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Review of Artificial Intelligence System For Correcting Exercise Movements and Health Monitoring

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Abstract: ***Exercising/yoga/fitness training is an important aspect in everyone's life especially with the modern hectic lifestyle which is very unhealthy. The correctness of an exercise can be judged by certain parameters such as perfect angles between body points and correct breathing techniques and also number of repetitions in some forms of exercise. In yoga, health benefits are achieved only when a person stays in the position for long enough. The Artificial Intelligence system which will help in tracking the movements of user while performing any exercise or yoga asanas will be beneficial. For this system Computer Vision will be used to visualize the body points of the user. Post visualizing the body points, machine learning algorithms are used to detect the posture of the user and check if it is correct or not. Accordingly, the system will generate an output to tell the user the correction to be made in the posture. Also a heartbeat tracking system is used to monitor the heartbeat of the user so that while performing any exercise or yoga asanas if user feels any abnormality in the body it can be tracked by the user's heartbeat and the system could guide the user before any injury occurs.***

Keywords: CV, CNN, R-CNN, Neural Network, OpenPose, BlazePose, PPG

I. INTRODUCTION

According to the National Safety Council (NSC), in the year 2019; exercise, with or without exercise equipment, accounted approximately 468,000 injuries, the foremost of any category of sports and recreation [1]. Exercise and yoga is one thing which everybody must do. But when someone tries to do it on their own as there is no trainer to train them, people end up doing it wrong and gain nothing from it. People are also prone to several injuries due to incorrect posture. So an Artificial Intelligence system which works as a trainer and helps people in correcting their posture would be beneficial. Figure 1 shows the architecture of pose estimation.

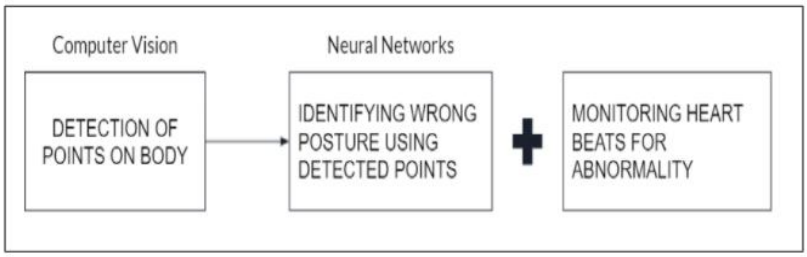

Figure 1: Architecture of Artificial Intelligence System for pose estimation

Computer Vision enables computers to perform certain operations or make meaningful recommendations based on input such as digital images, videos etc. It provides ability to the computers to see, observe and understand [2].
Computer Vision analyses data again and again till it can recognize images. For example, the computer vision model is required to feed a huge amount of data such as images or videos in the form of input so as to train the model so it can later recognize the object from an image or from a video.
Neural networks come under the branch of Machine learning [3]. The functions of Neural Networks are similar to that of a human brain. This function detects many patterns, allowing it to tackle challenges in the AI, deep learning, and machine learning domains. Figure 2 given below represents simple neural network.

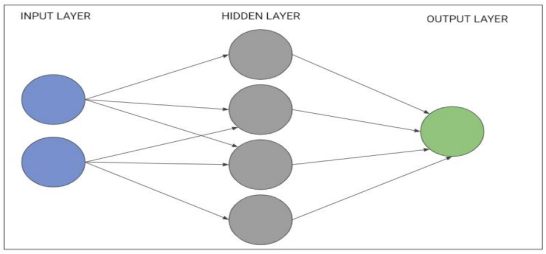

Figure 2: Simple Neural Network

Heart rate monitoring is necessary so that the person does not suffer due to exhaustion. It can be done using multiple techniques such as HeartPy and equipment such as smart watches, ECG (electrocardiography), machine learning based heart rate monitoring etc. The most accurate results are given by ECG. Some of the proper techniques include photoplethysmography which is used in smart watches such as fitbit and apple watch.

II. LITERATURE REVIEW

Fitness activities are essential to personal health and fitness; yet, if performed wrongly, they can be unproductive and potentially hazardous. When a user is not in an appropriate posture, they commit an exercise mistake. Pose Trainer is an app that assists in correcting the posture of the user by giving them noted feedback on their posture [12]. The initial level of Position Trainer uses human pose estimation, a difficult yet important computer vision domain. A trained machine learning model recognizes specific keypoints on a person's body such as his/ her joints or other skeletal keypoints using RGB image or Depth Map. For inference, Pose Trainer employs a state-of-the-art pose estimation deep neural network called OpenPose. The next step of the application is to determine the quality of posture Pose Trainer, which uses heuristic-based and machine learning algorithms, uses the postures and instruction of personal trainers and other trained professionals as the ground truth for flawless form.. Posture Trainer evaluates footage of exercises using human pose keypoints based on the output of pose estimations.

