iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VII **Month of publication:** July 2026

DOI: https://doi.org/10.22214/ijraset.2026.84428

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VII July 2026- Available at www.ijraset.com

An Automatic Diabetic Retinal Disease Classification Model Using Hybrid Convolutional Neural Networks Based on Fundus Images

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Abstract: ***Diabetic Retinopathy (DR) is a severe complication of diabetes that can cause retinal damage and lead to blindness if not properly managed. Traditional DR screening, conducted by ophthalmologists, is time-consuming, highlighting the need for more efficient detection methods. This project leverages Deep Learning (DL) to automate DR detection using Mobile Net, a lightweight model trained on 3,662 high-resolution fundus images from the APTOS 2019 dataset. The Mobile Net model is designed to classify DR into five stages, ranging from zero to four. To further enhance performance, we investigate hybrid models that combine Mobile Net with other architectures: Mobile Net + Graph Neural Network (GNN) and Mobile Net + Recurrent Neural Network (RNN). The Mobile Net + GNN hybrid aims to capture complex spatial relationships within retinal images, potentially improving classification accuracy by interpreting structural patterns. The Mobile Net + RNN hybrid focuses on addressing sequential dependencies and temporal patterns, thereby enhancing the model's capability to detect subtle changes across different DR stages. Our results demonstrate that the Mobile Net + GNN model achieved an accuracy of 92%, while the Mobile Net + RNN model reached an accuracy of 81%. These findings suggest that the hybrid approaches offer a promising path to optimize DR detection, improving both accuracy and efficiency compared to traditional methods.***
Keywords: Deep learning, Diabetic Retinopathy (DR), APTOS 2019 Dataset, Fundus Images, Mobile Net, Graph Neural Network (GNN), Recurrent Neural Network (RNN), Retinal Image Classification.

I. INTRODUTION

Diabetic Retinopathy (DR) is a significant and escalating health issue that affects millions of individuals with diabetes globally. As one of the leading causes of blindness, DR presents a critical challenge in ophthalmic care. The condition arises from prolonged exposure to high blood sugar levels, which damages the blood vessels in the retina, the vital light-sensitive tissue at the back of the eye. Over time, these damaged vessels can leak fluid or bleed, leading to vision impairment and, ultimately, blindness if left untreated. DR progresses through several stages, from mild non-proliferative DR (NPDR) to severe proliferative DR (PDR), each characterized by increasing levels of retinal damage and visual deterioration. Early detection and timely intervention are essential for preventing the progression of DR and preserving vision. However, the current methods for screening and diagnosing DR primarily involve manual examination by ophthalmologists, which is both labor-intensive and prone to variability. This traditional approach requires extensive training and experience, and despite the expertise of ophthalmologists, the process can be time-consuming and susceptible to human error. As a result, there is a pressing need for more efficient and accurate methods of DR screening that can complement and enhance existing diagnostic practices.

In recent years, advancements in artificial intelligence (AI) and deep learning (DL) have offered promising solutions to address these challenges. Deep learning, a subset of AI, involves training neural networks to recognize patterns and make decisions based on large datasets. These techniques have shown remarkable success in various medical imaging applications, including cancer detection, brain imaging, and now, retinal imaging. By leveraging DL models, it is possible to automate the analysis of fundus images photographs of the retina and provide consistent, high-quality assessments of DR severity. Our project aims to harness the power of deep learning to develop an automated DR detection system. We propose to utilize Mobile Net, a lightweight and efficient deep learning model, for this task. Mobile Net is particularly well-suited for image classification tasks due to its balance of accuracy and computational efficiency, making it an ideal choice for processing high-resolution fundus images.

The Mobile Net model will be trained on a substantial dataset of fundus images, enabling it to learn and identify the various stages of DR with high precision. The APTOS dataset, sourced from Kaggle, will be the foundation for our model training. This dataset includes 3,662 high-resolution fundus images, each labeled with one of five DR stages: Stage 0 (No DR), Stage 1 (Mild NPDR), Stage 2 (Moderate NPDR), Stage 3 (Severe NPDR), and Stage 4 (Proliferative DR). By employing Mobile Net, we aim to achieve accurate classification of these stages, which will facilitate early diagnosis and intervention

II. LITERATURE REVIEW

[1] Deep learning is a family of computational methods that allow an algorithm to program itself by learning from a large set of examples that demonstrate the desired behavior, removing the need to specify rules explicitly. Application of these methods to medical imaging requires further assessment and validation. The sensitivity and specificity of the algorithm for detecting referable diabetic retinopathy (RDR), defined as moderate and worse diabetic retinopathy, referable diabetic macular edema, or both, were generated based on the reference standard of the majority decision of the ophthalmologist panel. The algorithm was evaluated at 2 operating points selected from the development set, one selected for high specificity and another for high sensitivity.

