VBM based MR Imaging Volumetric Analysis of AD and MCI

M.M.Patil
Department of Electronics and Telecommunication,
College of Engg.Pandharpur,
Dist.Solapur, Maharashtra, India.

A.R.Yardi
Department of Electronics, Walchand College
Of Engg, Sangli,
Maharashtra, India.

ABSTRACT
Voxel-based morphometry is a method for detecting group differences in the density or volume of brain matter. The authors reviewed the literature on use of voxel-based morphometry in brain MRI imaging research to examine the capabilities of this method for clearly identifying specific differences in patients with MCI and AD (and compared with healthy subjects). A technique of segmenting human brain MRI image into total gray matter (GM) and total white matter (WM) - Voxel-bas**ed** morphometry (VBM) was performed using VBM 5.1 toolbox and SPM5 in a Matlab environment. Images from (ADNI database) 15 AD and 15 MCI were used for investigation. The analysis revealed significant gray matter, white matter and CSF volume loss in the AD as compared with MCI patients. Quantitative analysis of %GM and %WM volumes can help in distinguishing atrophy of AD patterns from characteristics of the MCI.

General Terms
Neurodegeneration, Dementia diagnosis, brain MRI analysis, volumetric analysis.

Keywords
Brain atrophy measurement, volumes of gray matter, white matter and cerebrospinal fluid,Matlab,SPM,VBM.

1. INTRODUCTION
Alzheimer's disease - Alzheimer's disease (AD) is an irreversible, progressive dementing disorder, which slowly deteriorates memory and thinking skills [1]. Since the incidence of the AD is strongly linked to the age, the AD is one of the major public health problems in countries with the longer life expectancy. According to recent estimates, as many as 2.4 million to 4.5 million Americans and 1.8 million Japanese have AD [1, 2]. AD is associated with the atrophy of gray matter in the cerebral cortex, which leads to a volume decrease of the cerebral cortex or a volume increase of cerebrospinal fluid (CSF) in cerebral sulci and lateral ventricles (LVs), which can be measured in magnetic resonance (MR) images. In order to provide appropriate care for AD patients, it is very important to quantitatively evaluate the degree of the atrophy in the early stages of AD. Neuroradiologists attempt to estimate the degree of atrophy by capturing atrophic image features on MR images, but it is very difficult and time consuming in routine clinical practice. Therefore, a number of automated methods have been studied for identification of AD patients among the large number of patients with dementia [3, 4].

The concept of mild cognitive impairment (MCI) is thought to be a transitional phase between being cognitively normal and having an AD diagnosis. Patients with MCI have a higher risk of developing AD than elderly with normal cognitive function. The concept of MCI is rather difficult to describe since it is a very heterogeneous group. The diagnostic accuracy of the criteria today is low to moderate [5]. In recent years, a whole-brain unbiased objective technique, known as voxel-based morphometry (VBM), has been developed for characterizing differences in the local composition of brain tissue using MR images, and can objectively map the losses on a voxel-by-voxel basis [6-8].Data used in the preparation of this article were obtained from the Alzheimer's disease Neuroimaging Initiative (ADNI) database (http://www.loni.ucla.edu/ADNI). We selected subjects from MCI and AD categories. Demographic characteristics of the studied population selected from the ADNI database are presented in Table 1.MRI data analysis was performed using statistical parametric mapping software (SPM5; Welcome Department of Cognitive Neurology, Institute of Neurology, London,UK, http://www.fil.ion.ucl.ac.uk/spm/) website accessed on 21 November 2010) with the VBM tool Updated version VBM5.1 toolbox Published by Christian Gaser on May 13, 2009. Jena script http://dbm.neuro.uni-jena.de/vbm.html; in MATLAB.

