Diagnosis Of Alzheimer’s And Parkinson’s Disease Using Artificial Neural Network

Nancy Noella R S, Priyadarshini J

Abstract: Dementia is referred as any syndrome related to memory loss. Memory related problems severely affects the normal functioning of a human brain and the patient feels difficulty in memory, thinking, behavior and the ability to perform everyday activities. There exist various types of dementia, but the decisive types are Alzheimer’s disease (AD) and Parkinson’s disease (PD). This paper presents an Artificial Neural Network (ANN) for the diagnosis of AD and PD using Positron Emission Tomography (PET) scanned images. AD and PD mainly affects to the individuals with more than 60 years old and in this paper brain image of patients with age 50 to 98 is selected. To identify the presence of AD and PD, 1000 PET images are selected and processed. Presented is a Computer Aided Diagnosis (CAD) tool based on ANN for dataset training, testing and classification. The results for the diagnosis are generated automatically by comparing the input image with the trained samples in the PET image database. The classification categories include AD, PD and Healthy brain with a better accuracy of 93.14% compared to the other existing systems like SVM, Decision Tree (ID3) and Naïve Bayes Classifiers.

Index Terms: Alzheimer’s Disease (AD), Artificial Neural Network (ANN), Decision tree, Dementia, Naive Bayes, Parkinson’s Disease (PD), Positron emission Tomography (PET), Support Vector Machine (SVM).

1 INTRODUCTION

The common term used to say about memory loss and other mental related problems is dementia. It is caused by physical changes in the human brain. The different types of dementias are AD, PD, Fronto temporal dementia, Vascular dementia, Lewy body dementia, Creutzfeldt Jakob disease, Wernicke Korsakoff syndrome, Mixed dementia, Huntington’s disease, Normal pressure hydrocephalus and Posterior cortical atrophy. The condition of dementia is so pathetic that there is no cure for these diseases [1, 2, 3]. Alzheimer’s disease is the mostly seen dementia consists of an average of 70% of reported dementia cases. In AD the outer parts of the brain get damaged. This is a severe type of memory loss condition completely destroys the proper doing of daily routines [4, 5, 6]. AD is the most commonly reported syndrome in all the dementia types.

This chronic neurodegenerative disease has early symptoms as difficulty in remembering recent events and problems with language. This condition developed to later symptoms as disorientation, mood swings, impaired judgment and difficulty in speaking, swallowing and walking. AD develops in human brain in three different levels such as mild, moderate, and severe level. The symptoms of early stage - mild AD includes difficulty in remembering names and recent events, forgetting about the works to be done in the work settings, losing or misplacing valuable objects, feeling difficulty in organizing activities etc. Moderate stage – mid level Alzheimer's is the lengthiest stage and can last for several years. The patient needs much care in this stage. The symptoms of moderate AD includes forgetting one's own personal past, seems to be moody, unable to recall their own address or telephone number or other personal details, forgetting recent events, trouble in controlling bladder and bowels, disturbance in normal sleep patterns, personality and behavioral changes, wrings on hands, tissue shred problems etc. In the last stage of this disease, individuals lose their ability to respond to their environment. They have trouble to express their feelings through proper communication. This time the patients need assistance from other individual for the daily routines too. The patients also feel difficulty in sitting, walking and swallowing etc. The patients will be too vulnerable to infections, especially pneumonia. This fatal brain disorder AD, mainly affects the significant parts of the brain like hippocampus, ventricles and cerebral cortex The communicating networks of cavities are called as ventricles and they are filled with cerebrospinal fluid. The information passage from short-term memory to long-term memory is controlled by hippocampus. They enable direction-finding in spatial memory. The largest region of the cerebrum is cerebral cortex and it plays a key role in memory, concentration, sensitivity, cognition, understanding, thinking, language, and realization. Parkinson's disease is the commonly seen memory and physical challenge problem in individuals after AD. This severely affects the human nervous system and thus the patient feels difficulty in movement [7, 8, 9].PD is the progressive disorder of the nervous system that mainly affects movement. In PD a few neurons in the brain gradually break down. This result in the production of chemical messenger in the brain called dopamine. The increase in dopamine level leads to the abnormal brain activity and affects the middle part of the brain called substantia nigra. The early symptoms of PD are constipation, depression, loss of smell, low blood pressure and sleep issues. Lately the symptoms develop to shaking, rigidity, slowness of movement and difficulty in walking. The brain structure of AD and PD compare with healthy brain is given in figure 1 and 2 respectively.

