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A Survey on Early Diagnosis of Alzheimer's Disease using fMRI Data and Neural Networks

[1]Abhijnashree, [2]Chandana K, [3]Rimsha Mariam, [4]Shanker Mahadev, [5]Karthik S A

[1,2,3,4]BE Students, Department of Information Science and Engineering,
[5]Assistant Professor, Department of Information Science and Engineering
[1,2,3,4,5]Dayananda Sagar Academy of Technology and Management, Bangalore, Karnataka, India.
[1]abhijna9739@gmail.com, [2]chandanak.2812@gmail.com, [3]rimsha.mariam17@gmail.com,
[4]shanker809@gmail.com, [5]karthiksa1990@gmail.com

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Abstract

Diagnosis of Alzheimer's disease at an early stage has undergone rapid improvement in the modernized medicinal services field. Determination of Alzheimer's Disease (AD) is frequently troublesome, particularly at the beginning times which is the Mild Cognitive Impairment (MCI) . Despite the fact that, at this stage treatment is destined to be viable, henceforth demonstrating to be progressively beneficial in improving the conclusion procedure. Some ongoing investigations have demonstrated promising outcomes in the determination of AD and MCI utilizing utilitarian Magnetic Resonance Imaging (fMRI). The principle of this paper is to recognize among techniques to locate the most proficient approach to separate an Alzheimer's cerebrum from a normal cerebrum. The different strategies utilize Neural Networks to become familiar with the deep hidden features.

Keywords: *Alzheimer's disease, Neural Networks, functional MRI (fMRI), early diagnosis.*

1. Introduction

Alzheimer's disease is a degenerative and progressive Cerebrum disease affecting lakhs of individuals all through the world. As per WHO 2018 reports, in the only us it was assessed that 58 lakh individuals were influenced with AD and it is a colossal worry as this number may grow up to 13.8 million by mid century [10]. AD is a constant neurodegenerative illness that generally begins gradually and deteriorates after some time [1]. The run of the mill side effects of AD are a nonstop decrease in deduction, conduct and social aptitudes that disturb an individual's day by day exercises. Mild cognitive impairment is a condition wherein a person's reasoning capacity shows mellow changes that can be seen by the individuals who are near the influenced person[14]. Past specialists have demonstrated that individuals with MCI have a higher danger of experiencing AD than typical people[1]. MCI is regularly found in old individuals running from the age of 60 - 80. MCI, assumes a basic job in averting movement of memory debilitation and improving the personal satisfaction for AD patients. At present, there are no fixes to stop or turn around AD progress, however a few medications can be created to postpone its movement particularly if AD is analyzed at a prior stage.

There are numerous powerful ways for finding of AD which incorporates Computer Aided frameworks. These frameworks utilize different AI approaches and pattern recognition techniques, for example, Magnetic reverberation Imaging (MRI), Positron outflow tomography (PET) and practical MRI (fMRI) [8]. fMRI is a non intrusive utilitarian approach to see changes in the mind and it has been broadly utilized in AD explore on account of its expanded openness , no radiation in the examining procedure, great spatial goals and high differentiation [10]. fMRI especially resting state fMRI reflects unconstrained blood oxygen level when a subject isn't playing out any undertakings. It is a compelling imaging methodology to analyze how fundamentally and practically cerebrum systems are interconnected. By utilizing fMRI, it is conceivable to manufacture a mind organize dependent on the movement of each mind area in the resting state and decide cerebrum work decay by contrasting the

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availability of cerebrum system of certain particular mind areas between solid subjects and AD patients [1].

As of late profound learning has arrived at incredible accomplishments in image processing, Computer vision and medical imaging applications, and thus the Convolutional Neural Networks are utilized in Alzheimer's malady determination [8]. A convolutional neural system (CNN) is a particular sort of artificial neural system that utilizes perceptrons for supervised learning, to analyze data. CNNs apply to image processing, natural language processing and different sorts of intellectual undertakings. In this paper, Convolutional Neural Network being a part of deep learning system engineering is used to recognize a sound mind from an Alzheimer's influenced cerebrum and give the outcome as a trained predictive model [2].

