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Mango Classification for Agro-based Industries using Transfer Learning Technique

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Abstract: Mango is the popular tropical fruit that is consumed all around the world. India is the largest producer of mango and it is exported to many countries. Proper classification of mango is must in agro-based industries. The conventional methods were time-consuming and tedious. The aim of this paper is to develop an automated system which can recognize and classify mango images. The identification of mango species is necessary in Indian market. Hence in this proposed paper, a deep learning approach known as Convolutional Neural Networks (CNN) using transfer learning is used to classify mango species with high accuracy and implemented by retraining the pretrained CNN. The Inception V3 model is trained on various image dataset of 12 categories of mango. This proposed work is simple and efficient. This model achieves an overall test accuracy of 97.6% for the task of classification of mango images.
Keywords: Deep learning, Convolutional neural network, Transfer learning, Inception V3, Mango classification

I. INTRODUCTION

Mango, "the king of fruits" is a tropical natural product that is devoured all round the world. India produces half of the absolute world's mango production. Due to flavour, nutrition, and taste, mango is one of the popular fruits. It is consumed either directly or indirectly. It is a very sought after fruit. Mango has extremely high nutritive worth and wealthy in carotenes. Mango production contributes to economic growth of a nation. Export value is very high. As mango is a regular organic product, it is gathered from the tree on that season and moved to various areas. Thus any kind of false identification or procedure, not only hinder the ecological prominence of the fruit but also the economic importance of the fruit. Mango classification and recognition are still a huge challenge since there are 283 types of mangoes present in India only, from that 30 types of mangoes are well known. Only the experienced taxonomies can identify variety of mango. But most of the common people cannot identify. Mango characterization is a progressively troublesome undertaking as a result of interclass closeness and a huge intra-class variety and some are effected because of climate conditions. Since the nutritional value of each variety of mango is significantly different, there is a high need for classification of mangoes using a effective and economic technique. In agribusiness, the agro-based industries requires classification, because variety of mangoes are collectively used for manufacturing of indirect consumption products.

Because of the lack of expertise and thought of time associated with manual recognition in agro-based industries, a mechanized classifying framework is necessary. Recent years, Deep Learning has been used in agriculture and CNN is popularly implemented model. An existing CNN which has been pretrained, retrained utilizing transfer learning for the purpose of classification of mango varieties.

II. PROPOSED METHODOLOGY

The approach used in this analysis is transfer learning on Convolutional Neural Network (CNN). The CNN method is proven to have strong performance in multiple classifications of images. The transfer learning is used since it learns task for a large dataset and this knowledge gained over large dataset can be used to train the dataset that we provide. This would reduce the computations and the model complexity. In the proposed system, the pre-trained model used is Inception V3 which is trained on large Imagenet dataset.

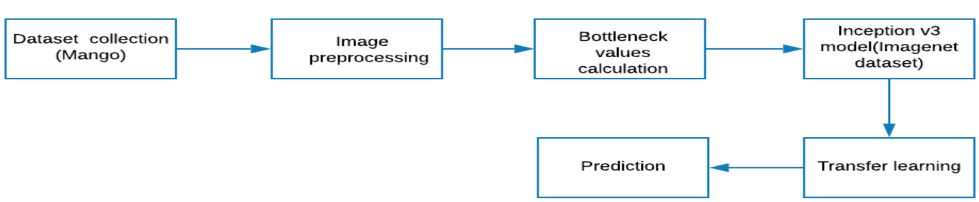

Fig. 1 Block diagram of the proposed methodology

A. *Pre-processing of Images*

Data pre-processing is an integral step in machine learning since the quality of the data and the useful information that can be derived from it directly affects our model's ability to learn. Therefore, it is extremely important that we pre-process our data before it is fed into our model. We process the data in this step to get it prepared for the training. It is composed of the following steps:

