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Social Distancing Detection in Real Time using DeepLearning and IoT

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Abstract: ***Social Distancing is the practice of maintaining a minimum amount of physical distance from your surrounding people or avoiding direct contact with people or objects in public places so as to minimize the exposure or transmission of diseases like COVID-19. This can also be coupled with wearing of face masks and regular sanitization of hands. The government has made social distancing norms compulsory and to be followed, and penalties would be imposed if violated. But there are a lot of examples of social distancing violations in public places due to negligence of people. There are approaches using bluetooth and mobile phones but it requires an app to be installed. This study provides a method for determining whether the social distancing rule has been broken by combining machine learning models and object detecting techniques. Appropriate actions would be taken in case of any violations detected. In this paper, a comparison is done on all the object detection techniques like Faster R-CNN, YOLO v3, SSD Mobile Net etc. based on accuracy, mean average precision, computational time and ease of integration. Based on this, SSD Mobile Net performed well on accuracy and had a faster computational time. This model can also be deployed on end devices like Raspberry Pi.***

Keywords: Social Distancing, Human Detection, Centroid, Euclidean Distance, Single-Shot Detector(SSD), OpenCV, YOLOv3, Firebase, Raspberry Pi.

I. INTRODUCTION

During this ongoing COVID-19 pandemic, social distancing is considered as a vital measure to contain the spreading of the disease. Tolimit the spread of an infectious disease, for instance, Covid-19, one of the most recommended measures is to practice social distancing. This is not a novel concept; for many generations, most communities have recognised the importance of staying away from those who are sick. To relieve pressure on the healthcare system, the goal is to limit transmission by postponing the epidemic peak, reducing the size of the epidemic peak, and spreading cases over a longer period of time. It is a method of limiting one's contact with other people. It has been indicated that keeping a distance of around 2 meters between yourself and another person reduces the transmission of most flu virus strains, including COVID 19.

Even after many proposed interventions and measures taken by the government, there are a lot of instances where social distancing norms are violated. There are approaches using bluetooth and mobile phones to check for social distancing violation, but it requires an app to be installed. The proposed system implements image processing and uses various methods of object detection. The input for the model would be a video stream and the output will be a video containing all the violations that are detected and bounding boxes marked across them in case of violations. The model uses edge computing. Edge computing is a distributed computing paradigm, where data is processed in the device itself or on a local computer or server. Here the device includes raspberry pi. The final model can be deployed on a raspberry pi. Raspberry pi is a single board computer(SBC) which can be integrated with various object detection models.

The raspberry pi can run tiny-YOLO models, the accuracy is compromised. The smaller model size results in very less accuracy. Therefore, models like Mobilenet SSD, which is accurate, fast and can also be integrated with Raspberry pi is used. Mobilenet SSD model provides near real-time human detection. Pre-trained person detection model using COCO dataset is used.

1) *Object Detection:* The model uses OpenCV and YOLO for image processing and object detection. The libraries used are open source. The MobileNet Single Shot Multibox Detector (SSD) object detection model and the OpenCV library for image processing are used in this study to detect social distance between people in areas of interest. YOLO is a state-of-the-art, real-time object detection system. Single Shot detector(SSD) like YOLO takes just one shot to detect multiple objects present in a picture using a multibox. It is ahigh-accuracy object detection algorithm and significantly faster in speed.
2) *Computing pairwise distance* : Once the objects are detected and classified, centroids are calculated. To calculate the distance between two people, Euclidean Distance is calculated. Euclidean Distance is the minimum distance between any two points on a given plane. It is the distance of the line segment drawn between those two points.

3) *Visualization:* If the calculated distance is less than the threshold value, it is classified as a violation and a red bounding box is marked and the violation count is incremented. Else, there is no violation detected, and a green bounding box is marked.