Figure 1. Structural difference between a Healthy Brain and an Alzheimer’s Brain.
2 LITERATURE REVIEW

There are a number of researches gave unbelievable contributions in the field of dementia detection. Most of them concentrate on the diagnosis of a single type of dementia using computer aided diagnosis. The different types of data they used are historical data, physical exam, cognitive test laboratory studies and imaging. Rather than imaging the entire different medical test can categorize only normal or abnormal conditions. So the best type of medical test for categorizing different types of dementia using a single or combination algorithms is medical imaging. The aim of the proposed study is to diagnose different types of dementia using an algorithm and it is a challenge to differentiate between the different dementia since the symptoms of the diseases seems to be similar. So the best type of disease identification is the study in the change of human brain in different dementia condition.

2.1 Existing Works:
The different existing works in the diagnosis of AD and PD given in the below table 1.

<table>
<thead>
<tr>
<th>Paper Title</th>
<th>Dataset Used</th>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMF-SVM Based CAD Tool Applied to Functional Brain Images for the Diagnosis of Alzheimer’s Disease [12]</td>
<td>PET Images</td>
<td>less number of convex functions is used</td>
<td>Possibility of two label classification only</td>
</tr>
<tr>
<td>Weighted Manhattan Distance Classifier; SELDI Data for Alzheimer’s Disease Diagnosis [13]</td>
<td>SELDI (saliva)</td>
<td>complex concepts learned by local approximation</td>
<td>Saliva dataset may leads to misclassification</td>
</tr>
<tr>
<td>An Ensemble Classification Approach for Automated Diagnosis of Alzheimer’s Disease and Mild Cognitive Impairment [14]</td>
<td>MRI Images</td>
<td>Appropriate for high dimensional data</td>
<td>More iterations for classification</td>
</tr>
<tr>
<td>Diagnosis of Alzheimer Diseases in Early Step</td>
<td>MRI Images</td>
<td>Less number of functionality</td>
<td>Complicated Kernel</td>
</tr>
</tbody>
</table>

Table 1: Study on different existing works.

2.2 Related machine learning works:
The different machine learning techniques used in the similar area are studied and explained below: Jack Albright [17] developed a work for the diagnosis and tracking the progression of Alzheimer’s disease using neural networks. He collected ADNI data of 1737 patients and trained data using “All-Pairs” technique. In the case of missing data, data were preprocessed to flag missing entries is the main advantage in this work. Chao Gao et.al [18] designed a work on Diagnostic Prediction and Classification of Parkinson’s disease using model based machine learning techniques. In their work they used clinical, demographic and neuroimaging data sets. They had done a comparative study on the different datasets using random forest, adaboost, XGboost, SVM and neural networks. William Rodman Shankle et.al [19] proposed a work on improving dementia screen test using machine learning. They collected data includes historical data, physical exam, cognitive test laboratory studies and imaging. They classified the status of dementia using Naïve Bayes classifier. Aram So et.al [20] did a work on diagnosis of dementia by machine learning. They developed a two layer model for the early diagnosis of dementia using mini mental state examination. They did a comparison of the proposed MLP algorithm with the other machine learning algorithms.

