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Alzheimer's Disease And Dementia Detection From 3D Brain MRI Data Using Deep Convolutional Neural Networks

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***Abstract*—As reported by the the Alzheimer's Association, there are more than 5 million Americans living with Alzheimer's today, with an anticipated 16 million by 2050. The neuro-degenerative disease is currently the 6th leading source of death in the US. In 2017 this disease would cost the nation $1.1 trillion. 1 in 3 seniors die in Alzheimer's disease or another dementia. It kills more than breast cancer and prostate cancer combined. [14] As of the this papers writing, detecting Alzheimer's is a difficult and time consuming task, but requires brain imaging report and human expertise. Needless to say, this conventional approach to detect Alzheimer's is costly and often error prone. In this paper an alternative approach has been discussed, that is fast, costs less and more reliable. Deep Learning represents the true bleeding edge of Machine Intelligence. Convolutional Neural Networks are biologically inspired Multilayer perceptron specially capable of image processing. In this paper we present a state of the art Deep Convolutional Neural Network to detect Alzheimer's Disease and Dementia from 3D MRI image.**

***Index Terms*—Neural Networks, Deep Learning, 3D Brain MRI, Alzheimer's Disease And Dementia, Machine Learning, Big Data, High Dimensional Input.**

I. Introduction

Alzheimer's disease is the most common type of dementia. One in every 3 seconds a new person someone somewhere is affected by dementia.

It's not the disease of age, it's the disease of the brain and patients may show Symptoms like loss of memory, difficulty in finding the right words or understanding what people are saying, difficulty in performing previously routine tasks and personality and mood changes. [1] Dementia knows no socio, economic, ethnic or geographical boundaries. There is currently no cure for most types of dementia, but treatments, advice, and support are available.

Conventional Machine Learning algorithms requires manual feature extraction whereas a Convolutional Neural Networks don't need any manual feature extraction. Rather it automates the whole thing. In Convolutional Neural Networks a kernel or filter convolve over the image pixel by pixel and automatically selects the features. With the advancements of GPU computing and cloud computing Convolutional Neural Networks and other Deep Learning methods are go to solution for the challenges of 21st century. 3D brain MRI data are historically very complex and time consuming to handle.

MRI stands for Magnetic Resonance Imaging. Its also known as nuclear magnetic resonance imaging. In MRI very sophisticated manipulation of magnetic field, radio waves and

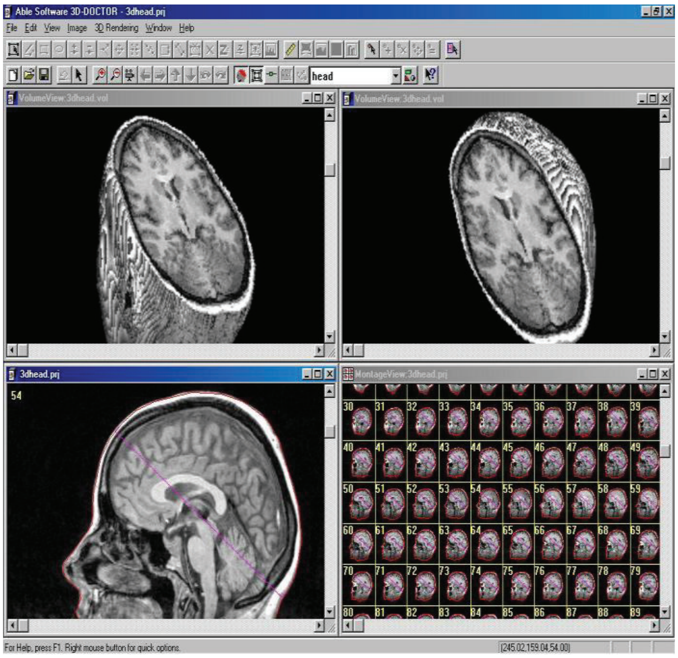

Fig. 1: Creating 3D image from 2D image slices.[3]

field gradients is used to generate highly accurate image of body internals without using any kind of invasive technology. Usually MRI scans the body in an axial plane, or simply put cutting the body into slices from from to back. Each of these slices are regular 2D images. All these 2D images can be knitted together to form an 3D image, hence the term 3D MRI.[2]