The presence of AD can be without a doubt affirmed distinctly upon the profundity of the patient through an after death assessment of the cerebrum. In this way an exact early analysis of AD is critical for both social consideration and patient.

2. Methodology

Probabilistic Neural Network Method

An MRI image is taken which is subjected to the process of normalization to align it into a single coordinate system. For this purpose we make use of **Affine Registration.** Using this approach the required highlights are accordingly extricated from the MRI pictures. In the next step, using Grey Level Co Occurrence matrix algorithm. Different highlights, for example, shape highlights are likewise determined. The accompanying procedure is rehashed for all preparation pictures and the highlights are extricated thusly. At the point when another MRI picture is bolstered as input to the classifier it would segregate them into the following categories: Alzheimer's Disease, Mild Cognitive Impairment or Normal Control with the aid of prior tutoring it undergoes. Scalar Vector machine, K Nearest Neighbours and Probabilistic Neural Network are compared in terms of their specificity, accuracy and sensitivity [6]. Figure below shows a schematic representation of the model proposed.

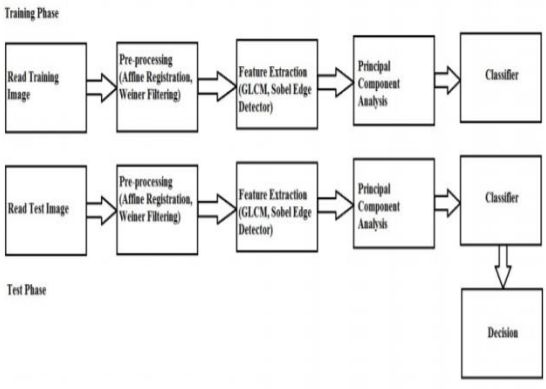

Figure 1: Proposed model

a. Affine Registration

Image Registration expect a fundamental part in medicinal image examination. Contrasts exist between pictures because of various imaging conditions. These Registrations are characterised as a procedure of overlaying multiple images taken at various circumstances or by difference in sensors. Affine Registration is a 2D geometric change connecting pixel intensity present at positions for example x1,y1 in an input to an output image of x2,y2.

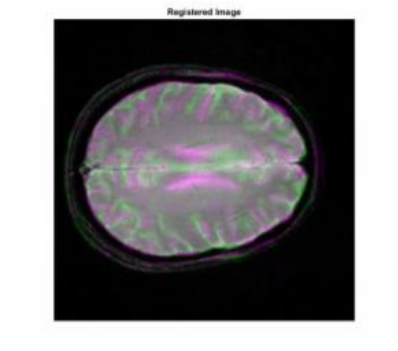

Figure 2: Registered Image

b. Grey Level Co Occurrence matrix

Grey Level Co-event Matrix is utilised as a surface descriptor. This figures the features dependent on grey level forces of an image. Utilising this differentiation, relationship, vitality and homogeneity are determined. This can be utilised to show the proportion of how different mixes of pixel powers happen in an image.

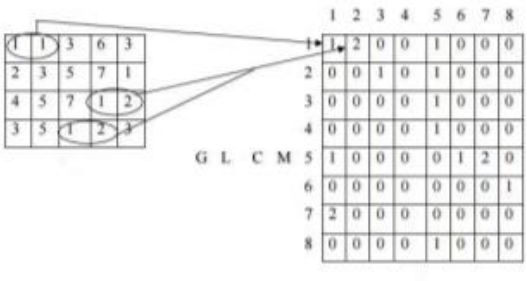

Figure 3: GLCM in 0^0direction

c. Principal Component Analysis (PCA)

PCA is a technique utilized for distinguishing a more modest number of uncorrelated constituents which is typically called as primary constituents from a large collection of data. The objective of this is to show the most extreme measure of difference with negligible number of head parts. The main objective of PCA is to reduce the dataset dimensionality.

