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Prediction of Alzheimer's Dementia Disease Stages and Cognitive Scores Using Machine Learning and Deep Learning

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Abstract: ***The most frequent form of dementia which is characterized by a low deterioration of memory, thinking, actions, and social skills, is Alzheimer's disease (AD). Those alterations have a ripple effect on an individual's ability to fulfil their duties. According to present thinking, the erroneous protein build-up in and around brain cells present thinking, the erroneous protein build-up in and around brain cells ultimately causes Alzheimer's disease. AD is not restricted to people over 65; it also affects individuals of all ages. The brain diminishes as the outcome of Alzheimer's disease, and subsequently, brain cells die away. In the early stages of the illness, victims exhibit modest memory loss, which is followed by a decrease in their capability to verbally interact and converse. While there is no curative treatment for the disease, early identification could decrease the severity of the illness and permit patients to lead quality lives. Alzheimer's disease, which particularly impacts elderly individuals and advances neurodegenerative, is a significant factor that leads to dementia. The disease can be divided into 5 stages: Cognitively Normal (CN), Mild Cognitive Impairment (MCI), Early MCI (EMCI), Late MCI (LMCI), and Alzheimer's Disease (AD). These stages are predicted using a well-developed AlexNet model and an OASIS dataset is utilized to predict Cognitive Scores based on the Mini-Mental State Examination (MMSE) using different machine learning algorithms.***

Keywords: Alzheimer's Disease, Cognitively Normal, Mild Cognitive Impairment, Cognitive Scores, Mini-Mental State Examination

I. INTRODUCTION

The phase of dementia that necessitate the most constant and comprehensive therapy is AD. Early & reliable analysis of AD prognostic is vital for beginning of therapeutic improvements as well as successful patient care [1]. Alzheimer's disorder (AD) a permanent neurobiological brain ailment that slowly eliminates brain cells, causes memory & cognitive deficits, inevitably increases deterioration of competence successfully carry out even the most essential duties [2]. The imaging of the brain and computer-assisted assessment techniques are used by doctors to identify AD in its infancy. According to the World Alzheimer's Association's evaluation of the nation's most recent census, which was literally 4.7 million Americans over 65 endured this disease [3]. They expected that 60 million people could be ravaged by AD throughout the next fifty years. All over the world, the condition known as Alzheimer's constitutes 60 to 80 percent of all dementia varieties. A single person acquires dementia every three seconds; 60% are connected to AD [4].

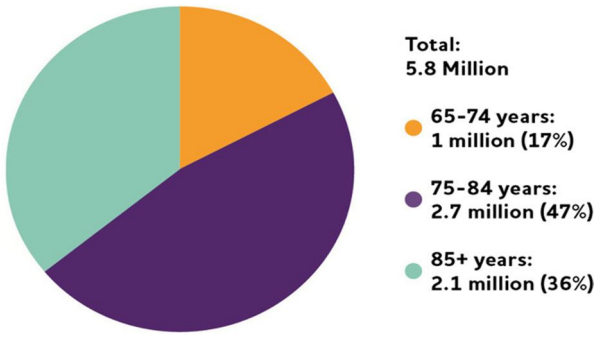

Figure1: Graph of Alzheimer's Disease Percentage

Additionally, modifications in several biological markers show biological markers show to be able to predict Alzheimer's disease long before initial signs and symptoms appear [3]. Hippocampal volume and atrophy are both detected by MRI, an accurate gauge for when individuals will develop from MCI to Alzheimer's disease [6]. Furthermore, lateral ventricular growth a signature feature of Alzheimer's disease & can be employed to assess the level of severity of the disorder [20]. In those suffering from the beginning Alzheimer's disease, the aforementioned structure increases to get bigger in the axial segments of brain's MR image [20]. Therefore, by employing the longitudinal magnetic resonance (MR) scans, progression of the disease can be readily evaluated. Here, estimating the patients' eventual illnesses based on prior MRI scans is an appealing difficulty. Anticipating the future symptoms of people could help physicians with estimating the velocity of the progression of illness while delivering the most effective potential treatment to patients [4].

