iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68905

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Lumbar Spine Degenerative Classification

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Abstract: Lumbar Spine Degenerative Classification is a deep learning-based initiative focused on the automated analysis of MRI images to detect and categorize spinal disc degeneration. The system classifies images into three levels: normal, mild/moderate, and severe, helping reduce subjectivity in medical diagnosis. By applying an efficient convolutional neural network architecture, the model captures subtle features in spinal structures, leading to improved diagnostic accuracy. This project aims to support healthcare professionals by offering consistent, fast, and reliable assessments of lumbar spine health. It enhances clinical workflows, encourages early detection, and facilitates ongoing monitoring. With a focus on scalability and accessibility, the system can be integrated into medical settings to improve patient care outcomes. The project demonstrates the potential of artificial intelligence in transforming medical imaging and contributes to building a more intelligent and supportive healthcare environment.

Keywords: Lumbar Spine Degeneration, MRI Analysis, Deep Learning, Convolutional Neural Network (CNN), Medical Image Classification, Automated Diagnosis, Spinal Disc Health, Disease Severity Detection, Clinical Decision Support.

I. INTRODUCTION

The Lumbar Spine Degenerative Classification system is a forward-thinking initiative that combines medical imaging and artificial intelligence to address the increasing need for efficient, and consistent diagnosis of spinal disc degeneration. This project aims to support the early detection and classification of lumbar spine conditions, which are a leading cause of chronic back pain and reduced mobility worldwide. By utilizing deep learning techniques, the system provides a scalable and objective solution to assist healthcare professionals in clinical decision-making. Through the use of advanced image analysis, the model processes MRI scans to classify spinal disc conditions into categories such as normal, mild/moderate, and severe. This classification not only supports clinical workflows by reducing the diagnostic burden on radiologists but also promotes timely treatment planning for improved patient outcomes. The system mimics the decision-making process of medical experts by identifying key visual patterns associated with disc degeneration.A critical element of this project is its focus on accessibility and clinical relevance. By providing a user-friendly interface and reliable predictions, the solution can be deployed in diverse healthcare settings, including areas with limited access to specialized radiological expertise. This initiative also reinforces the ethical use of AI in healthcare by ensuring transparency, reproducibility, and patient-centered care. Ultimately, the project demonstrates how artificial intelligence can be harnessed to enhance diagnostic capabilities and contribute to more effective, data-driven medical practices.

Beyond diagnostics, the project is built to encourage collaboration and learning. Whether used by radiologists in a hospital setting or by students in a medical classroom, the platform serves as a powerful educational and clinical tool. It reduces ambiguity in assessments and promotes a shared language around disease severity—ultimately helping to bridge the gap between complex medical imaging and practical healthcare decisions.At its heart, this project is about making spinal healthcare smarter, more accurate, and more human-centered. By empowering medical professionals with better tools and supporting patients through earlier and more personalized care, Lumbar Spine Degenerative Classification is shaping a future where technology and compassion go hand in hand to improve lives.

II. LITERATURE REVIEW

The *Lumbar Spine Degenerative Classification* project draws on interdisciplinary research spanning the fields of medical imaging, artificial intelligence, clinical diagnostics, and deep learning. This literature review explores current research in these areas to establish the academic foundation for the project, emphasizing the growing role of AI in supporting medical decision-making and enhancing diagnostic accuracy in spinal health.Recent developments in automated medical image analysis have focused on using convolutional neural networks (CNNs) for the classification of spinal MRI scans. These technologies aim to assist radiologists by reducing diagnostic subjectivity and improving the detection of degenerative changes in the lumbar spine. Existing systems and research highlight how AI can help streamline diagnosis, especially in high-volume clinical settings, by offering fast and consistent assessments of disc degeneration severity.

AI in Spinal Diagnostics: Various studies have implemented AI models to detect and categorize disc degeneration into normal, mild/moderate, and severe levels. These models use deep learning to extract subtle visual cues from MR images, aiding in early detection and continuous monitoring of spinal conditions. Projects like SpineNet and SpineNetV2 demonstrate the effectiveness of combining medical data with AI for reliable classification. This approach also showcases the potential for AI tools to be integrated into clinical workflows, offering support to healthcare professionals while improving patient outcomes. With a focus on accessibility and scalability, the literature supports the use of lightweight, efficient models that can function across diverse healthcare environments.

