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Drowsiness Detection for Motorized Vehicles Using Machine Learning

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Abstract: ***Driver drowsiness is one of the major causes for most of the accidents in the world. Detecting the driver's eye tiredness is the easiest way for measuring the drowsiness of the driver. The advent of high-speed motorized vehicles drowsy driving accidents has claimed the lives of millions of people across the globe. To avoid such accidents, proposes a Machine Learning based system drowsiness system for motorized vehicles with alarm and Web Push Notifications to notify the driver before any accident occurs. The driver's face is captured by a real-time camera system, and the eye borders are detected by a pre-trained machine learning model from the real-time video stream. Then each eye is represented by 6 – coordinates (x, y) starting from the left corner of the eye and then working clockwise around the eye. The EAR (Ear Aspect Ratio) is calculated across 20 consecutive frames, and if it falls below a certain threshold, it sounds an alarm and sends the details of the nearest coffee shop to your mobile device via a Web Push Notification. When the alarm is activated, it also displays a list of nearby coffee shops to help the driver stay awake.***

Keywords: Machine Learning, SVM, MOR, EAR

I. INTRODUCTION

Many accidents caused by fatigue driving have occurred frequently in recent years. Drowsy driving is one of the major causes of deaths in car accidents. Truck drivers that travel for lengthy periods of time (especially at night), long-distance bus drivers, and overnight bus drivers are more susceptible to this condition.

Drowsy driving is a passenger's worst fear. Passengers in every country face the nightmare of drowsy drivers. Fatigue-related traffic accidents result in a large number of injuries and deaths each year.

As a result, due to its wide practical application, detecting and indicating driver weariness is a hot topic of research. The acquisition system, processing system, and warning system are the three blocks/modules of the basic sleepiness detection system. The acquisition system captures a video of the driver's frontal face, which is then sent to the processing block, where it is analyzed online to detect drowsiness. The warning system sends a warning or alarm to the driver if drowsiness is detected.

Based on these recognized indications, machine learning algorithms have been routinely utilized to detect driver sleepiness levels. Machine learning is an artificial intelligence discipline that is used for data classification in a variety of fields, especially for the examination of huge datasets.

Previous studies used datasets containing behavioral indicators, physiological signals, and a variety of other metrics to evaluate machine learning algorithms for classification of the drowsy and alert states of drivers.

In general, there are three types of approaches for detecting drowsy drivers: vehicle-based, behavioral-based, and physiological-based. A number of parameters such as steering wheel movement, accelerator or brake pattern, vehicle speed, lateral acceleration, deviations from lane position, and so on are continuously monitored in the vehicle-based method. Driver drowsiness is defined as the detection of any abnormal change in these parameters. This is a nonintrusive measurement as the sensors are not attached to the driver. In behavioral based methods, the visual behavior of the driver i.e., eye blinking, eye closing, yawn, head bending etc. are analyzed to detect drowsiness.

This is also a non-intrusive measurement because the features are detected using a simple camera. Physiological signals such as electrocardiogram (ECG), electrooculogram (EOG), electroencephalogram (EEG), heartbeat, pulse rate, and others are monitored in physiological-based methods, and drowsiness or exhaustion is detected based on these metrics. Because the sensors are attached to the driver, this is an intrusive measurement that will distract the driver. The cost and size of the system will increase depending on the sensors used. However, including more parameters/features will improve the system's accuracy to some amount. These concerns lead us to create a low-cost, real-time sleepiness detection technology that is accurate enough. As a result, we've presented a webcam-based system that uses image processing and machine learning techniques to identify driver fatigue from a face image, making the device both low-cost and portable.

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II. RELATED WORK

In 2007, Arimitsu et al. [1], developed the driving simulator with the seat belt motor retractor, which was used in a commercial vehicle, to provide the vibration stimulus to the drivers. The limitation of this paper was variation of the portions, which was stimulated by the seat belt. In 2008, Liang et al. [3], proposed a novel brain computer interface (BCI) system that can acquire and analyze electroencephalogram (EEG) signals in real-time to monitor human physiological as well as cognitive states, and in turn, provide warning signals to the users when needed. The accuracy of the BCI system is slightly less when compared to the existing systems to detect the drowsiness.

O. Ursulescu, B. Ilie and G. Simion detected drowsiness [3] in the eyes by detecting eye blinks and then measured the time between each successive eye blink. They did that by counting the number of frames in which the driver's eyes are closed and if that exceeds a threshold then the driver gets a visual warning on his navigation display.

