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Grading and Sorting of Capsicum Using Convolutional Neural Networks (CNN): A Review

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Abstract: ***Grading and sorting of capsicum, or bell peppers, is a critical task in the agricultural industry to ensure consistent quality control and efficient distribution. In recent years, Grading & Sorting of Capsicum using Convolutional Neural Networks (CNNs), have shown promise in automating this process. The objective is to automate the Grading and Sorting process, which currently done manually and time-consuming. The proposed approach involves the collection of capturing dataset of capsicum images, extracting relevant features, and training a CNN model to classify the capsicum based on their quality criteria such as size, shape, color, and quality levels. These images are pre-processed to enhance their quality and standardize the inputs. A CNN architecture of 85 trained datasets and 33 tested datasets images using for accurate grading and sorting. After the training phase, the model's accuracy is evaluated using appropriate metrics such as precision, recall, or F1-score. The performance of the CNN model of grading and sorting system is determined based on the accuracy values, providing an objective measure of its effectiveness. Experimental results of testing datasets obtained an accuracy value of above 90% indicates that the system correctly classified, the capsicum into their respective grades or sorted categories 97.43% accuracy achieved.***
Keywords: PyCharm IDE, Python 3.11, OpenCV, Image Processing, Grading & Sorting (G&S), Convolutional Neural Network (CNN), Capsicum Images, etc.

I. INTRODUCTION

Capsicum, scientifically known as "*Capsicum Annuum*". Capsicum, other names such as; *Bell-pepper* or *sweet-pepper* in America, *Peppers* in United Kingdom, and *Shimla-mirch* in India. It is a *genus* of flowering plants, belongs to *Solanaceae* (nightshade) family. Capsicum originated in the Central American & Mexico and first use in food since 6000 BC [20]. Its cultivation started in Spain by Columbus in 1493, however it spread to Mediterranean region and England in 1548. It was brought to India by Portuguese from Brazil prior to 1885, & In China it came under cultivation during the late 1700s, now Capsicums spread all over the world. In India, grown in states like Punjab, Maharashtra, Andhra Pradesh, and Karnataka, & grown in countries like China, Mexico, Spain and the United States [8]. Capsicum obtained various Colors like, Green, Red, Yellow, orange, White, Chocolate, Candy cane striped, Black, and Purple, depending on the variety. But the most common colors of bell peppers are Green, Yellow, Orange and Red. Capsicum is the popular vegetable used in various cuisines around the world, Dishes like, curries, stir-fries, salads, and even stuffed peppers [31]. Capsicum, rich in vitamins C, B6, A, & K, which are essential for healthy immune system. Table.1 Shows the Capsicum nutritional components & its value composition of 100 grams. Capsicums, contains anti-oxidants that help protect against cell damage & inflammation. Also used for weight loss, improve digestion, pain relief, & Anti-cancer properties [10].

Table 1 Capsicum nutritional composition.

S. no.	Nutritional Components	Value composition of 100 grams
01.	Calories.	20 kcal
02.	Carbohydrates	4.6 grams
03.	Dietary fibre.	1.7 grams
04.	Sugar.	2.4 grams

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05.	Fat.	0.2 grams
06.	Protein.	0.9 grams
07.	Vitamin C.	127.7 milligrams (213% of the daily recommended intake)
08.	Vitamin A.	1577 international units (32% of the daily recommended intake)
09.	Vitamin B6.	0.3 milligrams (14% of the daily recommended intake)
10.	Vitamin K.	4.9 micrograms (6% of the daily recommended intake)
11.	Potassium.	211 milligrams
12.	Magnesium.	10 milligrams
13.	Folate.	10 micrograms

Grading & Sorting of Capsicum, is an important process in the agricultural industry. G&S involves evaluating the quality and characteristics of capsicum based on factors like size, shape, color, and texture. Helps ensure that only the highest quality capsicum reaches the market. Manual grading is traditionally done by human inspectors, but advancements in technology have led to development of automated systems that use computer vision and image processing techniques. These systems analyze capsicum images and classify them into different grades based on predetermined criteria. CNN's is an exciting application that combines the power of computer vision and machine learning techniques. By training a CNN model to recognize and classify dataset images into different quality & grades based on their visual features. The CNN model learns to extract relevant features from the images and make accurate predictions. This automated approach save time, improves accuracy, and efficiency to ensuring consistent quality control in Grading and Sorting process. The Literature reviews of the Research Papers studies that the comparison of the Automated classification shown in Table 2.

