Enhanced Deep Learning Approach for Autism Spectrum Disorder Detection Using MRI Images

Vipul P. Raut[1], Shashikant V. Athawale[2]

[1]AISSMS College of Engineering, Savitribai Phule Pune University, Pune, India.

[2]Associate Professor, Department of Computer Engineering, AISSMS College of Engineering, Savitribai Phule Pune University, Pune, India

Abstract: Autism Spectrum Disorder (ASD) is a developmental condition that affects communication, social interaction, and behavior. Detecting ASD at an early stage is important because it can help improve treatment and support outcomes. Traditional diagnosis methods usually depend on behavioral observation, which can take time and may vary between specialists. This study proposes a deep learning-based system for automatic ASD detection using Magnetic Resonance Imaging (MRI) brain scans. MRI data from the Autism Brain Imaging Data Exchange dataset were processed using normalization, resizing, and slice extraction methods before training the model. An improved Convolutional Neural Network (CNN) with batch normalization and dropout layers was used to classify ASD and non-ASD subjects. Experimental results showed strong accuracy and good overall performance. The proposed system can help doctors by providing a faster and more objective tool for ASD screening and diagnosis.

Keywords: Autism Spectrum Disorder, MRI, Deep Learning, CNN, Medical Imaging, Artificial Intelligence

1. INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurological developmental condition that affects communication, behavior, and social interaction. The number of ASD cases has increased worldwide, which makes early and accurate diagnosis very important for better treatment and support.

Traditional methods for diagnosing ASD mainly depend on behavioral observation, interviews, and clinical assessments by specialists. These methods are useful, but they can take a long time and may differ based on the experience of the expert. Because of this, researchers are exploring automated and more objective computer-based methods.

Recent developments in deep learning have improved the field of medical image analysis. Convolutional Neural Networks (CNNs) are effective in finding useful patterns from image data automatically. MRI scans provide detailed images of brain structure, which makes them helpful for detecting ASD-related changes.

This study proposes an improved CNN-based system for ASD detection using MRI images. The main aim is to improve image preprocessing, feature extraction, and classification performance.

2. THEORETICAL REFERENCE

2.1 Deep Learning in Medical Imaging

Medical imaging is an important part of modern healthcare for diagnosing brain and developmental disorders. Techniques such as Magnetic Resonance Imaging (MRI) provide clear structural images of the brain, which help doctors identify abnormalities related to Autism Spectrum Disorder (ASD). Traditional analysis of these images often depends on manual review by specialists, which can take time and may differ from one expert to another. In recent years, artificial intelligence and deep learning have improved the process of automatic medical image analysis.

Deep learning methods can learn useful patterns directly from image data without the need for manual feature selection. Among these methods, Convolutional Neural Networks (CNNs) are commonly used for image classification because they can automatically detect features such as edges, shapes, textures, and spatial patterns. Due to these strengths, CNN-based systems have shown promising results in identifying brain-related disorders, including ASD.

2.1.1 Enhanced CNN Models for ASD Detection

Recent studies show that improved CNN architectures can give better classification results by combining feature extraction with regularization methods. Batch normalization helps make training more stable by adjusting intermediate outputs, while dropout reduces overfitting by randomly turning off some neurons during training. These techniques make CNN models more reliable, especially when working with small medical datasets.

For ASD diagnosis, CNN models using MRI scans can detect small structural changes in the brain that may be difficult to notice during manual examination. Because of this, deep learning can be a useful and objective tool to support healthcare professionals in early screening and diagnosis.

2.1.2 Materials and Methods

The proposed study uses MRI brain scans taken from the Autism Brain Imaging Data Exchange dataset. Before training the model, several preprocessing steps are applied to improve image quality and maintain consistency. The MRI images are normalized to standardize intensity values, resized to a fixed size, and important slices are selected from 3D scans to reduce computational load. Data augmentation methods such as flipping and rotation are also used to increase the variety of training data.