P. R. Tabrizi and R. A. Zoroofi have used Image processing techniques by using the saturation or the S channel of the HSV colour model [4] for drowsiness detection. Their algorithm used the Eye Map to localize pupil centre and iris boundaries and then did drowsiness decision by the PERCLOS (PERcentage eye CLOSure) parameter. Their algorithm required no training and still achieved good results.

M. Dehnavi, N. Attarzadeh and M. Eshghi in their paper have used Image Processing techniques for eye state detection [5]. The algorithm followed by them determines the open or closed eye by different iris and pupil color and the white area present in the eye's open state. The vertical projection was used to determine the eye's state. Their algorithm had good speed, accuracy and less complexity.

In 2011, Kohji Murata et al. [6], developed a non-invasively system to detect individuals driving under the influence of alcohol by measuring biological signals. The algorithm for the time series of the frequency fluctuations generated in this study has this potential.

PERCLOS is the most widely used algorithm for detecting tiredness. Wierwille et al. [7] devised this algorithm. The percentage of time that eyes are closed over a window is measured by PERCLOS. The time limit can be as little as one minute. In simulator tests and in practise, experiments have demonstrated that PERCLOS can obtain a 90% accuracy rate.

McDonald et al. [8] use the steering wheel angle measurement to create a random forest model to detect drowsiness-related lane deviations. The accuracy and Area Under the Receiver Operating Characteristics Curve (AUC) of this random forest technique are higher than those of the commonly used PERCLOS algorithm.

2014, IsseyTakashashiet al.[9], induced CRPS by paced breathing (PB) using pulse sound, which synchronized with heartbeats. For greater safety, methods need to be developed to physiologically overcome drowsiness. In 2016, J. Pilataxi et al. [10], presented a driving assistance system which detects drowsiness in the driver. If the robot fails the working will not be performed.

To summarize, existing systems provide significantly less accurate findings due to low picture and video quality, which causes camera position variance. To address these issues, the suggested research introduces sleepiness detection, which is a shape predictor algorithm that identifies a person's eyes and counts the driver's eye blinks to prevent accidents.

III. THE PROPOSED METHOD

Figure 1 shows a block diagram of the proposed driver drowsiness monitoring system. The video is first recorded with a webcam. To capture the driver's front face image, the camera will be positioned in front of him. The frames are taken from the video to create 2-D images. The histogram of oriented gradients (HOG) and linear support vector machine (SVM) are used to detect faces in the frames. Facial landmarks such as the positions of the eye, nose, and mouth are marked on the images after the face has been detected. Eye aspect ratio, mouth opening ratio, and head position are all calculated from facial landmarks, and a conclusion concerning the driver's tiredness is made utilizing these features and a machine learning approach. If drowsiness is detected, an alarm will be sounded to notify the driver. The next sections go into the specifics of each block.

A. Data Acquisition

A webcam is used to record the video, and the frames are extracted and processed on a laptop. Image processing techniques are used to these 2D images after the frames have been extracted. Synthetic driver data has been generated at this time. The participants are invited to look at the camera while blinking, closing their eyes, yawning, and bending their heads. The footage was recorded for 30 minutes.

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B. Face Detection

The human faces are first discovered after the frames have been extracted. There are a plethora of online face detection techniques available. The histogram of oriented gradients (HOG) and linear SVM algorithm are employed in this study. Positive samples of a fixed window size are extracted from the images and HOG descriptors are computed on them in this method. The HOG descriptors are then generated using negative samples (samples that do not contain the needed object to be detected, in this case, a human face). In most cases, the number of negative samples much outnumbers the number of positive samples. A linear SVM is trained for the classification job after the characteristics for both classes are obtained. Hard negative mining is used to improve the accuracy of SVM. In this strategy, the classifier is evaluated with labeled data after training, and the false positive sample feature values are used for training again. The fixed size window is translated over the image for the test image, and the classifier computes the output for each window point. Finally, the maximum value produced is used to identify the detected face, which is surrounded by a bounding box. This non-maximum suppression phase removes \sthe superfluous and overlapping bounding boxes.

