ASD Diagnoses using Deep Learning and Neuroimaging as A Biomarker: A Review

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Abstract

Autism Spectrum Disorder (ASD) is a commonly occurring neurodevelopmental disorder characterized by problems occurring in social communication and the presence of restricted and repetitive behavior and interests. Up to now, ASD is being diagnosed considering clinical interview, behavior and developmental factors. Early diagnosis of it can help the autistic people to deal well in their lives. For this early detection different biomarker like Neuro-imaging data can be used which includes structural and functional magnetic resonance imaging. In order to explore the functional and structural differences in between TC and autistic group deep learning methods can be used. These deep learning methods will help in efficient classification and thus can help in autism diagnosis as well. In this paper studies related to various Deep Learning techniques used to diagnose autism are being looked at.

Keywords: Autism Spectrum Disorder, ABIDE, Neuroimaging, Deep neural network.

1 Introduction

Autism Spectrum Disorder (ASD) is a disorder that deals with the nervous system thus affecting the brain functioning. It results in repetitive behavioral patterns and deficits in social communication. About one in 54 children has been identified with Autism Spectrum Disorder (ASD) based on estimates from the CDC's Autism and Developmental Disabilities Surveillance Network (ADDM). According to the numbers this disorder is increasingly being seen among children so needs an early diagnosis. Though this disorder can be diagnosed in any stage of life but early diagnosis is always better. The disease effects can be seen in a child from an early age of say about 2-3 years. It is more likely to be seen in boys as compared to girls. In the U.S., around 3.63 percent of boys (in between 3-17 years of age) are seen autistic whereas around 1.27 percent of girls are being diagnosed.

There has been no such proper procedure to have the diagnoses of this disorder, it is just the clinical method that is being used in screening. Thus, only behavioral and developmental factors are being considered in accordance to diagnose it. It makes the diagnoses difficult as it is over all just based on a questionnaire evaluation based on ones' behavior, overall growth, social interaction and intelligence tests. Neuro-imaging can change this whole concept of clinical interviews and will help in earlier and better diagnosis of autism. Various studies are being done considering neuro-imaging as an efficient biomarker for autism detection. There can be various ways of having the brain images like electroencephalograph (EEG), computerized axial tomography (CAT), positron emission tomography (PET) or diffusion tensor imaging (DTI). The structural magnetic resonance imaging is a useful pathway which helps in showing the structural connectivity among various brain regions. In this structural neuroimaging there is another technique called Diffusion Tensor Imaging (DTI) which also deals with the anatomy and structure connections inside the brain. On the other hand, the functional neuroimaging deals with the brain activities and functional

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connections in the brain. The most basic mode of fMRI is EEG which helps in diagnosing brain disorders. Here what matters is the blood flow differences in different regions of brain in order to see the functioning of brain. The basic difference in structural and functional MRI is their ways of being processed. The structural one focuses on the hydrogen nuclei whereas the functional MRI stresses on the oxygen level. In recent times, the most relied on biomarker in studies for autism diagnosis is rs-fMRI which deals with the activities of brain while one being in rest state. In this kind of MRI, the cerebral blood supply changes in various regions of brain are seen.

For these neuro-imaging techniques artificial intelligence (AI) methods like traditional machine learning (ML) and deep learning (DL) are needed in order to diagnose the disease in an efficient way. Since ML is an older technique as compared to later one, so DL is yet less explored in terms of neuro-imaging. This paper reviews various deep learning algorithms being used in order to diagnose autism. The neural network which is mostly being used is convolution neural network.

2 dataset for asd

Data is very important in order to study about ASD and also a proper amount of data is required to train the deep learning networks. ABIDE is an openly available data set to work on for the researchers. Data taken for all the papers being studied is from Autism brain imaging data exchange (ABIDE). ABIDE has two subsets ABIDE I [1] and ABIDE II [2]. ABIDE I consists of 1112 datasets which includes 539 autistic individuals and typical control group is of 573 individuals ageing in between 7-64 years. This data is from 17 international sites whereas ABIDE II openly shares data from 19 international sites. ABIDE II shares data 1114 individuals in total in which 521 is ASD group and 593 is healthy group and this group is between age of 5-64 years. Now there is another series of ABIDE I available openly i.e., Preprocessed ABIDE [3]. In this data set the neuroimages are already preprocessed using different pipelines. Following the HIPAA directives and 1000 Functional Connectomes Project/ INDI protocols, all datasets are anonymous.