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d. SVM Classifier

It is broadly utilized for arrangement and is a type of generalised linear classifier. It minimizes the classification error by limiting mistake edge. Thus is known as Maximum Margin Classifier.

e. KNN

Object classification undertaking can be seen as an issue of sorting new perceptions dependent on completely known training datasets. KNN system is best for characterizing information dependent on the closeness of tests in the data space. This is one of the least difficult of all Machine Learning calculations utilized today.

f. PNN

A PNN is many layered forward feed network with four layers: pattern , input , output and summation layer in no particular order. A PNN will adapt more rapidly than numerous neural networks and demonstrates increasingly fruitful in numerous applications.

g. Wiener filter

It transforms an image that has been disturbed by the noise known as white. It gives a minimum mean square error channel for images corrupted by this.

h. Sobel Edge Detector

Sobel is a strategy for edge location basically utilised in image processing. It's because of the capacity to recognise edges contrasted with other edge discovery methods.

Deep Convolutional Neural Network Method

Magnetic resonance imaging (MRI) is utilized for this model. In MRI extremely complex control of magnetic field, radio waves and field slopes is utilized to deliver profoundly exact picture of body internals without utilizing any sort of intrusive innovation. Here all the 2D images are scanned and converted to form a 3D image which is used in our model.

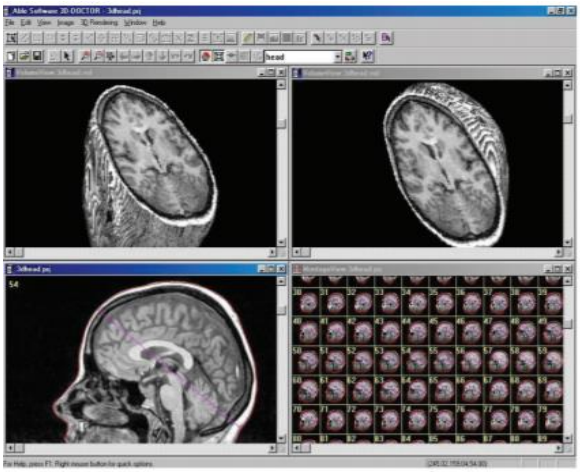

Figure 4: Converting a 3D image to an 2D image.

Figure 5: All slices of 3D MRI

This NN technique has 6 layers. Convolutional layer is the first layer which has a channel to clear over the input MRI pictures to make a feature map. The subsequent layer is the pool layer which is utilized to play out a decrease activity. The following layer is the fully connected layer with a dropout rate of 80%. This dropout rate is utilized to forestall control of certain neurons. In the fully connected layer, there are 248768 neurons. The pooling layer has 2 strides along each entrance, which lessens the size of 3D picture from 50*50*91 to 13*13*23 pixels making the first MRI picture into a feature map. Along these lines, 64 feature maps are made. To coordinate these to the dense layer the quantity of neurons in the dense layer brought about 248768. The last layer is the yield layer with just 2 neurons which gives one hot cluster which shows the patient has Alzheimer's or not. The convolution and fully connected layer have the rectifier direct unit actuation work. For the advancement of this neural system, and a streamlining agent (optimizer) with learning rate 0.001 was utilized. In the wake of testing this neural system there was an indication of overfitting. To redress the overfitting issue, half dropout was utilized in every convolution layer. In this manner in this whole model, 0.80 and 0.50 was the dropout likelihood utilized. The information was part into prepare and test information utilizing cross approval. This expanded the presentation of the neural system radically. For 545 Epoch the model appeared at precision of 80.25%. After 545 Epoch readings, the LF score(Loss function) results in an unhappiness score of 2106288.31519.

The Dem Net Convolutional Neural Networks

In this methodology , we build a 2D Convolutional Network which is called as DemNet. This is based on the VGGNet. The DemNet model as it's input takes the slices.

The procedures involved in this are:

a. **Convolutions**

The convolution tasks include the use of the kernel, stride and padding. Kernel is mainly used as a feature detector. At the point when this is applied on the

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image, it delivers a lot of convolved highlights. The bit is used to indicate the open field of a neuron. This applies a form of connection between the neurons and thereby reduces it to the previous volume. The quantity of convolutional layers are expanded before the reduction of the neuron volume is done, thus allowing us to include more ReLu operations.

b. Rectified Linear Unit

The rectifier is an activation function characterised as the positive piece of its argument: f(x) = max(0,x) where x is the input contribution to a neuron. A unit utilizing the rectifier is a Rectifier Linear Unit (ReLu). ReLu's training time is comparatively faster and hence the fully connected layers and the convolutional layer in this model are trailed by the ReLus.