III. SYSTEM ARCHITECTURE

For the project, "Lumbar Spine Degenerative Classification," the system is designed to support both technical functionality and ease of use for healthcare professionals. The architecture is thoughtfully structured into three key layers: the Input Layer, Processing Layer, and Output Layer, each playing an important role in delivering accurate and efficient results.

A. Input Layer (Data)

This is where everything begins. The system takes in MRI images of the lumbar spine, either from medical databases or directly from imaging equipment. These images are then loaded and prepared for analysis, ensuring that the data is clean and ready for the next stage.

B. Processing Layer

At the heart of the system is the processing layer. Here, we use a combination of EfficientDET and Convolutional Neural Networks (CNN) to do the heavy lifting. The images go through preprocessing steps to improve quality and consistency. CNNs then analyze the spinal features through several layers of convolution and pooling, identifying even the subtlest patterns. EfficientDET helps visualize and identify the severity of disc degeneration in specific spinal segments.

C. Output Layer

Finally, the system presents the results. It classifies the condition of the spine into categories like **normal**, **mild**or **severe**, and even marks affected vertebrae in the image. This output is designed to be clear and actionable, helping doctors make informed decisions quickly and confidently.

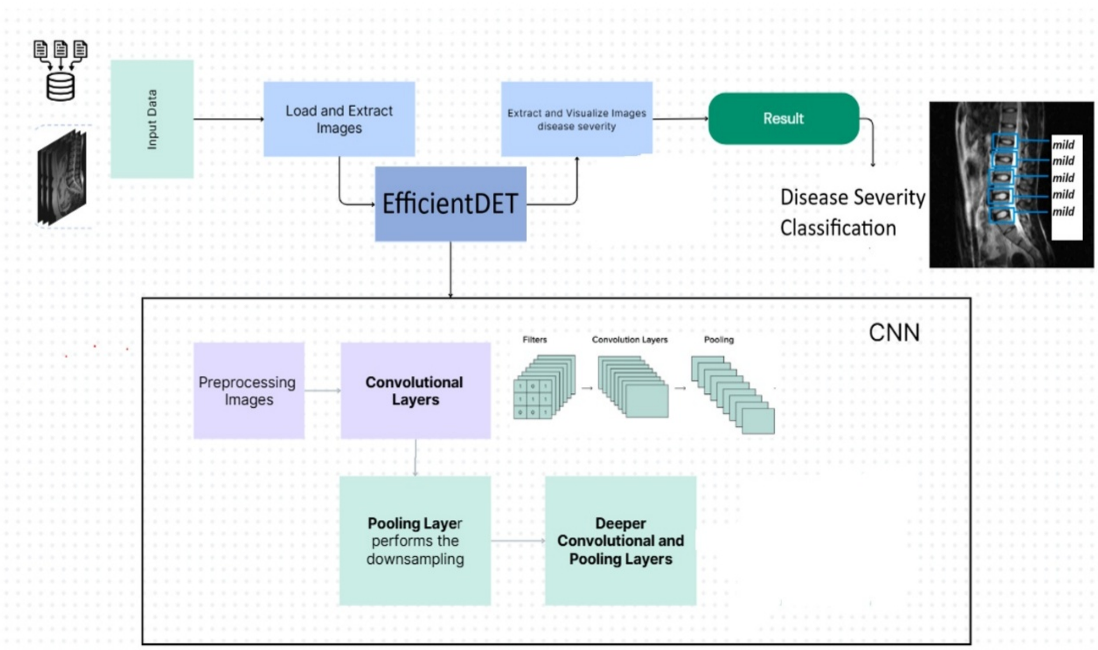

Fig.1System Architecture

IV. SYSTEM DESIGN

A. User Input(Healthcare professional)

The process starts with the user, typically a healthcare professional, who provides the input data. This data consists of lumbar spine MRI images used for training or testing.