3 Preprocessing

The data involving neuroimages needs to be processed before it is used to train the neural networks. It is important because such data set is complex in nature and if we don't use any preprocessing technique it can result in misdiagnosis or wrong results in ASD diagnosis. This preprocessing involves various already set toolboxes. Also, few researchers apply different pipeline processes in order to provide the preprocessed data for further studies just like Preprocessed ABIDE[3].

The techniques applied help in things like realignment, brain extraction, spatial smoothing, slice time correction, etc. The preprocessing can be done by low level preprocessing and high-level preprocessing. In the low level preprocessing it involves specified number of steps and already existing toolboxes applied over the data set to enhance the accuracy level. There are some good reputed tool-kits like FMRIB software libraries (FSL), FreeSurfer, SPM, etc. Then high-level preprocessing step improves the quality of the already preprocessed data thus enhancing the accuracy. The technique includes fast Fourier Transformation (FFT), Sliding Window (SW) and Data Augmentation (DA) and it is applied after low level processing.

There is another method called pipeline method. In the ABIDE database this method is used in order to have the preprocessed data. In this data set four pipeline methods [3] are used i.e., data processing assistant for rs-fMRI (DPARSF), the configurable pipeline for the analysis of connectomes (CPAC), neuroimaging analysis kit (NIAK) and connectome computation system (CCS). The main differences concern the algorithms for each step, the software simulations and the parameters used.

4 deep neural networks

In recent years, deep learning is being used extensively in medical field. In case of ASD diagnosis various DNN methods [13] are being studied. The various deep learning techniques being reviewed are CNN, RNN, AE and DBN.

5 Convolutional neural networks

This is the most used type of neural network for neuroimaging and also for ASD diagnosis. These networks take 2D or 3D images as input and make an appropriate use of spatial information. CNNs have convolutional layers followed by the pooling layer and at last has a fully connected layer. This network helps in feature extraction by using filters or kernels. The feature extraction can include edge detection, object detection, etc. Most of the studies related to neuroimaging and ASD diagnosis is done using this kind of neural network.

This is the most researched technique as compared to other DNN. The papers reviewed includes CNN 1D and CNN 3D otherwise there is CNN 2D as well. In CNN 1D [5] the data is converted into time series which further acts as data for training the model.

In case of CNN 2D is appropriate for image processing as image is 2D in structure so this kind of convolution model is said to be a 2D CNN. In [4] [9] [12] CNN 3D model has applied as the data was in 3D form. The application of it over different number of cases resulted in different performance overall.

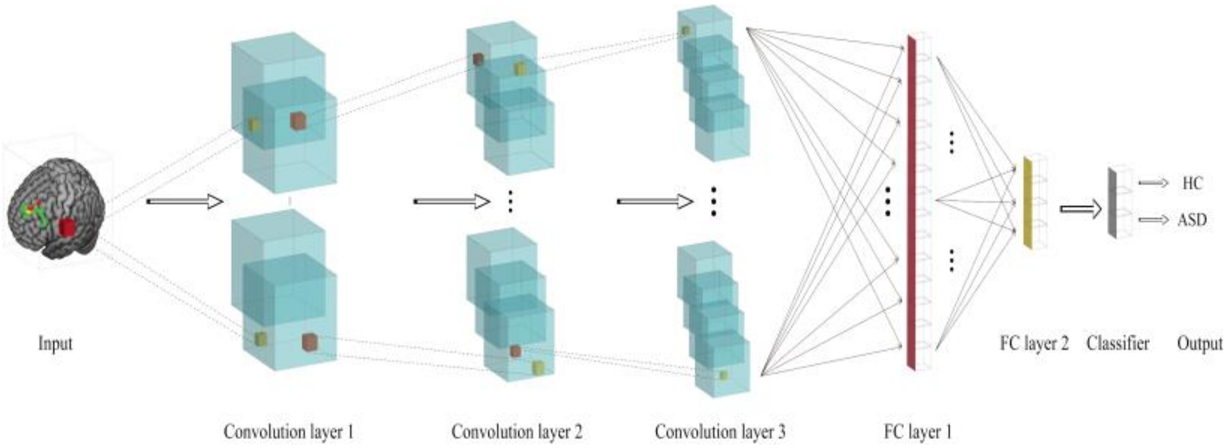

Fig. 1. Block Diagram of CNN 3D

6 Deep belief networks (DBNs)

These are not much in use now but irrespective of it there contribution towards DNN cannot be ignored. In this paper this network is used for extracting features and is unsupervised type of learning. It consists of input layer followed by several layers which are trained in a pattern from bottom to top. After the training process is completed this neural network is used for feature extraction [6].