The following categories roughly correspond to dementia with Alzheimer's:

1) *Mild Cognitive Impairment (MCI):* Many individuals have memory loss as they age, however, for many others, it promotes dementia to emerge as a threat.
2) *Cognitively Normal (CN):* Normal cognitive functioning is not associated with the degeneration of neurons or represents dementia. On the contrary, there are adjustments in the biology of the brain that could have an adverse economic effect on society. Aged individuals suffering from natural cognitive impairment are more prone to money laundering and can find it difficult with reaching financially prudent choices.
3) *Early Mild Cognitive Impairment (EMCI):* The beginning stages of forgetfulness or additional cognitive capacity (including language or mental picture/spatial awareness) loss in individuals with can still carry out most routine duties on their own without assistance threats and consequences.
4) *Late Mild Cognitive Impairment (LMCI):* The effects of dementia worsen all throughout middle stage of Alzheimer's. The individual could mispronounce phrases, lose his or her temper, act in unanticipated manners, which includes rejecting to take a shower. It may be difficult for individual to verbally express their ideas & carry out even simple tasks without help if there has been harm to brain's nerve cells.
5) *Alzheimer's Disease (AD):* Dementia symptoms are really bad when illness is in its later stage. People eventually forfeit their power to govern their gait as well as the capacity to react to their circumstances and carry off having a discussion. Even if they may still utilize phrases and words, it is harder for these individuals to communicate their feelings of grief. Persons may have important behavioral shifts and require medical attention as their recollections and mental abilities keep on deteriorate.

Cognitive decline is increasingly seen as undesirable & characteristic part of aging. Despite fact that elderly people are more endangered than general population as a whole, alterations to cognitive abilities often call for quick action. Whenever people over 65 are unwell ill damaged, their memory seems especially susceptible to decline. The capacity to acquire knowledge and assess therapeutic actions, as well as initial changes in physiologic state, are all influenced by the nurses' judgment of an aging adult's mental well-being. A thorough and meticulous assessment of mental status may be done using the Mini-Mental status Examination (MMSE). In this 11-question examination, orientation, registration, attention and calculation, recall, and language are the five cognitive functions that are tested. The scoring cap is set at 30. A score of 23 or lower indicates cognitive impairment. The MMSE is quick to administer, taking only 5 to 10 minutes, making it easy to use regularly. The ability to predict memory tests at different times in time using the traditional methods for determining Alzheimer's disease constitutes one of the reasons for doing this study. Discovering the part of the brain that is most closely associated with Alzheimer's disease would assist physicians who work in this field focused on the right domains, which is the second reason for this. The primary objective of this investigation was to properly distinguish between the Oasis dataset and magnetic resonance imaging (MRI). Our research aims to: (i) ascertain if the Mini-Mental State Examination (MMSE) is an important predictor of Clinical Dementia Rating (CDR) among elderly persons (ii) examine how markers using cognitive deterioration may improve the ability to predict a provided statistically models. The following objective was to identify the neural region that has been identified as essential in detecting possible variations.

II. RELATED WORK

Numerous researchers have used data mining to detect & evaluate diseases within medical field. The publications that follow can be seen as prominent instances of this field in general.

Kai Li et al [1] developed an innovative machine-learning methodology for EEG signal-based AD detection. Using VAE and TSK fuzzy system representations, model comprehension, and identification precision are improved.

In order to investigate traditional variations in AD treatments across people, latent variables are created. The classification of AD and regular EEG signals is performed using a fuzzy rules-based TSK model utilizing energy characteristics of the latent variables as independent inputs. The TSK fuzzy classifier improves a linear classifier in categorizing energy information from swap-frequency bands of latent variables as well.

Yan Zhao et al [2] proposed a framework for predicting the progression of a disease that combines a 3D multi-information generative adversarial network (mi-GAN) to forecast what an individual's complete brain is going to look like over the course of time, a 3D DenseNet-based multi-class classification network maximized with a focal loss to pinpoint the estimated brain's clinical stage. Based on each individual 3D brain sMRI and incorporating information at the baseline time-point, mi-GAN is capable of producing outstanding individual 3D brain MRI images.

