye detection using Dlib
3. Calculating PERCLOS, Eye Aspect Ratio, Mouth Aspect Ratio according to formulas already mentioned in equations (1), (2) and (3).
4. Classification of drowsiness of an individual into ”DROWSY” (by showing an alert on the screen) and ”NOT
   DROWSY”
5. If an individual is found to be ”DROWSY”, randomly generated questions are shown on the screen using NLP
   for the subject to answer in order to improve the attention level of the subject through engagement.

S.No	Parameter	Threshold Value
1.	EAR	Drowsy if EAR < 0.275 Not Drowsy if EAR > 0.275
2.	MAR	Drowsy if MAR > 0.5 Not Drowsy if MAR < 0.5
3.	PERCLOS	Drowsy if PERCLOS rate increasingly changes overtime with the number of frames, otherwise Not Drowsy

Figure 3: Classification of Drowsiness based on parameter value

IV. Results and Discussions

When the proposed algorithm was run on real faces, these are the results that we got. In Figure (3), since the value of EAR came out to be greater than 0.25 and the value of MAR for a set number of frames was also greater than 0, the subject was declared as “DROWSY” and an ALERT was shown on the screen along with a set of random questions for the subject to answer in order to increase the attention level by engagement. In Figure (4), NO ALERT was shown on the screen because the values for EAR and MAR (for a set number of frames) came out to be less than 0. PERCLOS rate is always being calculated to avoid the discrepancies and distinguish between normal blinking and napping.

In this paper, we have proposed an algorithm which detects drowsiness of an individual during online courses in real time. We have compared proposed algorithm with various other machine learning algorithms. It has been seen that accuracy obtained through proposed algorithm is better as compared to other algorithms' accuracy like Logistic Regression, Decision Trees, Random Forests, Naive Bayes Classifier.
We have also tried to improve the formula for Eye Aspect Ratio (EAR). In the few existing proposed algorithms, EAR was calculated using 6 reference points only. The formula used was as shown in Equation (4):

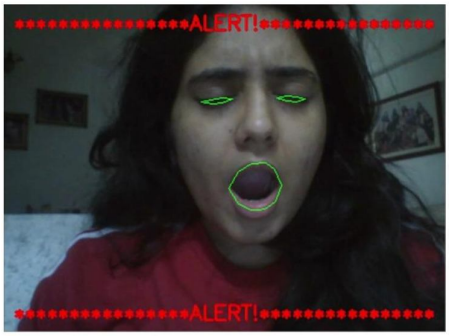

Figure 4: Alert when person is drowsy

Figure 5: No alert when person is not drowsy

$$\text{Previously Calculated Eye Aspect Ratio (EAR)} = \frac{|p3-p5| + |p4-p6|}{2*|p1-p2|}$$

But when this algorithm was run on given dataset, the accuracy came about to be a lot less. Therefore, we tried to improve the formula for EAR Calculation by incorporating 2 more reference points as mentioned by Equation (1).
As shown in Figure(6) the accuracy for our improved formula used in this algorithm came out to be 94% while the accuracy for the previously used formula came out to be only 82% when run on the given dataset.
In Figure(7) for Drowsiness Detection, proposed algorithm produces approximately 94% accuracy while Random Forests stands second with 84.6% accuracy followed by Logistic Regression, Decision Trees and Naive Bayes Classifier with accuracy of 76.92% , 76.92% and 69.23% on the chosen dataset. In this way the proposed algorithm outperforms rest of the algorithms in Drowsiness Detection. Here accuracy is taken as the average of accuracy's obtained in the above two cases.

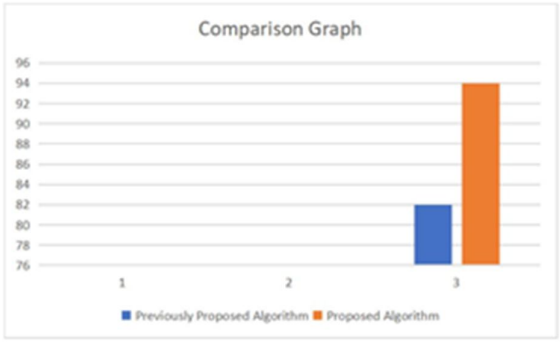

Figure 6: Accuracy comparison before and after improving formula for EAR

V. Conclusions and Future Work

In this paper, we have proposed an algorithm to detect drowsiness in an individual during online classes using Eye Aspect Ratio, Mouth Aspect Ratio and PERCLOS as parameters in order to improve the skill level of learning in young minds. We have also done a comparative study on the results obtained through proposed

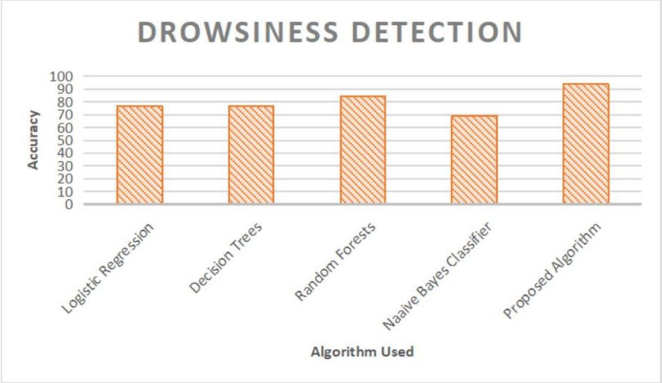

Figure 7: Accuracy comparison for different classification algorithms for Drowsiness Detection

algorithm and various another machine learning algorithms. In order to recognize facial points of mouth and eyes Dlib library has been used which successfully detects various facial coordinates. In order to increase accuracy , we have considered 8 coordinates for Eye Aspect Ratio and Mouth Aspect Ratio calculation. Proposed algorithm produces approximately 94% accuracy while Random Forests stands second with 84.6% accuracy followed by Logistic Regression, Decision Trees and Naive Bayes Classifier with accuracy of 76.92% , 76.92% , and 69.23% on the chosen dataset. We have found that proposed algorithm outperforms other machine learning algorithms on given dataset. In future when we might find ourselves equipped with laptops and PC's having different sensors that can detect drowsiness in an individual, we can use various another machine learning algorithms like XGBOOST and deep learning techniques in order to provide better accuracy on larger databases and help children receive quality education while in virtual mode.

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