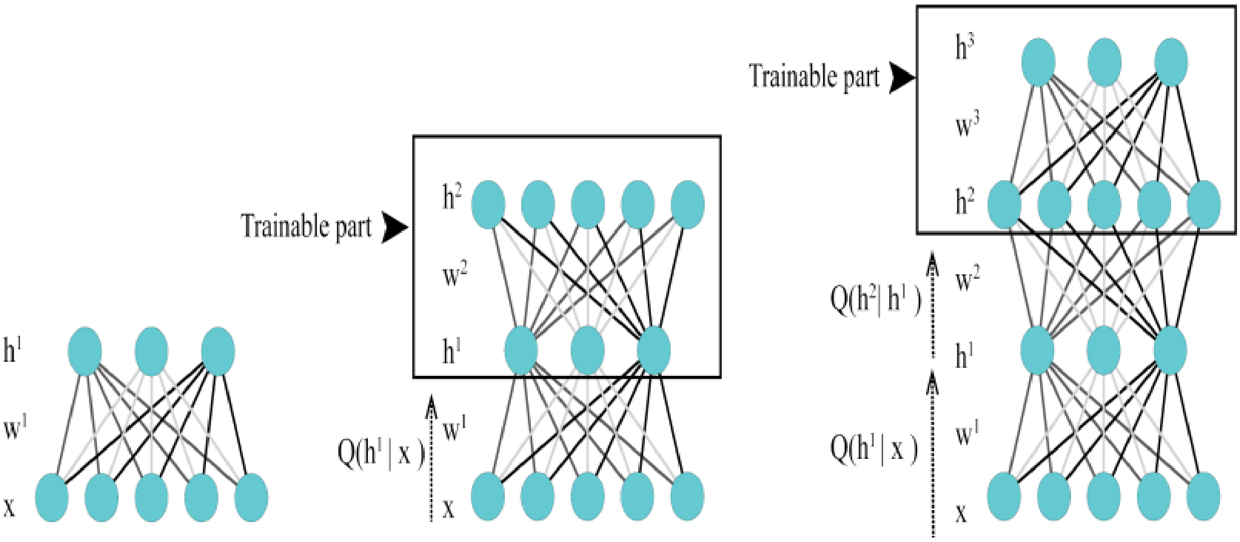

Fig. 2. Block Diagram of DBN

7 Autoencoders (AEs)

It includes two parts: a coder and a decoder. The coder codes the data and decoder gets back the coded data into the initial data. Here the input is same as the output thereby making it a feed forward neural network. They compress the input data into a code of lower dimension and then rebuild the output from the same representation. The code generated is the compressed form of input. The code helps in feature extraction [7].