Chima S. Eke et al [3] proposed an SVM model to detect blood plasma tests that are relatively non-invasive and easy to administer, making them a convenient and accessible diagnostic tool. There may be other factors that could influence blood plasma protein levels, such as age, gender, and other health conditions, which could affect the accuracy of the diagnosis. Suriya

Murugan et al [4] The CNN framework is recommended in this investigation to execute AD categorization by utilizing traditional Kaggle data for the classifying of dementia phases a model is developed and verified. The proposed DEMNET model utilizes deep learning and transfer learning, which are powerful techniques for image analysis and classification. Seong

Tae Kim et al [5] developed a fresh method employing individual learning to anticipate longitudinally brain MR images. Our approach consistently remaining brain structure as well as documented temporal modifications of brain in MR images, improving capacity of the model to forecast forthcoming scans versus scans that are currently missing likewise the quality of complicated brain MR images & changes were significantly enhanced by using virtual adaptive schooling to model individualized memory development.

Abol Basher et al [6] Based on slice-wise geometric attributes taken from left and right hippocampi utilizing structural MRI, suggested a technique to diagnose Dementia. The suggested method integrates an DNN model with a network CNN model. A two-phase ensemble was successfully used to dynamically localize left & right hippocampi Hough-CNN. Utilizing the localised hippocampus locations, (80 80x 80 voxels) 3-D regions are produced. The 3-D patches and 2-D slices are subsequently divided using axial, sagittal, and coronal standpoints. A discontinuous volume estimating convolutional neural networks (DVE-CNN) model is utilized to extract geometric data from each slice using previously processed 2-D patches. The categorization network was developed and evaluated using its generated volumetric attributes.

M. Tanveer et al [7] a brand-new combined model (DTE) for Alzheimer's disease classification. Deep learning, transfer learning, and ensemble learning all have been included in the DTE. DTE delivers accurate and trustworthy outcomes through the use of a number of models available and low generalization error hyperparameters to The DTE reached a maximum rating for the large ADNI base dataset.

Mumine Kaya Keles, and Umit Kilic [8] As a feature selector to determine AD utilizing geometrical and statistical analyses of frontal imaging studies (MRIs), an integer variant of the artificial colonies of bees algorithm (BABC) has been suggested. ADNI provided an MRI. A platform called volBrain provides morphological and mathematical data obtained from collected MRIs. Then binary differential evolution (BDE), binary grey wolf optimization (BPSO), and binary particle swarm optimization (BPSO) were utilized as contrasts. The following methods are utilized as classifications in the parameter choice process for an extensive contrast: KNN, RF, and SVM. The results of the comparison show that BGWO works far more effectively than BABC, a comparable methodology for this kind of application. The findings from each of the research investigations indicate that all tackles improve whenever RF is utilised as the classifier.

G. Palacios-Navarro et al [9] study's aim was to investigate the ease of usage and feasibility of an ADL-based test to identify cognitive impairment in individuals with Alzheimer's disease (AD). In total, 24 individuals took part in the study. Twelve elderly people with AD (aged 81.757.8 years; 12 female) comprised the AD group (ADG). Twelve older people (5 men, 77.7 6.4 years) make up the Healthy group (HG). With this study, we have shown how a memory evaluation based on a particular ADL activity may be used to identify cognitive impairments despite getting only a handful of participants, the task managed to distinguish between fit elderly people as well as those with dementia thanks to the inclusion of this demographic.

Yu Zhang et al [10] To tackle uncertainty and inconsistency in the precision of predictions, a tensor multi-task ensembles approach to learning based on the decomposition of tensors has been offered to predict AD development at different points in time. In this structure, a model for forecasting is created employing multi-task regress and spatial variation in morphology trend connections among markers. Tensor hidden components are used as multi-task communications to transfer the data & generate the final prediction conclusions.

III. METHODS

A. Machine Learning Algorithms

1) *Logistic Regression (LR):* LR algorithm may be used for both classification & regression problems, most frequently utilized for classification. Depending on parameters, LR is employed to predict categorical parameters. Consider 2 classes when it is necessary to ascertain the class to which a unique data element belongs. After that, the classifiers evaluate probability values between (0) and (1). The sigmoid function / LR is the cost function that LR uses, it is more advanced. A less detailed quantitative modeling approach is LR, therefore neither equal variance within each group nor linear correlations between the independent variables are required. In order to forecast the possibility of counterfeit credit cards, LR is applied.