B. Image Processing

Once the images are received, they go through a preprocessing stage where they are cleaned and standardized to make them suitable for analysis. These processed images are stored for further use.

C. Feature Extraction using CNN (EfficientDet)

The pre-processed images are passed through a Convolutional Neural Network (CNN) to extract meaningful features. These features capture important visual patterns from the MRI images that are crucial for classification. The extracted features are also stored for reuse and further training.

D. Classification

The extracted features are then fed into a classification model that identifies the type or stage of lumbar spine degeneration. The results of the classification are also used to refine and update the model, improving its accuracy over time.

E. Results and Visualization

Finally, the classification results are visualized in a user-friendly format. This helps healthcare professionals understand the diagnosis and make informed decisions based on the model's predictions.

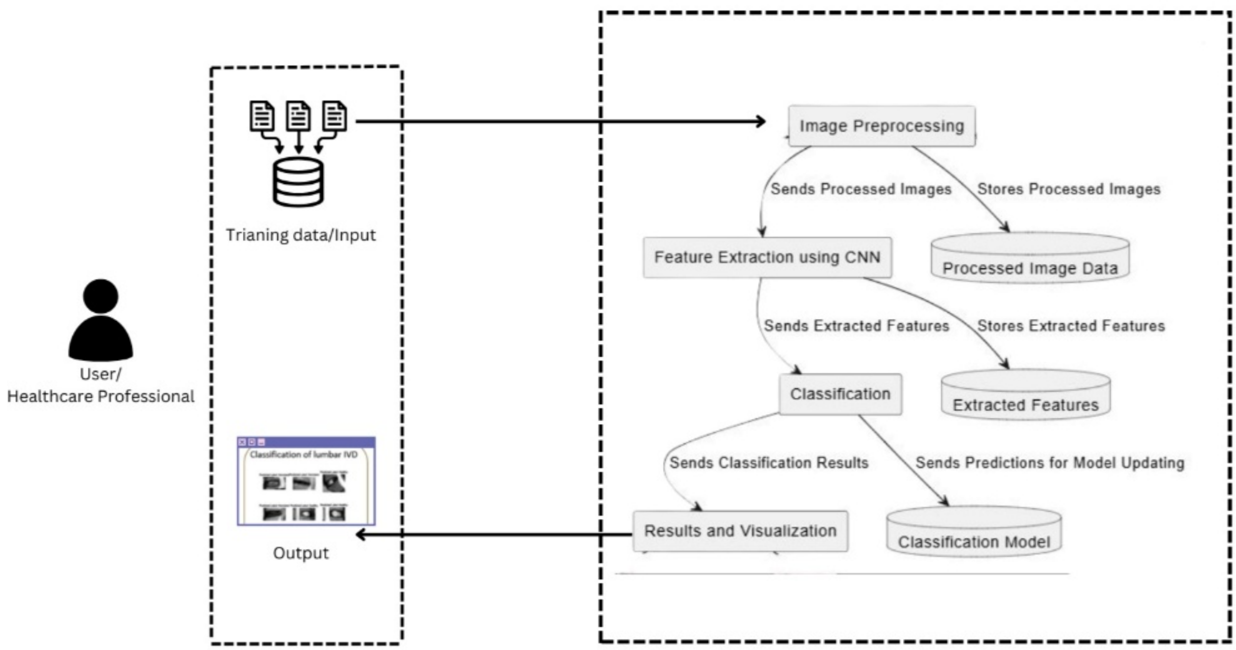

Fig.2System Design

V. DATA FLOW DIAGRAM

A. Data Acquisition

The process begins with the collection of lumbar spine MRI images. These images are gathered in various and standardized in height (H) and width (W). These raw MRI scans form the foundational dataset for the detection system.

B. Annotation

Specialists or trained radiologists annotate the MRI images to mark specific regions of interest (ROIs), like intervertebral discs (IVDs). These annotations act as ground truth labels that help the model learn where and what to detect.

C. Extraction Layer Selection

At this stage, the system identifies the appropriate layers from which features will be extracted in the CNN(EfficientDet) architecture. This selection helps the model focus on the most informative parts of the image, improving detection and classification performance.