2. METHOD

2.1 Image Analysis

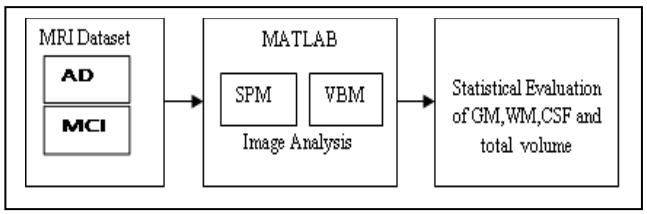

Figure 1: MRI volumetric process used

The images analyzed are obtained through tissue segmentation, spatial normalisation, Jacobian modulation, and spatial Smoothing using SPM5. Modulation refers to the procedure of multiplying the intensities in the spatially-normalised images by the Jacobian determinant of the transformation that map from coordinates in the template space to those in the original image. In the approach used here, subject images are 'backward-mapped' into the template space so as to give a seamless result. This involves considering where each voxel in the warped result in template space should be taken from in the individual source. If a particular structure is larger in the subject than the template, the transformation models the expansion of the template, and hence has $|J| > 1$. Similarly, the process of spatial normalisation

geometrically shrinks the subject's structure down to the size of the template. By multiplying the intensities in the warped result by the determinant, the original structure's volume is preserved. Smoothing is used primarily to compensate for residual misregistration following spatial normalisation methods with limited flexibility. It is also necessary for statistical parametric mapping in order to improve the normality of the data smoothing acts as a matched-filter sensitising the analysis to a particular scale of effect. Result of VBM morphometry for one AD case fig.2 and one MCI case fig.3.

Summary of Image Analysis in VBM- : 1) Normalisation of the original MR images, 2) Segmentation of normalized images, 3) Cleaning of grey matter images, 4) Modulation of grey matter images, and 5) Smoothing of modulated images.

Original images were normalised to the customised template through affine and non-linear transformations, medium regularisation, reslicing 2x2x2 mm, and no masking. The normalised images were segmented into GM, WM, and CSF using the customized prior probability maps. The Xbrain routine, based on erosions and dilatations, was used to remove voxels of non-brain tissue from the segmented images, thus obtaining a brain mask to clean the GM images. by intersection with the mask. In the modulation step, voxel values of the cleaned GM images were multiplied by the measure of relative volumes of warped and unwarped structures derived from the non-linear step of spatial normalisation (Jacobian determinant). The modulated GM images were smoothed with a 12 mm isotropic Gaussian kernel. The final output is a 3D matrix where the three indices are the spatial x, y, and z coordinates of voxels in the reference space, and each value of the matrix is proportional to the volume of GM within each voxel. [9-12]

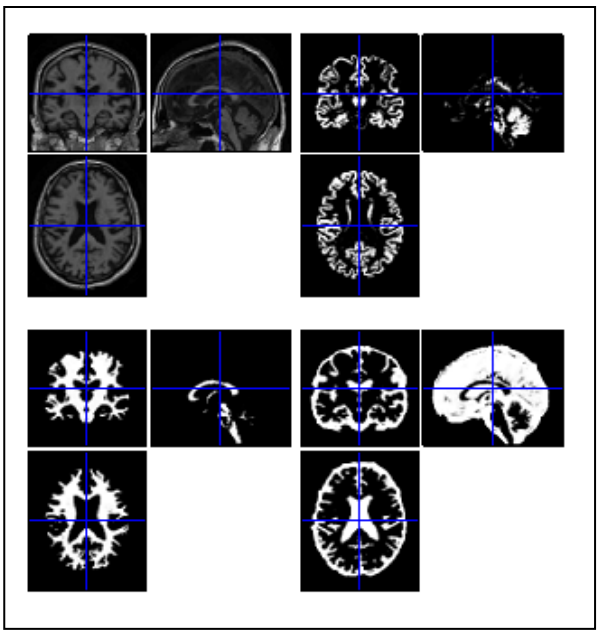

Figure 2: VBM result for AD subject (top left-original image, top right-GM tissue, bottom left-WM tissue, bottom right-CSF tissue)

.