Table 2 Comparison table of Automated classification.

S. No.	Authors	Fruits & Vegetables	Automated classification	Accuracy
1	H. Ayesha et al. (2022)	Mangoes	Classification & Grading using CNN, VGG16, ResNet152, and Inception v3 augmented data.	96.7%
2	Y. A. Azis et al. (2021)	Dried Chilli	Digital Image Processing & Artificial Neural Networks (ANN) i.e., Grades, Mean a*, Mean Blue, Mean Contrast.	94.4%
3	et al. (2020)	Capsicum annuum	Quality assessment using smartphone camera, i.e., ANN, GUI, MATLAB, red, green, a*, and intensity.	90.43%
4	N. Khuriyati et al. (2019)	Chilli Peppers	Sorting & Grading using Digital Image processing, ANN, MATLAB,3 Layers red input, energy, and correlation.	84.46%

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5	K. Yadav et al. (2018)	Real time Fruit	Sorting using Computer Vision & Machine Learning i.e., KNN, OpenCV, Preprocess, Feature Extraction.	88%
6	Shakshi Jha et al. (2016)	Tomatoes	Automated Grading technique, digital Image Processing, system enable the non-destructive gradation.	84%
7	WAN P.N.W.M. Tahir et al. (2015)	Rice	Grading using Image processing, RGB color model, histogram,	46.6%
8	Haider et al. (2012)	Dates	Nearest Neighbor (Euclidean), LDA, ANN.	96.7%
9	Leiva et al. (2011)	Blueberries	LDA, QDA, ANN, SVM, KNN, Image Processing.	96%
10	Yousef Al Ohali et al. (2010)	Date	Computer vision grading system, RGB, Extracted features, Neural networks, Hardware; Conveyor, Camera Control and Helm control systems.	80%
11	G. Bernard et al. (2005)	Apple	ANN-based segmentation, grading by machine vision, Pixel-wise processing, Linear discriminant, nearest neighbor, Fuzzy, Adaboost & Support vector machines (SVM) classifiers.	90.3%

II. MATERIAL & METHODS

A material requires of the capsicum grading and sorting using CNN of the several steps involved:

A. Integration with Hardware

To Integrate Hardware for grading and sorting of capsicum using CNN for used such that, Central Processing Unit (CPU) with a high-performance CPU, such as AMD Ryzen 5000 series 5, or Intel Core i7, with multiple cores for efficient computers. The Graphics Processing Unit (GPU) is used a powerful GPU such as AMD Radeon Graphics from Ryzen series, or other graphics used NVIDIA GPU from GeForce RTX or Tesla series, for accelerated Grades and Sorts of capsicum using CNN. To handle the datasets and implements results during training are sufficient memory used such as Random Access Memory (RAM) is 16 GB or more. The sufficient storage capacity used such as solid-state drive (SSD) is 512 SSD, or 1- 2 TB hard-drive, to store the Capsicum datasets, pre-processed images, and trained models.

B. Software and Frameworks

To implement the grading and sorting of capsicum using CNN, can use software tools such as Python 3.11, OpenCV, Keras, and TensorFlow. Use a suitable Operating System such as Windows 10 or 11, Linux, or macOS. Python provides a flexible programming environment, while OpenCV offers powerful image processing capabilities. TensorFlow or Keras is a popular framework for building and training CNN models. In CNN-model use the Software Anaconda Navigator, Spyder, & PyCharm IDE, which provides the Image Processing APIs supports a wide variety of media types that can be processed and transformed. It supports reading JPEG, PNG, WebP, GIF, JPG, AVIF, TIFF, SVG formats, that perform image processing in Grading and Sorting using CNN techniques and computer vision tasks. Construct a convolutional neural network (CNN) architecture using libraries like OpenCV, TensorFlow or Keras. It can involve using convolutional layers, pooling layers, and fully connected layers. Train the model on the preprocessed capsicum image dataset, adjusting the hyperparameters and optimizing the model's performance.