1) *Resizing of Images:* The dataset is collected from various sources due to which the dimensions of images vary. All the input images should have the same properties such as height , width, depth for a model to be trained. To make all the images with the same dimension, the images are resized to 299 x 299 pixels.
2) *Scaling of Images:* Scaling of images can be achieved by normalizing or standardizing real valued input and output variables. Standardizing a dataset means rescaling the value distribution, so that the observed values mean is 0 and the normal deviation is 1. Often, it's called "whitening". This could be considered as subtracting the mean value or centring the data.
3) *Labelling of Categories:* Data labelling is an essential part of data pre-processing, particularly for supervised learning, in which both input and output data are labelled for classification in order to provide a learning context for future data processing. During training we will need to define the class for every image in the dataset. The label for each class is taken from the subfolders of the training images directory.
4) *Train-Test Split:* Without splitting the dataset there wouldn't be certainty on how well the model performs on unseen data. So validation and test set are split so that there's a sense of how the model performs on various categories of data. This model takes 80% of data into training and remaining 20% of data for testing and validation.
5) *Bottleneck Layer Calculation:* Since the transfer learning approach is used, all the hidden neural network layers from the pre-trained model, including their structure and previously learned weights would be copied to the new model. The last layer of neural network that executes the true grouping into one of the classes, is strictly related to the old model, which will be disregarded in the new model. Hence the calculation of output values for the new dataset would be necessary to be fed into the final fully connected layer. These numeric values measured as next to last output layer of original model is called a "bottleneck".

B. *Brief Introduction of CNN*

A Convolutional neural network (CNN) is mostly applied in analysing visual images. The name CNN is derived from the fact that it uses a method called convolution instead of simple Mathematics. CNN is simplified version of multilayer perceptron. The basic structure of CNN consists of single input and output layers along with multiple hidden layers. There are several pooling, fully connected and normalization layers too. All these layers are together called as hidden layers. A pooling layer basically reduces the size of the output by reducing the dimension of the matrix. A ReLU layer acts as basically activation layer and removes the non-linearity by removing negative weights in the matrix. A fully connected layer in a neural network is a layer where all the inputs from one layer are connected to every activation unit of the next layer. Basically they are features of the training example. Then a softmax function is applied to the final layer to obtain the probabilities of the sample belonging to a particular class.

C. *Transfer Learning on CNN*

Training on image classification can be well accomplished from scratch. But, it's a very long and complicated process and could take weeks to complete due to high performance and hardware requirements. So, for simplification purpose, transfer learning approach is considered so that much of the computations and model complexity could be reduced. Transfer learning is a method in Machine learning where a model developed for a task can be reused as the starting point for a model on a second task. The below algorithm explains the working of it:

1) Obtain a pre-trained model, e.g. Inception v3.
2) Remove the last layer of the model that is used for classification since it strictly belongs to previously trained dataset. (Keep the weight values from the previously learned model is kept as it is).
3) Preprocess the images in the sub folders of the directory that has to be sent for training. Calculate the output values for this new dataset after passing through the first part of neural network .These output values are fed as input to the last layer.
4) Finally, add a fully connected layer which will calculate the probability of an image belonging to a particular class.
5) Now the final layer is trained with bottleneck values and ground truth labels that constitute the true labels of training images.

For each image, the top layer receives a 2048-dimensional vector as input. On top of this layer the training is done using softmax function. As the softmax layer contains N labels, it corresponds to learning N + 2048*N model parameters corresponding to the learned weights and biases.

The softmax layer is used to output the probabilities of belonging to a particular class and it ranges from 0 to 1. Cross entropy is a loss function that provides an insight into how well the learning process is advancing. The aim of this function is to minimize the loss as much as possible. After the loss has been calculated, the weight values and learning rate is updated using Adam optimizer. The model is trained for 500 epochs and for every 10 epoch, the training accuracy and validation accuracy is calculated.

III. EXPERIMENTAL SETUP

The experiments here are carried out with the help of TensorFlow library version 1.13.1. The code is written and executed in the PyCharm IDE. Experimental setup consists of data preparation and model training steps which are explained below.