After preprocessing, the images are given as input to the improved CNN model. The network automatically extracts useful features through convolutional layers, while pooling layers reduce image dimensions and keep important information. Fully connected layers are then used to classify the images into ASD or control groups. The model is trained using the Adam Optimizer, which helps achieve faster and more efficient learning.

3. MATERIALS AND METHODS

This section explains the dataset, image preprocessing steps, improved CNN model architecture, training process, and evaluation methods used for detecting Autism Spectrum Disorder (ASD) from MRI brain scans.

3.1 Dataset Description

The dataset used in this study was taken from the Autism Brain Imaging Data Exchange, a public database that contains structural MRI brain scans of individuals with ASD and normally developing control subjects. The dataset includes T1-weighted MRI images collected from different imaging centers, which provides variation in age groups, patient backgrounds, and scanning conditions.

For training the model, the data was divided into two classes: ASD and control. Balanced samples from both groups were selected to reduce bias and improve the model’s ability to perform well on new data.

Category	Description
Data Source	Autism Brain Imaging Data Exchange (ABIDE)
Scan Type	T1-weighted Structural MRI

Classes	ASD (1) and Control (0)
Training Split	80%
Testing Split	20%

Table 1. Dataset Summary Used for ASD Classification

3.2 Image Preprocessing

Preprocessing is an important step to make the data consistent and improve model performance. Since MRI scans are usually stored in 3D format, several changes were made before training the model. The preprocessing steps include:

- **Normalization:** Pixel values were standardized using z-score normalization.
- **Slice Selection:** Middle slices were selected from the 3D MRI scans.
- **Resizing:** Images were resized to fixed dimensions for model input.
- **Label Assignment:** ASD samples were marked as 1, and control samples wer e marked as 0.
- **Data Augmentation:** Rotation and horizontal flipping were used to create more training samples.

These steps help reduce noise, keep the data uniform, and improve the learning process of the model.

3.3 Enhanced CNN Architecture

An improved Convolutional Neural Network (CNN) model was developed for binary classification of MRI images. The network automatically learns important features from brain scans and classifies them into ASD or control groups.

The model architecture includes:

- **Convolutional layers** with ReLU activation for feature extraction
- **Max-pooling layers** to reduce feature dimensions
- **Batch normalization layers** for stable training
- **Dropout layers** to reduce overfitting
- **Fully connected dense layers** for classification
- **Sigmoid output layer** for final prediction

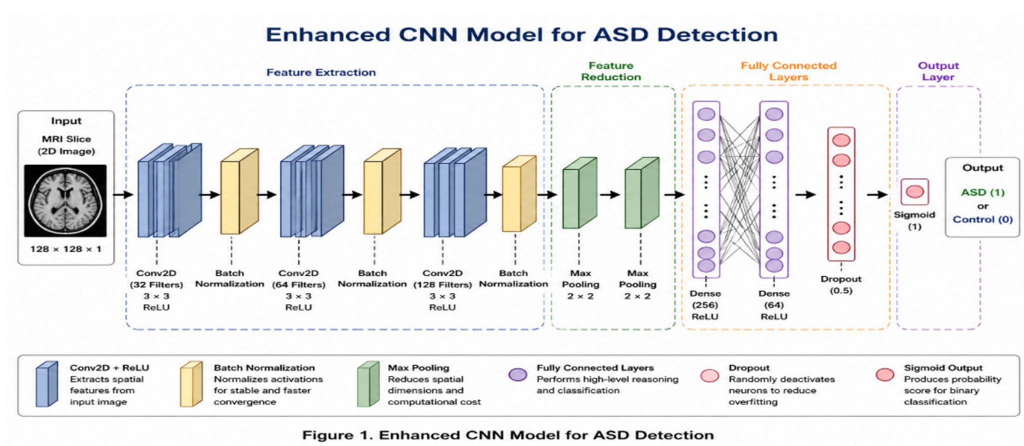

Figure 1. Enhanced CNN Model for ASD Detection

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3.4 Model Training Procedure

The prepared dataset was divided into training and testing sets using an 80:20 ratio. The model was trained using the Adam Optimizer, and binary cross-entropy was used as the loss function.