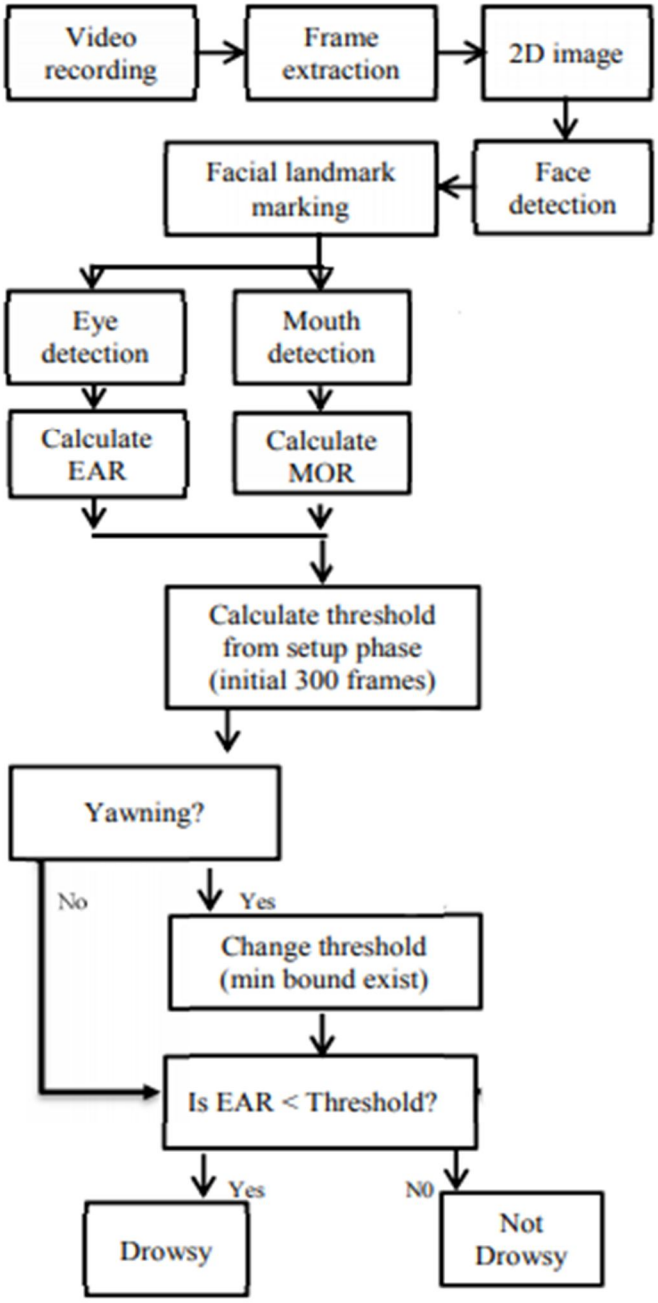


Fig. 1 The block diagram of the proposed drowsiness detection system

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C. Facial Landmark Marking

After the detection of the face, the next step is finding various facial features such as the corners of the eyes and mouth, the tip of the nose, and so on. Prior to that, the face images should be normalized to eliminate the effects of camera distance, non-uniform illumination, and varying image resolution. As a result, the facial image is shrunk to 500 pixels wide and transformed to grayscale. After image normalization, a sparse subset of pixel intensities is employed to estimate landmark positions on the face using an ensemble of regression trees. The sum of square error loss is improved using gradient boosting learning in this method. To find distinct structures, different priors are used. The boundary points of the eyes, mouth, and center line of the nose are defined using this method, and the number of points for each eye, mouth, and nose are listed in Table I. Figure 2 shows the facial landmarks. The red spots are the landmarks that have been detected and will be processed further.

Parts	Landmark Points
Mouth	[13-24]
Right eye	[1-6]
Left eye	[7-12]
Nose	[25-28]

Table I: Facial landmark points

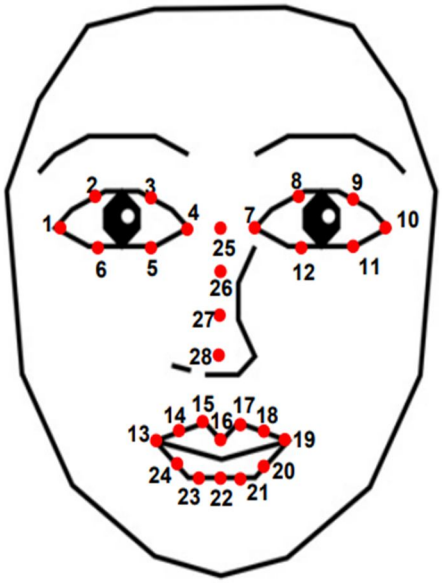


Fig. 2 The facial landmark points

D. Feature Extraction

The features are computed after the facial landmarks have been detected, as stated below.

