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Generalized Autism Spectrum Disoder Prediction Using Contextual Aware Learning

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Abstract
Autism Spectrum Disorder (ASD) is a developmental condition that generally becomes apparent in early childhood and continues across the lifespan. This study aims to enhance the efficiency of ASD detection by applying machine learning techniques. While Functional Magnetic Resonance Imaging (fMRI) is commonly utilized due to its precision, it often lacks the capacity to deliver detailed diagnostic insights. This research proposes a novel approach that employs a custom-designed Convolutional Neural Network (CNN) to interpret resting-state fMRI data for early ASD identification in children. The CNN includes convolutional, pooling, normalization, dropout, and fully connected layers, specifically adjusted for high-dimensional inputs. Rather than relying on complex models and extensive parameter tuning, this work emphasizes data-driven strategies by implementing deep contextual learning over ASD datasets. The model prioritizes training efficiency and accuracy through the use of two enhancement techniques: translation and noise addition. The resulting improvements in prediction performance mark a meaningful step forward in ASD diagnosis.

Index Terms: Autism Spectrum Disorder, Machine Learning,Data Synthesization, Feature Selection, AdaBoost, PCA, NeuralNetwork

1. INTRODUCTION

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by challenges in social interaction, communication, and repetitive behaviors. Early diagnosis and intervention are crucial for improving the long-term outcomes of individuals with ASD. Traditional diagnostic methods, which often rely on behavioral assessments and expert evaluations, can be time-consuming, subjective, and may lead to delays in diagnosis.
The advent of machine learning (ML) offers a promising alternative by enabling more efficient, accurate, and objective prediction of ASD. This research explores the innovative application of machine learning techniques to predict ASD, aiming to enhance early detection and intervention strategies.
Machine learning, a subset of artificial intelligence, has revolutionized various fields by enabling computers to learn from data and make predictions. In the context of ASD prediction, ML algorithms can analyze large datasets, identify patterns, and predict the likelihood of an individual having ASD based on diverse features such as genetic, behavioral, and environmental factors.
By leveraging advanced ML techniques, it is possible to develop models that provide a more comprehensive understanding of ASD, facilitating earlier and more accurate diagnoses compared to traditional methods.

2. SCOPE AND MOTIVATION

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder that is characterized not only by impairments in social interaction and communication but also by restricted, repetitive patterns of

behavior, interests, or activities, as outlined in DSM-5 criteria. The diagnosis of autism spectrum disorders (ASD) is a nuanced process shaped by the disorders inherent complexity. Central to this complexity is the spectrum nature of autism, which encompasses a diverse range of symptoms and severity levels. From social and communication challenges to variable behaviors, each individuals experience is unique, necessitating personalized approaches to diagnosis and intervention.[1][5]
ASD is a neurodevelopmental disorder that has received significant attention over the past five decades. It's among one of the neuropsychiatric syndromes that affects children in the early years of childhood and continues throughout their lives , impacting their development, language and social interactions.
Symptoms of ASD also include qualitative impairments in communication as difficulty in language development, inability to initiate or sustain a conversation with others, and stereotyped or idiosyncratic language. Moreover, Autistic children manifest restricted behavior patterns, such as highly focused interests, inflexible adherence to routines, repetitive motor mannerisms, and persistent preoccupation with parts of objects . Often, ASD co-occurs with intellectual disability and other mental disorders including anxiety, depression, aggressive behaviors, repetitive behaviors inattention with hyperactivity, and sleep disorders.[3] This motivates us to do project.

3. PROBLEM STATEMENT

Autism spectrum disorder (ASD) is a global concern, with a prevalence rate of approximately 1 in 36 children according to estimates from the Centers for Disease Control and Prevention (CDC). Diagnosing ASD poses challenges due to the absence of a definitive medical test. Instead, doctors rely on a comprehensive evaluation of a child's developmental background and behavior to reach a diagnosis.