D. Model Training

Using the annotated MRI images and selected layers, the Convolutional Neural Network (CNN) is trained. During this training, the system learns to recognize patterns and features associated with lumbar spine degeneration

E. Model Evaluation

After training, the model undergoes evaluation to test how well it performs. This step determines whether the model is ready for real-world use or needs further refinement. Evaluation metrics guide the decision-making process.

F. Results Validation

The results of the evaluation are assessed. If the model's performance is not satisfactory ("Bad"), the pipeline loops back to retrain the model, possibly adjusting parameters or annotations. If the results are acceptable ("Good"), the pipeline proceeds to the final step.

G. Region of Interest (ROI) Segmentation & Classification

The trained model then segments and identifies the Regions of Interest (ROIs) in new MRI scans. These ROIs are visually marked on the spine images and individually classified to determine the condition of each intervertebral disc. This leads to accurate classification of lumbar IVD (Intervertebral Disc) health, helping healthcare providers make informed diagnostic decisions.

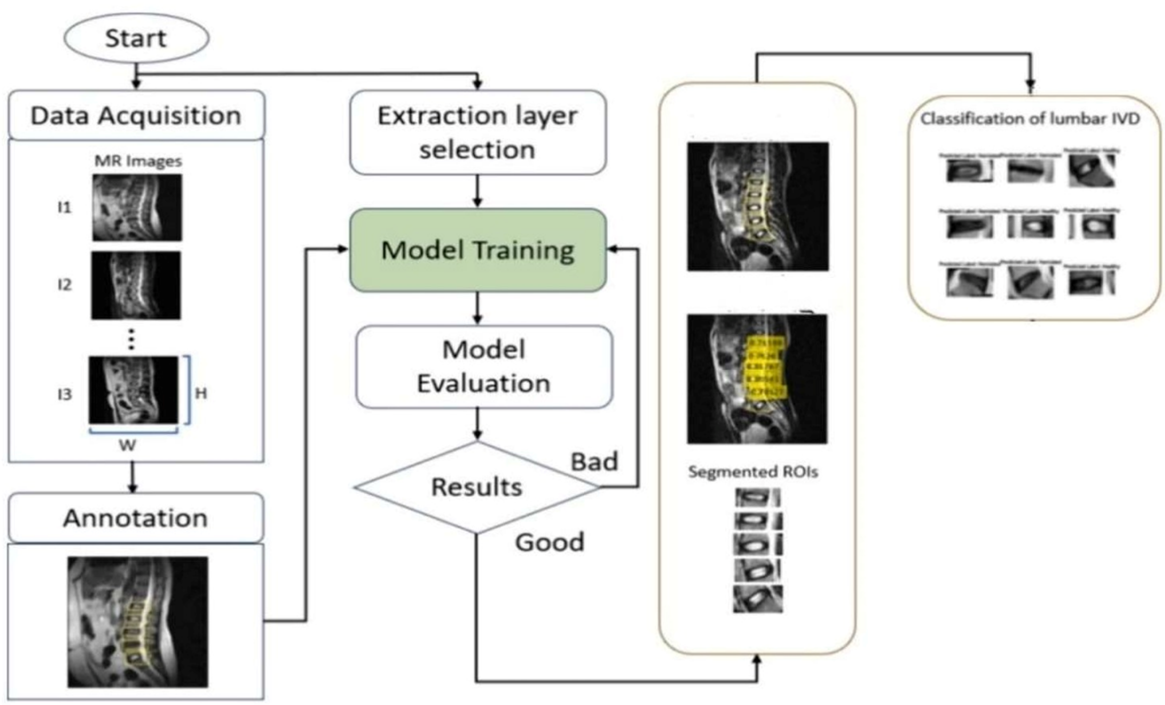

Fig.3Data Flow Diagram

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VI. IMPLEMENTATION

A. Data Acquisition and Annotation

The process begins with the collection of lumbar spine MR images. These images are sourced from datasets containing multiple slicesof the spine in sagittal view. Each image is annotated by experts to mark regions of interest (ROIs), such as intervertebral discs (IVDs), enabling supervised learning.