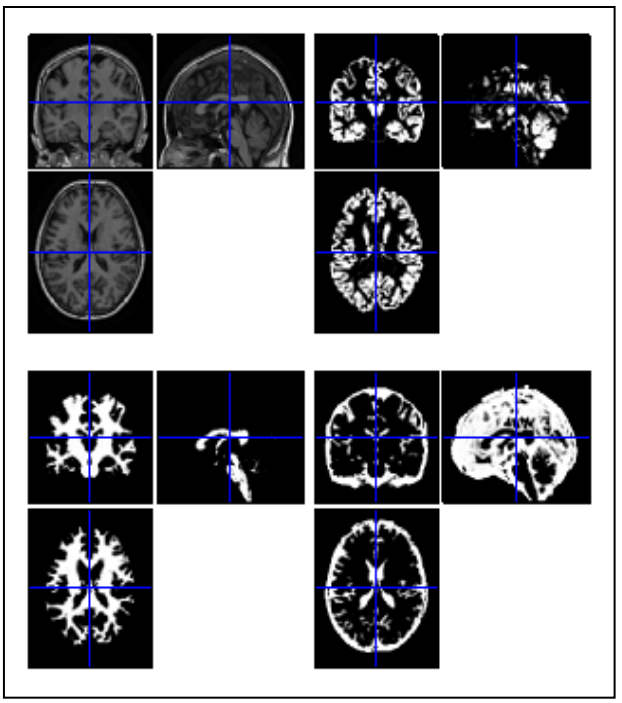

Figure 3: VBM result for MCI subject (top left-original image, top right-GM tissue, bottom left-WM tissue, bottom right-CSF tissue)

3. RESULTS

The objective of this study was to carry out voxel based morphometry steps on MRI images of AD and MCI patients and to analyze the volumetric changes in volumes of GM, WM and CSF and total volume.VBM steps were successfully carried out and the resulting tissue volumes were obtained by using the stat tool of VBM (Read raw volumes GM/WM/CSF/total volume). The means of obtained values are presented as in Tab. I. It reveals the fact that AD subjects exhibited the greatest atrophy, when compared to MCI. (Figure 4, Tab. I).There are many choices available to a researcher for quantitative MRI of the brain. Discussion in the current article was exclusive to volume estimation, and pertained to the software and techniques familiar to the authors. We have provided sufficient information for volume estimation of three brain structures that are of particular interest in cognitive, clinical and comparative neuroscience network. Scatter plots of Fig.4 show statistical mapping results for comparison. Top left plot shows reduction in GM volume of AD patients as compared to MCI; similar are the cases in top left WM volume and bottom right CSF volume. Bottom right plot reveals the fact that whole brain volume of AD patients is reduced (atrophy increased) as compared to MCI patients' volumes. Though VBM has basic limitation of processing time because of large number of MR images series per subject, studies on brain with different MR techniques are important to be applied in the future on even larger database of AD, MCI subjects formed in the limit of possibility to please both, the objectives and the technical factors implicated in the study protocols. However considering all study subjects the mean values of tissue volumes are calculated, as shown in Tab. I and plotted in Fig.5.

