# Alzheimer's Disease Detection using Structure Tensor with SPM based Segmentation

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***Abstract—*** **Alzheimer's disease is an irreversible, progressive brain disorder that slowly destroys memory and thinking skills and, eventually, the ability to carry out the simplest tasks. Neurons are the building blocks of our brain, that forms connections with other neurons for the signals to travel. The accumulation of the protein beta-amyloid outside neurons and the protein tangle inside neurons will results in damage of the brain. This paper focuses on the detection of Alzheimer's disease using Magnetic Resonance Imaging (MRI). The small changes in Gray Matter (GM) and White Matter (WM) is observed and processed for correct diagnosis. The GM and WM are segmented from the image and structure tensor analysis is performed to extract structural features of the brain from MRI. It is observed that the structural features are used for classifying AD and normal subjects.**

***Index terms*** **- Alzheimer's Disease, Gray Matter, Structure Tensor, Support Vector Machine, White Matter**

## I. INTRODUCTION

Alzheimer's is a brain disease and it's the common cause of dementia. Symptoms of AD vary among individuals. The common symptoms of AD include decline in memory, challenges in problem solving, confusion with time and place and some trouble in visual understandings.[1]

About 10% of people of age 65 or older and about 33% of people of age 85 or older have dementia and 70% of people with dementia have Alzheimer's disease [2]. There is no perfect clinical test to determine whether a person is affected with Alzheimer's disease. Normally several tests or examinations are usually done by doctors to detect the presence of Alzheimer's disease. The usual examination is performed by expert neurologists, who can figure out complex anatomical patterns and changes with clinical meaning [3].

In practice, diagnosis is largely performed on the basis of clinical history and examination supported by neuropsychological evidence of the pattern of cognitive impairment [4]. The examination supported for detection of Alzheimer's disease are usually difficult to carry out and results may not be proper.

Basically brain imaging can be done effectively by Magnetic Resonance Imaging (MRI) to rule out the alternative cause of dementia. This approach is consistent with established diagnostic consensus criteria such as those published by the NINCDS-ADRDA. MRI is a significant diagnostic imaging method which is normally employed for the detection of abnormal changes in tissues and organs. The brain matters mainly contain white matter, gray matter and cerebrospinal fluid. The brain structures are clearly described by the boundaries of the tissue classes, hence a segmentation technique is used to segment the tissues [5]. Manual segmentation is both time consuming and subject to manual variations. For morphometric analyses of the brain different segmentation techniques are essentially important. The real MR images are segmented into different tissue classes such as gray matter, white matter and cerebrospinal fluid using different automated brain segmentation algorithms. The unsupervised clustering techniques such as K-means and FCM are the widely used segmentation of brain MR images.

The main drawback of FCM is that the background intensity values and CSF are almost same. Hence, the algorithm efficiency is considerably reduced in the case of noisy MR images and leads to some misclassification[6]. In such case, a Statistical Parameter Mapping (SPM) version 8 is used for this purpose. This is a fully automatic system for model based tissue classification of MRI.

Feature extraction is highly subjective in nature, it all depends on what type of problem you are trying to handle. There is no generic feature extraction scheme which works in all cases. The Neuropsychological and Functional Measures are performed using filter method. The main advantage of this method is that if a wrapper were to be used along with NM, the highest accuracy would be achieved when using the top ranked feature. It is very easy to separate AD and NC groups. The drawback of NM is that it follows different assessment procedures for nearly every patient. Different examiners follow different procedures [7].

PCA is a standard technique for extracting the most significant features from a dataset and it is frequently used to reduce the raw data to a subset of features that contains the largest amount of variance [8]. In order to capture group differences from high order voxel relations, generating from the original average images sources, ICA transformation is used. The drawback of ICA is that there exist no criteria for determine how many components represent the dynamic of the data [9].

The purpose of our study is to examine the structural characteristics in specific brain regions and structure tensor features aid in unsupervised recognition of patterns in images. The goal of our study is to characterize the orientation and structural anisotropy of brain by carrying out texture analysis on MR images. It later derive quantitative measures to classify normal and Alzheimer's disease. Structure tensor (ST) analysis is used as a texture analysis method on MRI to visualize and quantify the microstructures in brain [10].

