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AI-Tool for Early-Stage Dementia Detection

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Abstract: Now a days we are hearing a lot about the disease named dementia and we see from the fact that cognitive degeneration in people that have dementia progresses very slow and goes almost unobserved. To health care providers this means solving a complex puzzle of cognitive tests and brain scans. We see that to close this gap in diagnosis we have developed a project for an AI Powered Diagnostic System to put forth a smart and dependable second opinion for health care professionals. This system is to put together the big picture and give a full assessment of a patient's neurological health by using two different kinds of AI. The system will do this by using a combination of a Machine Learning ensemble of algorithms, acting as a Voting Classifier consisting of Logistic Regression, Random Forest, and XGBoost to assess everyday patient metrics such as memory test scores, age, and health history. Additionally, a ResNet50 Deep Learning model will be used to function as an expert set of eyes and specifically be trained to spot hidden and microscopic structural changes in MRI brain scans. This system has been developed with a user-friendly interface using React, Flask, and Python and instantly integrates these two types of data into a cohesive and high-precision risk profile to allow clinicians to visualize a patient's neurological health in an instant. Ultimately, this platform eliminates uncertainty in screening and allows doctors to make quick and informed decisions to ensure their patients get the care they need.
Keywords: Dementia Detection, Multi-Modal AI, Voting Classifier, ResNet50, MRI Analysis, OASIS Dataset, Machine Learning Ensemble, Clinical Decision Support

I. INTRODUCTION

In the past few years early diagnosis of dementia has become a great medical priority which in turn requires that clinicians display high degree of diagnostic accuracy and the ability to work with complex neurology data. Also, many health care providers have been having a hard time noticing very early signs of cognitive decline which often is very easy to miss as it presents itself very much like normal aging. We see that present diagnostic tools which include manual cognitive scoring and visual assessment of brain scans do not do a good job at giving out a large scale, multi-modal analysis which is what we need to see very small-scale structural changes in the brain. In fact, many patients are still being diagnosed only once their disease has progressed greatly, which in turn is taking away the chance for early intervention.

Advances in artificial intelligence present new chances to transform the way we detect and manage neurological disorders. AI based systems can analyze large sets of medical data, identify patterns in imaging and put forth very precise risk assessments to clinicians. That which makes AI a good fit for use in dementia screening is the fact individualized data analysis and deep learning evaluation of neuroimaging which in turn improves diagnostic accuracy. By use of intelligent technologies such as ensemble learning and convolutional neural networks modern platforms can put forth tailored insights which in turn help doctors in their clinical decision making.

To improve on what we have seen from traditional diagnostic tools this work presents a Multi Modal AI Powered Diagnostic System which we have put into practice for clinicians in their dementia screening process. We have developed into this platform an advanced clinical analysis which looks at patient metrics, cognitive test results, and health history via a Machine Learning ensemble. Also, we have included into the system a module which does MRI analysis which we have based on ResNet50 architecture to identify very small-scale structural changes in brain scans. The system looks at all this data and returns a consolidated report which in turn helps health care providers to improve the clarity and confidence of their final diagnosis.

Another key feature of our platform is the delivery of personal risk assessments. From the patient's present health data and imaging reports the system puts forth a clear diagnostic which in turn brings to light issues in both clinical scores and physical brain structure. Also, we have included data driven support which allows clinicians to identify specific disease patterns as seen in the OASIS and Dementia Patient studies which in turn they may use to form their care plan.

In addition, the system also includes progress monitoring and analytics tool, which enable doctors to track the cognitive development of a patient over a period. With the help of a progress chart, doctors can also track the cognitive skills in which a patient lacks proficiency, thereby adopting a structured approach for the treatment of the patient. With the help of clinical metrics and MRI analysis, the proposed system can help bridge the gap between symptoms and a medical diagnosis.

Thus, the proposed diagnostic system represents a comprehensive approach towards utilizing artificial intelligence for the development of a highly personalized healthcare environment, where intelligent feedback, structured analytical support, and high-precision evaluation with the help of a Voting Classifier of Logistic Regression, Random Forest, and XGBoost can be used for improving the diagnosis, clinical readiness, and success rate of a patient.