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Use the trained CNN model to classify new capsicum images into multiple angles or different grade & sort categories. Apply image processing techniques, such as color analysis, to extract relevant features for grading.

These steps are high-level overview and the actual implementation may involve more specific details and codes & also needing access to specialized hardware like Cameras and conveyor belts, to make the sorting process more efficient. It can effectively grade and sort capsicum based on desired criteria, contributing to improved efficiency and productivity in the agricultural industry.

III. METHODOLOGY

To develop a system for the grading and sorting of capsicum using CNN involves several critical steps and methodologies. Below is a comprehensive methodology for achieving accurate and efficient capsicum grading and sorting using CNN are:

1) Gather a dataset of capsicum images with corresponding grading labels. This dataset should include images of capsicum at different stages of color development, & includes color, size, shape, and the presence of defects scenarios. Preprocess the collected images by resizing them to a consistent size, normalizing pixel values, and applying any necessary image enhancements or filtering techniques. Split the dataset into training and testing datasets. The training set will be used to train the CNN model, while the testing set will be used to evaluate its performance.

2) Design the architecture of the CNN model. This typically involves stacking convolutional layers, pooling layers, and fully connected layers. Experiment with different configurations to optimize the model's performance. Experiment with various CNN architectures, such as VGG, ResNet, or Inception, to find the most suitable architecture for capsicum grading. Train the CNN model using training dataset. This involves feeding the preprocessed capsicum images into the model and adjusting the model's weights or size through back-propagation and Gradient descent algorithms, and optimization other techniques. Iterate this process until the model achieves satisfactory accuracy. Evaluate the trained model's performance using the testing dataset. Measure metrics such as accuracy, precision, recall, and F1 score to assess its effectiveness in grading and sorting capsicum. Once the model is trained and evaluated, apply it to new, unseen capsicum images for grading and sorting. The model will classify the images based on their color attributes and assign them to the appropriate grade or sort category. Validate the grading and sorting system by testing it on a separate test dataset or real-time images. Make adjustments and refinements as needed to improve the accuracy and reliability of the system.

3) Deploy the grading and sorting system in the desired production environment. In CNN to integrate the trained model into a practical system that can process images in real-time. This could involve developing a user-friendly interface, connecting with cameras or image sensors, and implementing the necessary algorithms for grading and sorting based on the CNN model's predictions. Analyze the performance of the grading and sorting system. Assess its accuracy, efficiency, and any potential limitations or challenges encountered during the process. This methodology can develop a robust and accurate system for grading and sorting capsicum using CNN. Sucessful implementation can lead to highly accurate, efficient, and cost-effective capsicum grading and sorting systems.

IV. IMPLEMENTATION & RESULTS

Grading and Sorting capsicum (bell peppers) using CNN (Convolutional Neural Networks) can be a fascinating application. CNNs analyze the visual characteristics of Capsicum such as color, shape, size, and defects, to accurately grade and sort them. To implement this, a dataset of labelled capsicum images is needed for training the CNN model. The model learns from these images to recognize and classify different grades or categories of capsicum based on predetermined criteria. During the grading and sorting process, the capsicum is visually inspected by capturing images from multiple angles. These images are then fed into the trained CNN model, which makes predictions about the grade or category of each capsicum based on its visual features. The CNN model can effectively detect and classify various attributes, such as color uniformity, size consistency, absence of defects, and overall appearance. This automation improves efficiency, reduces human error, and ensures consistent grading and sorting results. Implementing CNN-based grading and sorting systems for capsicum can greatly benefit the agricultural industry by enhancing productivity, optimizing quality control, and reducing manual labor. It's an exciting application that shows the power of computer vision and machine learning in agriculture. The implement of the grading and sorting of capsicum using CNN, is need a dataset of labelled images of different grades of capsicum (i.e., Class A, Class B, & Class C). Then, the train the CNN model to recognize and classify the capsicum based on their grades. It's a complex task, but with the right data and training, it can be done! It's important to have a good understanding of the underlying concepts and access to relevant tools and libraries like TensorFlow, Keras, OpenCV, or PyTorch., etc. Let's see results, How to implement that training & testing datasets of the Grading and Sorting of Capsicums using CNN model techniques.