Support Vector Machine is employed for the classification of features that are obtained from the structure tensor analysis. SVM is an important classifier that results in excellent AD discovery [11]

## II. Related Work

### *A. Methods and Materials*

The overview of the proposed system is shown in Fig.1. The ADNI database contain a set of MRI images. The gray matter and white matter are then segmented using the SPM tool. From the segmented image, the structural features are extracted by the structure tensor method. Then SVM classifier is used to classify the AD and normal subjects.

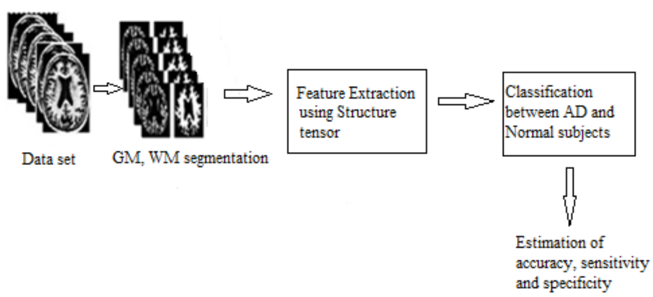


Fig 1: Proposed system

2.1 DATA

The Alzheimer's Disease Neuroimaging Initiative (ADNI) is a consortium of universities and medical centers in the United States and Canada established to develop standardized imaging techniques and biomarker procedures in normal subjects, subjects with MCI, and subjects with mild AD. Data collection is performed using a standard set of protocols and procedures to eliminate inconsistencies.

2.2 SPM 8

Statistical Parameter Mapping version 8 is a segmentation tool used to segment the gray matter, white matter and CSF from the brain MRI. SPM is a fully automated system for tissue based classification. This system interleaves classification with evaluation of the model parameters and also improves the classification in each iteration. The algorithm segments single- and multispectral MRI/S and corrects for MR signal inhomogeneities by Markov Random Fields (MRF) and also integrates appropriate information by means of Markov random Fields. A digital brain atlas containing prior prospect about the spatial location of tissue classes is used to initialize the algorithm. This makes the system fully automatic and therefore it presents objective and reproducible segmentations.

2.3 Structure Tensor

The structure tensor is a powerful tool for the characterization and analysis of structures in multidimensional images. This technique is used in image processing and computer vision. This method uses the gradient information of an image in order to determine the orientation information of the edges and corners. Structure tensor, J, of an image is a matrix that is derived from the partial derivatives. It is defined as,

$$J = \begin{bmatrix} < f_x , f_x >_w & < f_x , f_y >_w \\ < f_x , f_y >_w & < f_y , f_y >_w \end{bmatrix}$$

here $f_x$, $f_y$ are the partial derivatives of an image f(x,y) along with x and y directions. It is defined for each pixel as the second order symmetric positive matrix. And the weighted inner product between two images g and h is defined as

$$<g , h>_w = \iint_{R^2} w(x,y) g(x,y) h(x,y) dxdy$$

here w(x,y) is a Gaussian weighting function with a specified width σ . The eigenvalues $\lambda_1$ and $\lambda_2$ and their eigenvectors e1 and e2 summarize the distribution of the gradient of the image within the window defined by w.

If an eigenvalue is zero, then the grey values in the direction of the corresponding eigenvector do not change. If one eigenvalue is zero and one greater than zero, then it have a simple neighborhood with ideal orientation. An isotropic structure is observed when $\lambda_1$ and $\lambda_2$ .