II. LITERATURE SURVEY

The use of artificial intelligence and machine learning in medical diagnostics has significantly changed the approach to the early detection of neurodegenerative diseases. Research findings have indicated that manual diagnostic procedures are not effective in detecting early-stage symptoms associated with cognitive decline. Notably, recent theoretical and applied research has been highly focused on the development of automated diagnostic systems to ensure high-precision medical evaluations, with the research being categorized into clinical data analysis, advanced neuroimaging, and multi-modal fusion.

Traditionally, predictive diagnostics heavily depended on observable clinical factors and a physician's intuition. However, groundbreaking research by So et al. [9] proved that it is theoretically possible to diagnose dementia using machine learning algorithms based purely on clinical factors. This research provided a new paradigm that allows computational processing to identify non-linear relationships in patient histories that might be overlooked by human evaluators. Further research by Al-Hammadi et al. [3] provided extensive research and evaluation of different machine learning approaches to dementia detection and concluded that none of these approaches are universally best. This research theorized that a combination of different approaches is required for a stable and accurate output in dementia detection.

In a comprehensive systematic review, this sentiment was echoed by Javeed et al. [4]. This article focused on the importance of ensemble techniques in robust dementia prediction and encouraged a complete paradigm shift towards automated analytical models. In this vein of thought, Grueso and Viejo-Sobera [5] sought to explore predictive modeling in relation to the onset of full-scale Alzheimer's Disease from Mild Cognitive Impairment. This article can be seen as a theoretical underpinning of the notion that machine learning can recognize early markers of cognitive shift long before any physical degeneration is detectable.

Parallel to the advancements in the processing of clinical data, the field of deep learning has revolutionized the processing of underlying features in neuroimages. However, the major challenge in the analysis of MRI images has always been the intricate nature of the brain's anatomy and the microscopic nature of early atrophy in the brain. Keeping this in view, Basheer et al. [6] presented a new framework for the prediction of Alzheimer’s disease by utilizing a capsule network-based framework, which assumed that advanced neural networks are more adept at maintaining the spatial characteristics of the anatomy of the brain in comparison to the conventional convolutional network. Expanding the capabilities of the existing deep learning framework, Hashmi and Barukab [8] presented a new framework of deep reinforcement learning in the early stages of classification, which proved that AI-based models are capable of "learning" the most suitable diagnostic protocol by utilizing the reward function in the form of feature extraction in images. Furthermore, Bayahya et al. [1] proved the theory that the overall diagnostic accuracy of the system could be significantly enhanced by utilizing a multi-model framework of deep learning.

While these unimodal systems perform best in their own domains, human cognition is inherently multi-faceted, making a holistic diagnostic approach necessary. Recent research has also begun to explore different modalities, as evidenced by the work done by Ksibi et al. [2] and Kumar et al. [10], where they employed deep learning to diagnose dementia based on speech patterns and vocal characteristics. Although speech and EEG provide important behavioral context, structural imaging with tabular clinical data represents the gold standard in medical diagnostics. Ortiz-Perez et al. [13] emphasized the clinical potential of a multimodal framework based on deep learning. This framework demonstrated the potential benefits of combining structural imaging with tabular patient data to improve predictive performance and patient outcomes over the evaluation of each modality in isolation.

Despite these considerable theoretical contributions, there is an important gap in how these technologies can be effectively integrated into an accessible system. The majority of the existing research has centered on specific domains, such as either exploring advanced neuroimaging methods or only assessing basic clinical risk factors. There is a notable lack of integrated and understandable systems that combine these theories into an accessible system for immediate physician feedback.

To overcome this limitation, the proposed Dementia Diagnostic System presents a unified theoretical and practical framework. By incorporating the Machine Learning Ensemble, consisting of Logistic Regression, Random Forest, and XGBoost as a Voting

Classifier for processing clinical metrics, and the ResNet50 Deep Learning model for microscopic MRI analysis, the proposed work presents a comprehensive diagnostic system. By seamlessly integrating the proposed diagnostic system through a Flask-based web platform, the proposed solution seeks to overcome the limitation of fragmented research and provide a holistic "second opinion" in the early intervention of dementia.

