Neuroanatomical Analysis of Brain Morphometric Changes

S. R. Sridhar[1]
Assistant Professor, Department of Computer Science and Engineering, Muthayammal Engineering College, Rasipuram,Namakkal District.Tamil Nadu, India

R. Keerthana[2]
Assistant Professor, Department of Computer Science and Engineering , Muthayammal College of Engineering, Rasipuram,Namakkal District.Tamil Nadu, India

Abstract: **Diffusion MRI is very sensitive to motion, due to phase shifts induced microscopically by diffusion-driven water molecular displacements. Sensitivity increases with the intensity and duration of gradient pulses, the scalar that defines the amount of diffusion weighting. During the acquisition, strong gradients are applied causing low-frequency mechanical resonances of the MR system that lead to small brain tissue movements. When these movements occur in the direction of the diffusion-encoding gradient, phase offsets will occur inducing signal dropouts in DWI images. Optimizing diffusion-imaging sequences is, thus, crucial to obtain more precise data. Aims to provide an idea for parameters in a typical DTI acquisition. The spatial resolution is also important for DTI quality and when using isotropic voxels that is recommended for fibre tracking, using interleaved acquisitions to minimize crosstalk between contiguous sections. The technique implied is registration algorithms and arbitrariness of spatial smoothing is Tract-Based Spatial Statistics which introduce bias in the quantitative assessment of fibre orientation and anisotropy voxels which are more likely to have more than one fibre tract orientation.**

Keywords - Brain, image matching, image registration, image analysis, magnetic resonance imaging (MRI), Multivariate analysis, Pattern based morphometry (PBM), Surface based Morphometry (SBM). Diffusion tensor imaging (DTI)

I. INTRODUCTION

Alzheimer's disease (AD) is an irreversible neurodegenerative disease characterized by progressive deterioration of cognitive and memory functions. There is a growing body of evidence suggesting that the cognitive decline may arise from integrative abnormalities between functionally and/or anatomically related brain regions. The biological hypothesis of AD as a disconnection syndrome involves progressive biochemical and structural changes, which begin at the cellular and synaptic level, and ultimately culminate in neuronal death and white matter (WM) degeneration. Diffusion tensor imaging (DTI) is a noninvasive technique that can be used to reflect the microstructural tissue status and orientations. The orientations of WM pathways can also be inferred by the principal eigenvector of the diffusion, which provides a new opportunity to investigate WM pathways in living. In AD patients, neural degenerations have been identified in a variety of WM tracts, including the corpus callosum and posterior cingulate fasciculus. Despite these advances for alterations of specific tracts, however, little is known about the abnormalities of topological organization in WM network in AD. Non-demented individual with memory complaints or mild memory impairment may represent a transitional state between healthy aging and AD. It has been established that individuals with memory complaints perform poorly on episodic memory tests even though they do not meet criteria for dementia. Additionally, individuals with amnestic mild cognitive impairment (MCI) convert to probable AD at an increased rate compared to older adults without memory problems and decline in episodic memory performance at a faster rate than healthy aging, but less rapidly than individuals diagnosed with mild AD .Because of the known relationship of medial temporal lobe structures and episodic memory processing and because of the profound declarative memory impairment associated with AD and MCI, these structures have been a major focus of MRI investigations. Structural MRI studies have documented hippocampal and entorhinal atrophy in patients with AD, individuals with MCI and even in individuals with cognitive complaints but no objective memory testing impairments.

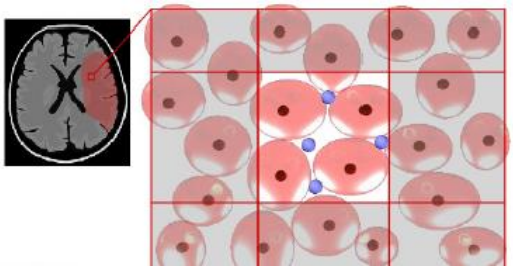


Fig-1.Transistional liquid molecules.

In this paper we will exploit a new technique Diffusion Tensor Imaging (DTI) along with Pattern and Surface based Morphometry (PBM) and (SBM), in which former is a data driven technique and later measures geometric models of cortical surfaces which also defines the transition of liquid molecules.

