A SURVEY: EARLY DETECTION OF ALZHEIMER'S DISEASE USING DIFFERENT TECHNIQUES

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ABSTRACT

Alzheimer's disease(AD) is a neurological disease. It affects memory. The livelihood of the people that are diagnosed with AD. In this paper, we have discussed various imaging modalities, feature selection and extraction, segmentation and classification techniques.

KEYWORDS

Alzheimer's disease, Mild Cognitive Impairment, Partial Least Squares, Gaussian Mixture Model, Non-negative Matrix Factorization, Support Vector Machine.

1.INTRODUCTION

Alzheimer's disease (AD) is the most popular dementia in elderly people worldwide. Its expectation is 1 in 85 people will be affected by 2050 and the number of affected people is double in the next 20 years [6]. Alzheimer's disease [12] was named after the German psychiatrist and pathologist Alois Alzheimer after he examined a female patient (post mortem) in 1906 that had died at age 51 after having severe memory problems, confusion, and difficulty understanding questions. Alzheimer reported two common abnormalities in the brain of this patient, "1. Dense layers of protein deposited outside and between the nerve cells. 2. Areas of damaged nerve fibers, inside the nerve cells, which instead of being straight had become tangled". Moreover, these plaques and tangles have been used to help diagnose AD [29].

There are 3 phases of AD: preclinical, mild cognitive impairment, and dementia. Preclinical means the starting stage of AD. MCI includes "mild changes in memory. Dementia means severity of the disease. The symptoms of AD different between patients. The following are common Symptoms [26] of Alzheimer's:

- Memory loss that disrupts daily life.
- Challenges in planning or solving problems.
- Confusion with time or place.
- Trouble understanding visual images and spatial relationships.
- Decreased or poor judgment.
- Withdrawal from work or social activities.

2.EARLY DETECTION OF ALZHEIMER'S DISEASE

In this survey different technique was mentioned for early diagnosis of AD. Various AD diagnosis techniques are proposed in past. Following subsection describes the techniques. In this section different imaging modalities are discussed.

2.1.IMAGING MODALITIES

2.1.1.SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)

Functional imaging modalities including SPECT [2, 3] and PET are mainly used for achieving early diagnosis. To make reliable decisions about the presence of such abnormalities it is desirable to develop computer-aided diagnosis (CAD) tools than can offer meaningful comparison in the functional brain image in contrast to normal cases (analysis of certain features in the image),regarding the appearance of the abnormalities. These CAD tools are composed of different stages in order to get final classification decision from the original functional image database as source data.

2.1.2.POSITRON EMISSION TOMOGRAPHY (PET)

PET [4, 6] is a non-invasive medical imaging modality that provides 3D maps modeling the glucose consumption rate of the brain. Since glucose consumption is related to the brain activity, PET images can be used for diagnosing several diseases, including AD.

2.1.3.MAGNETIC RESONANCE IMAGING (MRI)

The features are extracted from the structural MRI [6, 30, 31], the existing classification methods can be divided into three categories, using 1) voxel-wise tissue probability 2) cortical thickness 3) hippocampal volumes. It's used to find more effective features for AD or MCI classification are actually extracted from hippocampus, entorhinal cortex and cingulated. It provides rich information about detecting Cerebrospinal Fluid (CSF) level in brain images.

The images are spatially normalized [2, 3, 4]. This process was done by using Statistical Parametric Mapping (SPM) [1] yielding normalized images. In MRI segmentation consists in delimiting neuroanatomical tissues present on a normal brain: gray matter (GM), white matter (WM), and cerebrospinal fluid (CSF) [34].

2.2.FEATURE SELECTION AND EXTRACTION BASED TECHNIQUES

2.2.1.FISHER DISCRIMINATES RATIO (FDR)

The database is analyzed by applying the FDR [2] for feature selection. The total numbers of voxels are down sampled by a factor of 0.5 and the most discriminative features are selected, with the application of the Fisher discriminant ratio criterion which is characterized by its separation ability.

2.2.2.NON-NEGATIVE MATRIX FACTORIZATION (NMF)

NMF [2] for feature extraction of relevant components of each subject. The resulting NMF-transformed set of data, which contains a reduced number of features. In order to reduce the curse of dimensionality, the total numbers of voxels are down sampled by a factor of 0.5 and the most discriminative features are selected, with the application of the Fisher discriminant ratio.NMF is a recently developed technique for finding reduced linear representations of non-negative data being a useful decomposition tool for multivariate data.