III. PROPOSED SYSTEM

The AI-Powered Dementia Diagnostic System is designed and built to be a smart platform for early dementia screening by using structured data and high-precision evaluation tools. The system combines the analysis of clinical metrics and neuroimaging in one web-based system. The main goal of making this system is to help doctors find early signs of cognitive decline, improve the accuracy of diagnoses, and give a reliable second opinion for complicated neurological tests.

The system is built in a modular way, with different computational modules that work together to give a more accurate diagnosis. The system lets doctors enter patient health information, upload MRI brain scans, and get an immediate assessment of a patient's neurological risk profile.

The Clinical Data Analysis Module is one of the most important parts of this platform. It uses a Machine Learning approach with a group of Machine Learning algorithms to look at a patient's health history and cognitive test results. It is a Voting Classifier that uses Logistic Regression, Random Forest, and XGBoost to look at important things like memory test scores, patient ages, and health conditions. It helps doctors look at broken-up clinical data more quickly and find statistical patterns that are linked to dementia.

The Neuroimaging Analysis Module is the second most important part of this platform. It helps doctors find structural problems in a patient's brain. It uses a ResNet50 neural network and a Deep Learning approach.

Apart from the above features, the platform also offers a Dataset-Driven Diagnostic Insights tool. This tool has been trained on actual medical records from the OASIS and Dementia Patient datasets and provides benchmarks for the recruitment patterns of neurological decline. This allows the healthcare provider to understand how the patient’s information compares to thousands of actual medical cases, making it easier to develop a plan of action.

Overall, the diagnostic platform that has been proposed allows healthcare providers to take advantage of intelligent clinical evaluation, MRI analysis, and risk assessment in a single tool. This allows the healthcare provider to take advantage of a single tool that provides a vital head start in the fight against dementia.

IV. SYSTEM ARCHITECTURE

The architecture of the dementia diagnostic process is designed as an end-to-end machine learning pipeline, ranging from raw neuroimaging inputs to a definitive binary output. At its core, the system relies on the seamless integration of initial neuroimage preprocessing, deep-layered feature extraction, and a sophisticated ensemble voting mechanism. This integrated approach ensures that data flows logically from one stage to the next, maintaining the integrity of the medical information while optimizing it for automated analysis. The process begins at the input layer, where raw MRI scans are ingested and standardized to meet the system’s specific computational requirements. This stage is critical because it ensures that neuroimages are refined to remove distracting visual noise and artifacts that could interfere with the model's accuracy. By emphasizing the structural brain densities necessary for a proper diagnosis, this preprocessing phase prepares the data for high-precision evaluation of the patient’s neurological condition.

Then, after the data is ready, the platform uses its feature extraction part, where the data is examined using the ResNet50 model, which analyses the features of the MRI images. The ResNet50 model looks at the small important features and biomarkers, which are difficult for humans to get into this. After the feature extraction process, these features are sent to the models. In this part, instead of relying only on one algorithm, the data is taken using the combined results of the four models they are Random Forest, Logistic Regression, XGBoost, and Gradient Boosting, where the chances of error's are low.

The frontend layer acts as the primary interface through which users interact with the system. It is responsible for providing various preparation modules that assist students in improving their placement readiness. The front end includes several key components such as the Mock Interview module, Resume Analyzer, Roadmap Generator, and Company-Specific Preparation module. Through these modules, students can upload resumes, practice interview questions, and access preparation resources tailored to specific companies. The system utilizes an AI-powered processing component based on a large language model (LLM) to analyze user inputs and generate intelligent feedback. When students participate in mock interviews or upload their resumes, the AI module evaluates the content and provides suggestions for improvement. The LLM also assists in generating interview questions, evaluating responses, and recommending suitable preparation strategies for students based on their profiles.

The backend layer, implemented using Node.js APIs, manages the communication between the frontend interface and the AI processing module. It handles request processing, data exchange, and system logic. The backend ensures that user requests such as re uploads, interview responses, and roadmap generation are properly processed and routed to the appropriate services.

In addition to these components, the platform maintains a PYQ (Previous Year Questions) database, which stores interview questions, company-specific preparation material, and related resources. This database allows the system to retrieve relevant questions and preparation content that can help students practice effectively for real recruitment processes.