II. Related Research and Methodology

This s thesis work has been done using OASIS data. [13] The dataset has 416 Subjects cross-sectional brain MRI data and all of them were diagnosed from mild to severe dementia and non dementia. The problem this thesis work is trying to solve is a supervised classification problem problem. Clinical Dementia Rating or CDR score is the basis of the classification. [4] OASIS has also an spreadsheet file that contains information of 416 subjects (Cross sectional Brain MRI Scan). The main concern here is the attribute named CDR. If CDR score is greater than Zero then the person has Alzheimer's disease. And if CDR=0 then No Alzheimer's disease. So it is now binary classification problem. Our X-input is 3D MRI scan and Y input is whether the person has an Alzheimer's disease or not (1 or 0). [5]

CDR score for all subjects are not given. Some has NaN CDR score. In this thesis NaN CDR score has been replaced by 1. Since Alzheimer's disease mostly affect the Gray matter of Brain, while image pre-processing white matter and gray matter have been divided from each MRI using. Then Gray matter has been the main concern. [6]

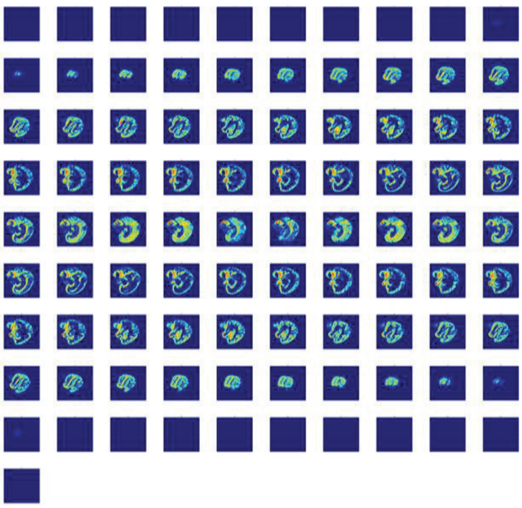

Fig. 2: All slices of one 3D MRI

In a thesis paper using Support Vector Machine (SVM) to detect Alzheimer's Disease with the same OASIS dataset got an accuracy level of 80%. [7] In another thesis using v-SVM an alternative formulation of SVM they have got an accuracy of 92%. [15] But all these are conventional Machine Learning approach where we have to extract the features manually.

III. Neural Network Structure

The neural network structure consists of total 6 layers. The first layer is a Convolutional layer. In this layer a filter is sweep over the input images, to create a feature map. After that a pool layer is used to perform a reduction operation. After that again 1 convolution and a pool is added to perform the same operation. After that a fully connected layer is used, with 80% dropout rate. The dropout was used to prevent domination of only some neurons. [8] The fully connected layer has 248768 neurons. 248768 neurons were particularly necessary because there are two max pooling layers with 2 strides along each axis. these strides reduce the size of the 3d image from 50x50x91 to 13x13x23, transforming the original image into a feature map. Before approaching the dense layer, 64 such feature maps are created. So, to map all these feature maps to the dense layer, for feed forward operations, number of neurons in dense layer resulted in 13x13x23x64 = 248768. And after that finally there is the output layer, with only 2 neurons providing an one hot array indicating if there is Alzheimer's or not. For 2 convolution and the fully connected layer, Rectifier Linear Unit activation function was used. To optimize the neural network, stochastic optimization function Adam Optimizer with learning rate 0.001 was used. The neural network was put to test as is, described above. And it was showing clear sign of overfitting. To counter the overfitting problem, 50% dropout was introduced in each convolution. So the dropout probabilities we have used in our entire model is 0.80 and 0.50. [9] And the data was split into train test data, randomly using cross validation. After that, performance of the neural network was increased drastically.