II. BACKGROUND

The specificity of region-based approach along with the boundary-based approach were used to combine the localization and sensitivity advantages. By using TBM we can find the volume changes typically that appear at tissue boundaries in homogenous brain regions [1]. Brain registration is also one of the tools used for studying morphometry. Registration can be difficult depending on anatomical variability and complexity in structures. Log-jacobian images of such warps should be uniformly close to zero [1].

Multiple atlases of brain MRI is collected across subjects and computed. For atlases OASIS (Open Access series of

Imaging Studies) database is used that range from 18 to 96[15].

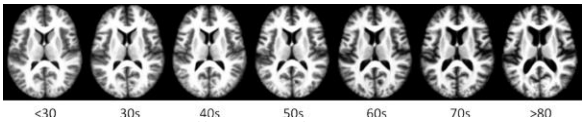


Fig-2. Atlases across different ages for subjects in the OASIS data set.

The atlases compute sharpness and features of image to higher degree. A method to overlay the images from their source and the manipulation of their transparency attributes or by assigning them to different color channels. Image fusion can be performed at three different levels 1.Pixel/data level, 2.Feature/attribute level and 3.Symbol/decision level. These are done to serve for different purposes. Fusion rule is being used here to determine the fusion results [12].

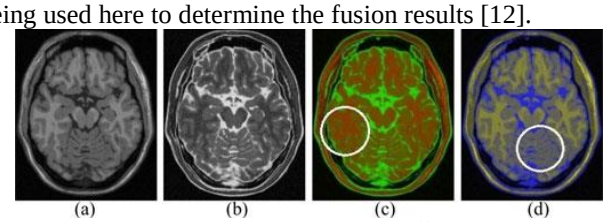


Fig-3.Overlaying monochrome images using different color channels.

Multistructure deffeomorphic registration approach to approve accuracy and robustness [2]. Many Group-based Neuroanatomical studies is the extraction of morphometric features that can be used for characterization of anatomical variability across or within groups .This study has approaches like voxel-based and tensor-based. Voxel-based morphometry computes the changes in volume due to registration [6]. It generates specific hypothesis about brain changes overtime. It is an automated technique that has grown in popularity .It uses statistics to identify difference in brain anatomy between collections of subjects, which in turn can be used to assume the presence of atrophy or, less normally, tissue development in subjects with disease.

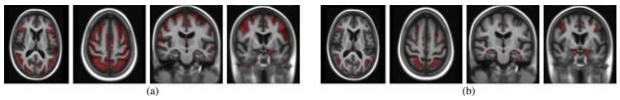


Fig-4.Visualization of the residual variance from group wise registration of all subjects in the OASIS database.

Tensor-based morphometry is done in deformation fields. TBM uses the log-determinant jacobians. Studies the longitudinal changes. The image determines the multistucture and MRI-based approach. Elevated specific absorption rate (SAR) associated with increased main magnetic field strength remains a major safety concern in ultra –high-field (UHF) [14]. SAR calculation requires the knowledge of electric field induced, and the local electrical properties of tissues.

Cortical thickness estimation performed [8] in-vivo via MRI is a technique to understand the progression of neuro-degenerative diseases. Longitudinal results for control and AD (Alzheimer Disease) subjects are done by three methods [4] .1.Free surfer, 2.laplacian, 3.Registration. Free Surfer cortical thickness pipeline processing involves intensity normalization, registration segmentation and automatic topology correction. Laplacian method segments Gray matter (GM), white Matter (WM) and cerbro spinal fluid (CSF) is done in T1 weighted image of tissue type. Registration method calculates WM, GM & CSF segmentation and a greedy diffeomorphic registration was being used. Various methods are used to compute deformation of brain. Pattern based morphometry is used to discover this dictionary of image patterns. The identification is done using MAT lab.

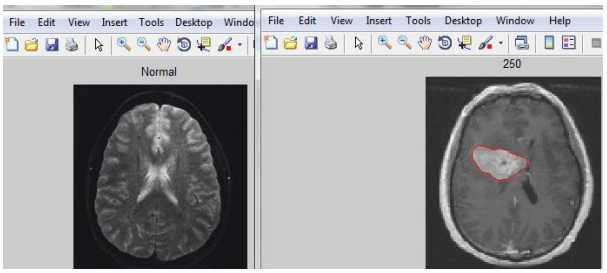


Fig-5. Image generated by subtracting an image using ADNI database images.

