PREDICTING THE DIAGNOSIS OF AUTISM USING CLASSIFICATION MODELS BASED ON FUNCTIONAL MAGNETIC RESONANCE IMAGNG DATA

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Abstract

Autism spectrum disorder is a lifelong neurodevelopmental disorder that is diagnosed based on behavioral and social interaction patterns. Predictive algorithms provide a novel approach in identifying key neurological biomarkers and subsequent psychiatric diagnosis using functional magnetic resonance imaging (fMRI) data. This study analyzes a dataset collected from studies at 17 international locations as part of the Autism Brain Imaging Dataset Exchange (ABIDE). To classify the medical images, we extract regional homogeneity scores and compare random forest models with convolutional neural networks. The accuracy for a five-fold cross validated random forest model and neural network having the highest validation score were found to be 0.57 and 0.54 respectively using the holdout test dataset.

1. Introduction

Autism spectrum disorder is a complex neurodevelopmental disorder characterized by marked social, communicative and sensorimotor impairments (Heinsfeld et al. 2018). Current diagnosis methods require significant behavioral assessments (DSM-5/ICD-10) as physical biomarkers are unknown. There is an interest in developing neuroimaging-based diagnostic biomarkers to aid in diagnosis before reliable behavioral symptoms are apparent (Plitt, Barnes, and Martin 2015). Machine learning classification methods offer a robust way to analyze images or fMRI data as it is highly dimensional (Thomas et al. 2020).

This study's central research topic is to analyze a dataset derived from ABIDE of 800 individuals (400 controls, 400 affected samples) using random forest and convolutional neural network models. The 4-dimensional images (length, height, width and time) is preprocessed before input into the model by transforming it into three dimensions using a suitable measure for fMRI analysis – regional homogeneity (Zang et al. 2004). Research questions include whether traditional machine learning models such as random forest are more suitable than neural networks (scored using the accuracy metric). Other questions will deeply explore the suitability of neural networks such as the evaluation of different convolutional neural network architectures (traditional, 3-D and deep 3-D networks) as well as their resulting image embedding representations.

2. Literature Review

Many machine learning classification models have been used with fMRI data from ABIDE including both convolutional neural networks and random forests but reliable classification of images (>70%) remains elusive due to the neurofunctional complexity and heterogeneity of the disorder (Nair et al. 2018). Indeed, incorporating behavioral metrics had higher performance in machine learning models (Plitt, Barnes, and Martin 2015). As the dimensionality of the data is too large with 20 million dimensions, the literature includes a wide variety of feature engineering and data preprocessing methods (Thomas et al. 2020). The ABIDE Preprocessed Connectomes was used in most studies with preloaded brain atlases describing regions of interest and derivatives for short to long-range connectivity or whole brain analysis (di Martino et al. 2014). This study uses convolutional neural networks because the model preserves some of the dimensionality of the input with 3-D convolutional layers being commonly employed (Sharif and Khan 2022; Thomas et al. 2020). This study also used a the local regional homogeneity derivative which was found to be the best in other studies (Thomas et al. 2020; Nair et al. 2018), though long range connectivity measures such as Craddock 400 are also used (Sherkatghanad et al. 2020; Heinsfeld et al. 2018). Other studies have also used standard preprocessing techniques of neuroimaging data and focused on specific areas of the brain such as the corpus callosum (Sharif and Khan 2022). Due to the lack of academic consensus in processing techniques for this dataset and divergent findings, it is difficult to assess and compare models with the literature but convolutional neural networks have been shown to have higher accuracy score than random forest models (Sharif and Khan 2022).

3. Methods

This research will be conducted on the ABIDE dataset downloaded from the Preprocessed Connectomes project (Cameron et al. 2013) using the CPAC pipeline for all male patients (controls and affected) using the regional homogeneity derivative and input of shape (61, 73, 61). Analysis is done in a Jupyter notebook using kernels for Python3 with models in the keras and sklearn packages and preprocessing and image visualization with the nibabel package for fMRI data. Real neuroimaging data is used in the classification models with 50% used for training, 25% used for validation and 25% for testing using accuracy scores. The key objectives include comparing different neural network architectures, exploring neural network embeddings and comparing with five-fold cross validated random forest model. The base Conv2D layer contatining LeNet5 architecture (Géron 2017) used for the convolutional neural networks will be compared to a 3-D version as well as a version with an added Dense layer and larger size 10 kernel. Various embeddings can be derived from the convolutional neural networks using the weights of the model parameters in a desired layer. Embeddings will be compared for the control and affected groups using the Dense layer with 256 parameters in the base LeNet5 architecture by transforming them and plotting in three dimensions using t-SNE.