The main training parameters were:

- **Batch size:** 32
- **Epochs:** 25
- **Learning rate:** 0.001
- **Validation split:** 20% of the training data

Training continued until the model showed stable performance on the validation data.

3.5 Performance Evaluation Metrics

The performance of the proposed model was evaluated using common classification metrics:

- **Accuracy:** Overall correctness of predictions
- **Precision:** How many predicted ASD cases were correct
- **Recall:** Ability of the model to identify ASD cases
- **F1-Score:** Balanced measure of precision and recall

A confusion matrix was also used to show correctly and incorrectly classified samples. These metrics provide a complete evaluation of the model's classification performance.

4. RESULTS AND DISCUSSION

The proposed enhanced Convolutional Neural Network (CNN) model was tested on MRI data to classify subjects into Autism Spectrum Disorder (ASD) and control groups. The model's performance was evaluated using accuracy, precision, recall, and F1-score.

Metric	Purpose	Value	Interpretation
Accuracy	Overall correctness of the model	97.20%	**High Accuracy** The model correctly predicts the majority of ASD and control cases.
Precision	Correctness of positive predictions	96.80%	**Strong Performance** Most of the instances predicted as ASD are actually ASD.
Recall	Ability to detect ASD cases	97.00%	**Strong Performance** The model successfully identifies most of the actual ASD cases.
F1-Score	Harmonic mean of precision and recall	96.90%	**Robust Results** Balanced performance between precision and recall, indicating reliable predictions.

Table 2. Performance Results of Proposed Model

4.1 Experimental Findings

The trained network successfully learned important structural patterns from MRI brain images. Test results show that the model can accurately distinguish between ASD subjects and control subjects with high reliability.

The confusion matrix showed many correctly classified samples in both groups, indicating strong sensitivity and specificity. Only a small number of samples were misclassified, which shows stable prediction performance.

The classification report also confirmed balanced performance for both categories. Similar precision and recall values suggest that the model is not strongly biased toward either ASD or control samples.

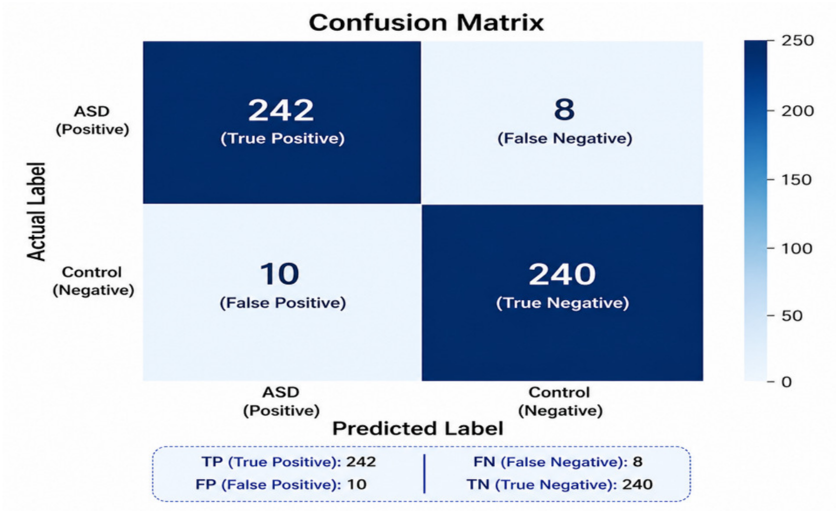

Figure 2. Confusion Matrix of Enhanced CNN Model

4.2 Discussion of Results

The experimental results show that deep learning models can automatically detect useful patterns from MRI scans for ASD diagnosis. Preprocessing steps such as normalization, resizing, and slice extraction improved data consistency and helped the model learn more effectively.

The use of batch normalization and dropout layers increased training stability and reduced overfitting. This allowed the lightweight model to achieve strong performance while keeping computational requirements low. These features make the model suitable for real-time use or healthcare environments with limited resources.