The time taken to identify single image is 8.765559 seconds. The cortical surface has the grey matter, white matter and CSF (cerebrospinal fluid). The Kullback – Liebler Penalty Term [1] use a fluid-flow implementation in which the matching term is MI(mutual information), the velocity is computed by Gaussian convolution, and the penalty term is based on the Kullback–Liebler divergence metric and a method for change detection, called G-KL, compares it to a TBM method having no boundary information (KL).

DTI is based on sensitizing the MR signal to movement of hydrogen on the order of several microns through the application of diffusion weighted gradients in at least six non-collinear gradients simultaneously, and measuring the direction and magnitude of hydrogen movement [7]. The application of at least six non-collinear gradients allows for examination of diffusion characteristics irrespective of head position. The three-dimensional geometry of the diffusion in a particular volume element (voxel) can be described by a mathematical construct called a “tensor” [8] that can be represented by a 3×3 matrix. From the diffusion tensor in each voxel, one can derive three eigenvalues (λ1, λ2 and λ3) defining the magnitude of the diffusion system and the three associated eigenvectors that describe the direction of the diffusion system. The average of the three eigenvalues represents the mean molecular motion (mean diffusivity: MD) that is affected by barriers to diffusion, but does not provide information on the directionality of the diffusion. Based on the ratio of the three eigenvalues, the intra-voxel direction of hydrogen diffusion can be determined. This scalar measure is termed fractional anisotropy (FA), and can range from 0 to 1 [8], with 0 indicating completely random diffusion (isotropic diffusion) and 1 representing completely directional diffusion (anisotropic diffusion).

CSF has extremely low FA values because hydrogen is free to diffuse in any direction. Gray matter has low FA because cellular structures (e.g., cell membrane, organelles) impede the free diffusion of hydrogen, but these structures do not promote organized, directional diffusion. Highly organized white matter tracts have high FA because hydrogen diffusion is directionally constrained by the tract’s cellular

organization. There is some evidence that changes in the individual eigenvalues of the tensor can provide information about the specifics of white matter damage. The primary eigenvalue represent the longitudinal direction of diffusion, or axial diffusion.

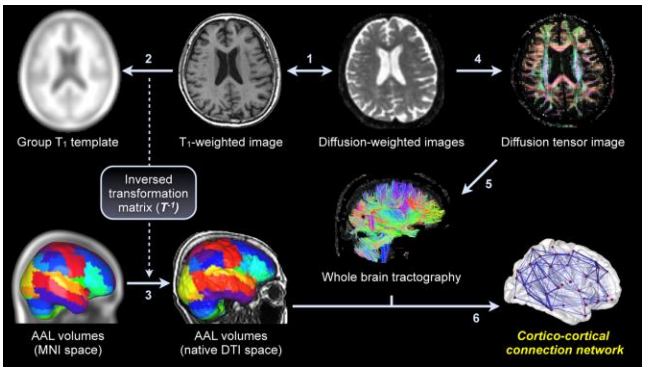


Fig-6 (1) Individual T1-weighted image were registered to the corresponding non-diffusion-weighted (*b* _ 0) images using a 12 degrees of freedom affine transformation. (2) To obtain the transformation matrix (**T**), the coregistered T1-weighted images were registered to the customized group T1 template, which was in MNI space, by applying a nonlinear spatial normalization. (3) The inverse transformation matrix (**T**_1) was applied to the AAL atlas to generate corresponding AAL volumes in each individual's diffusion-weighted image native space. (4) The construction of DTI from diffusion-weighted images. The color-coded map represents the directions of first eigenvectors: red, left–right; green, anterior–posterior; blue, inferior–superior. (5) Fiber pathways were performed using fiber assignment by continuous tracking (FACT) algorithm to reconstruct whole-brain tractography. (6) Network constructions by determining the white matter connections for each pair of AAL volumes.

The secondary and tertiary eigenvalues represent the transverse direction of diffusion, or radial diffusion. As axial diffusion decreases and radial diffusion increases, the shape of diffusion becomes more spherical. As axial diffusion increases and radial diffusion decreases, the shape of diffusion becomes more prolate. Decreased axial diffusion has been associated with axonal damage in mouse models [8], perhaps reflecting increased barriers to organized diffusion in the axial plane. Increased radial diffusion has been associated with damage to myelin [7], perhaps reflecting increased diffusion in the plane orthogonal to the axial plane.