II. RELATED WORK

Since December 2019, COVID-19, which emerged in Wuhan, China, has infected many countries around the world. The World Health Organization (WHO) declared it a pandemic disease on March 11, 2020, after the virus spread to 114 countries, resulting in 4000 deaths and 118,000 active cases. They reported 142,733,066 confirmed COVID-19 cases as of April 22, 2021, with 3,071,798 deaths [1]. The global community is looking for new ways to stop the virus from spreading. The virus is primarily transmitted by people who are in close proximity to one another (within 6 feet) over an extended period of time. When an infected person coughs, sneezes, or speaks, the virus spreads through the air when droplets from their nose or mouth scatter and infect surrounding people. The droplets often travel through the respiratory system to the lungs, where they begin to destroy lung cells. According to a recent study, people who have no symptoms yet are infected with the virus play a role in the virus's spread. As a result, even if there are no signs of the virus, it is best to keep a distance of at least 6 feet from others.

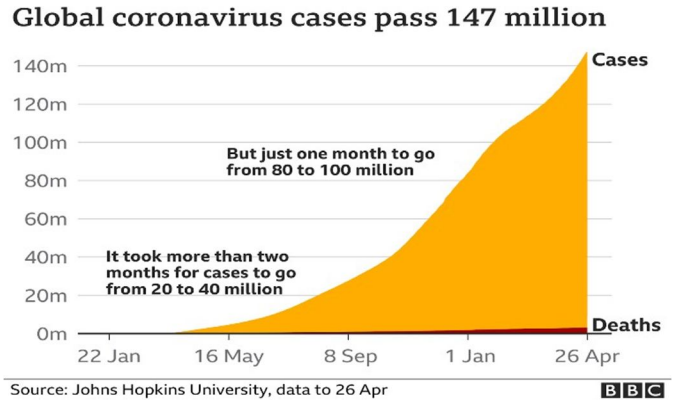

Fig 1. Covid-19 cases growth data provided by Johns Hopkins University

Following the emergence of the COVID-19 pandemic in late December 2019, social distancing was considered to be the most effectivemethod of preventing the spread of the infectious virus and was adopted as common practice on January 23, 2020. Many countries have relied on technological solutions to combat pandemic losses so far. Several developed countries started using GPS technology to monitor infected and suspected individuals' movements. [2] provides a study of emerging technologies such as Wi-Fi, Bluetooth, smartphones, and GPS, as well as positioning (localization), computer vision, and deep learning, which can all play a role in a variety of realistic social distancing scenarios. Drones and other surveillance cameras are used by some researchers to detect crowds [3] [4]. Until now, researchers have put in a lot of effort to identify pandemics, and some have even built a smart healthcare system for pandemics using the Internet of Medical Things [5]. [6] studied the social distancing impacts on the spread of the COVID-19 outbreak. According to the findings, early and immediate social distancing may help to minimize the peak of the virus attack. While social distancing is critical for flattening the infection curve, it is an economically inconvenient measure, as we all know. It was not adopted at an early stage due to a lack of widespread support among decision-makers, resulting in public health damage. However, social distance had an effect on economic productivity, even then many researchers looked for ways to compensate for the loss. Researchers use surveillance recordings, as well as computer vision, machine learning, and deep learning-based methods, to provide useful solutions for social distance measurement. [7] proposed a method that uses the YOLOv3 model to detect humans and the Deepsort approach to monitoring them using bounding boxes and assigned IDs. They used a frontal view data collection from an open image data set (OID) repository. The authors have compared the findings with SSD and faster-RCNN. [8] created a social distance tracking model focused on an autonomous drone. They used the custom data set to train the YOLOv3 model. The data collection consists of frontal and side views of a small number of individuals. The study is also being expanded to include facial mask tracking. The YOLOv3 algorithm and the drone camera help distinguish social distance and observe people wearing masks in public from the side or front. [9] proposed a graph-based monitoring paradigm for crowd management and physical distancing. [10] performed human detection in a crowded situation. The model is intended for people who do not adhere to a social distance limit of 6 feet between them. The authors used a handheld robot with an RGB-D camera and a 2-D lidar to navigate through crowds without colliding.