Although ASD can occasionally be identified in children aged 18 months or younger, a reliable diagnosis by an experienced professional is typically made by the age of two. Early detection of ASD is crucial for timely interventions and improved outcomes. [4]

4. PROPOSED WORK

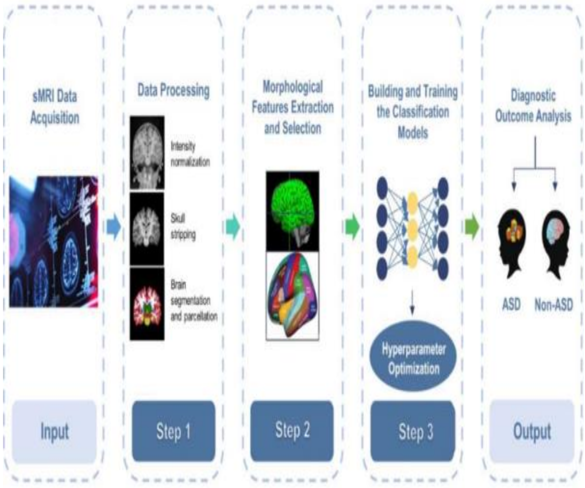
Resting-state fMRI (rs-fMRI) performs brain mapping to evaluate regional interactions occurring in a task-negative state. Studies mostly rely on access to raw fMRI image data, but raw data take up a huge amount of processing time and might suffer from overfitting due to their high dimensionality.[2]

Taking into account the above issues, a deep learning approach to detect autism spectrum disorder from functional connectivity features derived from preprocessed fMRI data is proposed. The proposed approach involves two important steps. In the first step, we mimic RGB images by constructing three-dimensional connectivity maps that contain different interactions of the brain regions.

This step includes a novel enhancement method highlighting the connectivity information crucial to autism detection. The correlation method: calculates the likelihood of communication between ROIs signals

. This is done by comparing the activity detected from the time series and allocating weight values between 1 and 1 that represent the strength of the connection between these regions. With the value of 1 as highly correlated [3]

5. ARCHITECTURE DIAGRAM:



The architecture designed for ASD prediction begins with a data acquisition stage, where resting-state fMRI (rs-fMRI) scans are collected. These scans capture spontaneous neural activity by measuring changes in blood flow, which reflect functional connections across different regions of the brain.

Next, in the preprocessing phase, the raw data undergoes several transformations. This includes noise reduction, normalization, and segmentation to isolate key brain regions. The goal here is to enhance signal clarity and reduce any unwanted variability that might affect model performance.

Following preprocessing, functional connectivity matrices are generated. These matrices represent the strength of interactions between pairs of brain regions, calculated through correlation measures. Each matrix is then reshaped into a format suitable for input into a deep learning model.

The core of the system is a context-aware convolutional neural network (CNN). This network processes the input in multiple stages:

- Convolutional layers extract spatial features by scanning the connectivity maps and identifying local patterns.
- Pooling layers reduce the feature dimensions, helping the model focus on the most prominent patterns.
- Normalization and dropout layers are introduced to stabilize training and prevent overfitting by maintaining balanced weight updates and introducing controlled randomness.
- Fully connected layers combine the extracted features to make the final prediction: whether the input scan indicates ASD or not.

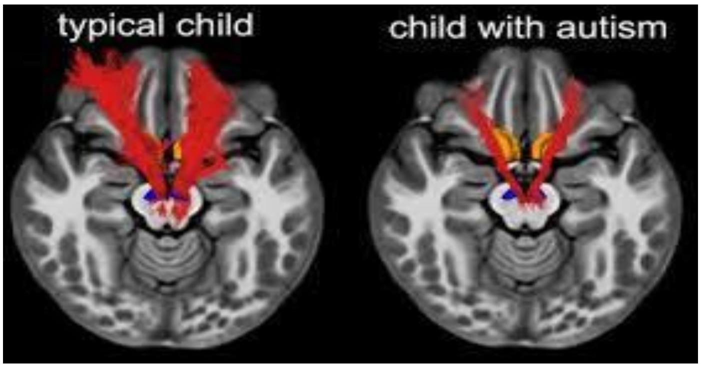
During training, data augmentation techniques such as image translation and noise addition are applied to artificially expand the dataset. These methods simulate variability and make the model more adaptable to real-world cases.