3 PROPOSED WORK

The work flow of the proposed system is as in the given below architecture diagram figure 3.
3.1 Image Dataset
The datasets used in the proposed work are ADNI and PPMI. ADNI is the standard dataset for Alzheimer’s disease and PPMI for Parkinson’s disease. The Alzheimer’s disease Neuroimaging Initiative (ADNI) is the record based on the study of researchers about AD. ADNI researchers collect, validate and utilize data, including MRI and PET images, genetics, cognitive tests and blood biomarkers as predictors of the disease. The Parkinson’s Progression Markers Initiative (PPMI) is a landmark observational clinical study to comprehensively evaluate cohorts of significant interest using advanced imaging, biologic sampling and clinical and behavioral assessments to identify biomarkers of Parkinson’s disease progression. The ADNI and PPMI images collected for the work are FDG-PET scanned images. PET refers to Positron Emission tomography and it is the nuclear medicine functional imaging technique used for the diagnosis of different diseases by observing the metabolic processes in the body [21]. The selected PET images are scanned by using the biologically active tracer molecule fluorodeoxyglucose (FDG), indicate tissue metabolic activity related with the presence of glucose content.

3.2 Preprocessing
The images get preprocessed one by one using the given three segments: contrast stretching, histogram equalization and wiener filter [22, 23].
1. Contrast stretching improves the quality of the input image by stretching the range of intensity values.
2. The output image from the above segment is taken in this segment. Histogram equalization is done to the input image is calculated for the contrast enhancement of the image using image’s histogram.
3. The Histogram equalization image from the above segment is then processed by wiener filtering method. It is used to remove the mean square error at the time of noise smoothing.

The above mentioned three methods done one by one in the selected PET image in the database and the resultant is the improved quality version of the image. This helps in the information gathering from the medical image for the next layer.

3.3 Segmentation of Proposed Image
Image segmentation is used to convert a digital image into multiple segments. In the proposed work the segmentation method used is a modified K means technique [24, 25]. K means algorithm used for several applications like in the field of, image segmentation, data mining, bioinformatics etc. A normal k means algorithm mainly fits for limited number of data. So the proposed system uses modified version of k means algorithm. The modified k means clustering uses power of Euclidian distance for centroid calculation. Thus the local optimal solution gets avoided and the adoption of cluster error criterion is reduced.

3.4 Feature Extraction
The features of the image from segmentation layer are extracted using GLCM, SURF and Gradient Magnitude Histogram and stored in the database [26, 27].
1. Speeded up Robust Features (SURF) is a patented local feature descriptor and feature detector. Its main application includes in the field of image classification and registration, object recognition and 3D reconstruction. The SURF algorithm has three parts: detection of interest points, description of local neighborhood and matching. In the proposed work the SURF algorithm is applied to the segmented input image and the data values are stored in the database.
2. Gray-level co-occurrence matrix (GLCM) examines the texture of the segmented and returns the spatial relationship of pixels. There are a lot of GLCM features available and among that Autocorrelation, Contrast, Entropy, Energy, Maximum probability and Mean calculation is used in this work.
3. Gradient Magnitude Histogram (GHM) count the occurrence of gradient orientation in localized portions of an image. The gradient values from the histogram is calculated and stored in the database.

3.5 Classification
The database with AD, PD and healthy images are trained and classified using an Artificial ANN with the values got from the feature extracted layer [28, 29, 30, 31]. A neural network is a distinct set of input output units with each unit contains its own weights and a bias. To predict the correct class by using a neural network classifier the training is done by adjusting the weights associated with it. ANN commonly referred as the neural networks with intelligence and its structure is given in figure 4. An ANN is typically defined by three types of parameters:
1. The interconnection pattern - connects the different layers.
2. The learning process – from one layer to another layer it updates the associated weights.
3. The activation function – retrieves output from the given input sample.

![Figure 4. Structure of multilayer artificial neural network](image)

In this paper an artificial neural network with the combination of feed forward and back propagation is used. The input layer calculates the output values and passes them forward to hidden layer. Each hidden layer retrieves signals from every input layer using its own weights and bias function. These values are given to the output layer to obtain the output. An activation function is used to combine retrieve the output from the inputs. Each input symbol is checked by a threshold value to check whether it is above or below threshold value. In the proposed work, the classification process is separated into two phases: training phase and testing phase. In training phase the images to be trained are selected and then the features of the images are extracted in which the label of the image is already known. Then this gets stored in trained database. In the test phase, an image from the test database is selected and the disease category is identified.
4 RESULTS

The proposed system worked on FDG - PET image database with 1000 images. All PET images are downloaded from the Laboratory of Neuroimaging (LONI) in DICOM file formats (https://ida.loni.usc.edu) with Alzheimer’s images, Parkinson’s images and Healthy brain. In the database of 1000 images, 700 images were set for training and 300 images for testing is used. Both training data and test data was processed by an Artificial Neural Network. It classified the test data from trained data into three different classes.