2) *Random Forest (RF):* The RF classifier locates decision trees in a subset of the data & integrates their data to that to evaluate the prediction potential of the complete dataset, instead of depending just on one DT. The RF anticipates ultimate results utilizing predictions from every & each tree and the majority vote forecasts. Precision increased the overfitting problem resolved by utilizing a huge no. of trees in a forest. It produces extremely accurate output predictions and functions well even with large datasets. It can also retain accuracy even when a sizable portion of data is lost. Using Random Forest, classification and regression tasks may both be completed. It can manage large datasets with several dimensions. It improves the model's accuracy and minimizes overfitting.

3) *Gradient Boosting Classifier (XGB):* In Gradient Boosting Classifier, the model is trained sequentially, where each new tree is trained to correct errors of previous tree. The algorithm starts by training a single decision tree on the input data, and then iteratively adds new trees to ensemble. In each iteration, algorithm calculates gradient (or the derivative) of the loss function with respect to predictions of the current ensemble. The new tree is then trained to predict negative gradient so that the overall ensemble can minimize the loss function.

4) *Support Vector Classifier (SVC):* Classification & Regression problems are solved using an SVM, one of most utilized supervised learning methodologies. It is utilized, in ML classification difficulties. In order to describe good info points in future, the most appropriate line of decision line to divide the space with n dimensions into classes is defined by the SVM classifier goals. This ideal decision border is known as a hyperplane. SVM is used to determine the extreme vectors and points to assist in the development of a hyperplane. Support vectors were the foundation of the method known as SVM and are employed for representing these life-threatening situations.

B. Deep Learning Algorithms

1) *AlexNet:* Eight balanced layers, five convolutional layers, and three completely connected layers make up the Alex Net. ReLu reactivation is carried out at the conclusion of each layer, with the exception of the final stage, which generates a softmax dispersion over the 1000 labels for each class. In one of the 2 totally linked layers, dropouts are used. Max-pooling is also used following the initial, second, and five layers of convolution, as the picture depicts. The only kernels that are used correspond in the layer prior to this one, which resides on the same graphics card, and have connectivity to the kernels of the second, fourth, as well as fifth convolutional layers in turn. All of the kernel maps in the second layer's convolutional component have connections to the three layer's kernel. All of the cells in the layer below are linked to the other neurons in all of the coupled tiers.

