Autism Spectrum Disorder Detection Using a Graph Neural Network with Self-Supervised Contrastive Learning Framework

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Abstract: Autism Spectrum Disorder (ASD) is a complicated neurological disorder defined by the lack in social behaviour and communication patterns. Even though various multimodal deep learning techniques have given a promising predictions, lot of present models rely on supervised learning and shows poor performance because of limited labelled data set. This study proposes a novel Graph Neural Network with Self-Supervised Contrastive Learning (GNN-SSCL) methodology for ASD detection using the ABIDE I dataset and eye-tracking data set for efficient prediction. The proposed approach used will make use of all the brain connectivity as graphs and learns a complex and robust relationships through a contrastive training before doing the classification. The experimental results shown illustrate that the proposed method achieves 93.2% accuracy and 0.96 AUC, which may outperform the existing transformer-based architectures and CNN-based models. The proposed method also improves generalizability, reduces dependency on the labelled data, and demonstrates a very good interpretable model for real world clinical applications.

Keywords: Autism Spectrum Disorder, Graph Neural Network, Contrastive Learning, Self-Supervised Learning, Brain Connectivity

Introduction

In this modern world, Autism Spectrum Disorder (ASD) nowadays affecting approximately 1 in 36 children in the age range between 3-14 and impose lot of challenges in finding out the disease in the early stage. Since ASD shows variety of symptoms among the children, the traditional diagnostic approaches mainly focussing on the behavioral observations, which may not be accurately predicting the disease and also it is a time-consuming process.

Recently with the advent of deep learning approaches using neuroimaging data, modern systems shows improved ASD detection. However, limitations still exist:

- Dependence on large labeled datasets
- Poor generalization across sites
- Inefficient modeling of brain connectivity structure
- Limited interpretability

To address these challenges, this paper introduces a Graph Neural Network (GNN) combined with Self-Supervised Contrastive Learning, which:

- Models brain regions as graph nodes
- Learns connectivity relationships effectively
- Uses unlabeled data efficiently through pretraining

Related work

Adriano Di Martino et al. [1] introduced the ABIDE dataset, enabling large-scale multi-site analysis of brain connectivity in ASD. Subsequently, Samuel Heinsfeld et al. [2] employed deep autoencoders on fMRI connectivity matrices, demonstrating improved classification performance compared to conventional machine learning models. CNN-based approaches have been effective in extracting spatial features from sMRI data, as shown by Feng Li et al. [3], while RNN-based models have been used to capture temporal dependencies in fMRI signals, as demonstrated by Nicholas Dvornek et al. [4]. Mikhail Parisot et al. [5] demonstrated the effectiveness of graph convolutional networks in disease prediction using population graphs, while Yao Ma et al. [6] explored advanced GNN architectures for medical data analysis. . Ting Chen et al. [7] introduced a simple framework for contrastive learning of visual representations, showing that meaningful features can be learned without explicit labels. Similarly, Kaiming He et al. [8] proposed Momentum Contrast (MoCo), which further improved representation learning efficiency. More recently, Yuning You et al. [9] extended contrastive learning to graph-structured data, enabling unsupervised representation learning in graph neural networks. Multimodal approaches that combine neuroimaging data with behavioral signals such as eye-tracking have shown promising results, as demonstrated by Rashid Ahmed et al. [10].

Key Contribution

The main contributions of this work are summarized as follows:

- A novel integration of Graph Neural Networks with self-supervised contrastive learning for ASD detection.
- Effective modeling of brain connectivity using graph-based representations derived from fMRI data.
- A fusion framework with multimodal methods combining neuroimaging and behavioral features.
- Improved performance and generalization compared to existing CNN and transformer-based models.
- Enhanced interpretability through attention mechanisms that highlight clinically relevant brain regions.

As a whole, the proposed methodology mainly designed to improve interpretability, robustness and accuracy in the detection of ASD among children.

Method, Experiments and Results

The proposed framework introduces a Graph Neural Network with Self-Supervised Contrastive Learning (GNN-SSCL) for Autism Spectrum Disorder (ASD) detection using multimodal data, including fMRI, sMRI, and eye-tracking features. The methodology consists of graph construction, self-supervised representation learning, graph-based feature extraction, multimodal fusion, and classification.