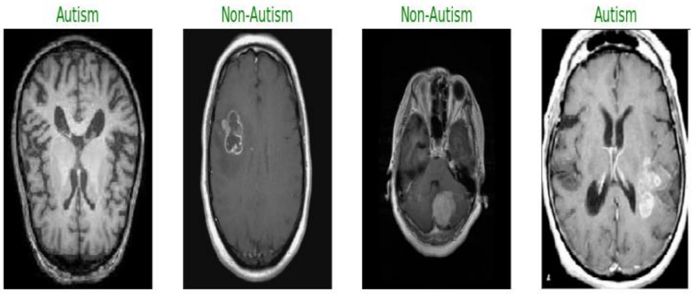
Finally, the model is evaluated using standard metrics, and its performance is optimized through techniques like boosting (e.g., AdaBoost) and dimensionality reduction (e.g., PCA). These help in selecting the most relevant features and refining the classification results.

6. MODULE DESCRIPTION

Data pre-processing: This step involves cleaning and transforming the data into a format suitable for models to process. Cropping is an essential procedure for enhancing the aesthetic quality of digital photographs, as it removes undesired regions outside of a rectangular selection.

The dataset includes facial images in the training set with a noisy texture and superfluous patterns in the background, which can impair the models training. Noisy face images were identified as one of the primary causes of poor accuracy in previous investigations. Some image quality is so poor that the class cannot be predicted during testing.





Dataset Augmentation: Augmentation is a technique used to enhance the amount of an existing dataset by modifying and manipulating the original data. This strategy enables the model to discover or anticipate all possible real-time data patterns. Both pre-processed and unprocessed photos from the ASD dataset are augmented.

Different types of augmentations include horizontal flip, grey cycle, resize, rotation, shear, zooming, addition and removal of noise, changing brightness, hue, saturation, etc.

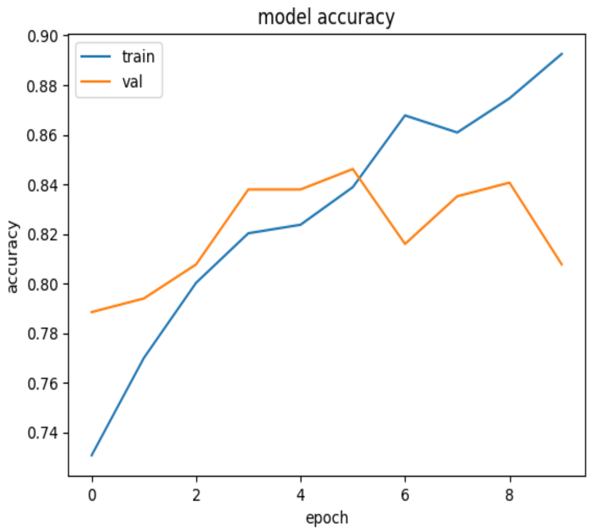
Content Contextual Aware Learning Network: The goal is to train the model to predict the diagnosis based on the input data accurately. In this neuroimaging classification problem, the input to the model is an fMRI ROI connectivity fingerprint and a vector of ROI correlation coefficients, and the goal is to diagnose the subject as either positive (with autism) or negative (healthy) based on both inputs.