III. PROPOSED METHOD

To analyse these patterns we use DTI along with pattern and surface based morphometry. Here DTI is used to measure the neuroanatomy of liquid molecules. Pattern based morphometry uses the dictionary learning algorithm to characterize the differences among the groups while the surface based morphometry models the cortical surface. DTI works on the image contrast in MRI. Methods used to analyse are pattern-based and surface-based. Pattern-based morphometry (PBM) is data driven technique. It uses dictionary-learning algorithm to extract global patterns that characterize group-differences.

Surface-based analysis derive measures of morphometry from geometric models of the cortical surface. Algorithm used for Pattern-based and surface-based morphometry (P-S BM). PBM, which does not suffer from the limitations of VBM. The usual TBM algorithm optimizes an energy functional E to generate a matching u between the images. E has the format

$$E(\mathrm{T}_1, \mathrm{T}_2, \mathbf{u}) = M(\mathrm{T}_1, \mathrm{T}_2, \mathbf{u}) + \lambda R(\mathbf{u}) \qquad (1)$$

Where an image dissimilarity term and R is a regularizing penalty term, both dependent on deformation u.

PBM can identify subtypes of patterns that don't necessarily involve the same brain regions and facilitate a global analysis of heterogeneous diseases. Also PBM could be extended to diffusion imaging, fMRI and longitudinal analysis.

A. Pre-processing And Change In-Synthetic Images

This is the procedure done before processing by correcting image from different errors.Different images is generated by subtracting an image in group from its neighbour group and discovers dictionary of image patterns.

B. Surface Extraction

Cortical white matter and cortical grey matter is extracted from the surface and Cerebrospinal fluid is extracted from pial surface, many manipulations are applied to the surface.

C. Evaluation Of Extraction

It evaluates grey and white matter of the simulated images and Renders cerebrospinal volume from pial surface. The variational derivative of the matching term M takes the form,

$$\partial_{\mathbf{u}} M = m(\mathrm{T}_1, \mathrm{T}_2, \mathbf{u}) \nabla \mathrm{T}_1(\mathbf{g}(\mathbf{x})) \qquad (2)$$

Where m is a scalar function and ΔT1(g(x)) is the intensity gradient of T1 at the location specified by g(x) and T1 is the target image.

This Generates high dimensional morphological patterns representing group differences.Image is smoothed and reconstructed by surface based analysis.Track changes associated with age and disease process globally.

D. Brain Development

MR imaging is rarely performed during pregnancy and the neonatal period, to avoid stress of mother and child. In case of birth complications and other events, such data are being acquired. For instance, Dubois et al. analyzed gyrification in premature newborns at birth and found it to be predictive of a functional score at term-equivalent age, and Serag et al. built a 4D atlas of the developing neonatal brain which has led to the construction of brain growth curves from 28–44 weeks postmenstrual age. Beyond that,there have been a number of large-scale longitudinal MR-morphometric studies (often combined with cross-sectional approaches and other neuroimaging modalities) of normal brain development in humans.

E. Aging

While white matter increases throughout early development, adolescence, and gray matter decreases. The situation is different beyond the age of about 50 years when atrophy affects gray and possibly white matter. The convincing explanation is that, individual neurons- die, leading to the loss of their cell bodies (i.e. gray matter) and their myelinated

axons (i.e. white matter). The gray matter changes can be observed via both gray matter density and gyrification. The white matter loss is not nearly as clear as that for gray matter indicates that changes also occur in nonneural tissue, e.g. the vasculature or microglia.

F. Brain Disease

Brain diseases are field brain morphometry is often applied, and the volume of the literature on this is vast. Euler Integration is given by,

$$\mathbf{u}(\mathbf{x}, t + \Delta t) = \mathbf{u}(\mathbf{x}, t) + (\mathbf{v} - \mathbf{v} \cdot \nabla \mathbf{u})\Delta t. \qquad (3)$$

This formula is based on a discrete approximation to the total time derivative of u. The size of the time increment Δt is often varied so that a maximal displacement is not exceeded at each iteration.

G. Brain Evolution

Brain changes also accumulate over periods longer than an individual life but even though twin studies have established that human brain structure is heritable. However, in the context of disorders with a known or suspected hereditary component, more studies have compared the brain morphometry of patients with both that of non-affected controls and that of subjects at high risk for developing the disorder. The next group usually includes family members.