The interaction between the front-end modules, AI processing system, backend APIs, and database forms the overall architecture of the Dementia platform. This integrated design enables the system to provide clinical data analysis, interview simulation, personalized preparation guidance, and company-focused learning resources in a unified environment.

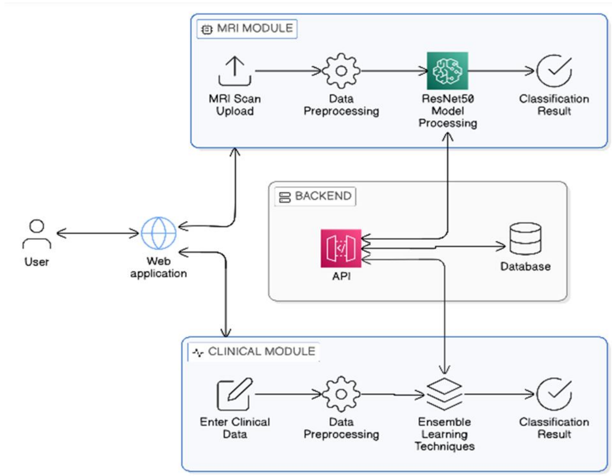

Fig. 1 System Architecture of the Dementia system

V. IMPLEMENTATION

The implementation of the Dementia platform is centered on creating an interactive medical diagnostic system that assists healthcare professionals in the early detection of Dementia disease. The system is developed using a decoupled architecture, with React used in building the frontend. The backend is developed using Fast API, which is implemented in Python. This is an essential part of the system since it enables the integration of high-powered AI libraries such as TensorFlow and Scikit-learn. The system is developed with several modules that work in conjunction with each other in delivering an automated system for clinical evaluation and neuroimaging analysis.

A. User Registration and Authentication Module

This module provides a secure entry point into the Dementia platform. Unlike other projects that have used traditional password-based authentication systems, this project uses an OTP (One-Time Password) verification system. From the interface, the project uses an OTP system. When users want to access the system, they must fill in their email address. A unique OTP is then sent to that email address. This provides an additional layer of security since the user's identity is verified in real time.

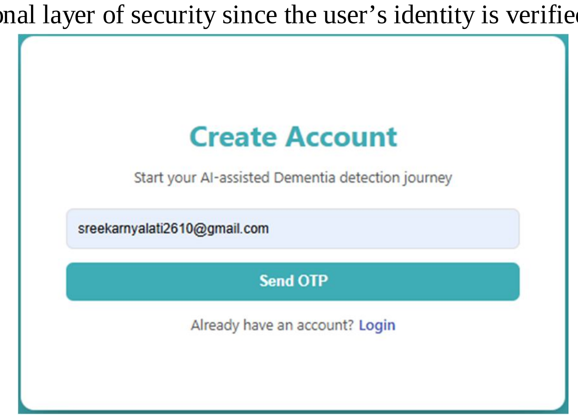

Fig. 2 User Registration page

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B. Clinical Assessment Module

This module provides healthcare professionals with an interface where they enter patients' metrics. Metrics include MMSE (Mini-Mental State Examination), age, and socioeconomic status. This data is then processed using a pre-trained Machine Learning model (Voting Classifier), which processes tabular data. Data normalization is used in conjunction with feature scaling in delivering an accurate "Demented" or "Non-Demented" classification.