A study [11] proposed automated power supply monitoring in the classroom, with motion detection as the primary means of detecting human presence. Context subtraction was used to detect the motion caused by human presence using image processing. The suggested approach involves pixel-level differentiation between two images and frames. One image is used as a reference image and as a background image in the background subtraction process. If there is slight motion, such as strong wind, this approach has a downside, and animals will mistakenly believe they are in the presence of humans.

The study [12] compared the performance of different object detection algorithms used in the convolutional neural network to find the best combination of speed and accuracy. Single Shot Detector (SSD), Faster Region-based Convolutional Neural Network (Faster R- CNN), and Region-based Fully Convolutional Neural Network (R-FCN) were the three models compared. [13] The authors used the Popular Object in Context (COCO) dataset as the benchmark input in a related study. The Inception Resnet extractor model yields a maximum mean average precision (mAP) score of 30 and a minimum mAP score of 20 as a result of the experiment. The table below will show the results of the frontier models evaluation. As far as results, SSD MobileNet is the faster model, with a test dev mAP score of 19, and Faster R-CNN Inception Resnet is the most accurate, with a score of 34.2. This project gives a good overview in comparing pre-trained models from the various algorithms in terms of time rate and accuracy. It's useful for figuring out which pre-trained model is best for implementing the proposed idea.

Table 1. Pre-trained models comparison

Model	Mini validation mAP	Test dev mAP
SSD MobileNet	19.3	19
Faster R-CNN Resnet-101	31	30.9
Faster R-CNN Resnet-101	33.2	33
Faster R-CNN Inception Resnet	34.7	34.2
R-FCN MobileNet	13.8	13.4

A comparison of several pre-trained models with different data sets, such as COCO, Kitti, and Open Images, was made for model selection. With the selected Test Images Collection, the comparison was made to see how long it took to execute, how accurate it was, and how many objects it identified. A comparative study of variegated pre-trained models for discrete class-labels was explored in a study [12]. The image dataset was compared using the COCO object detection model. As a result of this discovery, Mask R-CNN Inception Resnet version 2 Atrous and Faster RCNN Inception version 2 COCO have the best accuracy, with 99 percent accuracy across all 27 test images. The table below shows the implications of this comparison. Mask R-CNN Inception Resnet version 2 Atrous often detects more images than the other model. In terms of accuracy and execution time, SSD MobileNet Vl COCO is a better fit for the proposed object detection idea, as we want the device to be as accurate as possible while still executing quickly.

Table 2. Pre-trained models accuracy comparison

Model Name	Execution Time (s)	Highest Accuracy	Object Detected
SSD Mobilenet V1 COCO	219.58	94%	2
SSD Inception V2 COCO	298.22	97%	2
Faster RCNN Inception V2 COCO	420.71	99%	3
Mask RCNN Inception Resenet V2 Atrous	6008.02	99%	5

[14] contains detailed information about the accuracy, speed of all the object detection models that are open-sourced by tensorflow. The data obtained from this study indicated that the MobileNet SSD object detection model has a faster object detection executiontime, according to the findings, and requires less computation time for processing. As a result of the hardware constraints, the MobileNet SSD object detection model will be used in our study.

Study on proximity algorithms that can be used for social distancing detection:

Proximity problems are a type of computational geometry problem that deals with estimating distances between objects. Closest point problems are a subset of these problems that are expressed solely in terms of points, though the term "closest point problem" is often used interchangeably with "nearest neighbour search." [15], [16] are some of the studies done so far on various algorithms

where some algorithms are for different dimensions and geometry, but for this study, the most basic Euclidean distance [17] algorithm will be used for better performance. Euclidean distance between each and every pair of centroids of the humans detected will be used to find whether people are violating social distancing norms or not.