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Fig 1 Training and Testing datasets of Grading and Sorting of Capsicums.

A. Collections of Training datasets

The 85 samples of training datasets are divided into 3 classes (i.e., Class A, Class B, & Class C). This dataset collections of tests are determined the relationship between color of the Capsicums and quality classes as shown in Table 3. Image capturing of Fresh and Defected Capsicums with a OPPO Reno8T 5G smartphone of the rare camera 108MP + 2MP +2MP with a blur background of some images and some simple Camera images. The images was taken fresh and defected capsicums 4-5 times each and then moved to the laptop for check Grading & Sorting of capsicum using CNN techniques. Check all datasets images was implements Python programme codes using Python 3.11 software, open Anaconda Navigator, & install PyCharm IDE and Spyder software used. The using libraries such that OpenCV, Keras, or TensorFlow, for CNN-parameters technique used for Grading and sorting of Capsicum.

Table 3 Training dataset collections of all classes of Capsicum.

S.no.	Class	Capsicum Colors & Weight	Training Datasets
01.	Class A (Pure Green)	Pure Green (Green>98%) & Weight>300g /1 Capsicum.	42
02.	Class B (Mix Green)	Green, Yellow, Orange, Red (Green<90%) & Weight>250g/ 1 Capsicum.	27
03.	Class C (Defected Green)	Dark Green or Black (Green<50%) & Weight<150g/1 Capsicum.	16
			Total: 85 capsicum pieces.

B. Data Preprocessing

The preprocessing datasets of Capsicum images by resizing, normalizing, filtering, by using Python programming language & libraries such as OpenCV or PIL (Python Imaging Library). In Python using OpenCV library is resize an image to a desired dimension, such as 'cv2.resize(image, (200, 200))' by using 'resize' function, normalize pixel values to a specific range, such as [0,1] or [-1,1] by using the 'normalize' function, and convert color spaces,such as grayscale or HSV by using the 'cvtColor' function, and apply other preprocessing techniques. Remember to install the required libraries and modify the code based on specific preprocessing needs. To complete the codes in OpenCV, need to use trained model to predict the grades and sort of the capsicum. Implement any sorting algorithm or logic based on the predict grades or sort the capsicum accordingly.