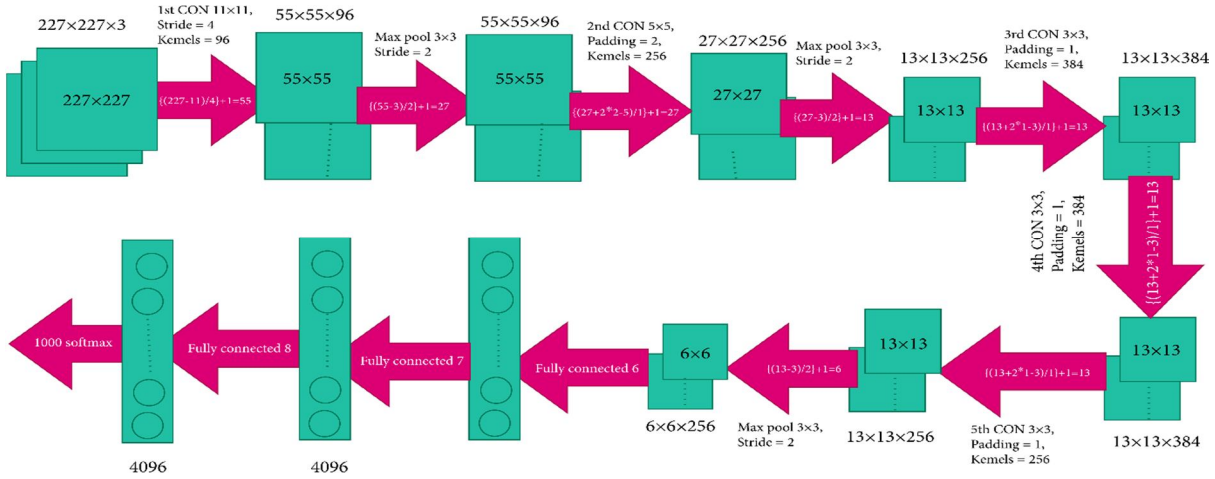

Figure 2: AlexNet Architecture

IV. PROPOSED SYSTEM

For this proposed method we took more than 2659 Brian MRI sample images from The Alzheimer's Disease Neuroimaging Initiative (ADNI) used for predicting Alzheimer's disease stages using the AlexNet model and the Open Access Series of Imaging Studies (OASIS) Human MRI Brain database. From this dataset, we have considered 80% of brain images for training and the rest of the 20% of brain images for testing purposes using machine learning algorithms.

The below diagram describes the proposed model of the project using various machine learning and deep learning models:

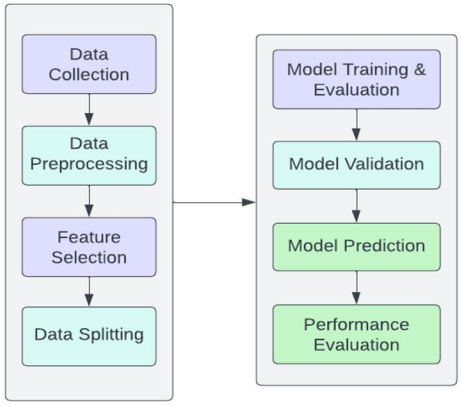

Figure 3: The Proposed Model

Data Preprocessing - Generating clean information sets by removing unclean info utilizing a pre-processing strategy for data. In other words, if information sourced from numerous sources is gathered in a raw style, analysis is becomes impracticable. Data use requires preparation before use. Data cleanup is the method of cleansing up dirty data. Before the classifier runs, the information being analyzed undergoes processing to look for values that are unavailable, inaccurate information, and other irregularities.

Feature Selection - When solving data science issues and machine learning those who practice typically start using analytical instruments to look into the dataset. They do research to fully understand each possible variables and pick the variables that are going to result in an effective prediction system. During machine learning, the procedure of identifying the least amount of variables that are possible for use for creating the most precise forecasting algorithm has been referred to as the selection of features.

Dividing the data – By using comparable data for training and testing, data discrepancies will be less of an issue, and the features of the model will be better understood. After a model has been trained using the training set, it is tested by making predictions against the test set. To improve performance, info is separated into training & testing after preprocessing and sampling.

Classification – Classification is done to read some input and generates an output that classifies the input into some category using different ml and dl classifiers. After classifying then the model is detected and analyzed for better and best output results.

V. RESULTS AND DISCUSSIONS

The performance of proposed method was examined over two datasets. First, MRI images were analyzed and predicted using the AlexNet model. The AlexNet model has given 94.53% accuracy.

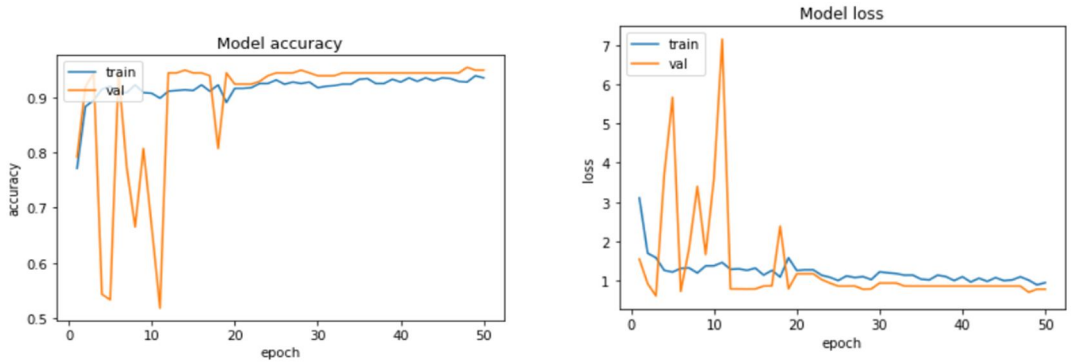

Figure 4: Accuracy and Loss Graph

The below figure shows the ALexNet model prediction:

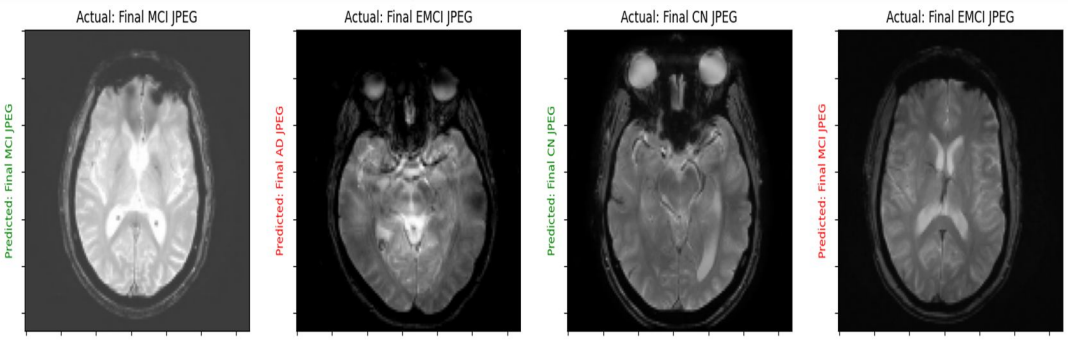

Figure 5: Prediction of Stages in Alzheimer's Disease

Second the Oasis dataset was analyzed using different machine-learning algorithms like LR, RF, XGB & SVC to predict Cognitive scores. The RF gives the best result with 94% accuracy.

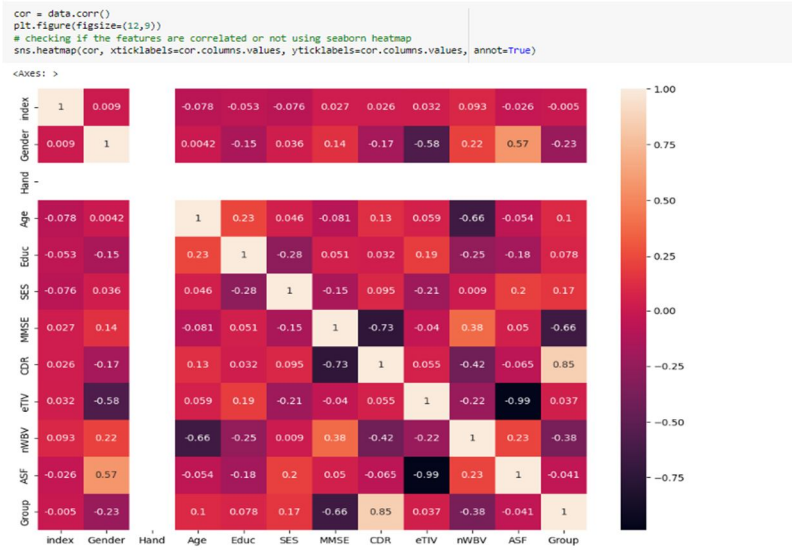

Figure 6: Heat map

```
# comparing predicted with actual value
pred = model1.predict(x_test)

comp = pd.DataFrame({"Real": y_test, "Predicted": pred})
print(comp)
```

```
     Real  Predicted
172     0          0
468     0          0
196     0          0
416     1          1
534     1          0
..    ...        ...
493     1          1
225     1          1
336     1          1
443     0          1
10      0          0

[108 rows x 2 columns]
```

Figure 7: Prediction of Cognitive Scores

VI. CONCLUSION AND FUTURE WORK

In this paper, we proposed an AlexNet model to predict different stages of Alzheimer's disease, the Alexnet model gives an accuracy of 94.53% using 2659 MRI images from the ADNI dataset, where the dataset has different stages like CN, MCI, LMCI, EMCI, and AD. Then we used Oasis dataset to predict the cognitive scores using different machine-learning algorithms like LR, RF, XGB, and SVC. The RF gives the best result with 94% accuracy.