Postmortem samples of living or extinct species, on other hand, generally allow to obtain MR image qualities sufficient for morphometric analyses, preservation artifacts would have to be taken. Previous MR imaging studies include specimens preserved in formalin, by freezing or in alcohol.

H. BrainAnalysis

Analysis of cognitive processes in man usually involves multiple examination modalities. It maps different aspects of the brain. One or more functional modalities are involved .These different examination methods yield complimentary information about Anatomical, Metabolical and Neurophysiological state of the brain. Handling of image datasets (MRI, PET, SPECT, CCT) and signal datasets (EEG, MEG) which allows a combined analysis of these data sources in a four dimensional coordinate space x, y, z, and time.

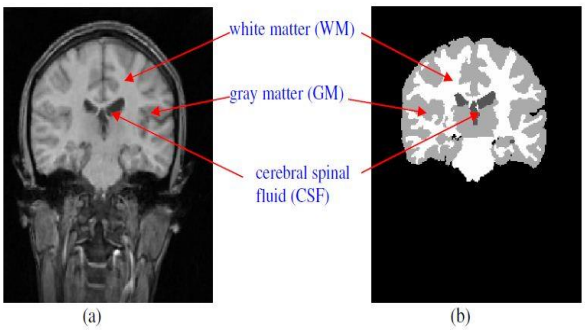
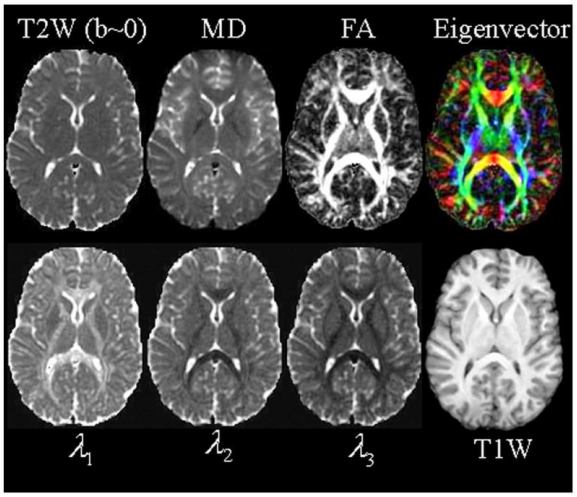


Fig.7, Surface Extraction

Magnetic resonance imaging (MRI) provides detailed information about brain tumor anatomy, cellular structure and vascular supply.It's an important tool for diagnosis, treatment and monitoring of disease. This article provides an overview of brain tumor, with a focus on gliomas, followed by a description of the principles of MRI signal and image generation. It then reviews the most established MRI techniques for brain tumor imaging, and their clinical utilities for differential diagnosis, tumor grading, and response to treatment assessment. The neurosurgical applications of MRI used to maximize tumor resection while avoiding damage to healthy brain tissue are also described. Subsequently, the six independent elements of the diffusion tensor (D_{xx}, D_{yy}, D_{zz}, $D_{xy} = D_{yx}$, $D_{xz}=D_{zx}$, and $D_{yz}=D_{zy}$) may be estimated from the apparent diffusivities . Conventional MRI exploits three physical properties of tissue protons to generate signals that are imaged as areas of different contrast, which reflects, anatomy and physiology of the organ, under investigation.



The orientation of the diffusion tensor major eigenvector is generally assumed to be parallel to the local white matter fascicles. Protons are positively-charged particles inside the nucleus of elements' atoms. Because it is mainly made up of water, the most abundant element in our body is hydrogen, each atom of which has one proton. To understand how the MRI signal is generated, and can imagine this proton as a minute magnet bar that moves like a spinning –top.