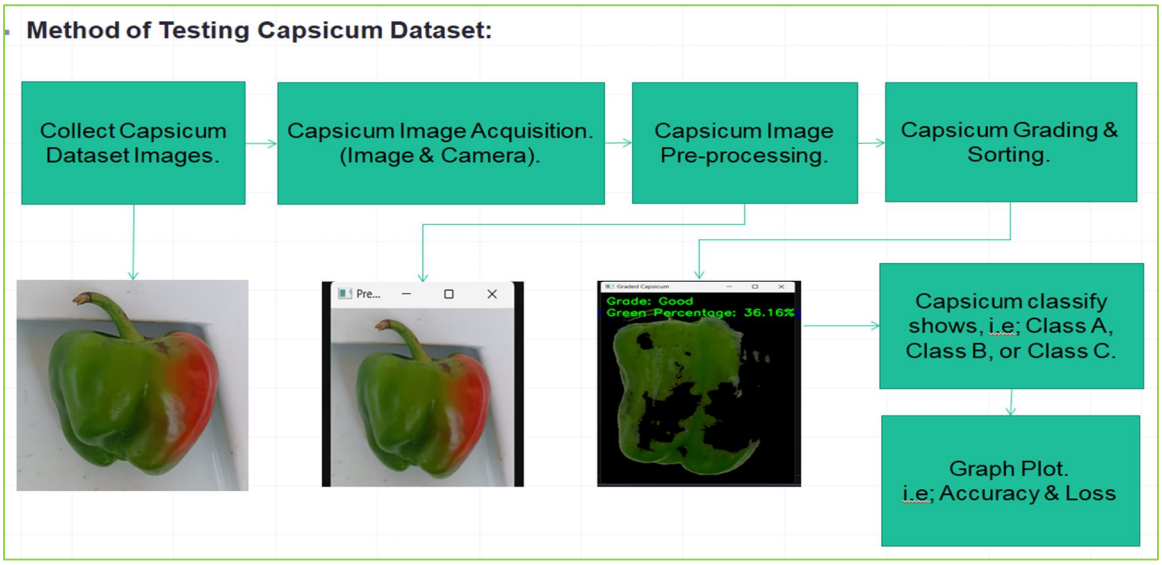


Fig 2 Block diagram of the Training & Testing datasets of Capsicum Grading & Sorting using CNN.

C. Model Architecture

Built CNN model architecture suitable for grading and sorting of the capsicum using CNN. Stack convolutional layers, pooling layers, and fully connected layers. Train the CNN model using training dataset. Perform forward propagation, calculate loss, update the model's parameters through backpropogation, adjusting hyper-parameters and optimizing the model's performance.Evaluate the trained model using the testing dataset to measure its accuracy, loss and performance. Apply the classify image & training model is trained and evaluated, its use to predict the grade of new capsicum images. Predict the grade of each image based on the model's output. To plot a graph of the model's performance, the metrics like accuracy and loss during training and testing. Then, use libraries like Matplotlib to visualize the metrics over epochs.

D. Experimental results of Testing datasets

The classification of actual testing datasets is 33 samples and also divided into 3 classes and represented the predictions (i.e., correct prediction & false prediction) and also its accuracy level shown in Table 4. The Class A & Class C is correct predictions, but the Class B is False prediction because of the color of Capsicum. Then, the level of accuracy is 97.43% achieved.

Table 4 The 33 testing dataset results of the Grading & Sorting Capsicum.

S. no.	Class	Actual Testing dataset	Correct prediction	False Prediction	Level of Accuracy
01.	Class A (Pure Green)	11	11	0	100%
02.	Class B (Mix Green)	13	12	1	92.307 %
03.	Class C (Defected Capsicums)	9	9	0	100%
					Average Accuracy: 97.43%

E. Result of Accuracy & Loss of Training Datasets & validation datasets

When the training datasets and validation datasets for grading and sorting capsicum using a CNN (Convolutional neural Network), accuracy is a key factor. The training dataset should consist of a large number of labelled images of capsicum at different grades & quality. To ensure accuracy it is important to have a diverse dataset that covers various lighting conditions, angles, and backgrounds. This helps the CNN learn to recognize and classify capsicum accurately in different scenarios.The augment the dataset by applying transformations such as rotations, flip, and changes in brightness to increase its variability. Once the training dataset process is completed. Then, split it into two parts: the training set and the validation set. The training set is used to train the CNN, while the validation set is used to evaluate its performance during training. This helps prevent overfitting the model performs well on the training data but poorly on new, unseen data. During training dataset the CNN learns to features extract from the images and make predictions based on these features. It optimizes its parameters to minimize the loss function, which measures the difference between the predicted and actual grades of the capsicum. The goal is to minimize this loss and maximize the accuracy of the predictions.