III. IMPLEMENTATION

The model is implemented based on the mobilenet-ssd model for object detection. The mobilenet-ssd model is a Single-Shot multibox Detection (SSD) graph used for object detection. It has less computation time and good accuracy so that it can be easily deployed on Raspberry Pi. The model also uses OpenCV and TensorFlow for object classification. OpenCV is a huge open-source library for computer , machine learning, and image processing and now it plays a major role in real-time operation which is very important in today's systems.

It may be used to process photos and videos in order to recognise items, faces, and even human handwriting. TensorFlow is a free and open-source software library for machine learning in the field of computer vision.

The model has been trained on the COCO dataset. It contains 120,000 images containing a total of 880,000 labeled items. It consists of90 different categories of object classes among which humans are at an index 1. After a few tests in order to analyze the quality of the model depending on the speed and accuracy of prediction, we use the Mobilenet SSD model which has less computation time and goodaccuracy so that it can be easily deployed on Rpi. SSD Mobilenet V2 Object detection model is trained on COCO dataset for human detection. The model is loaded into a tensorflow graph in the first step. This graph will show the various operations that will be carried out to obtain the desired detections. Pass every frame of input through the model. Each frame is processed by creating a new session. When doing so, some parameters are defined. These involve the model input requirements and the outputs are obtained from it. Bounding boxes coordinates of each object, The confidence of each prediction (0 to 1), Class of the prediction (0 to 90) will be our outputs. Filter out weak predictions and non-relevant objects. A person is one of the many classes detected by the model. The classwith which an individual is associated is 1. In order to exclude both weak predictions and all other classes of objects except person, a threshold value will be used.

In the next step based on the threshold, the distance between any two people is calculated. A list containing all the new transformed points is returned after calling the function on each frame. The distance between each pair of points will be calculated using this list. The Euclidean distance method will be used to calculate the distance between two points. When two points are found to be too close together, the colour of the box that represents the person is changed from green to red. The system will alert everyone to violations of social distancing norms.

A firebase storage will be used for uploading the recorded frames into the cloud . The videos are initially recorded during the live stream and are parallelly uploaded to the cloud from where the admin can retrieve those clips anytime in the future. The videos will be recorded in regular intervals using OpenCV and parallelly uploaded to firebase using python libraries. This entire module is embedded into Raspberry pi so that Raspberry pi does the live stream recording and uploads everything to the cloud. Installing python in Rpi will allow it to run our social distancing module. All the necessary python libraries and virtual environment is set in the Raspberry pi and this module will run inside that environment.

A. Steps

1) The model developed accepts video streams as input. The model can accept .mp4 and .avi files.
2) Perform Person Detection for the given input video.
3) Calculate the centroids for each person and compute pairwise distances between centroids.
4) The Euclidean Distance is calculated by using:$d = \sqrt{[(x_2 - x_1)^2 + (y_2 - y_1)^2]}$
5) Check if the distance between the centroids is less than the minimum value.
6) If the distance is less thanthe minimum value, mark those people with a red bounding box.Else, with a green bounding box.
7) Display the results.
8) Store the output in the cloud.
9) Deploy the model on Rpi.

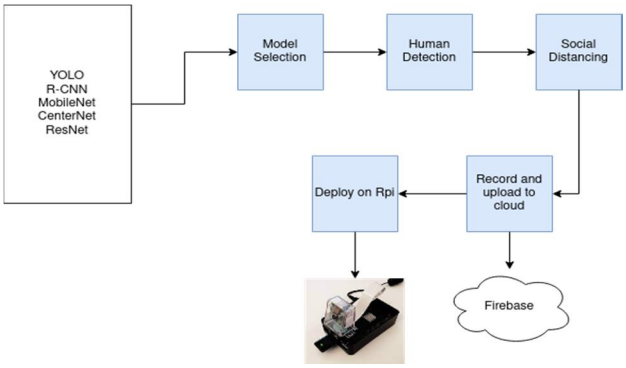

Fig 2. Block diagram of the proposed system

IV. RESULTS

The Model was tested that uses the YOLOv3 model to detect humans and to monitor them using bounding boxes and assigned IDs. Then compared the findings with SSD . Created a social distance model to detect humans. It used the same custom data set to train the YOLOv3 model. The data collection consists of a COCO image dataset. The YOLOv3 algorithm helps to distinguish people violating social distance. It was observed that YOLO took more computational time and gave more accuracy(96%) but cannot be embedded onto the end device. It required a comparatively larger amount of memory.