I. Neuro anatomical analysis

Post-processing methods are also highly relevant to interpreting DTI literature. To date, a number of analysis strategies have been used including region-average, histogram or voxel-/cluster-based. No method, however, has demonstrated systematic superiority in every scenario; though it is widely accepted that for unbiased whole-brain assessments, the tract-based spatial statistics (TBSS) approach has advantages and is the most desirable technique for volumetric DTI analysis at present (see Figure 8). TBSS—part of FMRIB's software library or FSL enables whole brain assessment of WM tract integrity in neurodegenerative diseases using DTI data without the need for a priori hypotheses about the spatial location of degenerative involvement. TBSS circumvents the lack of anatomical landmarks in WM, which is a limiting factor for manual tracing of tracts of interest in native space. TBSS deals with this problem by automatically co-registering all DTI parametric maps to a standard template; also, unlike histogram analyses, it can resolve the specific location of abnormal clusters; it is not biased by the dependency issues known to affect tractography based regional analysis; and finally, TBSS does not require convolution with a smoothing

kernel, as is used in standard VBA methods, due to the introduction of a skeletonisation step.

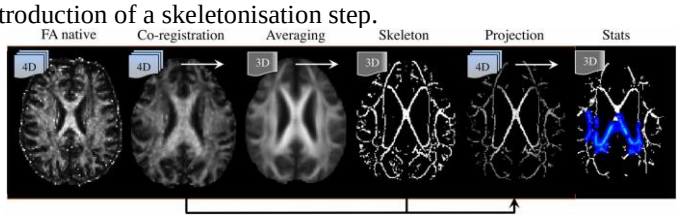


Fig.7 Tract-based spatial statistics (TBSS) processing pipeline

The skeleton is derived from averaging FA images across all subjects and subsequent identification of tract centers; this ensures the analysis is carried out exclusively on definite WM.

But the main advantage of projecting DTI data to a WM skeleton is that it corrects, to some extent, co-registration inaccuracies, rendering the data more comparable than in VBA. In addition, performing statistics only along the center of major WM bundles minimizes the effects of partial volume contamination and reduces the number of statistical tests.

IV. CONCLUSION

Neuroimaging is a stimulating tool for investigation of the epidemiology, diagnostic efficacy, rate of progression, therapeutic effects, and offers considerable potential to explain the earliest functional changes in AD and other dementias. Most studies of these emerging technologies are at the developmental stage, exploring the underlying disease process and defining differences across various subject groups. DTI is an MRI scanning technique that allows for the examination of white matter microstructural integrity based on the directionality of diffusion in the brain. Two measures are most commonly reported: FA and MD. FA provides a measure of the directionality of diffusion and MD provides a measure of translational diffusion. In intact tissue, MD in constrained by barriers to free diffusion and FA is determined by the parallel organization of the tissue. In white matter, directional diffusion is promoted along the long axis of the axons and perpendicular diffusion is impeded. Damage to white matter results in an increase in MD through the loss of barriers to free diffusion, and FA is decreased by a loss of barriers toperpendicular diffusion. Pattern-based morphometry (PBM) is a data driven technique and uses dictionary learning algorithm to extract global patterns. Surface-based analysis derives morphometric-measures from geometric models of the cortical surface. The technique of PBM with SBM measures both volume and surface of MR images and computes the inverse consistency of it and identifies across three control groups leaving penalty term. Sensitivity is increased with specificity and localization. DTI has also been used to demonstrate subtle abnormalities in a variety of diseases (including stroke, multiple sclerosis, dyslexia, and schizophrenia) and is currently becoming part of many routine clinical protocols.

V. ACKNOWLEDGEMENT

Data used in the preparation of result were obtained

[1] Alzheimer's disease Neuroimaging Initiative (ADNI) database (www. loni. ucla. edu/ADNI). ADNI www.loni.Ucla.edu/ADNI/Collaboration/ADNICitatationshtml.

[2] http://www.bic.mni.mcgill.ca/brainweb.

VI. REFERENCES

[1] Evan Fletcher, Alexander Knaack, Baljeet Singh, Evan Lloyd, Evan Wu, Owen Carmichael, Charles DeCarli and Alzheimer 's Disease Neuroimaging Initiative. "Combining Boundary-Based Methods With Tensor-Based Morphometry in the Measurement of Longitudinal Brain Change" *IEEE Transactions On Medical Imaging*, Vol. 32, No. 2, February 2013 223.

[2] Ali R. Khan, LeiWang$, and Mirza Faisal Beg$, "Multistructure Large Deformation Diffeomorphic Brain Registration," *IEEE Transactions On Biomedical Engineering*, Vol. 60, No. 2, February 2013.

[3] Bilwaj Gaonkar, Kilian Pohl, and Christos Davatzikos, "Pattern Based Morphometry," *Section for Biomedical Image Analysis*, University of Pennsylvania.