2.2.3. PARTIAL LEAST SQUARES (PLS)

PLS [3] feature extraction is more effective for extracting the exactly correct information's from the data. It for modeling relations between the sets of observed variables that means of latent variables. It comprises of classification tasks, regression as well as modeling tools, dimension reduction techniques. It extended to regression problems naturally. The predictor and predicted variables are each considered as a block of variables. PLS serve as a new predictor representation, and also regresses the response variables on these new predictors by extracts the score vectors. The appropriate classifier can be applied when the relevant latent vectors are extracted.

2.2.4. GAUSSIAN MIXTURE MODEL (GMM)

GMM [4, 28] and models the Regions of Interests (ROIs) defined as differences between controls and AD subject. It's the most mature methods for classical clustering and also used intensively for density estimation. The texture features are also used early diagnosis of AD [11].

2.2.5.NEUROPSYCHOLOGICAL AND FUNCTIONAL MEASURES (NM)

Neuropsychological [8] feature selection was performed using a filter method. If a wrapper were to be used, the highest accuracy would be achieved when using the top ranked feature. Therefore, only one feature can be selected in NC and AD groups, whereas this feature may be not an optimal subset for MCI classification. NM features based on 2 rankings. First mutual information between features, clinical labels. Second AUC values in SVM classification of each individual NM to discriminate between NC and AD. Linear feature Normalization was applied before ranking. In order to reduce variability, we carried out two feature ranking schemes 20 times using 10-fold cross-validation on the training set.

2.2.6.WAVELET PACKET TRANSFORM

Wavelet Feature Extraction [19] is a well-known image analysis technique it provides excellent time, richer feature space and frequency resolution. It yields the robust features for improve the probability of correct classification. The wavelet called mother wavelet when many wavelets can be constructed from that. A mother wavelet compressed for changing the size of the window. In this paper [19], the feature extraction is performed using wavelet-packet transform.

2.2.7.PRINCIPAL COMPONENT ANALYSIS (PCA)

PCA [20, 33] is a standard technique for extracting the most significant features from a dataset, frequently used to reduce the raw data to a subset of features that contains the largest amount of variance. The use of PCA [32] within this work is justified not as a dimensional reduction technique but it is applied to the average images vector. Therefore, this paper [20] introduce PCA

as a procedure for extracting a decorrelated eigenvector basis from the previous defined average image vectors. Similar frameworks in which a reduced number of sources are obtained from a linear combination of the mixtures have also been used in other fields as face recognition problem [23], or functional magnetic resonance imaging (fMRI) [21].

The number of vectors in this new basis is the same as the number of classes used to define the average images. Therefore, none of the eigenbrains are neglected, independently from its variance eigenvalue.

2.2.8.INDEPENDENT COMPONENT ANALYSIS (ICA)

The ICA transformation is used for capturing group-differences from high order voxel relations, generating from the original average images sources characteristic vectors (pk) a new set of statistically independent components. For achieving the ICA transformation, we make use of FastICA [22] for iterative fixed-point algorithm and it has the contrast function chosen to be a cubic polynomial. Once the basis vector {pk} of the subspace S is obtained, a set of features can be extracted to train a SVM with labeled data.

2.3.SEGMENTATION TECHNIQUES

The brain matters are mainly classified as gray matter, white matter, cerebrospinal fluid (CSF). CSF protein level changes connected to the neurological diseases. Cerebrospinal Fluid (CSF) is a colorless liquid. CSF surrounds and fills the spinal cord and brain. CSF protein level changes are found in any stages of people. The intracranial pressure to the normal level is maintained by the normal flow of CSF. The disorder is diagnosed by the simulation of CSF and to help for the treatment. Clustering [5] is the important method in pattern recognition and is defined as data compression for a large number of samples are converted into a small number of representative clusters.

2.3.1.FUZZY C-MEANS (FCM)

FCM [5, 28] used to partition a finite collection of elements into a collection of fuzzy clusters. It's an efficient clustering method. Disadvantage of FCM is presence of noise in MRI images.

2.3.2.TOTAL VARIATION REGULARIZER (TV)

TV [5] regularizes works efficiently for removing spurious oscillations while preserving edges. However, TV regularized methods are not suited to handle the varying in homogeneities as it would introduce the typical stair casing effect.

2.3.3.ANISOTROPIC DIFFUSED TOTAL VARIATION FCM (ADTVFCM)

ADTVFCM [5] algorithm smooth textures in an image by applying the law of diffusion on pixel intensities. It preserves edges in the image and prevents diffusion to happen across edges using threshold function.

2.3.4.CONSTRAINED GAUSSIAN MIXTURE MODEL (CGMM)

CGMM [24] framework, each tissue Gray Matter, White Matter, CSF is modeled with multiple four-dimensional (4-D) Gaussians, where each Gaussian represents a localized region (three spatial features) and the intensity characteristic per region (T1 intensity feature).