1) Key Components: High-resolution MRI scans, annotation tools, domain expert input.
2) How It Works: Each MRI scan is annotated manually or semi-automatically to label vertebral segments and disc locations. This forms the foundational training data for the model.

B. Model Training with CNN-based Architecture

A Convolutional Neural Network (CNN) is implemented to detect and classify degenerative changes in the lumbar spine. The model is trained using the annotated images to recognize patterns and features indicative of degeneration.

1) Key Technologies Used: TensorFlow/Keras or PyTorch, CNN layers (Conv2D, MaxPooling, Dense), data augmentation techniques, ROI extraction methods.
2) Working: The input images are passed through a feature extraction layer to highlight important anatomical structures. The CNN learns to map these features to specific degenerative categories. The model is trained iteratively, using loss optimization and backpropagation to improve accuracy.

C. Model Evaluation and Feedback Loop

After training, the model is validated using a test dataset. The output includes segmented ROIs and classification labels for each disc. The performance is evaluated based on metrics such as accuracy, precision, recall, and F1-score.

1) Evaluation Process: Comparison of predicted labels with ground truth, visual inspection of segmented discs, and feedback from medical professionals.
2) Working: If results are not satisfactory (e.g., low classification accuracy), the process loops back to re-adjust the extraction layer or model parameters. If the performance is good, the model proceeds to deployment.

D. Classification of Lumbar Spine Degeneration

The final model classifies each intervertebral disc into specific degenerative grades or conditions (e.g., normal, mild, severe). This helps identify the severity and location of degeneration for further diagnosis or treatment planning.

1) Output Format: Segmented disc regions with annotated degeneration levels.
2) Utility: Supports radiologists and spine specialists by offering an AI-assisted second opinion, improving diagnostic efficiency and consistency.

VII. RESULT

The result section of the system provides a clear and informative output after analyzing the uploaded lumbar spine MRI images. Once the model processes the input scans using the CNN-based architecture, it classifies the condition of each intervertebral disc into specific degeneration categories such as:

1) Normal
2) Mild Degeneration
3) Severe Degeneration

Each disc level is visually represented, often with heatmaps or bounding boxes over the affected areas, to help users understand which regions show signs of degeneration. Along with the classification, the model provides a confidence score or probability percentage for each prediction, indicating how certain the model is about its output.

This result can assist radiologists, medical researchers, or practitioners in making informed decisions for diagnosis, treatment planning, or patient monitoring. The outputs are structured in a user-friendly format, either downloadable as a PDF or viewable through the system's result dashboard.

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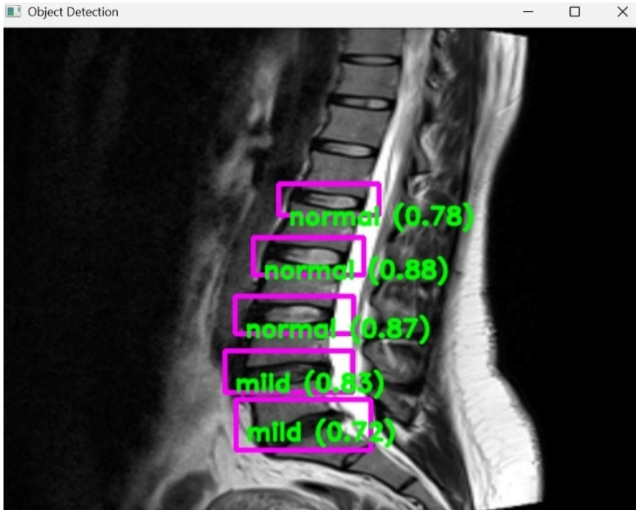

Fig.4Test Result 1.