A. Data Preparation

For any model to predict the output, input data has to be provided. The dataset collected were from various public sources like the Kaggle, Mendeley, GitHub, Image data etc. The image datasets of the mangoes obtained were fit enough to train the neural network model. . The acquired dataset consists of 2000 images belonging to 12 different classes of mango. The images are in JPEG format with three colour channels that is, RGB. The datasets are pre-processed before inputting them into the model. The images have been resized to 299*299 pixels, scaling of the images have been done by normalizing or standardizing real valued input and output variables. The proposed model employs supervised learning process, hence input labelling process is done by assigning each class of the mangoes a name out of the 12 categories. Individual categories of mango in the dataset consists around 100-260 images each which are divided into training and validation datasets with the percentages 80% and 20% respectively. Bottleneck values are calculated from the input images to train the final layer of the model.
The sample of the collected data set is shown in the Figure 2.

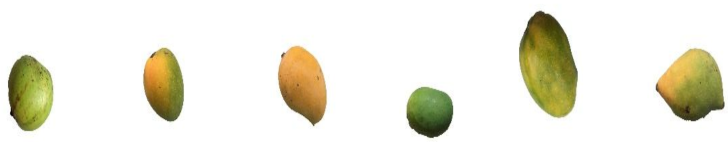

Fig. 2 Dataset samples

The details of the dataset collected are listed in the table below:

Table I
List of Mango Varieties

A. Serial No.	Variety	Image count
1	Aafush	261
2	Badami	143
3	Banganapalli	107
4	Dasheri	100
5	Desicada	106
6	Jamedar	136
7	Kesar	216
8	Mundapa	250
9	Neelam	150
10	Pairi	184
11	Rajapuri	147
12	Totapuri	200

B. Model Training

After the data preparation step, we proceed to train the model. As we are implementing transfer learning in CNN, we import the Inception V3 model which is a pre-trained convolutional neural network model, trained over a large dataset, ImageNet. The bottleneck values are calculated from the input data and stored in cache on the disk. These values are used to train the last layer of the model which is specific to our classification task. The model is trained for 500 epochs with training batch size of 100. The learning rate was set to 0.01. Cross entropy loss was chosen as the loss function and Adam optimizer was used as the optimization function. Softmax was used as the activation function for the final fully connected layer of the network. The performance of the model was evaluated by plotting epoch versus cross entropy and epoch versus accuracy graphs. The model showed maximum accuracy value at the 500^{th} epoch. The inception v3 architecture is as shown in the Figure 3.

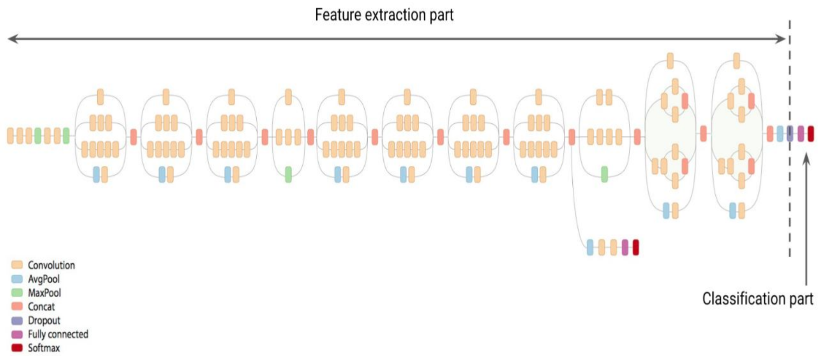

Fig. 3 Inception V3 Architecture [9]

IV. RESULTS AND DISCUSSIONS

In this section, the effectiveness of the method that is being implemented has been discussed. After implementing any model, inference is very much essential to check for the correctness. Around 2000 images of 12 varieties of mangoes has been collected from various sources such as GitHub, Kaggle, Mendeley etc. The images are classified as training and testing datasets. The dataset used for testing the model is entirely different from the dataset used for training .This is very much beneficial in predicting the accuracy of the model with new image datasets. Training dataset can be further divided for training and validation purposes. Initially, the model is trained using the training dataset. After training the model, the error in prediction can be calculated using the validation images. Validation datasets are very useful in increasing the accuracy of prediction of the model. The batch size is 100. The model is provided with the testing dataset samples with batch size 208.