The model will inevitably be taught and reviewed on multiple datasets as a separate structure for identifying Alzheimer's disease by screening all stages of dementia in the future. The initial model for the classification will be constructed using the Inception Network and Residual Networks. By omitting pre-processing techniques like intensity normalization and skull the process of stripping we may obtain identical or better performance. Additionally, by tweaking the pre-trained layers using convolution, the overall efficiency of the base model can be increased whether the data used is sufficient and the tools open allow for the rise in the level of complexity.

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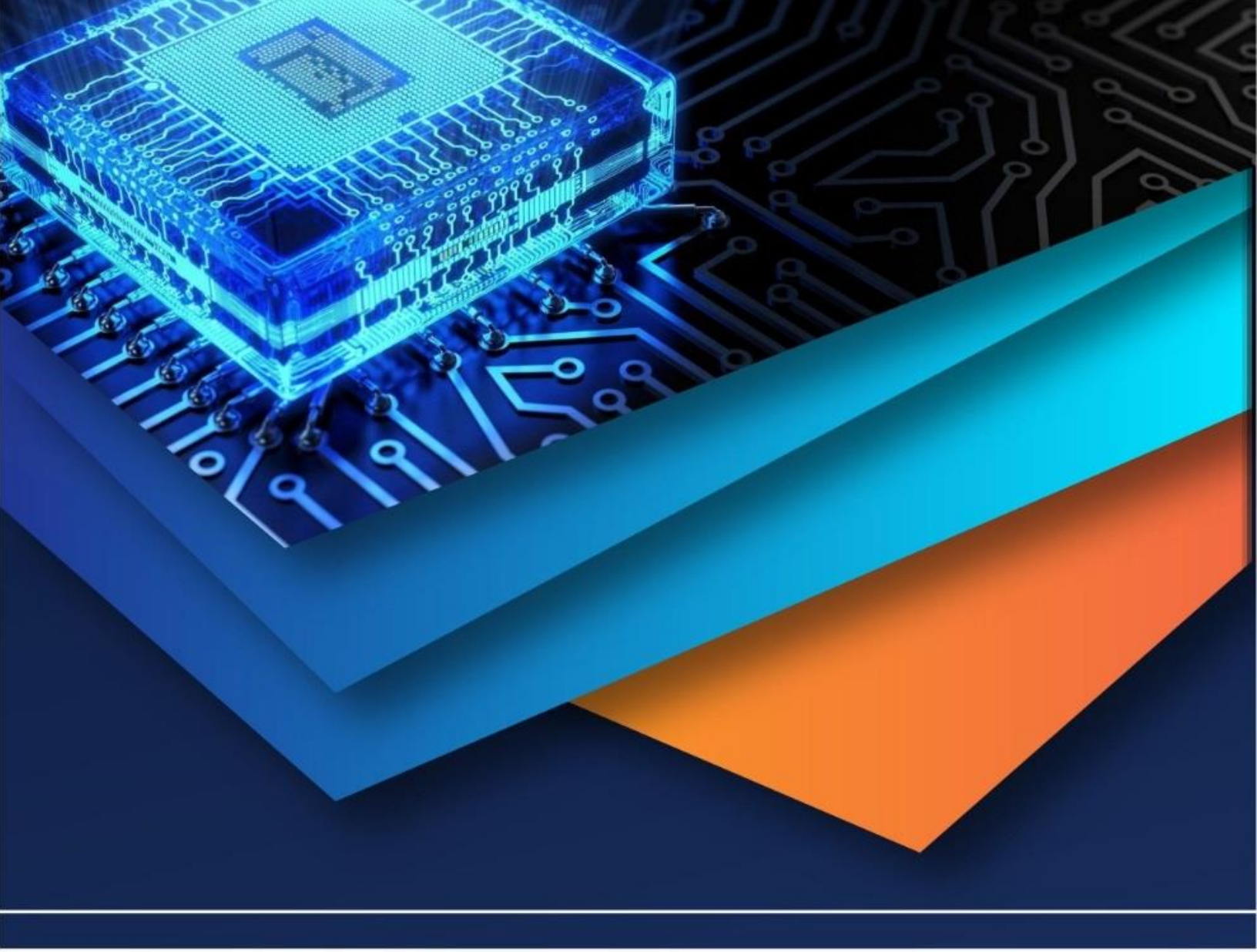

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