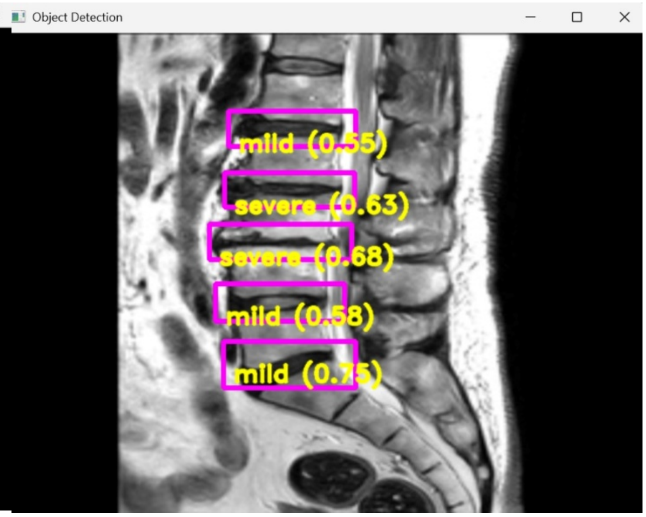

Fig.5Test Result 2

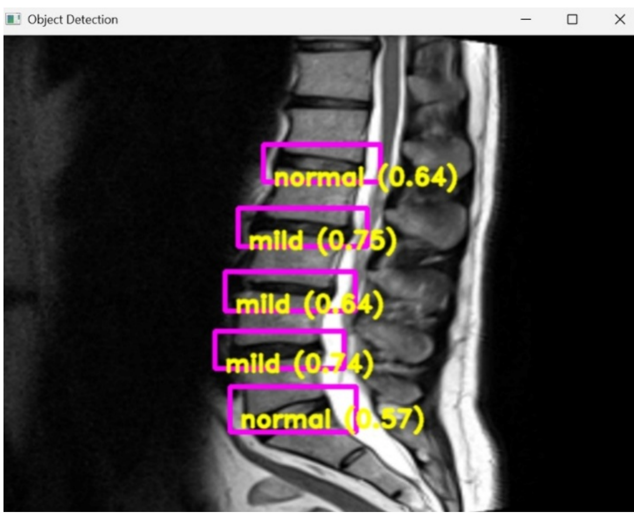

Fig. 6Test Result 3

Fig.7Test Result 4

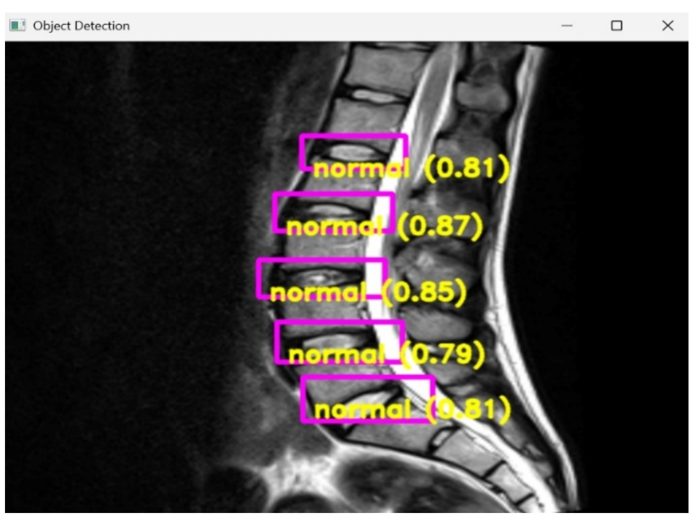

Fig.8Test Result 5

VIII. CONCLUSION

The Lumbar Spine Degenerative Classification system represents a major step forward in the use of artificial intelligence in medical diagnostics. By leveraging a Convolutional Neural Network (CNN), this system efficiently analyses lumbar spine MRI images to detect and classify different stages of disc degeneration. It is designed to support radiologists and healthcare professionals by providing fast, accurate, and consistent results, ultimately improving diagnostic confidence and patient outcomes.The Classification Module plays a central role by automatically identifying and labelling degenerative conditions across various disc levels. This not only reduces manual workload but also helps in tracking the progression of spine-related issues over time. With its ability to generate interpretable outputs and maintain historical records, the system offers a smart, reliable tool that integrates smoothly into clinical workflowenhancing both decision-making and patient care.