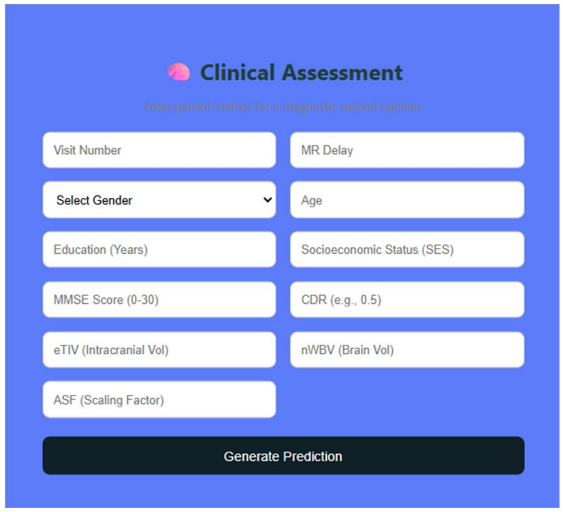

Fig. 3 Clinical Assessment Page

C. MRI Image Analysis Module

This module deals with the analysis of structural MRI images. Using Fast Api's File Upload features, a user can upload brain images, and this module will then perform the analysis of the images. So here we used a ResNet50 Deep Learning Model, implemented in TensorFlow, for analysis. The images are analyzed, and features are extracted to identify patterns of brain atrophy or any structural changes. The system gives accurate results for large size images and quick results for diagnosis.

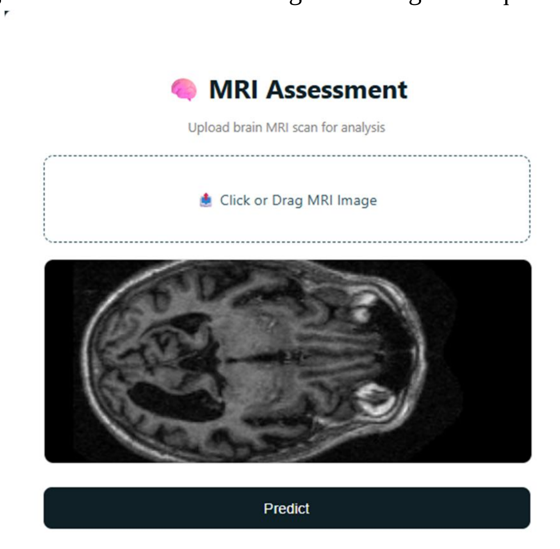

Fig. 4 MRI Assessment Page

VI. RESULTS AND DISCUSSION

From the results of the Dementia system, it's clear that the OTP-based authentication system works well and is effective. Once a user logs in, the diagnostic modules perform as expected. The clinical metrics are parsed and classified by the ML models, and the MRI images are analyzed by the ResNet50 model. The system can give results in real-time that helps in a quicker diagnosis than a human could.

The results show that the integration of React and Fast API ensures the low-latency response times required for the medical domain. Although the implementation is presently binary classification based (Demented vs. Non-Demented), the architecture is extensible enough to accommodate the addition of multi-stage dementia classification in the future.

VII. CONCLUSION

The AI-based dementia diagnostic platform was presented in this paper. The platform was developed to assist healthcare professionals in the early-stage dementia screening process. The platform was developed by integrating various diagnostic tools such as automated clinical metric analysis, structural MRI evaluation via deep learning algorithms, and OTP-based session management. The platform was developed using modern web technologies and multi-modal artificial intelligence. The platform provides data-based "second opinions" that assist healthcare professionals in the detection of early signs of neuro degeneration with greater accuracy. The implementation and testing of the platform proves that the AI-based platform performs the functions for which it was developed. The clinical assessment tool provides highly accurate classifications via the analysis of cognitive scores such as MMSE and CDR, and patient demographics via an ensemble-based machine learning approach. Concurrently, the platform's neuroimaging tool uses the ResNet50 deep learning architecture for the detection of structural brain atrophy in the patient's MRI scan. The diagnostic tool dashboard provides the healthcare professional with the ability to organize the patient's data and obtain immediate feedback regarding the patient's neurological condition. The platform bridges the gap between clinical observation and computational diagnostics. The platform provides an intelligent and interactive environment that assists the medical practitioners in providing precise diagnostic insights and facilitates the improvement of diagnostic accuracy. The AI-based platform provides precise diagnostic insights and facilitates the improvement of diagnostic accuracy. The platform assists the medical practitioners in the diagnosis and treatment of Dementia and various other disorders.

VIII. FUTURE WORK

Coming to the Future work of Our System we can add an extra option of Speech and video options. Although the currently we have several useful features for detecting in early stage, they are clinical and Magnetic resource imaging Images. So, by adding up video and speech system could analyse a person's facial expressions, speech fluency, and linguistic characteristics, thus providing a more detailed analysis and report. In addition, the dataset can be expanded to include the genomic data and the levels of protein biomarkers, such as Beta Amyloid and Tau, to enhance the diagnostic depth of the system. Future research may also investigate the integration of "Explainable AI" to generate "heatmaps" on the MRI scans, indicating the exact parts of the brain that the ResNet50 model has identified as abnormal, thereby increasing trust among medical professionals.