The automatic detection of diabetic retinopathy is of vital importance, as it is the main cause of irreversible vision loss in the working-age population in the developed world. The early detection of diabetic retinopathy occurrence can be very helpful for clinical treatment; although several different feature extraction approaches have been proposed, in this paper, we explored the use of deep convolutional neural network methodology for the automatic classification of diabetic retinopathy using color fundus image, and obtained good accuracy on our dataset, outperforming the results obtained by using classical approaches [2].

Diabetic Retinopathy (DR) is a constantly deteriorating disease, being one of the leading causes of vision impairment and blindness. Subtle distinction among different grades and existence of many significant small features make the task of recognition very challenging. In addition, the present approach of retinopathy detection is a very laborious and time-intensive task, which heavily relies on the skill of a physician. Automated detection of diabetic retinopathy is essential to tackle these problems. Early-stage detection of diabetic retinopathy is also very important for diagnosis, [3] which can prevent blindness with proper treatment. In this paper, we developed a novel deep convolutional neural network, which performs the early-stage detection by identifying all micro aneurysm (MAs), the first signs of DR, along with correctly assigning labels to retinal fundus images which are graded into five categories. We have tested our network on the largest publicly available Kaggle diabetic retinopathy dataset, and achieved 0.851 quadratic weighted kappa score and 0.844 AUC score, which achieves the state-of-the-art performance on severity grading.

[4] Diabetic retinopathy is a leading cause of blindness among working-age adults. Early detection of this condition is critical for good prognosis. In this paper, we demonstrate the use of convolutional neural networks (CNNs) on color fundus images for the recognition task of diabetic retinopathy staging. Our network models achieved test metric performance comparable to baseline literature results, with validation sensitivity of 95%.

We additionally explored multinomial classification models, and demonstrate that errors primarily occur in the misclassification of mild disease as normal due to the CNNs inability to detect subtle disease features. We discovered that preprocessing with contrast limited adaptive histogram equalization and ensuring dataset fidelity by expert verification of class labels improves recognition of subtle features. Transfer learning on pretrained GoogLeNet and AlexNet models from ImageNet improved peak test set accuracies to 74.5%, 68.8%, and 57.2% on 2-ary, 3-ary, and 4-ary classification models, respectively.

[5] Diabetic retinopathy (DR) is one of the major causes of blindness worldwide. With proper treatment, early diagnosis of DR can prevent the progression of the disease. In this paper, we present a new feature extraction method using a modified Xception architecture for the diagnosis of DR disease. The proposed method is based on deep layer aggregation that combines multilevel features from different convolutional layers of Xception architecture. The extracted features are subsequently fed into a multi-layer perceptron (MLP) to be trained for DR severity classification.

The performance of the proposed approach was assessed with four deep feature extractors, including Inception V3,MobileNet, and ResNet50 and original Xception architecture. Compared with typical Xception architecture, the aggregation of deep CNN layers can effectively fuse deep features and improve the learning process. Additionally, a transfer learning strategy and hyper-parameter tuning are adopted to further improve the overall classification performance.

III. EXISTING SYSTEM

Current state-of-the-art systems for DR detection primarily use Convolutional Neural Networks (CNNs) for feature extraction and classification. These systems include models like VGG, ResNet, and Inception. While effective, they often require significant computational resources and may not fully capture the spatial relationships between retinal features.

Additionally, some approaches use ensemble methods or multiple stages of processing, which can further increase the computational complexity and inference time.

Disadvantages

- Less feature compatibility
- Low accuracy

IV. PROPOSED METHOD

Our proposed system for Diabetic Retinopathy (DR) screening integrates MobileNet with advanced neural network architectures to enhance detection accuracy and efficiency. The core model, MobileNet, is trained on 3,662 high-resolution fundus images from the APTOS dataset to classify DR into five stages. To further improve performance, we introduce two hybrid models: MobileNet + Graph Neural Network (GNN) to capture complex spatial relationships in retinal images, and MobileNet + Recurrent Neural Network (RNN) to address sequential dependencies and temporal patterns. These hybrids aim to optimize DR classification by leveraging both structural and sequential data insights.

Advantages

- Accurate classification
- Less complexity
- High performance
- Easy Identification

V. METHODOLOGY

A. Data Collection

Gathered retinal images and metadata from multiple sources including Kaggle and public medical databases. Ensured all patient data are anonymized for ethical compliance. Utilized a secure and compliant data storage system to hold the collected data.