Table 3. Model Comparison Table

Model Name	Accuracy	Mean Average Precision	Size
SSD Mobile Net	94%	28	22.24 MB
Faster R-CNN	98%	34.2	138 MB
HAAR Classifier	86%	26.4	48.1 KB
YOLO V3	96%	32.4	248 MB

So according to this R-CNN gave the best accuracy and precision but it took more computational time. The HAAR classifier gave poor accuracy and less precision compared to the SSD. Even YOLO took more time compared to SSD. This led to the conclusion that SSD works better with lesser memory, faster computational time and can be easily embedded on to end devices.

Human detection is done with the help of object class identifiers in which humans are assigned an index of 1 and the corresponding bounding boxes are marked. The social distancing model will calculate distance between centroid of each bounding box and compare it with the threshold. Red boxes as shown in Fig 3 indicate violation of norms .Similar approach is used for detecting people following social distancing norms properly as shown below where boxes are marked with green colour as shown in Fig 4. Once the recorded frames are processed it is uploaded to the cloud for which firebase is used. The recorded frames are uploaded at regular time intervals to avoid any loss of frames as shown in Fig 5.

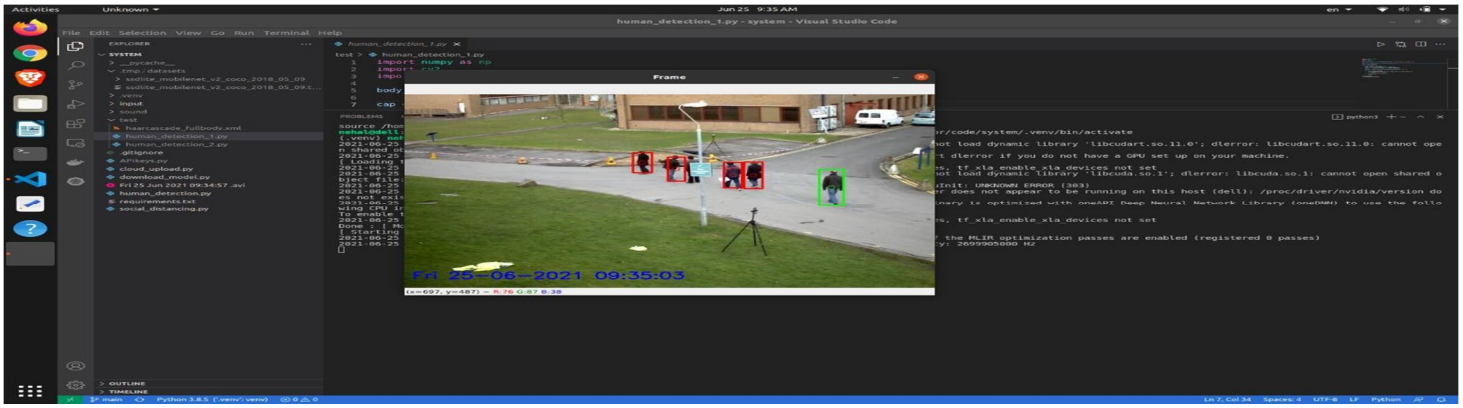

Fig 3. Detection of people violating social distancing norms(red bounding boxes)