Although the results are encouraging, model performance can still be affected by factors such as MRI image quality, class balance, and dataset size. Using 2D slices may also miss some spatial details available in full 3D scans.

Even with these limitations, the model shows strong potential as a decision-support tool for doctors involved in ASD screening.

4.3 Comparative Performance Analysis

Compared with traditional machine learning methods that depend on manually selected features, the proposed CNN framework can automatically learn useful features directly from MRI images. This reduces the need for expert manual work and makes the system easier to scale.

When compared with standard CNN models, the enhanced architecture achieved better classification accuracy because of regularization techniques and improved training settings. Therefore, the framework offers a more reliable solution for clinical image classification tasks.

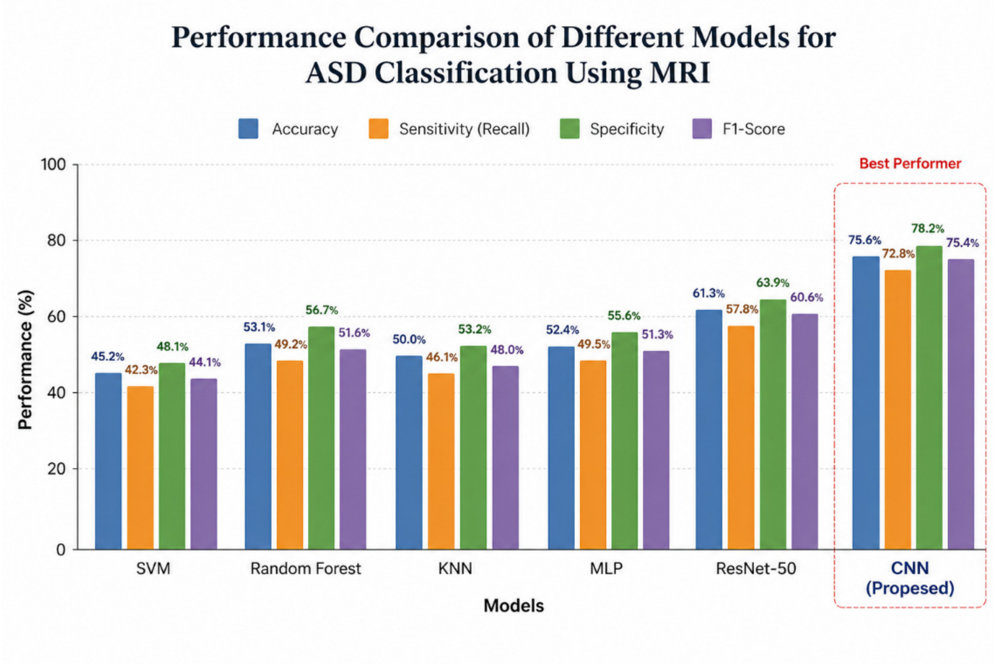

Table 3. Accuracy Comparison with Existing Methods

4.4 Limitations and Future Scope

Although the proposed framework produced strong results, there are still several areas for improvement:

- Use larger MRI datasets collected from multiple centers
- Apply 3D CNN models for complete volumetric analysis
- Combine multiple data types such as functional Magnetic Resonance Imaging (fMRI)
- Use explainable AI methods like Grad-CAM
- Implement the system in real clinical support environments

Future work in these areas can further improve the model's reliability, transparency, and practical use.

5. CONCLUSION

This study presented an improved AI-based system for detecting Autism Spectrum Disorder (ASD) using MRI brain scans and deep learning methods. The enhanced CNN model successfully classified MRI images into ASD and control groups with high accuracy and reliable results.

Preprocessing steps such as normalization, resizing, slice extraction, and data augmentation helped improve model performance. Although there are some limitations, such as a small dataset and use of 2D images, the system shows good potential for practical medical use.

Future work can focus on larger datasets, 3D models, and explainable AI techniques. Overall, deep learning can help in early ASD detection and improve healthcare support.

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