[4] Douglas N. Greve, Martinos, "An Absolute Beginner's Guide to Surface- and Voxel-based Morphometric Analysis," *Center for Biomedical Imaging*, Massachusetts General Hospital Harvard Medical School.

[5] Jennifer L. Whitwell, "Voxel-Based Morphometry: An Automated Technique for Assessing Structural Changes in the Brain," *The Journal of Neuroscience*, Department of Radiology, Mayo Clinic, Rochester, Minnesota 55905, August 5, 2009 • 29(31):9661–9664 • 9661.

[6] Matthew J. Clarkson, M. Jorge Cardoso, Gerard R. Ridgway, Marc Modat, Kelvin K. Leung, Jonathan D. Rohrer , Nick C. Fox, Sébastien Ourselin, "A comparison of voxel and surface based cortical thickness estimation methods," *Centre for Medical Image Computing (CMIC)*, The Engineering Front Building, University College London, London, WC1E 6BT, UK, *Dementia Research Centre*, UCL Institute of Neurology, University College London, London, WC1N 3BG, UK, NeuroImage 57 (2011) 856–865.

[7] M. Vatsa, R. Singh, and A. Noore, "Denoising and Segmentation of 3D Brain Images," *IIIT Delhi*, India, {mayank, rsingh}iiitd.ac.in, *West Virginia University*, Morgantown, USA, afzel.noore@mail.wvu.edu.

[8] Rui Shen, *Member, IEEE*, Irene Cheng, *Senior Member, IEEE*, and Anup Basu, *Senior Member, IEEE*, "Cross-Scale Coefficient Selection for Volumetric Medical Image Fusion," *IEEE Transactions On Biomedical Engineering*, Vol. 60, No. 4, April 2013 1069.

[9] Xiaotong Zhang, Sebastian Schmitter, Pierre-François Van de Moortele, Jiaen Liu, and Bin He, *Fellow IEEE*, "From Complex B1 Mapping to Local SAR Estimation for Human Brain MR Imaging Using Multi-Channel Transceiver Coil at 7T" *IEEE Transactions On Medical Imaging*, Vol. 32, No. 6, June 2013.

[10] Yuchen Xie, Jeffrey Ho, and Baba C. Vemuri, *Fellow, IEEE,* "Multiple Atlas Construction From A Heterogeneous Brain MR Image Collection" *IEEE Transactions On Medical Imaging*, Vol. 32, No. 3, March 2013

[11] "Digital Image Processing", Rafael C.Gonzalez & Richard E. Woods, Addison-Wesley, 2002.

[12] Khalid Sayood, "Introduction to Data Compression", Third Edition, PP.423-513, 2011.

[13] R.C.Gonzalez and Wood, "Digital image processing using MATLAB" Reading, Second addition, McGraw Hill Companies, PP. 331-439, 2011.

[14] David salomon, ``Data compression- the complete reference", 4th Edition, Springer international edition, PP.532-639, 2011.

[15] A.K.Jain, "Fundamentals of Digital Image Processing", Reading, New Jersey: Prentice Hall Inc., PP. 479 - 533, 1989.
[16] Basser PJ, Mattiello J, LeBihan D. Estimation of the effective self-diffusion tensor from the NMR spin echo. J Magn Reson B. 1994;103:247–254. [PubMed]
[17] Basser PJ, Mattiello J, LeBihan D. MR diffusion tensor spectroscopy and imaging. Biophys J.1994;66:259–267. [PMC free article] [PubMed]
[18] Conturo TE, Lori NF, Cull TS, et al. Tracking neuronal fiber pathways in the living human brain. Proc Natl Acad Sci USA. 1999;96:10422–10427. [PMC free article] [PubMed]
[19] G.T. Stebbins* and C.M. Murphy. Diffusion tensor imaging in Alzheimer's disease and mild cognitive impairment. The Department of Neurological Sciences, Rush University Medical Center, Chicago, IL.
[20] Acosta-Cabronero* and PeterJ.Nestor. Diffusion tensor imaging in Alzheimer's disease : insights into the limbic-diencephalic network and methodological considerations. BrainPlasticityandNeurodegenerationGroup,GermanCenterforNeurodegenerativeDiseases(DZNE),Magdeburg,Germany