Recognizing body posture from image or video is very important in automatic gesture detection or sign language detection. Due to the multiple positions, degrees of freedom, and occlusions, this work is difficult. A typical method involves creating heatmaps for each joint and modifying offsets for each point. Heatmaps let model scale to many people with minimum overhead but the model for one person is heavier than the adequate size that a phone can handle [6]. BlazePose is a real-time inference-optimized lightweight convolutional neural network architecture for human pose estimation on mobile devices. BlazePose approach predicts heatmaps for all joints using an encoder-decoder network architecture, followed by another encoder that connects (regression) directly to the co-ordinates of all joints. This approach scales to numerous keypoints, 3D support, and added keypoint characteristics without requiring an additional full-resolution layer for each new feature type.

Heart Rate Detection is a feature in many wearable smart watches such as Apple Watches, Garmin Vivoactive and Samasung Galaxy Watch. Heart Rate is detected using PPG (Photoplethysmographic) signals on the user's wrist. Zhilin Zhang's paper investigates the difficulties in getting accurate heart rate data from sensory devices which use wrist-type PPG technique (such as smart watches) when user is very active or engaged in vigorous movements [9]. A new method that relies on singular spectrum analysis was proposed in the study to eliminate motion artifact in raw PPG signals. To overcome the constraints of standard spectrum estimation techniques, a new sparse signal recovery-based spectrum estimation method was presented. According to experimental results on recordings from ten people, a new technique based on ground-truth heart rates from simultaneously recorded ECG has a 1.94 percent error rate when compared to motion artefact in raw PPG signals.

Sensors that touch the user's skin are required in most existing heart rate monitoring devices. Contactless physiological signal advancements have paved the way for a slew of new possibilities. The technology proposed in an IEEE paper [10] claims to be able to monitor heart rate an just through video. This technology's usefulness, as well as its limitations and potential remedies, necessitate careful evaluation. In this study, the HR measurement approach was put to the test in an environment with precisely regulated parameters , an environment where humans interacted naturally with the testing interface, and an exercise condition where there was vigorous movement by the test subject. During all sessions, HR was measured simultaneously with an electrocardiography equipment for comparison. The findings confirmed previous findings in controlled settings, but they could not be regarded a meaningful HR metric in the natural human-computer interaction. A machine learning strategy is suggested to increase the accuracy of HR detection in natural human-computer interaction measurements. The proposed technique reduces the root mean squared error from 43.76 to 3.64 beats per minute, according to the data.

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III. KNOWLEDGE REPRESENTATION

The complexity of the task involved in determining a pose is that it can vary from simple movements like walking to complex exercises like asanas and contortions. There are also various constraints such as the degree of freedom and the size of the limbs [4].

A. Computer Vision

OpenCV library enables developers to create computer vision models and object detection algorithms. It has more than 2,500 optimized algorithms and can be used to identify faces, monitor movements through camera, and identify object. The two important algorithms of OpenCV library are i) OpenPose and ii) BlazePose. Let us go through this algorithms.

1) OpenPose

OpenPose is a system which detects 135 body key-points on a single image. It was the first real-time multi-person system [5]. The Architecture of OpenPose is given as:

a) The feature maps are extracted in the beginning of the process itself by passing the image through a baseline Convolutional Neural Network.
b) Part Confidence Maps and part Affinity Field are generated by passing the feature map to a multi-stage Convolutional Neural Network pipeline
c) In the later stages of the method, the poses for every person in the image is extracted by executing a greedy bipartite matching algorithm on the arrogance maps and Part Affinity Fields.
d) Confidence Maps: A Confidence Map states that a particular body part can be located in a 2D fashion in any given pixel.
e) Part Affinity Fields: it's a gaggle of 2D vector fields that encodes location and limb's orientation of various people within the photographs. It encodes the knowledge within the type of pairwise connections between different body parts.

- *Limitations of OpenPose Algorithm:* When the images have non typical poses or upside-down objects, the OpenPose have problems detecting those objects or poses.

For example OpenPose tries to combine different people's annotations, in that it ignores some people due to the overlapped caused in the image. Because of this the Part Affinity Field fails the parsing of multi-person.