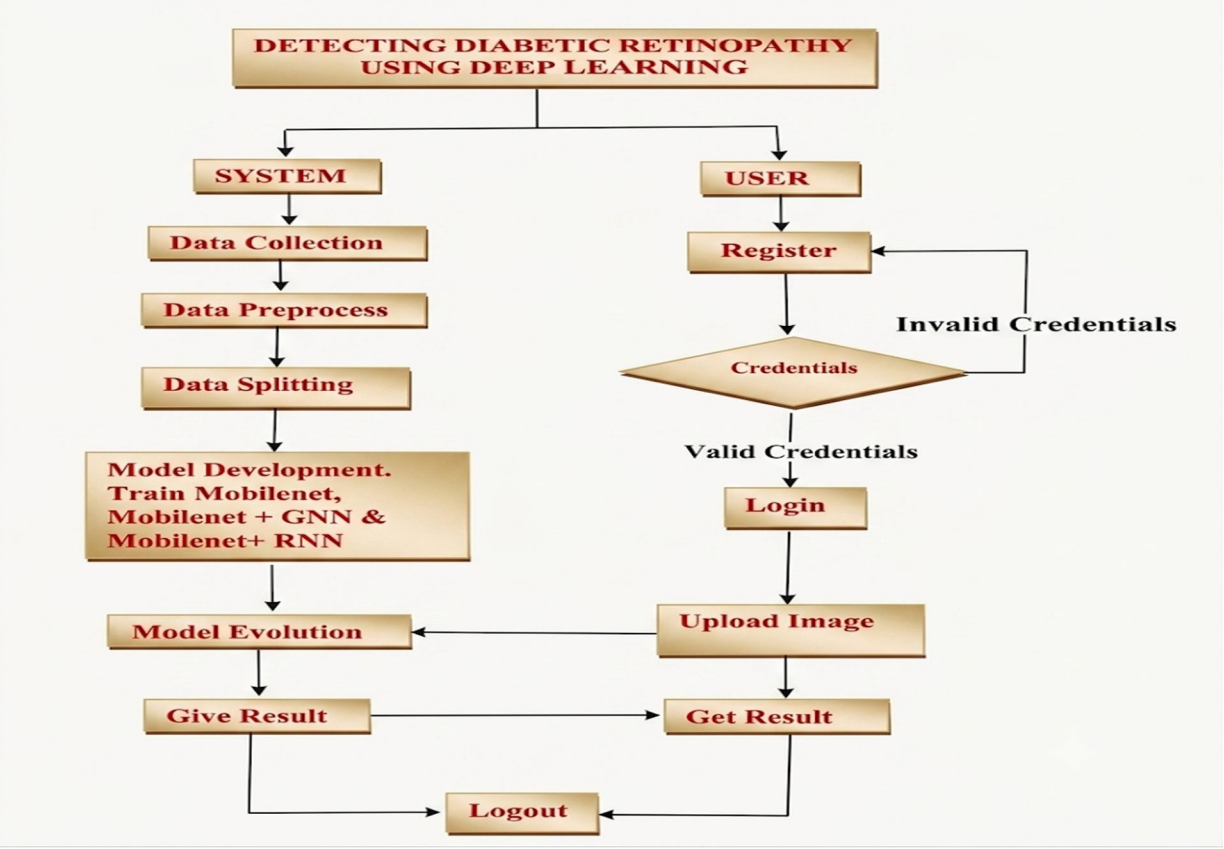

Fig 1: Proposed System Architecture

1) Data Pre-processing: Standardized all images to 224x224 pixels.Scaled pixel values to the range [0, 1]. Transformed textual labels ('No DR', 'DR') into numerical values (0, 1).
2) Data Augmentation: Applied random rotations to images up to 30 degrees. Incorporated random zooms ranging from 0.8x to 1.2x. Performed horizontal flipping on images to augment the dataset.
3) Model Training: Utilized a MobileNet+GNN and MobileNet+RNN with multiple layers. Employed Binary Cross-Entropy for the loss function. Used the Adam optimizer for weight updates. Batch size set at 20, epochs set at 15.
4) Evaluation: Partitioned the data into training (70%), validation (15%), and test (15%) sets. We used Accuracy, Precision, and Recall as primary evaluation metrics. Leveraged the validation set for hyper parameter tuning and model optimization.