c. Pooling

Its purpose is to continuously decrease the spatial size of the depiction to diminish the measure of parameters and calculation in the neural system. Pooling layer works on each component map autonomously. The well-known methodology utilized in this method is max pooling. It is an accumulation activity to get the maximum incentive in a local region which is determined by the Kernel and the strides. This kernel and stride helps in operating on the regions that are non-overlapped. Pooling also helps in reducing the dimensions of the inputs to get a summarized version of the output layers as well.

d. Dropout

This system is for the most part utilized so as to diminish the test blunders shaped by abstaining from overfitting. The Dropout layer here has a dropout ratio of 0 and is used to define the yield of neurons present in the hidden layers. Neurons which have been dropped out have no contribution towards the forward pass and the backward propagation in the neural network. This way the neural system provides a distinctive design at every forward and back propagation step. And hence, dropout layers are added after every pooling layer.

e. Fully Connected Layer

This layer is utilized after the last pooling layer. It's neurons have complete and fully fledged connections to every one of the initiations in the layer present before it . 256-256-3 is the number of output neurons used for the three-way classifications and 256-256-2 are used for the two-way classifications.

f. Network Architecture

The architecture used here is the DemNet and it is a changed variant of the 16-layer CNN. Comprising of thirteen convolutional layers and three completely and fully connected layers. Convolutional layers are separated into five batches using a maximum pooling layer. This CNN takes a contribution of an MRI slice and resizes it to an estimate of 224*224. At this point it creates the outputs to each grouping of the classification. This method is trained and checked out in both binary classification and three-way classification. For this three-way classification of DemNet just the precision score was utilized to assess the grouping. We derived a general exactness of 90.85% for the three-way classification with AD being simplest to group, MCI mistook for both AD and HC. Essentially, HC being marginally mistaken for MCI.

For binary classification, the specificity and sensitivity were calculated in addition to accuracy. It was then observed that DemNet had obtained the most optimum accuracy for AD versus HC and AC versus MCI, consequently outperforming Payon and Montana's 3D Convolution.

The proposed architecture diagram is shown in the figure below.

Layer	Output	k-s-p	dr
conv1_1	64	3-1-1	
conv1_2	64	3-1-1	
pool1		2-2-0	
dropout1			0.25
conv2_1	128	3-1-1	
conv2_2	128	3-1-1	
pool2		2-2-1	
dropout2			0.25
conv3_1	256	3-1-1	
conv3_2	256	3-1-1	
conv3_3	256	3-1-1	
pool3		2-2-1	
dropout3			0.25
conv4_1	512	3-1-1	
conv4_2	512	3-1-1	
conv4_3	512	3-1-1	
pool4		2-2-1	
dropout4			0.40
conv5_1	512	3-1-1	
conv5_2	512	3-1-1	
conv5_3	512	3-1-1	
pool5		2-2-1	
dropout5		2-2-1	0.40
fc6_demnet	256		
dropout6		2-2-1	0.50
fc7_demnet	256		
dropout7		2-2-1	0.50
fc8_demnet	3		

The LeNet Convolutional Neural Network

Convolutional Neural Networks are motivated by the human visual framework and are fundamentally the same as great neural networks. In this model little parts of the picture are used as contributions to the most minimal layer of the various levelled structure. The network is built of neurons having loads and predispositions forming a convolutional layer.

a. Convolutional Layer

This layer processes the yield of neurons that are associated with nearby locales in the input. It figures the dot product between its region and the weight that it is associated with the input volume. It plays a significant job in the CNN architecture and comprises of a lot of learnable filters. During this convolving the

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system learns the channels that initiate when they see some particular element in the information.

b. Pooling Layer

The pooling layer is additionally called as pool which plays out a down testing activity along the dimensions. This layer is generally embedded between successive convolution layers and decreases the spatial size of the portrayal so as to control the measure of hyper parameters and subsequently controls overfitting. It works freely on each information and resizes utilizing the maximum operation.

c. Normalization Layer

The Normalization layer or Rectilinear Unit(RELU) applies a component wise activation function, for example, max(0,x). This layer doesn't upset the size of the picture volume.

d. Fully Connected Layer

This layer registers class course bringing about the volume of the quantity of classes.