The final test accuracy for the testing samples is found to be 97.6%. Initially, the user need to choose the image from the device and select “Submit Image” as shown in Figure 4.

The trained model predicts the variety and displays the output along with the region where that variety is grown. Here as shown in the output, the model has accurately predicted the varieties ’Dasheri’ and ’Kesar’. (Figure 5 & Figure 6).

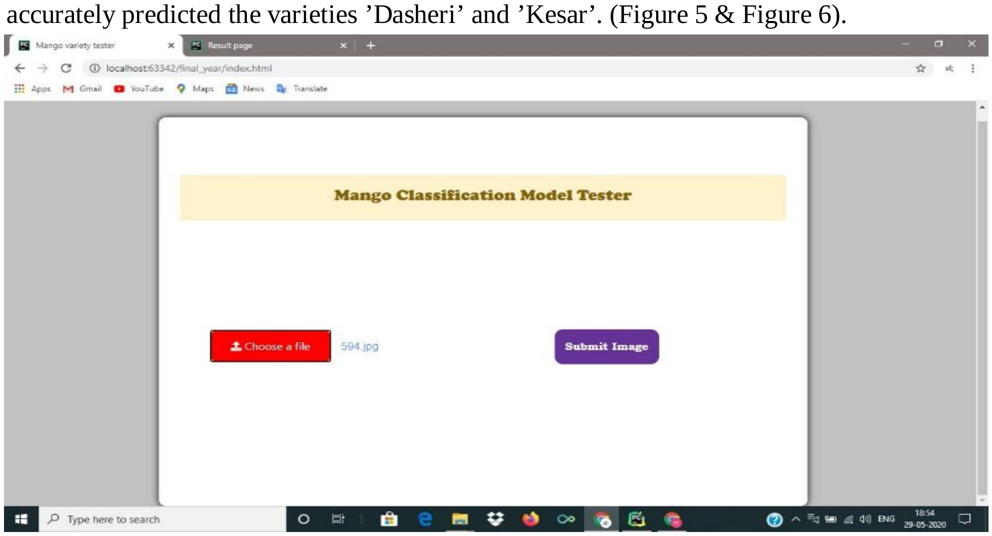

Fig. 4 Obtain User Input Image

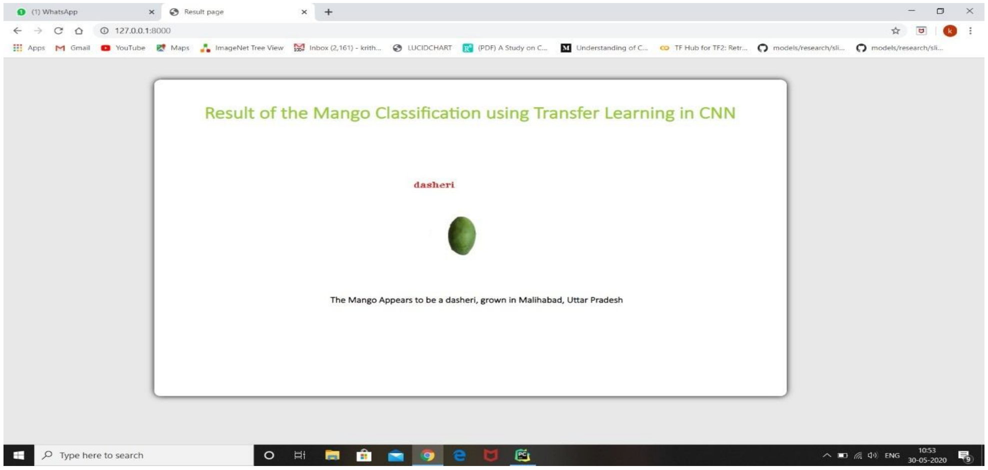

Fig. 5 Predicted Output is Dasheri

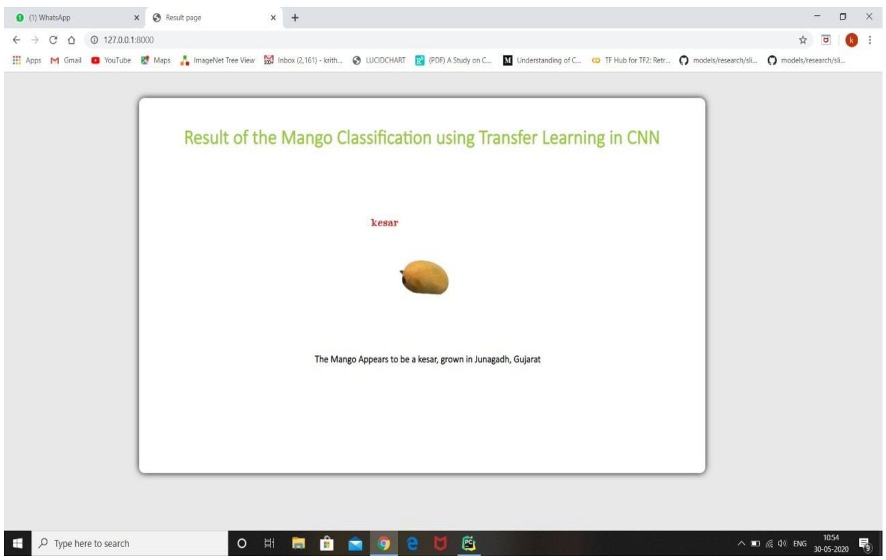

Fig. 6 Predicted Output is Kesar

The cross entropy value versus epoch graph is shown in the below Figure 7.This curve is used to study the error values during training with the various epoch values. As shown in the graph, the value of the cross entropy is maximum in the beginning and it reduces to minimum value (almost nearer to zero) at the 500th epoch. Thus, as the number of epochs increases, the cross entropy value decreases.

Figure 8 shows the accuracy curve. It represents the accuracy of both training and validation. The graph is plot between the accuracy and epochs. This graph implies that with the increasing number of epochs, the accuracy of both training and validation increases.