2) Blazepoze

For human pose estimation a lightweight CNN architecture called BlazePose is available. BlazePose tracks 33 points in 2D on body for tracking the pose of human body in one frame [6]. BlazePose accurately localizes more keypoints. One of the advantages of using BlazePose is that it gives real time output on mobile phones. So BlazePose can be used for real time pose tracking for example: exercise pose tracking and dance pose estimation. The architecture of BlazePose is given as:

a) The machine learning models in BlazePose perform following functions: The Detector crops the human region from the image fed to the model, while the Estimator takes a 256x256 resolution image of the detected person as input and outputs the key points.
b) The Detector is a Single-Shot Detector (SSD) based architecture. Given an input image, it produces a bounding box and a confidence score. There are two ways to use the detector: i) In box mode and ii) In alignment mode.
c) The Estimator uses heatmap for training, but produces keypoints directly without using heatmap for faster inference. The first output of the Estimator is landmarks, the second output is flags. The landmarks are made of 165 elements for every 33 keypoints.

- *Pros:* Approaches which are used currently requires more computing power than BlazePose. Instead it works efficiently on mobile CPUs as well. Considering the inference of GPU, BlazePose gives real time output on CPU inference. It is able to run Machine learning models efficiently without powerful computation.
- *Cons:* BlazePose performs slightly worse on AR datasets as compared to OpenPose.

B. Machine Learning Algorithm

A neural network in machine learning acts more like the neural network in human brains. A neuron which is a mathematical function, collects information and classifies it based on its architecture. Statistical methods such as curve fitting and regression analysis have a similar functionality to that of a network. Because neural networks have the flexibility to adapt to changing input, they can produce the optimal results without having to rethink the output criteria.

The neural networks will detect the wrong posture by the identified body points from computer vision. As the points are detected by using CV the neural network will go through the identification of the body parts by using those points. The algorithm will be fed with correct exercise postures. The ML model will then learn the correct exercise posture. The input images will go through the hidden layers of neural networks. For identification of the wrong posture in the image CNN or R-CNN can be used.

CNN (Convolution Neural Network) is a Deep Learning algorithm that takes an image as input, priorities various things in the image, and then classifies the objects. CNN requires significantly less pre-processing as compared to other classification algorithm [7].

The architecture of a CNN is analogous to the neuronal connection patterns in the human brain, notably the Visual Cortex organization. There are various architectures of CNNs available. Some of them are LeNet, AlexNet, VGGNet, ZFNet, GoogLeNet, ResNet. **I**nput images are an array of pixels that are dependent on the image resolution in relation to computers. According to the resolution of image, it will observe h * w * d where h is equal to Height, w is equal to Width, d is equal to Dimension.

Classification of images are majorly done with the help of CNN. But the problem lies in detecting an object in a picture and drawing bounding boxes around it [8].

1) R-CNN Algorithm Was Based On The Following Processes

a) First, extracting the image's Region proposals.

b) Convolutional Neural Network (CNN) for computing features.

c) Classifications of objects and create bounding boxes in the image.

Using a selective search algorithm the R-CNN algorithm first generates region proposals. And this algorithm is for around 2,000 region proposals. The region proposals in the image are cropped out and then resized. Then, CNN is used in order to compute features. Using these features, trained SVM is then used for classification and bounding-box regressor for refined regions.

2) Problems with R-CNN

a) Training an R-CNN networks consumes a huge amount of time.

b) Implementing in real-time is very difficult.

C. Heart Rate Monitoring

Heart rate is checked very often by doctors because it is an important parameter that determines how healthy you are. Now a days heart rate monitoring has become one of the most important part of our lifestyle. To fulfill this need there are many electronic devices available in market and in our mobile phones which helps in monitoring our heart rate. HeartPy is a python library which contains heart rate analysis tools. There are various methods for measurement of heart rate including Electrocardiography, Photoplethysmography, Oscillometry and Phonocardiography. Each of these methods measures heart rate in a different way [11].

a) Electrocardiography: Electrodes are placed in specific points on the human body to detect the electrical pulses generated by pacemaker of the heart. This pacemaker is called sino-atrial node. These nodes are called by group of tissues which does the job of contraction and relaxation of cardiac muscles.

b) Photoplethysmography: Blood has absorption properties where it absorbs infrared light to a certain extent based on its rhythmic flow in the body. Similar method is used by photoplethysmography. The infrared light is passed through the finger's or earlobe's blood vessel and then the signal which is received is checked. Through this signal the heart rate is detected by observing the blood flow and it's rhythm. [9]. This is the most common technique and is used in smart watches such as fitbit or apple watch.

c) Oscillometry: Pressure or piezo sensors put at appropriate locations on the human body can detect the pulsing of blood vessels caused by changes in blood pressure. This is used to assess the heart rate in a blood pressure monitor. The pulsing of blood vessels in an arm is shown in the diagram below using a pressure sensor with filtering and amplification. The oscillometric pulses that are measured in automatic vital sign monitors are known as oscillometric pulses. Figure 3 displays the graph of oscillometric pulses.