EAR (eye aspect ratio): The eye aspect ratio is computed from the eye corner points as the ratio of the eye's height and width as stated by

$$EAR = \frac{||p2 - p6|| + ||p3 - p5||}{2||p1 - p4||}$$

Fig. 3 EAR calculation

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The distance between locations marked as I and j is (pi-pj), where pi represents the point marked as I in the facial landmark. As a result, EAR has a high value when the eyes are fully open. The EAR value decreases while the eyelids are closed. Thus, EAR levels that are steadily lowering imply that things are getting better. It's virtually 0 for completely closed eyes when you close your eyes.(a blink of the eye) As a result, EAR levels imply drowsiness. As a result of tiredness, the driver's eye blinks.

Mouth opening ratio (MOR): Mouth opening ratio is a parameter to detect yawning during drowsiness. It is calculated in the same way as EAR.

$$MOR = \frac{(p_{15} - p_{23}) + (p_{16} - p_{22}) + (p_{17} - p_{21})}{3(p_{19} - p_{13})}$$

Fig. 4 MOR calculation

It increases rapidly when the mouth opens owing to yawning and stays at that high value for a long time due to the yawn, as stated.(indicates that the mouth is open) and then rapidly drops to zero. The ability to yawn is one of the traits of sleepiness, MOR provides a drowsy score for drivers.

E. Alert System

The Raspberry Pi employs a Web Socket based alert system that runs on any internet enabled device by sending a Web Push notification, and the IoT based alert system consists of a buzzer that is triggered when the threshold limit is met. When you click the notification, you'll be taken to Google Maps, where the keyword "Coffee Shops" near the person's location is searched. As a result, the entire procedure is automated.When the EAR falls below the threshold limit, the Raspberry Pi, as a Web Socket Server, sends a message. When this Web Socket Server, which also serves as our Notification Server, is triggered, it sends a JSON (JavaScript Object Notation) response to all subscribing internet-enabled devices, resulting in a Web Push Notification. The Tornado Python library was used to communicate via Web Socket with the Raspberry Pi, and the WebPush PHP library was utilized to create the notification JSON response.

IV. RESULT AND ANALYSIS

With the generated data, the proposed system was constructed and tested. The webcam is connected to the laptop so that the video streaming can be further processed and classified online. The feature values are then saved for statistical analysis and categorization purposes. Table 2 shows sample values for the parameters in various states. Drowsiness can also be detected by the created method in those who wear spectacles.

State	EAR	MOR
Normal	0.36	0.33
Yawning	0.18	0.86
Eye closed	0.12	0.42

Table2. Example values for various parameters in various states

On the Tarunkr dataset, the created approach was evaluated. It's a picture database of in-vehicle automotive drivers' faces. The developed algorithm was put to the test on several driver photos. The same's performance on this data is adequate in terms of accuracy. Fisher's linear discriminant is a Bayesian classifier, Support Vector Machine (SVM) and FLDA analysis for classification, a linear kernel was adopted. This is currently the case on the saved data, this was done in an offline way. Two-third of the data is utilized for training, while the remaining one-third is used for testing.

Table 3 shows the results of the classifier. The ratio of correctly classifying drowsy states out of all actual drowsy states is computed as sensitivity, and the ratio of correctly classifying awake states out of all actual awake states is computed as specificity. The correctly classified states out of all the frames are used to calculate overall accuracy. It is clear that FLDA and SVM have higher overall accuracy than Bayesian, however Bayesian has the highest sensitivity of 97 %.Bayesian specificity, on the other hand, is quite low (56%). This could be due to a miscalculation in the probability distributions' estimate. Due of the alarm's low specificity, it may sound if no drowsiness exists.

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Method	sensitivity	specificity	Overall accuracy
Bayesian Classifier	0.98	0.57	0.84
FLDA	0.87	1	0.93
SVM	0.96	1	0.96

Table3. Accuracy of several classifiers.

V. CONCLUSION

Based on visual behavior and machine learning, a low-cost, real-time driver drowsiness monitoring system is proposed in this paper. From the streaming video collected by a camera, visual behavior features such as eye aspect ratio, mouth opening ratio are computed. To identify driver drowsiness in real time, an adaptive thresholding technique has been developed. With the generated synthetic data, the built system works well. Following that, the feature values are saved, and machine learning methods are used to classify the data. The Bayesian classifier, FLDA, and SVM have all been studied. FLDA and SVM have been outperformed Bayesian classifiers. FLDA and SVM have a sensitivity of 0.896 and 0.956, respectively, and a specificity of 1. Because FLDA and SVM are more accurate, work will be done to include them into the existing system for online classification (i.e., drowsiness detection). A pilot study on drivers will be done to verify the developed system, which will be implemented in hardware to make it portable for car systems.