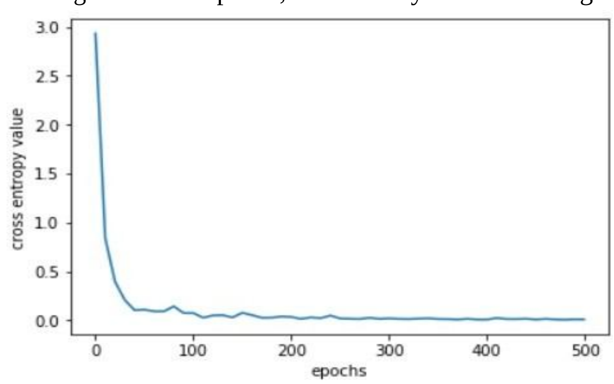

Fig. 7 Epochs versus Cross Entropy Value

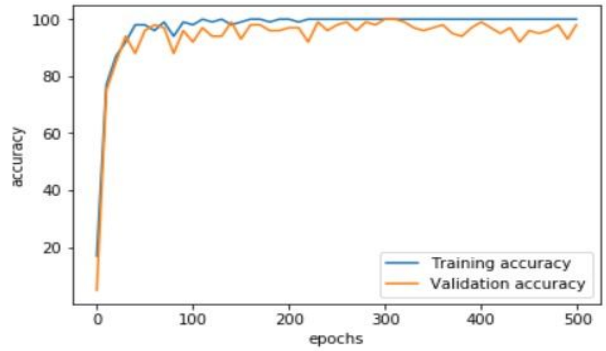

Fig. 8 Accuracy Curve

V. CONCLUSION AND FUTURE WORK

The experiment proposed in this paper has been implemented successfully. Transfer learning technique has been used because of its advantages like lesser time for training. Inception V3 model is used for the higher accuracy it offers. Also using color images instead of converting them into grayscale is advantageous since several features can be extracted. The proposed method can be improved by training model with more number of images.

Only 12 categories of mango have been used which can further be increased in the future to few more varieties as and when the datasets become available. Also mango images without any background information have been used, so the proposed model can be further extended to work for even images with background information. The proposed ideology can also be extended to mobile applications where people can recognize mango varieties via their mobile devices. This can be achieved by training the model with a large varieties of mango and by making some changes to the model so that it would be computationally compatible with the mobile devices.