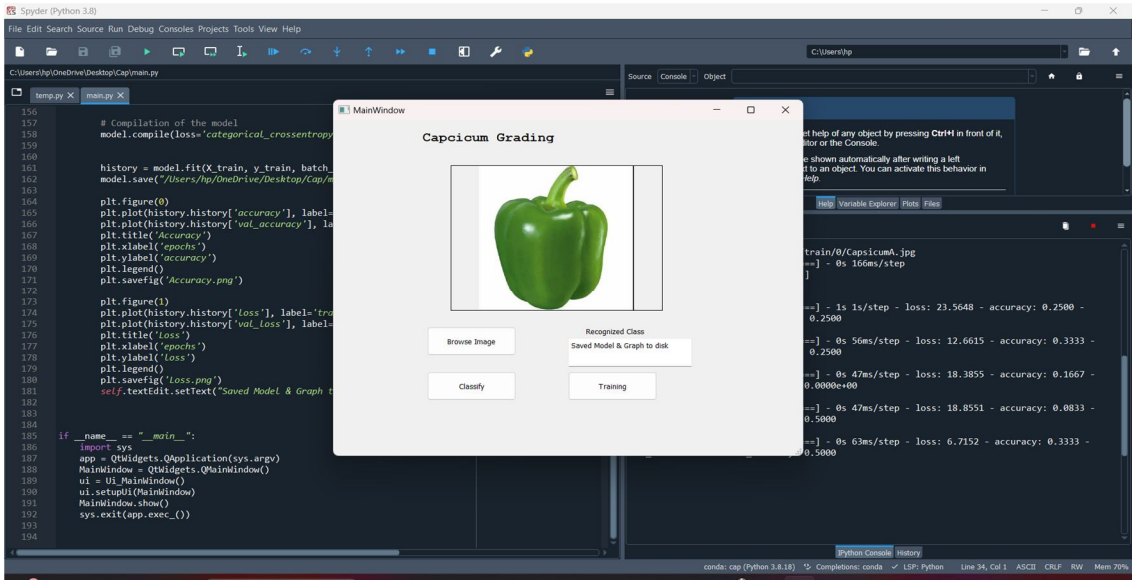


Fig 3 The Grading & Sorting of capsicum using CNN model & recognized Classes & its epochs.

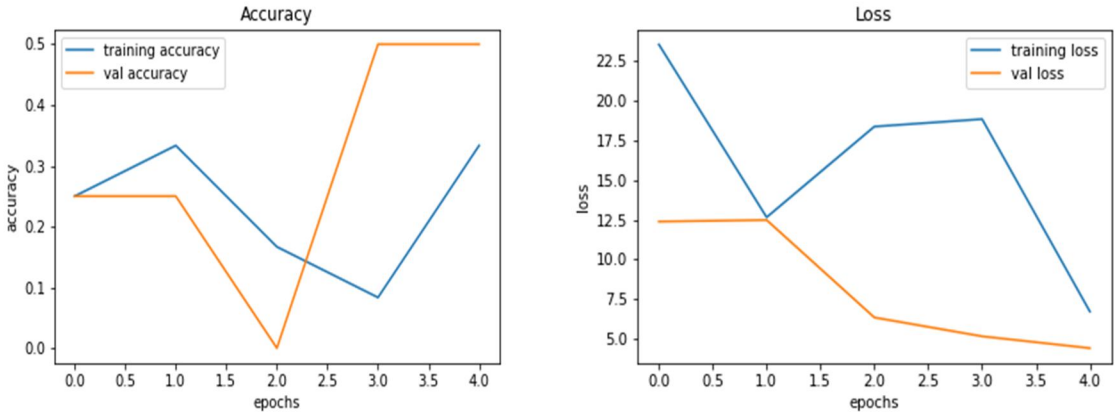


Fig 4 The graphs plot the epochs of accuracy & loss of the training & validation datasets.

The final graph output result shows accuracy/epochs & loss/epochs of the training & validation datasets of all grades of the Grading & Sorting of capsicum using CNN model in Fig 4. To further enhance accuracy, use techniques like transfer learning, this means start with a pre-trained CNN model and fine-tuning it with capsicum dataset. This leverages the knowledge already learned by the pre-trained model, saving training time and potentially improving the accuracy. The quality and diversity of training and validation datasets play a crucial role in the accuracy of CNN model for Grading and Sorting Capsicum.

V. CONCLUSIONS

Based on the research and experimentation conducted on grading and sorting of capsicum using CNN, It's concluded that this research paper offers a promising solution by leveraging computer vision techniques, It becomes possible to accurately classify and sort capsicum based on various parameters such as color, size, and shape. This automated process not only improves efficiency, but also reduces human error in the grading and sorting process. Further research and refinement of the CNN models can lead to even more accurate and efficient results. Overall, the integration of Grading and Sorting using CNN model holds great potential for enhancing productivity and quality control in the agricultural industry. The future work, for Grading and Sorting of Capsicum using CNN is quite promising. When Integrating it with hardware, it can develop a Robotics system for automated grading & sorting process, increasing efficiency, reducing human error or enhance accuracy, Real-time processing, and expansion to other agricultural products. The advancements in CNN models, can expect even more precise and automated grading systems in the future. It's an exciting time ahead for capsicum sorting in agricultural technology.