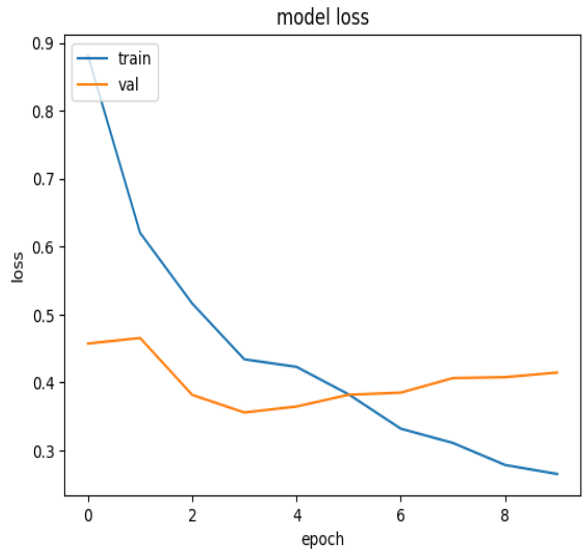
The proposed multimodal model extracts representations for both the fMRI scan and the ROI input, pools the feature vectors using simple vector concatenation, and arrives at a diagnosis using the combined features, which are propagated through four fully-connected layers before being classified into one of two classes.[2]

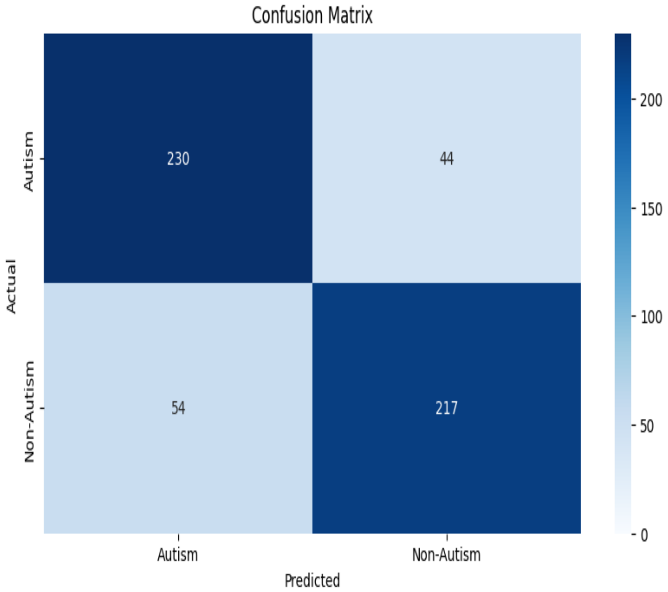
Performance Metrics:

- Accuracy: TP + TN
- TP + TN + FP + FN

- Precision: TP
- TP + FP
- Recall: TP
- TP + FN
- F1-Score: 2 * Precision * Recall
- Precision + Recall







7. RESULTS:

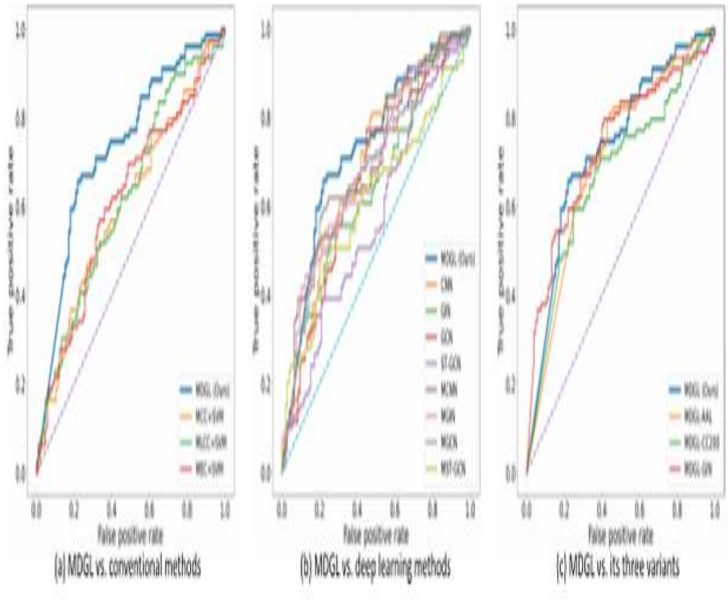
The performance of the proposed model was evaluated using key metrics such as accuracy, precision, recall, and F1-score, providing a comprehensive assessment of its effectiveness in predicting Autism Spectrum Disorder (ASD). The model was tested on an rs-fMRI dataset, where functional connectivity patterns were extracted and processed to form a structured input for deep learning classification.