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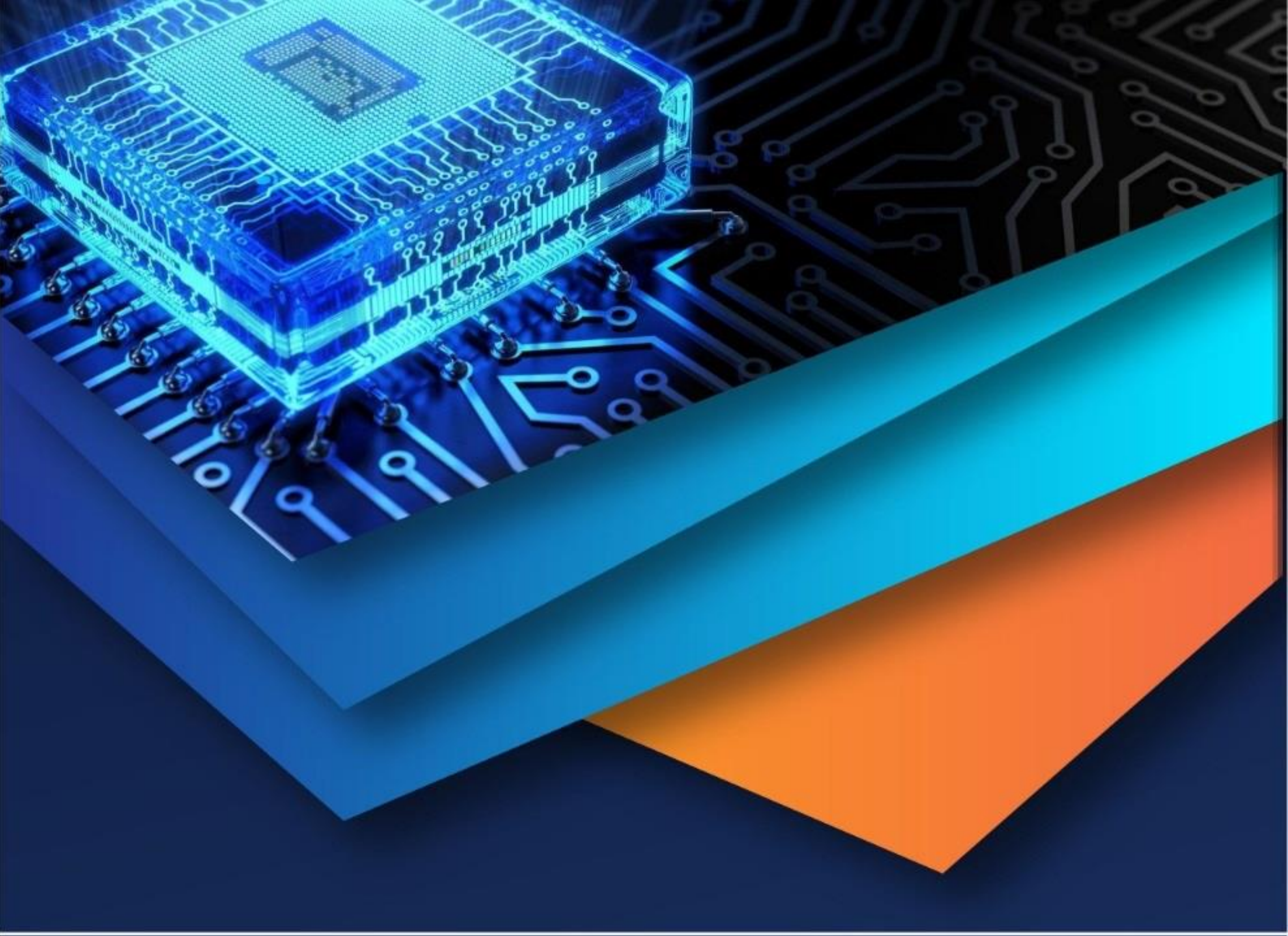

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