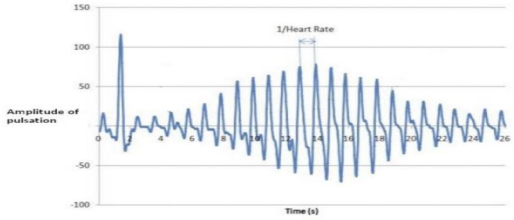

Figure 3: Oscillometric Pulses [11]

d) Phonocardiograph: Stethoscope is used to hear the sound produced by heart's opening and closing valves. These sounds are in phase with the heartbeat. Abnormal sounds called as murmurs are also heard along with the normal sounds such as S1, S2-Lub and Dub. With proper analysis of the normal sounds and the murmurs, the heart beat as well as abnormalities of the heart can be detected. Figure 4 given below shows normal and abnormal heart sounds.

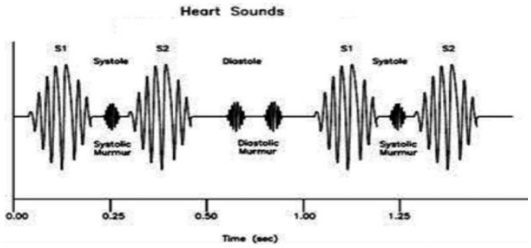

Figure 4: Heart Sounds [11]

e) Machine Learning based approach: This technique uses PPG to detect light reflected off the face to detect heart rate. However this technique is used least because of its comparatively low accuracy [10]. The artificial Intelligence based exercise app will take heart rate as an input from the user to avoid excessive exhaustion. In many instances people who are exercising exert more than what is healthy for their body and then sustain injuries. This can be avoided if the heart rate tracker keeps a track of the person's condition and tailor the exercise accordingly.

IV. ANALYSIS

An Artificial Intelligence System for correcting exercise movements is a complicated/intricrate system with multiple sub modules. These sub modules include pose detection, pose correction and heart rate monitoring. Some of the important factors to be considered are efficiency, latency, accuracy of pose. The system would require good internet connection for instantaneous feedback.

For body point detection possible technologies include Openpose, Blazepose, Posenet etc. Among these the most significant ones are openpose and blazepose. Openpose was the first body point tracking algorithm which was available to the developer. It detects 16 key-points on an image of an individual and detects 135 key-points if an image consists of more than 1 individual. Limitations of the openpose algorithm includes overlapping of some body parts in an image. This reduces the efficiency of the openpose algorithm and openpose also requires high system specifications to run. To overcome the problem, BlazePose algorithm can be used. Blazepose can detect upto 33 body key-points on an image of an individual and also it can run on mobile CPUs as well.

After detecting the body points through OpenPose or BlazePose the next step is to correct the posture of the user by the help of machine learning model. It can be implemented by using neural networks. CNN or R-CNN are used to detect the wrong posture in the images of the body points obtained from Computer vision. CNN as explained above takes image input and process it accordingly to detect the object in the images or estimate the wrong position while performing a particular exercise.

R-CNN also does the similar job like CNN but it is just region based where the regions in the images are selected first and then computing is performed not that region. It will be useful for posture correction as it will only focus on the body parts which have to be observed for that particular exercise or yoga asanas. But implementing R-CNN for realtime output is difficult. This is due to the factor that it requires time to train the network because around 2000 region proposals are generated.

Lastly the heart rate monitoring module will monitor the user for abnormal heart conditions. Multiple technologies exist in the market for heart rate detection and analysis. HeartPy is a python library with many inbuilt tools for heart rate analysis. The actual monitoring can be done through a various means such and PPG based wrist band, ECG, Oscillometry, phonocardiograph and machine learning based strategy. This strategy detects change in heart rate by detecting change in light reflecting off the users face when he/she is exercising. However advanced this method is, it is also very inefficient as accuracy changes with tilting of head, hence movement is highly restricted. The best choices include Electrocardiography and Photoplethysmography. Of the two, Electrocardiography gives the most accurate results but requires a lot of equipment and is mostly used in medical facilities. There are multiple electrodes stuck to the body in this process hence it will be very messy for the person to exercise with wires stuck to his body. Photoplethysmography is a simple technique where a low intensity infrared light is released on blood vessels so when there are volumetric changes in the blood due to change in heart rate, the reflection of light changes, thus indicating heart rate. PPG is used in most smartwatches as it is simple to use and very cheap . It provides fairly accurate results.