IV. Result and Conclusion

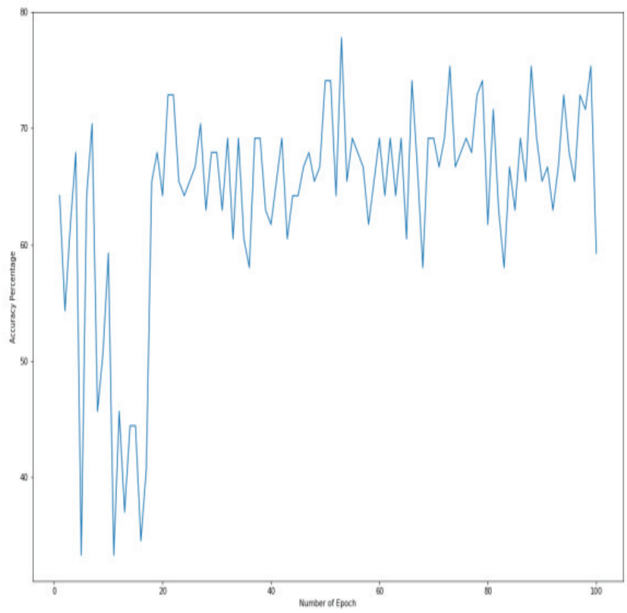

Fig. 3(a): First 100 epoch VS Accuracy

This model has been trained using Floydhub's GPU. [10] After 545 epochs the model has showed 80.25% accuracy.

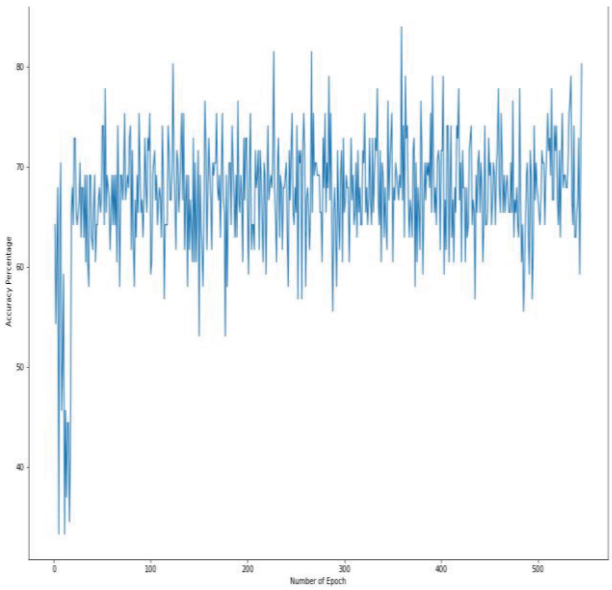

Fig. 3(b): All Epoch VS Accuracy

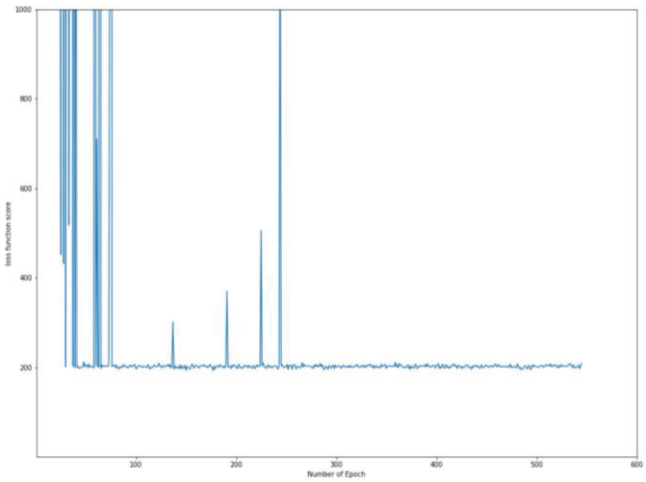

Fig. 4: Epoch VS Loss

From the loss function score after 545 epochs this models unhappiness score is 2106288.31519. The graphs above clearly demonstrates that with more training the accuracy will definitely increase. 3D MRI data is extremely important for detecting not only Alzheimer's disease but also a large variety of other diseases from heart failure detection to brain tumor detection and breast cancer detection. This paper introduced a deep learning based method to detect Alzheimer's disease and dementia. However similar approach can be applied to detect other diseases from 3D MRI data. This paper can also serve as an inspiration to other kind of 3D image analysis using deep learning.

V. Future Research

This thesis work can be extended in following directions : Most of the modern deep learning models can not represent uncertainty perfectly and this is not an exception. If the well studied tools and techniques of statistics and probability can be leveraged by combining Bayesian approaches with deep learning and then feed it into Active Learning Acquisition function, it would be interesting to see how well the neural network performs in case of 3D Neuroimaging data. [11] Modern deep learning models have millions of parameters and can take thousands of hours to train them before using them in production. There are already pre-trained models using Imagenet dataset like Oxfords VGG16, Microsofts ResNet. The weights of these well trained models can be downloaded and chop off the top layer and replaced classification layer there. Then the final layer of this neural network can be retrained and all other layer left untouched. This method has been proven very effective in many applications. [12]

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