Class 1: Alzheimer’s disease (AD)
Class 2: Parkinson’s disease (PD)
Class 3: Healthy Brain (HB)

The PET image database (total: 1000 images) details with image count, patient’s details and disease category is given in the below table 2.

Table 2: Count of images in the FDG – PET image database

<table>
<thead>
<tr>
<th>Type of disease</th>
<th>AD</th>
<th>PD</th>
<th>HB</th>
</tr>
</thead>
<tbody>
<tr>
<td>No: of images</td>
<td>480</td>
<td>420</td>
<td>100</td>
</tr>
<tr>
<td>No: of male patients</td>
<td>238</td>
<td>343</td>
<td>50</td>
</tr>
<tr>
<td>No: of female patients</td>
<td>242</td>
<td>77</td>
<td>50</td>
</tr>
<tr>
<td>Range of age</td>
<td>61-98</td>
<td>50-85</td>
<td>50-90</td>
</tr>
</tbody>
</table>

The different preprocessing steps done by one to the input image for the classification of AD, PD or Healthy. Table 3 below shows the output generated for the preprocessing steps in the diagnosis of AD and PD using FDG-PET images. Table 3. Preprocessing steps in the diagnosis of AD and PD using FDG-PET images.

<table>
<thead>
<tr>
<th>Preprocessing Steps</th>
<th>Input 1</th>
<th>Input 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Image</td>
<td><img src="image1" alt="Resized Image" /></td>
<td><img src="image2" alt="Resized Image" /></td>
</tr>
<tr>
<td>Resized Image</td>
<td><img src="image3" alt="Contrast Stretching" /></td>
<td><img src="image4" alt="Contrast Stretching" /></td>
</tr>
<tr>
<td>Contrast Stretching</td>
<td><img src="image5" alt="Histogram equalization" /></td>
<td><img src="image6" alt="Histogram equalization" /></td>
</tr>
<tr>
<td>Weiner Filtering</td>
<td><img src="image7" alt="Weiner Filtering" /></td>
<td><img src="image8" alt="Weiner Filtering" /></td>
</tr>
</tbody>
</table>

To check the performance efficiency of proposed ANN, it is compared with other existing algorithms such as Naïve Bayes classifier, SVM and ID3 [32, 33]. The comparison results are shown in table 4 and figure 5.

Table 4: Mean Accuracy, sensitivity and specificity measures in percentages.

<table>
<thead>
<tr>
<th>Performance measures</th>
<th>Mean Accuracy (%)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial Neural Network (Proposed)</td>
<td>93.14%</td>
<td>93%</td>
<td>94%</td>
</tr>
<tr>
<td>Naive Bayes Classifier</td>
<td>69%</td>
<td>65%</td>
<td>70%</td>
</tr>
<tr>
<td>Support Vector machine</td>
<td>87.6%</td>
<td>82%</td>
<td>89%</td>
</tr>
<tr>
<td>Decision tree (ID3) Classifier</td>
<td>85.6%</td>
<td>80%</td>
<td>88%</td>
</tr>
</tbody>
</table>

The different performance measures are defined below.

1. Sensitivity = \( \frac{TP}{TP + FN} \)
2. Specificity = \( \frac{TN}{FP + TN} \)
3. Accuracy = \( \frac{TP + TN}{TP + TN + FP + FN} \)

5 CONCLUSION AND FUTURE SCOPE

The proposed system worked using ANN and yields the mean accuracy of 93.14% for the diagnosis of AD and PD.
performance of proposed system is more accurate and precise compared with other existing systems (ID3, Naïve Bayes and SVM classifiers). Further as the future scope, the paper aims in using other different machine learning techniques and optimization techniques like swarm optimization and genetic algorithm in diagnosis of AD and PD with the specification of its stages.

6 REFERENCES