V. CONCLUSION

In this paper we have reviewed the different techniques and algorithms for the implementation of an AI systems for correcting exercise postures. The paper focuses on three modules: Computer Vision, Machine Learning algorithm and Heart rate monitoring. This paper analyses different algorithms for object detection such as BlazePose and OpenPose. CNN and R-CNN are discussed and how they are useful for the wrong posture identification. For Heart Rate monitoring 5 techniques have been explored; Electrocardiography, Photoplethysmography, Oscillometry, phonocardiography and machine learning based heart rate detection. After exploring all technologies and techniques for developing an AI based system for correcting exercise postures, the attempt will be to use such a model for making workout at home easy and safe from injury, hence promoting fitness to a new level.

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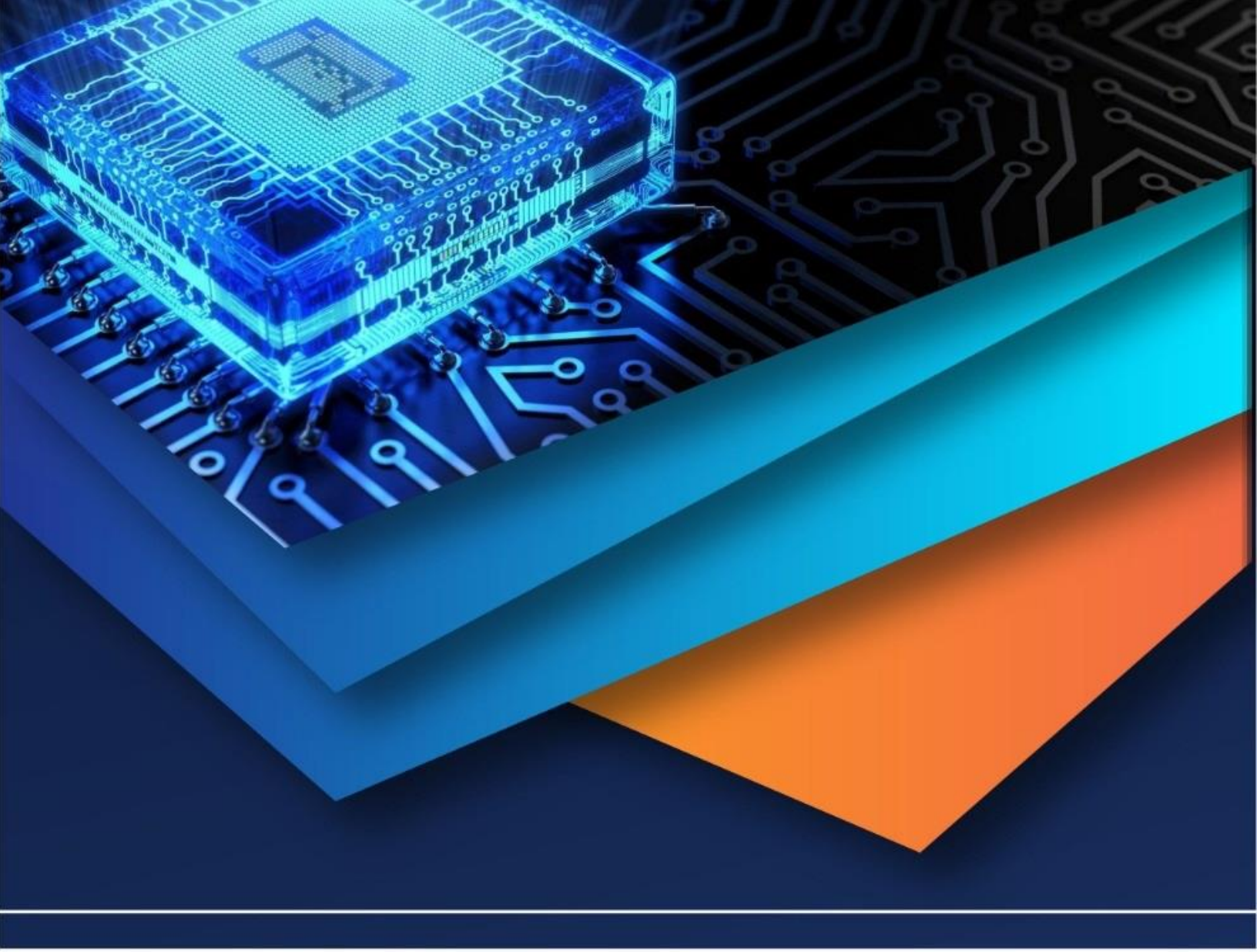

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