Local orientation, anisotropy and energy for each pixel can be calculated for the structure tensor matrix . The direction of the largest Eigen vector of the tensor corresponds to the local predominant orientation θ given by

$$\theta = \frac{1}{2} \arctan\left(2 \frac{< f_x , f_y >_w}{< f_y , f_y >_w - < f_x , f_x >_w}\right)$$

$$AI = \frac{\left(\sqrt{(< f_y , f_y >_w - < f_x , f_x >_w)^2 + 4 < f_x , f_y >_w}\right)}{< f_x , f_x >_w + < f_y , f_y >_w}$$

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The anisotropy measure gives a relation between the length of the orientation vector to the length of the gradient vector. The values of anisotropy measure vary from 0, indicating isotropic to 1 indicating highly oriented structures.
Energy is given by the trace of the structure tensor J

$$E= Trace(J)= < f_x , f_x >_w + < f_y , f_y >_w$$

Higher value of energy indicates highly oriented structures. Energy and anisotropy of the structure tensor can be used for structure analysis. Homogeneous areas in an image cause the energy to be small. In areas around edges, the structure tensor has a large energy as well as a large anisotropy, while corners result in a large energy but small anisotropy. In this work orientation, anisotropy, energy, $\lambda_1$ and $\lambda_2$ are considered as features. The resulting values are visualized by combining in a composite image where hue, saturation and brightness correspond to local orientation, coherency and the original image intensities.

### 2.4 Classification

There are different classification methods. The classification methods are used to differentiate between the MRI of patients with the normal and AD subjects. The classifiers performance can be calculated using standard parameters accuracy, specificity and sensitivity.

Support Vector Machine (SVM) is a powerful tool for data classification. It is a supervised probabilistic classifier based on Bayes' theorem. In this classifier the feature vectors are linearly mapped to a higher dimension feature space. In this feature space, a hyperplane is created to linearly separate the training data by maximizing the distance between the vectors of the two classes.

## III. Performance Evaluation

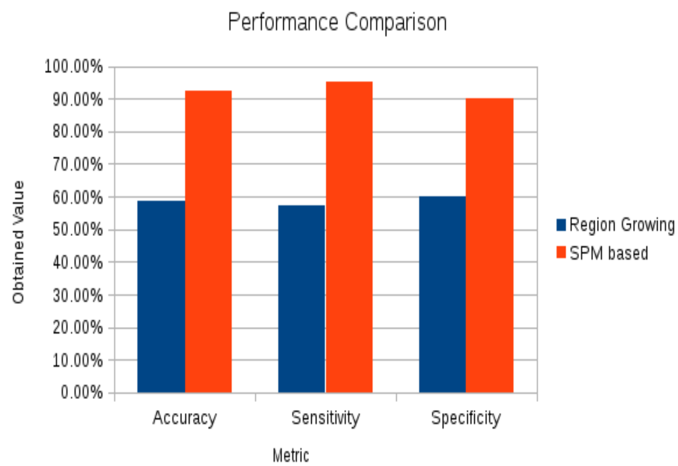
### *A. Simulation Model and Parameters*

The parameters are calculated for segmented slices and are given as input to the support vector machine. The training set for the SVM consists of 70% of the total images and the testing set is 30% of the total images. The accuracy, sensitivity and specificity are calculated from the results and tabulated below.

The performance evaluation was done on the basis of accuracy, sensitivity and specificity index parameters. Sensitivity is defined as the measure of the percentage of actual positive values that are correctly identified whereas specificity is the measure of percentage of negative values that are correctly identified. Accuracy deals with the quality of data and no of errors included in the data.

| **Metric** | **Observed value (%)** |
|---|---|
| Accuracy | 92.5 |
| Sensitivity | 95 |
| Specificity | 90 |

Table 1 Classification results using SVM for normal and AD subjects




From the validation results has shown good performance in using SPM 8 based segmentation. In this paper we have developed a SVM classifier to distinguish normal and abnormal brain MRIs. The results show that our method obtained 92.5 % accuracy on both training and test images.

## IV. Conclusion

In this study structure tensor is used to identify AD from MR images. The brain tissue is segmented by SPM 8. It is observed that, leakage of contour at weak boundaries is reduced by using gradient diffusion process and phase information in segmentation. It is observed that structural changes in the brain could be captured using structure tensor analysis and quantitate measures obtained could classify normal and AD subjects up to an accuracy of 92.5% using SVM. Furthermore, the classification accuracy can be improved by considering additional features for classification and different stages of alzheimer's can be detected.

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