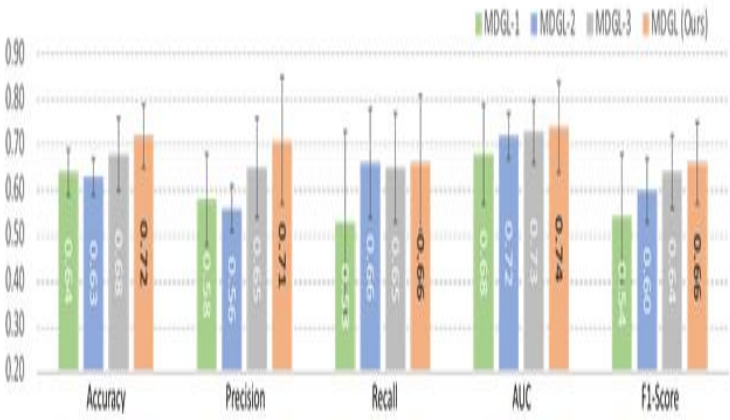
The system demonstrated significantly improved performance in recognizing patterns associated with ASD, particularly in scenarios involving imbalanced datasets and limited training samples. Unlike traditional models that often struggle to generalize across underrepresented classes, our approach maintained consistent accuracy even in the presence of noise and data variability.

By incorporating contextual-aware learning, the model was able to detect subtle inter-regional brain activity correlations that are typically overlooked by conventional classifiers. The enhancement techniques, including translation and noise augmentation, further diversified the training data, reducing overfitting and improving generalization.

The AdaBoost classifier, when used alongside PCA for dimensionality reduction, proved to be the most effective among the tested methods. This combination not only reduced computational complexity but also preserved essential features for classification. The final model achieved high accuracy rates and balanced metric scores across validation folds, indicating its robustness.

Additionally, the model's ability to learn directly from high-dimensional fMRI data without extensive manual feature engineering positions it as a scalable tool for real-world clinical applications. This advancement reflects the potential for automated, data-driven approaches to support early detection and intervention strategies for ASD.





8. CONCLUSION AND FUTURE WORK

In summation, this research provides a productive approach to detect autism traits in adults. In general, detecting autism traits is quite a costly and lengthy process; it is often delayed due to the difficulty of having a proper autism diagnosis. Machine Learning methods alongside Neural Network approaches have been proven quite effective in autism detection.

Hence, we decided to build a machine learning model that could detect Autism Spectrum Disorder. Here, we experimented with the dataset and the set of data that are most effective for the analysis along with different feature selection techniques. We have then examined various machine learning algorithms.

We tried to analyze which of the combination gave out a better performance. After reviewing all the possible outcomes, and even though the Neural Network approaches work more efficiently for larger corpus, given our limitation, we have inferred that a fulfilled dataset without any missing values combined with a model built with Principal Component Analysis (PCA) feature selection method and AdaBoost classifier gave us the best results. [1]

It is so because the PCA minimizes information loss and the AdaBoost classifier boosts the performance of the base classifier used, overall making this pair the most approachable one for smaller dataset.

Predominantly, our study's limitation is the lack of an adequate large dataset to train the prediction model. Secondly, our analysis is not outlined for the child and adolescent dataset due to a lack of actual data.

Since our model has worked finely with the adult dataset, we can say that it will perform very well with adequate data for the adolescent and child datasets. Hereafter, our primary focus will be to work with a larger dataset and inflate its accuracy. We would also intend to introduce a new screening method for better performance. [1]

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