IX. ACKNOWLEDGEMENT

We would like to express our deepest gratitude to Ms. Bhagya K, Assistant Professor, Department of Computer Science and Engineering, CMRUniversity, Bengalurufor her invaluable guidance and support throughout the development of this project. Her expertise, insights, and encouragement have been instrumental in shaping our research and bringing it to reality. We are truly grateful for her mentorship and the opportunity to learn from her.

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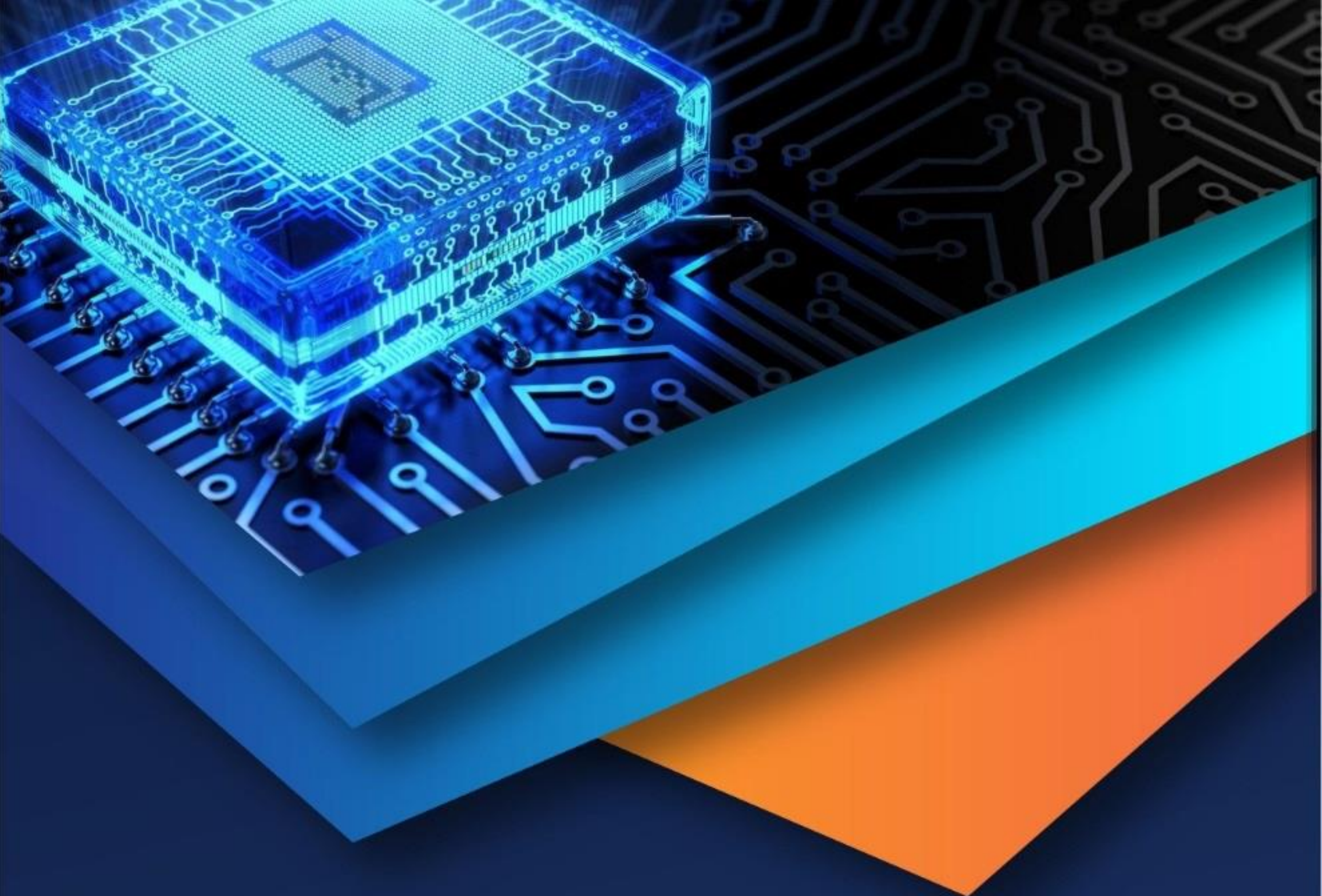

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