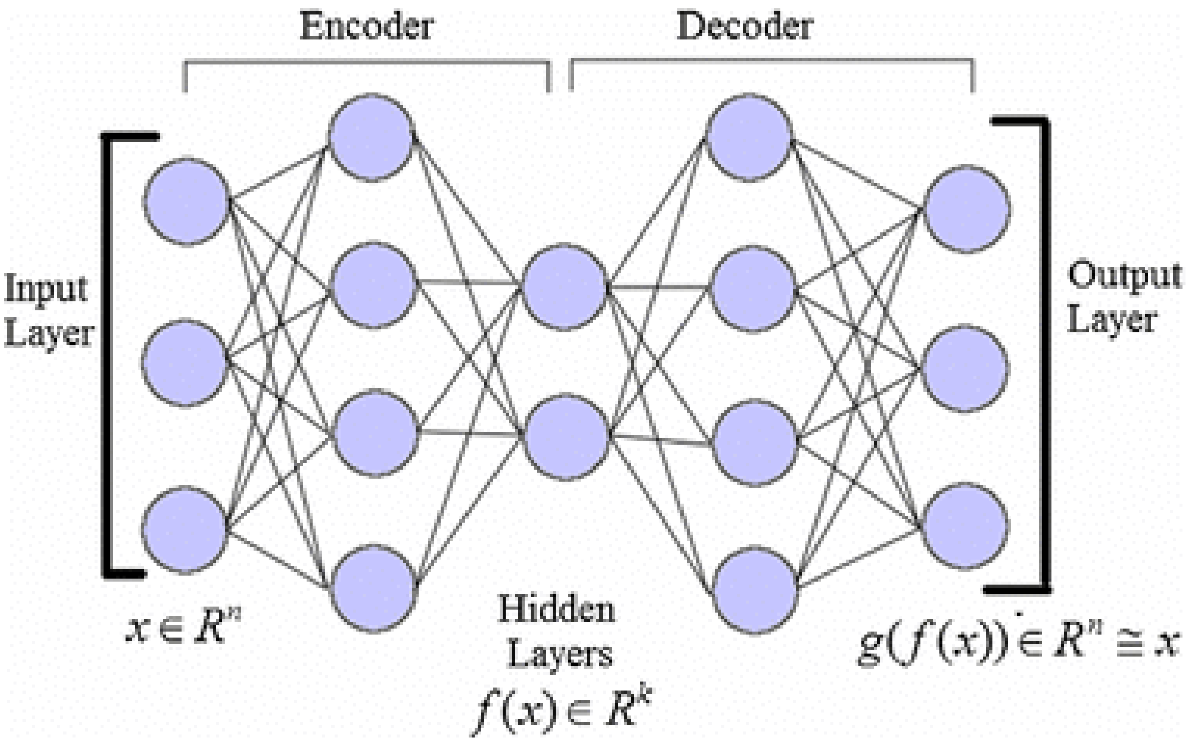

Fig. 3. Block diagram of AE

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8 Recurrent neural networks (RNNs)

In case of CNN it deals with the spatial dependency of the data and doesn't focus on the interdependence of the data. This is overcome by RNNs. It feeds the input with the saved output of the specific layer in order to predict the output. To improve this architecture long term-short term (LSTM) [11] was introduced which gave the network the pertinent information about the past until more recently. There is another variant called as GRU.

These models can be combined together in order to see the accuracy enhancing. There can be combinations like CNN-GRU. This CNN-GRU [8] model provided with ABIDE I fMRI data set resulted in accuracy of 74.54. Thus just like this various combination models can be made like in case of CNN-RNN, it will overcome the performance issues of RNN model with the help of convolution layers in CNN model.

TABLE: Summary of papers reviewed

Reference	**Neuroimaging data set**	**Cases considered**	**Pipelining or preprocessing toolbox**		**High level preprocessing**	**Deep neural network**	**Number of layers**	**Performance accuracy (%)**
[4]	ABIDE I-II Rs-fMRI	542 ASD 625 TC	CPAC		FSM	3D CNN	7	73.33
[5]	ABIDE Rs-fMRI	993 ASD 1092 TC	NA		NA	1D CNN	5	68
[6]	ABIDE I Rs-fMRI ABIDE II sMRI	116 ASD 69 TC	AAL		SPM	DBN	6	65.56
[7]	ABIDE rs-fMRI sMRI	403 ASD 463 TC	FSL		FCM	AE	7	79.2
[8]	ABIDE I rs-fMRI	270 ASD 305 TC	CPAC		Filtering and calculating mean time	CNN-GRU	14	74.54
[9]	ABIDE I rs-fMRI	100 ASD 100 TC	FSL		NA	3D CNN	14	70.5
[10]	ABIDE I rs-fMRI	505 ASD 530 TC	CPAC		FCM, DA	AE	NA	70.1
[11]	ABIDE I rs-fMRI & phenotypic data	403 ASD 468TC	CCS		DA	LSTM	6	70.1
[12]	ABIDE I sMRI	500 ASD 500 TC	FSL		NA	3D CNN	11	70

9 conclusion

Autism is a disorder related to brain which involves repetitive behavior, social deficits and issues in communication. Till now there is no reliable diagnostic solution to this disorder rather it involves just the clinical interview. The interview includes DSM-5 which is just in the question answer form. So, there is a need of a biomarker which can help in diagnosing this disorder. In case of considering neuroimaging as a biomarker and using various DNN it results that CNN is the most studied neural network. The studies are being done on combination models to increase the accuracy. The data in this field is not sufficient to make the system train itself well so this being a drawback. In future multisite data can be taken in consideration and using various combination models can be used to get a better accuracy.

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