3. Results

The accuracy scores for each of the tested models including neural network models base LeNet5, 3-D LeNet5, deeper 3-D LeNet10 and the five-fold cross-validated random forest model on the test set were 0.469, 0.465, 0.535 and 0.565 respectively. The validation dataset scores for each neural network model were the same for each of the neural network models since all of these values are fairly poor and close to random (50% of the samples are controls). Moreover, the best neural network model showed a precision score of 0 for the control class classifying all the images in the whole dataset into the autism group. Precision scores for the random forest model were comparable between the control and autism groups at 0.53 and 0.61 respectively. These results suggest the unsuitability of using neural networks in the classification of medical images. This is clearly seen in the embedding representation with no clustering of samples seen between the autism and control groups as shown in Figure 2.

4. Conclusions

Within this study, the random forest model is the best because it had the highest accuracy score of 0.565 on the test set. This is quite poor but comparable to literature values of 0.54 (Sharif and Khan 2022). Neural network models were found to be unsuitable for classification with values close to 0.5 but did show slightly higher scores with more layers. Neural network models in the literature had better performance than in this study (accuracy score of 70%) likely due to cleaner input data by employing denoising autoencoders (Heinsfeld et al. 2018). Unsurprisingly, incorporating behavioral features increased accuracy 78% to 96% in random forest models (Plitt, Barnes, and Martin 2015). To leverage neural network embeddings, deeper architectures such as VG116 and differently preprocessed features should be tested to attain higher accuracy.

5. Appendices

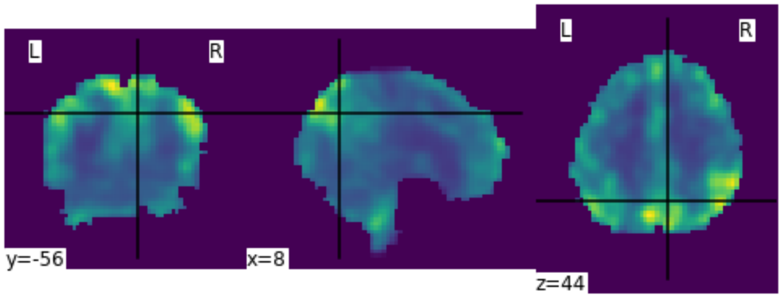

Figure 1. View of brain using nibabel package for regional homogeneity scores in a sample individual from the Caltech site.

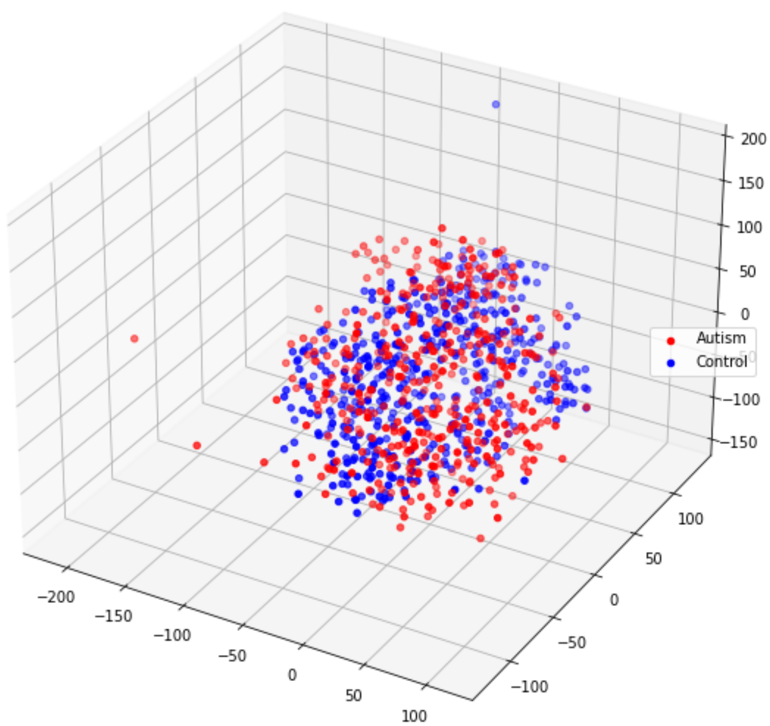

Figure 2. Embedding representation for autism and control groups using dense layer with 256 variables for each image in base LeNet convolutional neural network model.

<u>Supporting Files</u>

- Assignment5.html
- Assignment5.py
- Assignment5.ipynb
- Caltech_0051487_reho.nii (example image)
- nii.gz file folders for males (autism and controls)

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