This model pursues LeNet-5 which effectively characterizes digits and is applied to transcribed numbers. This model was utilized to address a convoluted double arrangement of Alzheimer's information and ordinary information. LeNet-5 was utilized due to the confused dataset. The picture underneath shows the system actualized for fMRI information.

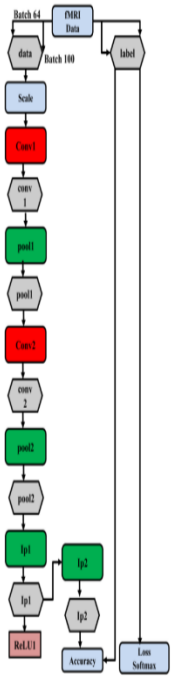

Figure 6: LeNet-5 network implemented for fMRI data

3. Result Comparison

Comparing the results obtained from all the five methods we get different accuracy scores shown in the table below.

METHOD	ACCURACY
Method 1	PNN - 86.14%
Method 2	Deep CNN - 80.25%
Method 3	DemNet - 90.85%
Method 4	LeNet5 - 86.88%

Figure 7: Table denoting the results obtained

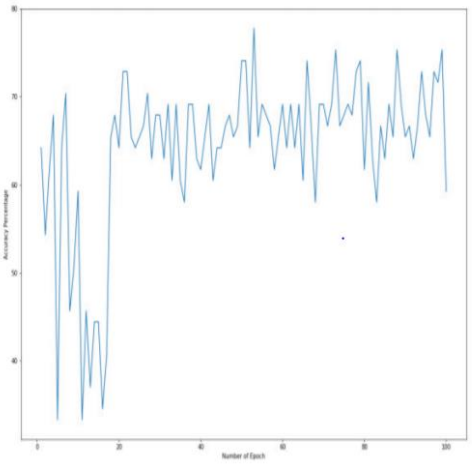

Figure 8: Epoch Vs Accuracy for Methodology 2

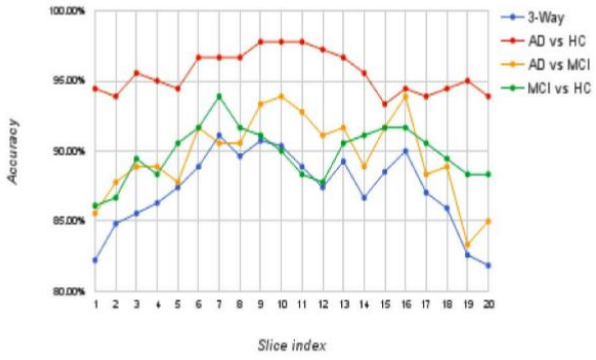

Figure 9: Accuracy for the Methodology 3

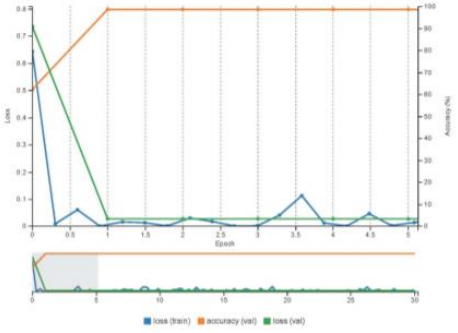

Figure 10: Accuracy for Methodology 4

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4. Conclusion

From the survey of the ongoing papers we can infer that contrasted with conventional strategies, the techniques determined above has accomplished about 20% of enhancement for exactness of the grouping demonstrating the blend of deep learning and brain network is a powerful asset for the early determination of neurological diseases. These techniques permit forecast of Alzheimer's disease at various stages for various age groups. Besides, this deep learning arrangement enables analysts to perform feature selection and classification effectively.

5. Future Enhancements

We intend to improve our model by the deeper classification of AD after its detection into different stages like Early-stage, Middle-stage and Late-stage Alzheimer's which can be helpful in finding the exact treatment required. Potential future work also includes applying the model to other neurological diseases which can prove helpful in the medical field. The overall accuracy of the model can further be enhanced by implementing a methodology with a higher accuracy and can also be done for larger medical datasets that provide more data.

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