If the driver falls asleep for more than 5 seconds, a more accurate system with more networking capabilities can be used to implement context-sensitive applications like applying the brakes, bringing the car in park, and turning on the parking lights, which will require control over the essential parts of the car.

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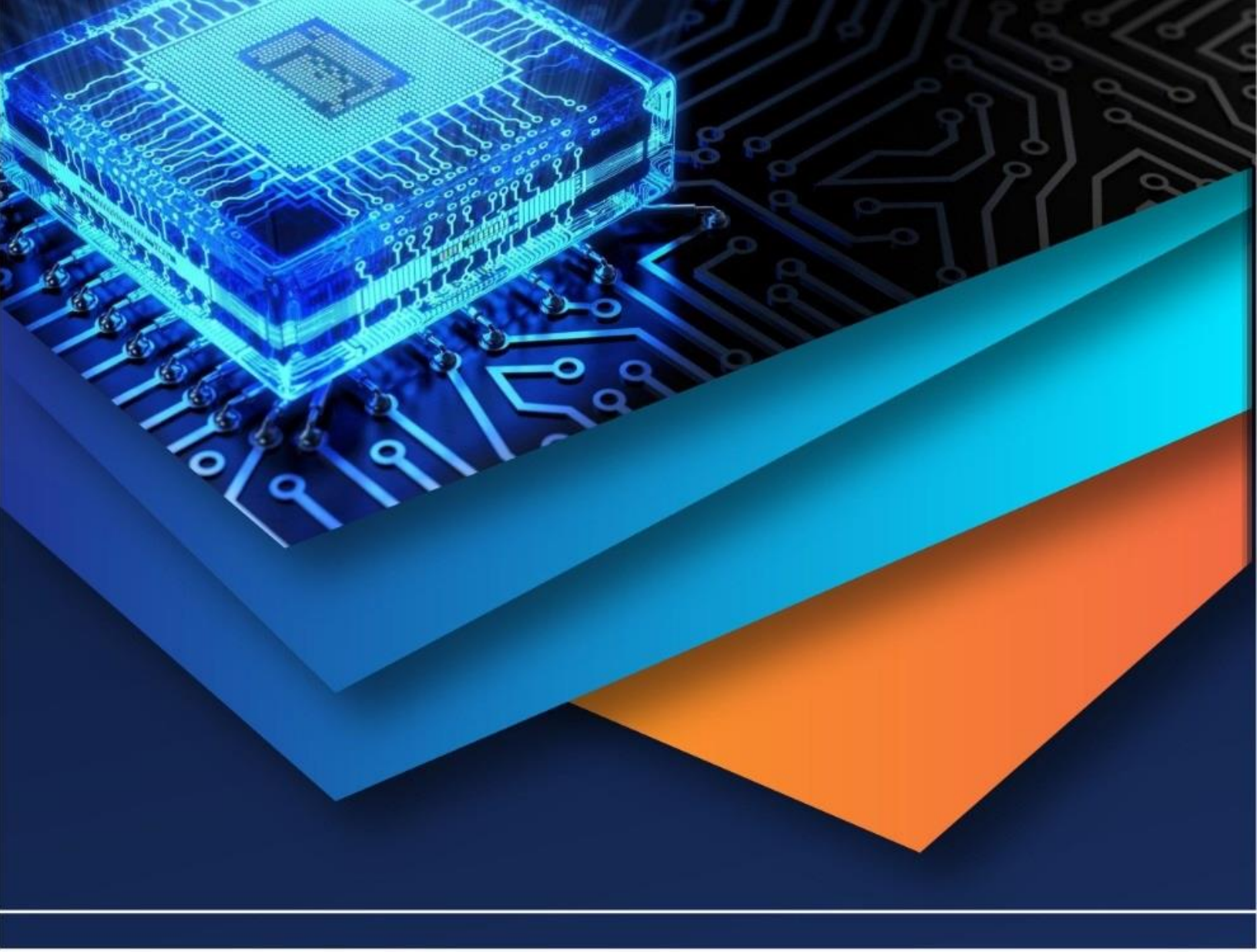
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