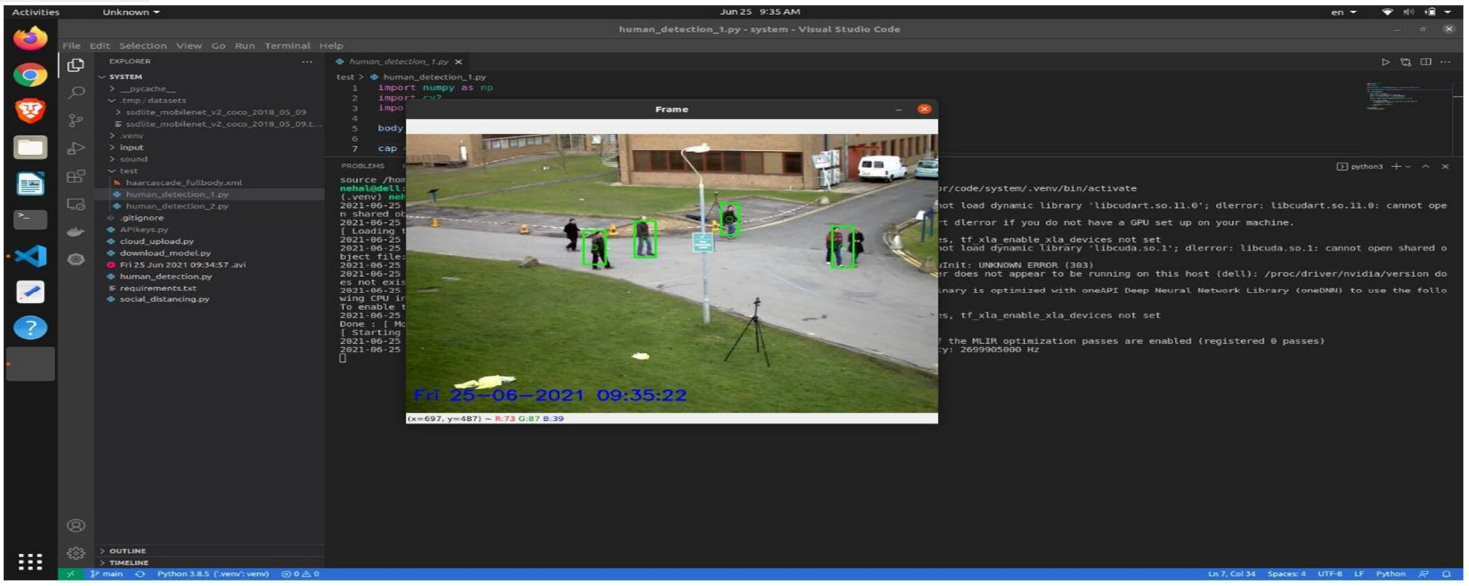

Fig 4. Detection of people who are following social distancing properly

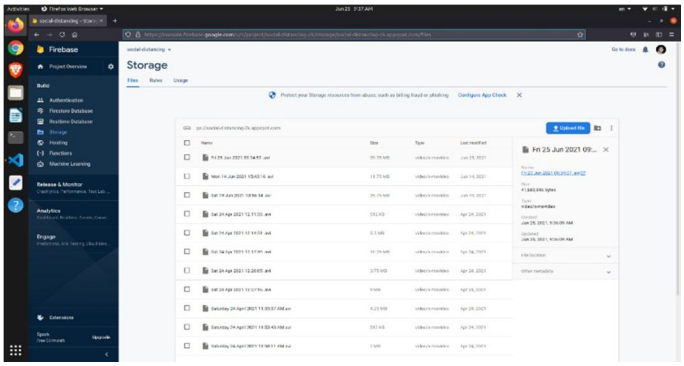

Fig 5. Uploading recorded frames to the firebase

V. CONCLUSION

In this study, a system is proposed that can detect violations of social distancing norms from a video stream and store them. It can also be integrated with Raspberry Pi. The study also compares different object detection techniques based on accuracy, run time, mean average precision. Based on the comparisons, the SSD Mobile Net model has the advantages as compared to other models, including higher accuracy, lesser computational time and can be integrated on end devices like raspberry pi. The violations detected are marked with appropriate bounding boxes and stored onto the cloud for future references. The model can be deployed and integrated with CCTV surveillance cameras to achieve real time social distancing monitoring.