2.3.5.DYNAMIC NEURO-FUZZY TECHNIQUE

Two major stages are involved in this methodology [10]

1. Classification
2. Segmentation

The classification process is made on the MRI brain images. The preprocessing process removed non cortical tissues in the normal images before the segmentation process. Normal tissues are segmented from the normal images and mental tissues such as tumor, edema are segmented from the abnormal images.

2.3.6. K-MEANS CLUSTERING ALGORITHM

K-Means [9] is a well known partitioning method. Iterative reallocation of cluster members used to minimizes the overall within-cluster dispersion. If variables are few, then K-Means faster than hierarchical clustering, if we keep k smalls.

2.4.CLASSIFICATION TECHNIQUES

2.4.1. RANDOM FOREST (RF)

A RF [3] predictor then forms a group of classification and regression tree (CART) its output determined by a majority vote of the trees in the forest. Random forests based on a group of decision trees, majority voting and bagging are stronger than a single decision tree classifier. It produces the improved results when compared to other formal methods in a number of applications. PLS and RF combinations reducing the subjectivity in visual interpretation of SPECT scans by clinicians. It improving the detection of the AD in its early stage.

2.4.2. SUPPORT VECTOR MACHINE (SVM)

SVM [2, 4, 6, 27] is used for classification and pattern recognition in a different applications for its ability for detecting patterns in experimental databases. Classification consists of two steps. First training it considers a given set of binary-labeled training. Second classification it considers a new unlabeled data based on the learned behavior. SVM separate a given set of training data from the two possible classes ie.NOR and AD.

Proximal support vector machine (PSVM) [15] classifies data points based on the proximity of the two parallel planes. In this paper [13] classify the data points into three classes (Normal Case, MCI, and AD).

2.4.3.K-NEAREST NEIGHBOUR (KNN)

KNN is a data mining algorithm with a large range of applications in the image processing domain [14]. In this paper [13] three classes are classified from testing set uses Riemannian distance [16] and Euclidean.

2.4.4.ARTIFICIAL NEURAL NETWORKS (ANN)

ANN [17] [18] is the data mining algorithms used to carry information from inside brain. In this paper [13] classify the test data points in the three classes comparing two classes using matlab neural network toolbox. Two different neural network configurations are used.

2.4.5. PULSE COUPLED NEURAL NETWORK (PCNN)

The PCNN [19] used to explain neuronal burst phenomena in the cat visual cortex. The PCNN is very generic. Different types of data are operating with few changes. This is a different advantage compared to other image segmentation algorithms. But parameters are set manually.

2.4.6. SELF-ORGANIZING MAP (SOM)

A SOM [25] is a type of artificial neural network for the visualization of high-dimensional data. In general, SOMs are divided into two parts: training and mapping. Training using input examples for builds the map called a Kohonen map [7]. An SOM consider the components called nodes or neurons. Each node has a set of neighbors. The node not only adjusted its weight, but the neighbors are also changed when this node wins a competition. They are not changed as much though.

2.5.COMPARATIVE CHART OF DIFFERENT TECHNIQUES

Techniques	Advantages	Disadvantages	Specific Problem For Selecting The Techniques
Magnetic Resonance Imaging (MRI)	MRI is used for detecting and scanning of abnormalities in soft tissue like the cartilage tissues and soft organs like the brain or the heart.	MRI scanners are very expensive.	MRI used to find changes in Tissue Atrophy. It is more specific in grey matter.
Positron Emission Tomography (PET)	Can help diagnose, treat, or predict the outcome for a wide range of conditions.	Radioactive material may cause allergic or injection-site reactions in some people.	It's used to find Changes in cerebral perfusion.
Single Photon Emission Computed Tomography (SPECT)	Tracing the blood flow and the metabolic activities are occurring and enabling of brain functions.	Radioactive compounds quite expensive.	It's used to find Changes in glucose metabolism.
Non-Negative Matrix Factorization (NMF)	Reduce the large dimensionality of the input data.	Non negativity constraints can restrict correct clustering to only non-negative data.	NMF is used to find the reduced linear representations of non-negative data, being a useful decomposition tool