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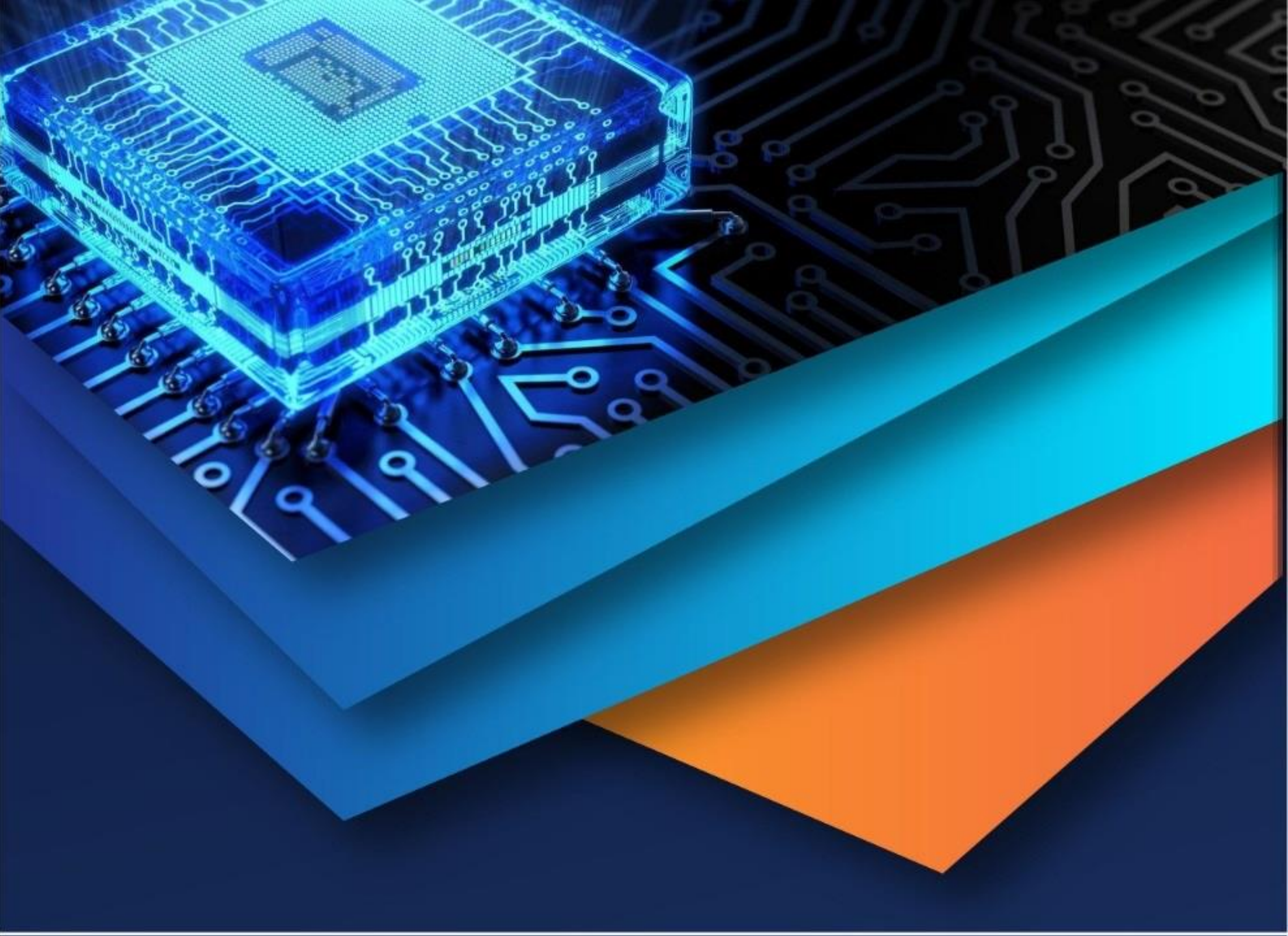

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