VI. RESULTS

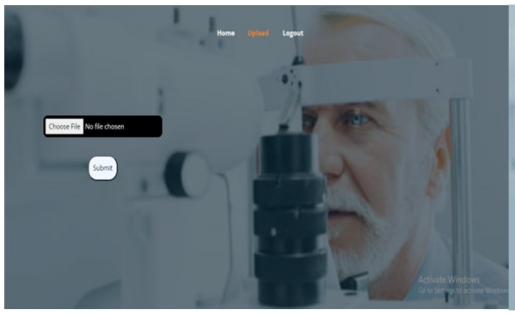

Figure 2: Home Page to upload the image

Fig 3: Severe DR

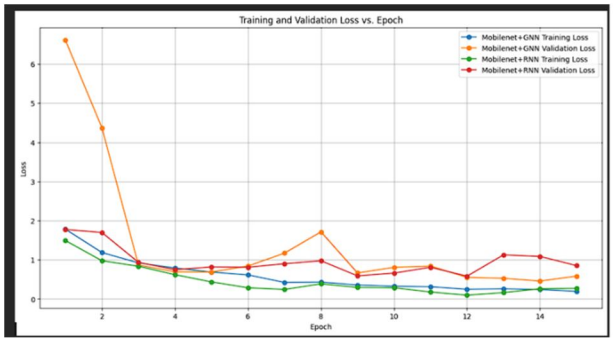

Fig 4: Training Loss

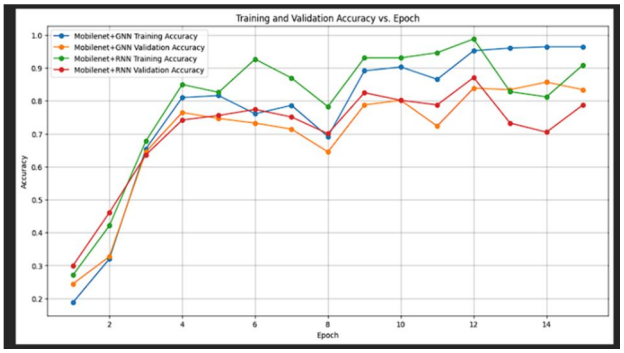

Fig 5: Training Accuracy

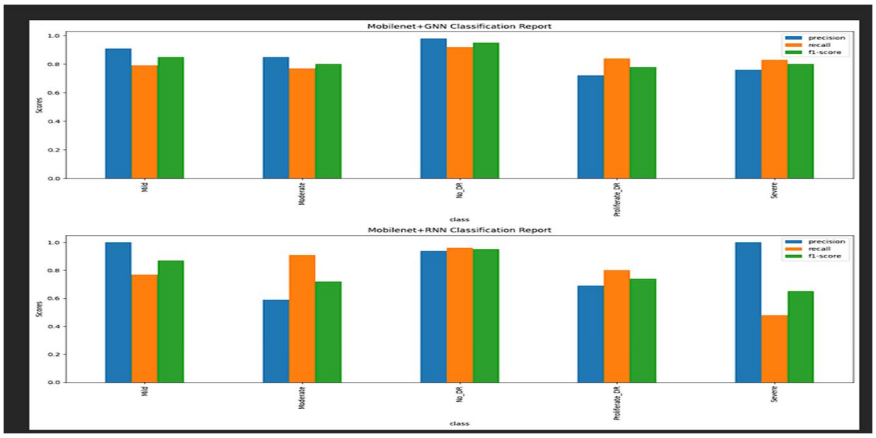

Fig 6: Classification Report for Mobilenet+GNN & Mobilenet+RNN

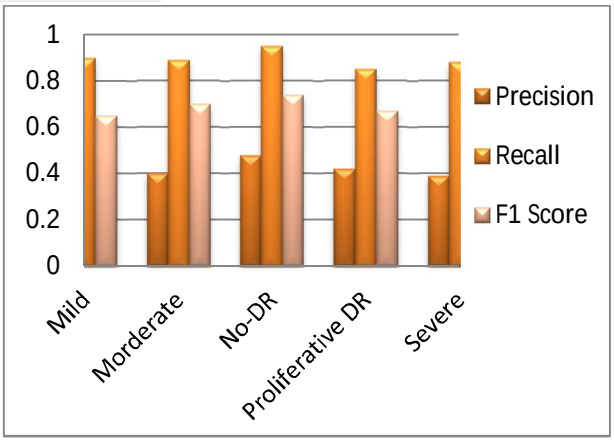

Fig 7: Classification Report for Mobilenet

Model	Accuracy	Precision	Recall	F1-score
Mobilenet	78	48	95	74
Mobilenet + GNN	92	90	86	86
Mobilenet + RNN	80	81	79	80