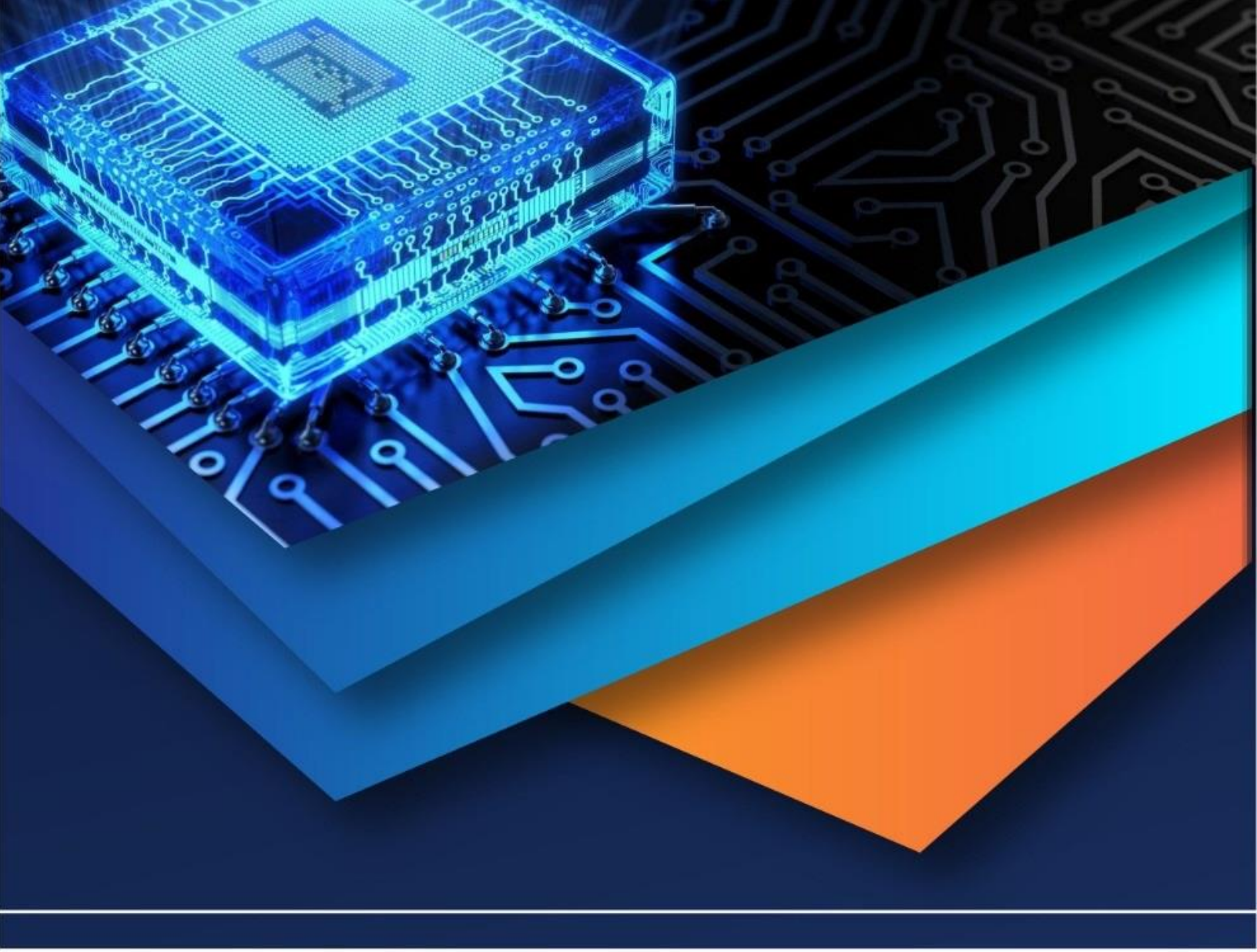
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