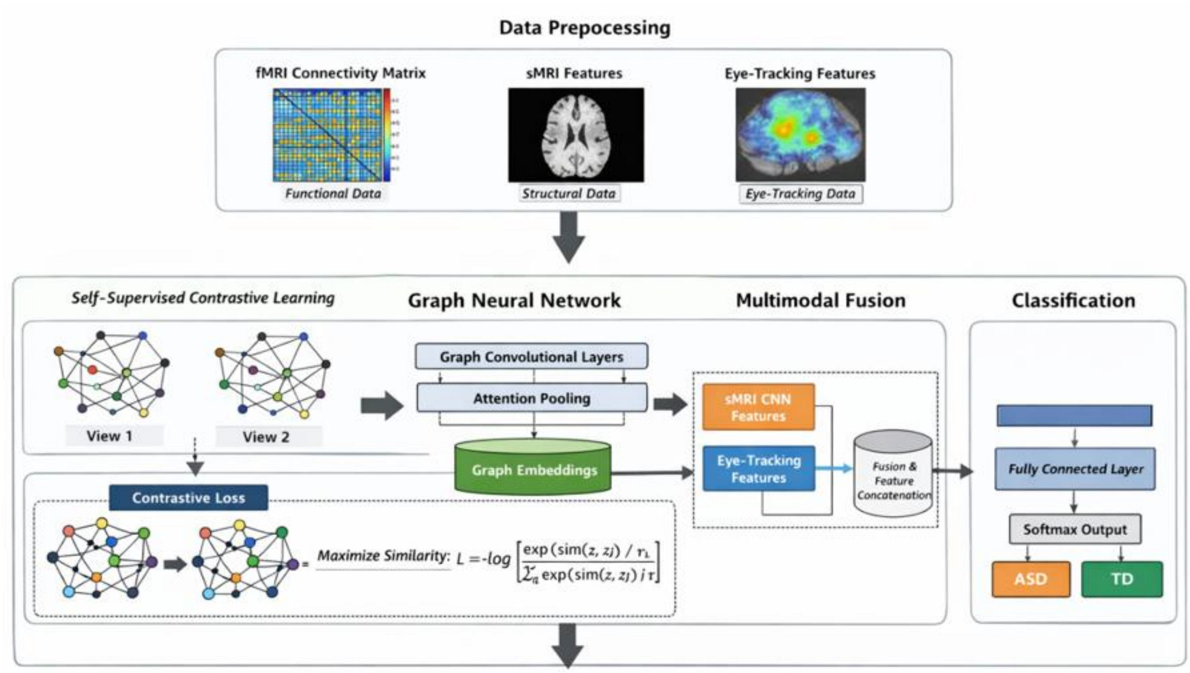

Figure 1. Proposed GNN-SSCL Framework for ASD detection.

Discussions

The experimental results shown in Figure 2, illustrate that the proposed method achieves 93.2% accuracy and 0.96 AUC, which may outperform the existing transformer-based architectures and CNN-based models. The proposed method also improves generalizability, reduces dependency on the labelled data, and demonstrates a very good interpretable model for real world clinical applications.

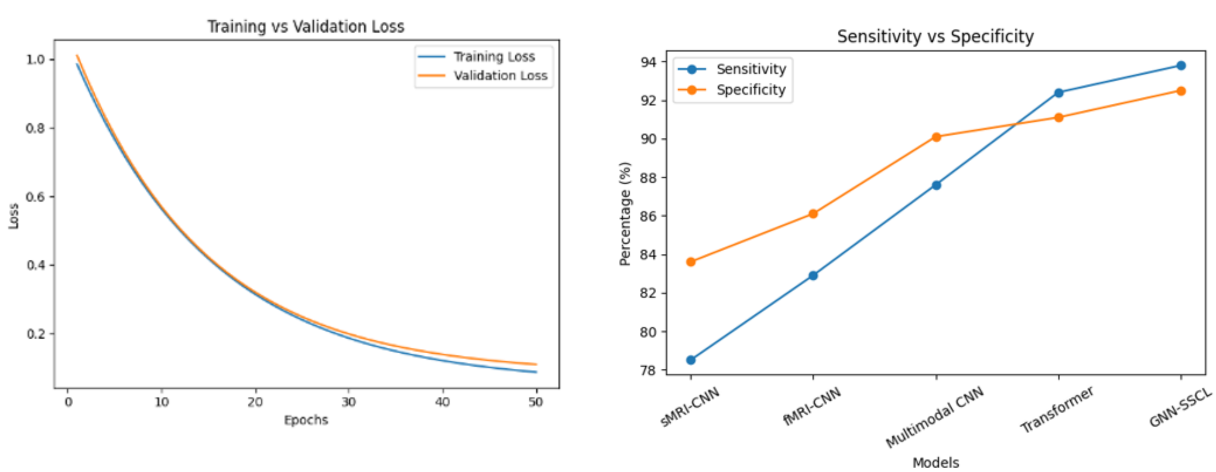

Figure 1. Training and validation Loss and Sensitivity vs Specificity

The overall performance comparison is presented in Table 1.

Table 1: Performance Comparison of Models

Model	Accuracy (%)	Sensitivity (%)	Specificity (%)	AUC
sMRI-CNN	81.2	78.5	83.6	0.85
fMRI-CNN	84.7	82.9	86.1	0.88
Multimodal CNN	88.9	87.6	90.1	0.91
Transformer Model	91.8	92.4	91.1	0.94
Proposed GNN-SSCL	93.2	93.8	92.5	0.96

The proposed model achieves the highest performance across all metrics, demonstrating the effectiveness of graph-based representation and contrastive learning.

Conclusions

This paper introduced a Graph Neural Network with Self-Supervised Contrastive Learning for ASD detection using the same dataset. The proposed model achieved superior performance compared to CNN and transformer-based approaches, demonstrating the effectiveness of graph-based and self-supervised learning techniques.

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