Table 1: Evaluation Metrics Report

VII. CONCLUSION

In conclusion, the application of deep learning in detecting diabetic retinopathy represents a significant advancement in the field of medical diagnostics. This innovative approach has shown promising results in automating the early detection of diabetic retinopathy, thereby enabling timely interventions and reducing the risk of vision loss in diabetic patients. With further refinement and integration into healthcare systems, deep learning models can contribute to more efficient and accessible screening, ultimately improving the quality of life for individuals with diabetes. In this Project we are using Mobile Net Architecture, Mobile Net along with GNN and Mobile Net with RNN in this GNN hybrid model is giving Best accuracy compared to others.

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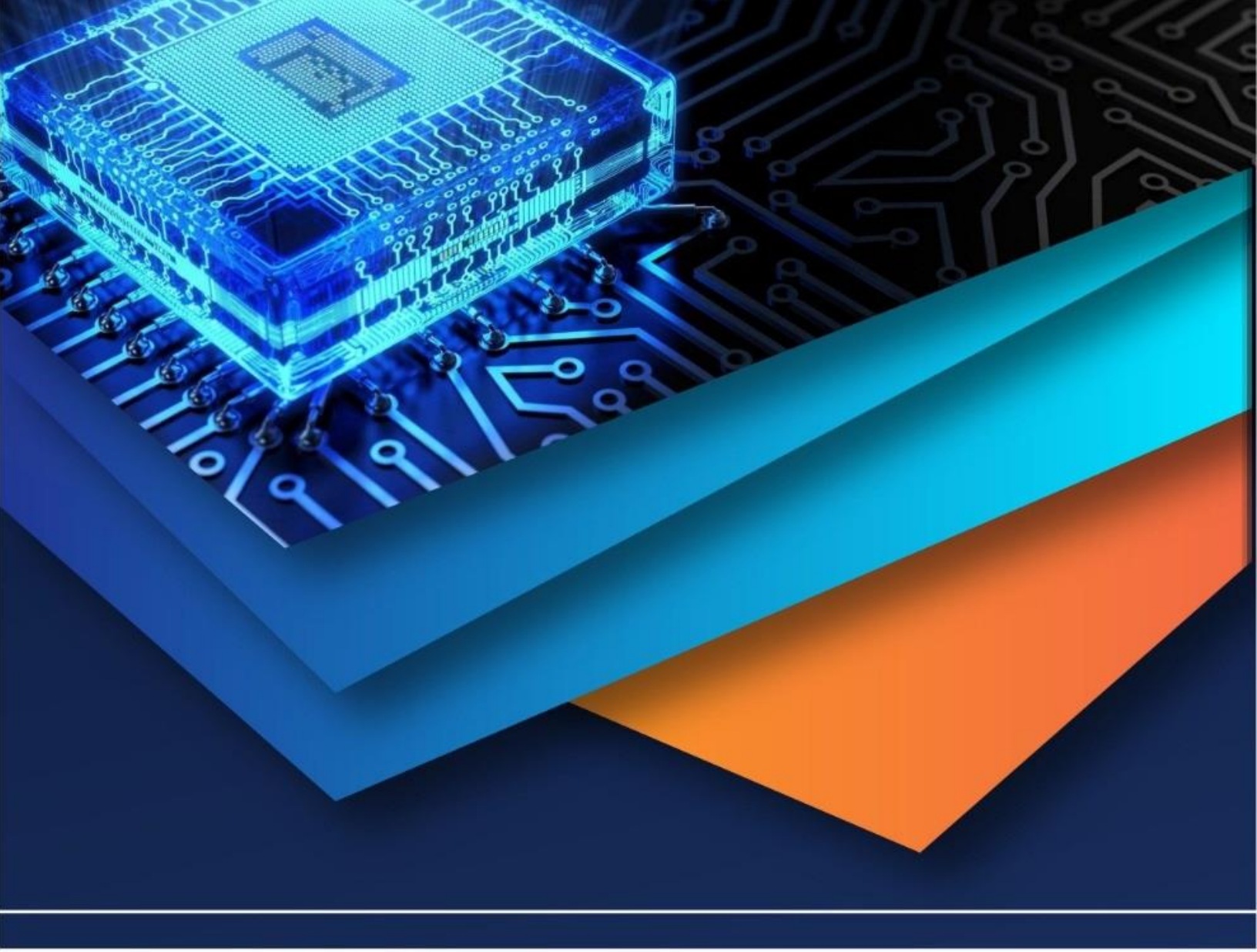

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