VI. ACKNOWLEDGEMENT

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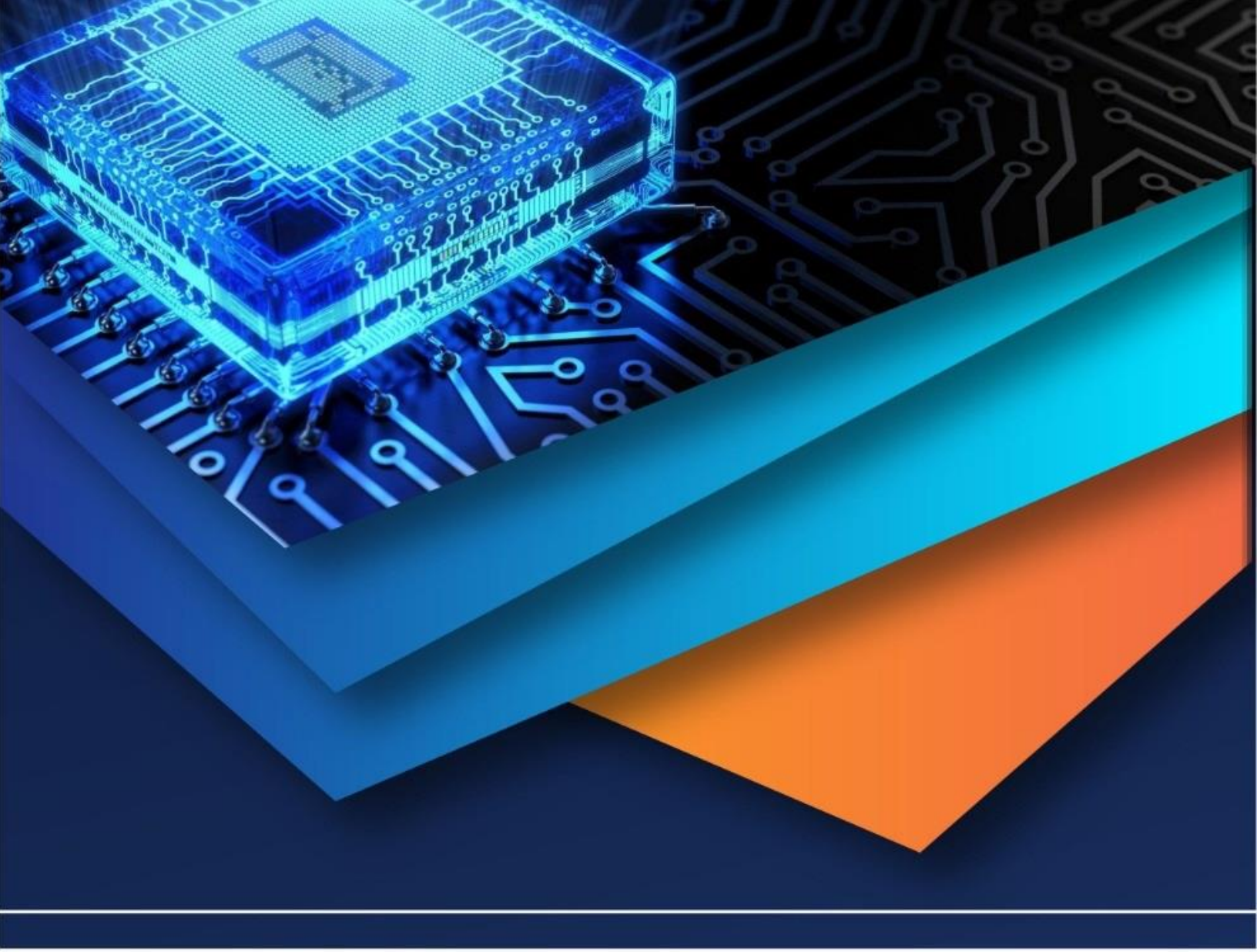

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