			for multivariate data.
Partial Least Squares (PLS)	Feature extraction is more effective for extracting the exactly correct information's from the data.	Measuring process more complex.	PLS yields a significant improvement in the out-of-bag error rate.
Gaussian Mixture Model (GMM)	GMM requires less feature vectors and produce good result.	GMM take time consuming and more samples.	GMM mainly for classical clustering and also used intensively for density estimation.
Neuropsychological And Functional Measures (NM)	NM was performed using a filter method. NMs are very separable between NC and AD groups.	Different assessment procedures for nearly every patient. Different assessment procedures across different examiners.	NM achieved better prediction performance and good accuracy.
Principal Component Analysis (PCA)	Reduce the redundant features and large dimensionality of the data.	PCA only takes into account pair-wise relationships between voxels of the brain images.	PCA used to extract the most significant features from a dataset.
Independent Component Analysis (ICA)	The ICA transformation is used for capturing group-differences from high order voxel relations, generating from the original average images sources.	Don't exist a criteria for determining how many components represent the dynamic of the data.	Basic concept is motivated by the theory of redundancy reduction.
Fuzzy C Means (FCM)	It's used to partition a finite collection of elements into a collection of fuzzy clusters with respect to given rules.	Segmentation is not clear and the noise is present in the image.	FCM algorithm considered as efficient clustering method.

Total Variation regularizer Fuzzy C Means (TVFCM)	TV method eliminates the noise and makes the segmentation result better.	It has the stair casing effect, smooth, destroy, small scale structures with high bending edges.	The value of the regularizing parameter is select manually for the best segmentation result and also get the good visual quality of the image.
Anisotropic Diffused Total Variation Fuzzy C Means (ADTVFCM)	Mainly used to reduce image noise without removing the image content, edges, lines and other details of the image.	Clusters number specify first.	ADTVFCM is to eliminate the stair casing effect and reducing the time.
Constrained Gaussian Mixture Model (CGMM)	It capture the complicated spatial layout of the individual tissues.	Time consuming for taking the spatial information and decision making of data into consideration.	Each tissue Gray Matter, White Matter, CSF is modeled with multiple 4D Gaussians.
Dynamic Neuro-Fuzzy Technique	The natural rules representation make easy interpretation of the results.	It answers only to what is written in its rule base.	It's an effective method to segment the normal and mental tissues in the MRI brain images.
K-Means Clustering Algorithm	If variables are few, then K-Means faster than hierarchical clustering, if we keep k smalls.	It does not work well with clusters of Different size and Different density.	K-Means used to segment the abnormal portion on the datasets classified by its type, size, and number of clusters.
Random Forest (RF)	It's used to estimate the missing data and maintains good accuracy when a large proportion of the data's are missing.	It has the noisy classification with some datasets.	It's based on majority voting and produces good results.
Support Vector Machine (SVM)	SVM is a powerful classification algorithm.	It give poor performances and it do not directly provide probability estimates.	SVM for pattern recognition, classification and accuracy was good.
K-Nearest Neighbour (KNN)	It's the simplest technique that provides good classification accuracy.	It has a slow running time.	Classification is satisfactory in terms of accuracy.

Artificial Neural Networks (ANN)	It can handle large amount of data sets.	The images go through many stages. Programming is difficult. Again to run the program, experts are not needed. ANNs are black-box modeling.	ANN is the biologically inspired by connections inside the brain used to carry information.
Pulse Coupled Neural Network (PCNN)	It was originally presented in order to explain the synchronous neuronal burst phenomena in the cat visual cortex.	The problem of PCNN is properly setting the various parameters so that a uniform response is achieved over a set of imagery.	It's the ability to perform extraction of edges, texture information from images and image segmentation.
Self-Organizing Map (SOM)	Visualization of high-dimensional data. It easy to understand. It's very simple.	Similar samples are not always near each other.	SOM has higher learning rate and less iterative time

Table 1. Comparative chart of different techniques

3.CONCLUSION

In this paper, imaging modalities and techniques for diagnosing of AD were discussed. Using this survey concluded that NMF [2], PLS [3], Wavelet Packet Transform [19] techniques are good for feature extraction using SPECT images. Whereas in PET images GMM, PLS [4] PCA, ICA [20], Wavelet Packet Transform [19] techniques are used for feature extraction. The combination of modalities is also producing the proper accuracy for AD and MCI. The MRI+FDG-PET+CSF biomarkers [6] are one of the combinations for early diagnosis of AD.MRI+ Neuropsychological and functional Measures (NM) + CSF biomarkers [8] are another combination. Clustering based segmentation is also having the different techniques for segmenting the brain tissues. ADTVFCM [5] yield good result with the help of MRI images. PET images are segmented using K-Means and FCM [9]. Dynamic Neuro-Fuzzy Technique [10] can also be used for segmenting tissues in MRI images. Constrained Gaussian Mixture Model (CGMM) [24] is used to segment the MRI images. Classifying Alzheimer's disease from Normal, MCI and AD by the use of SVM algorithm [2, 4, 6, 8], KNN, ANN, SOM, PCNN and RF [3] algorithm. The above Table 1 represents the comparative chart of different techniques and it's shows the advantages and disadvantages and also mention the specific problem for selecting the above different techniques.

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