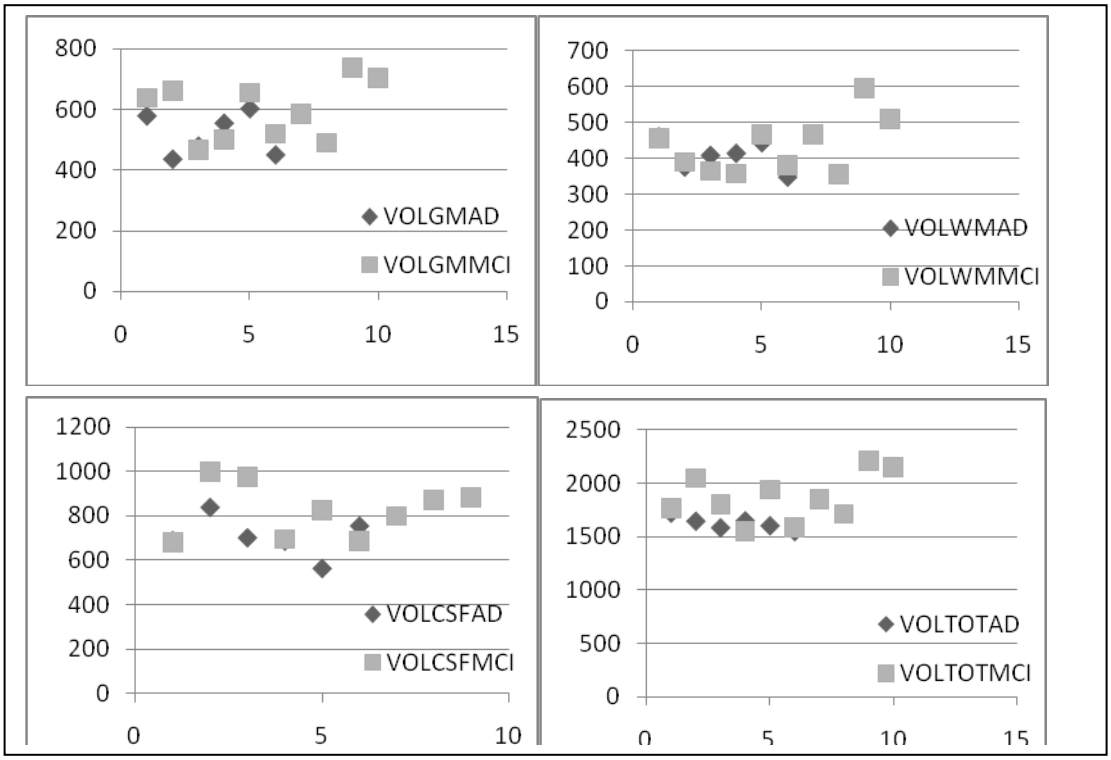

Figure 4: VBM volumetric outcome scatter plots: top left - intracranial GM tissue volume of AD patients and MCI patients, top right - intracranial WM tissue volume of AD patients and MCI patients, bottom left - intracranial CSF tissue volume of AD patients and MCI patients, bottom right – intracranial total volume of AD patients and MCI patients.

Table 1. VBM evaluation

Tissue Volumes(cm^3)	Mean for AD patients	Mean for MCI patients
GM Volume	516.5083	571.5314
WM Volume	407.6617	427.1207
CSF Volume	705.47	831.4393
Total Volume	1629.64	1830.091

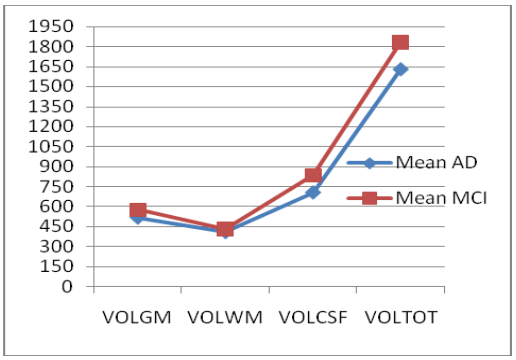

Figure 5: Mean tissue volumes in AD and MCI

4. CONCLUSION AND DISCUSSION

This quantitative volumetric study demonstrated intracranial GM, WM, CSF and total volumes of AD and MCI subjects from ADNI dataset. The changes in mean values of tissue volumes indicate that tissue volumes could stand as significant feature for discriminating AD cases from MCI. Based on these tissue volume features it is further planned develop artificial neural network based diagnostic system, which will be used as early diagnosis tool for Alziemers Disease.

5. ACKNOWLEDGMENTS

The authors would like to thank the Alzheimer's disease Neuroimaging Initiative (ADNI) database (http://www.loni.ucla.edu/ADNI), for approving the research rational and providing access to the database.

6. REFERENCES

[1] U.S. National Institute of Health, http://www.nia.nih.gov/Alzheimers/

[2] Ministry of Health, Labour and Welfare in Japan, http://www.mhlw.go.jp/index.html

[3] Colliot, O.; Chételat, G.; Chupin, M.; Desgranges, B.; Magnin, B.; Benali, H.; Dubois, B.; Garnero, L.; Eustache, F.; Lehéricy, S. Discrimination between Alzheimer disease, mild cognitive impairment, and normal aging by using automated segmentation of the hippocampus. Radiology 2008, 248, 194-201.

[4] Arimura, H.; Yoshiura, T.; Kumazawa, S.; Tanaka, K.; Koga, H.; Mihara, F.; Honda, H.; Sakai, S.; Toyofuku, F.; Higashida, Y. Automated method for identification of patients with Alzheimer's disease based on three-dimensional MR images. Academic Radiology 2008, 15, 274–284.

[5] Kantarci K. Magnetic resonance markers for early diagnosis and progression of Alzheimer's disease. Expert Rev Neurother. Sep 2005;5(5):663-670

[6] Daniel Mietchen and Christian Gaser; Computational morphometry for detecting changes in brain structure due to development, aging, learning,disease and evolution; Frontiers in Neuroinformatics www.frontiersin.org August 2009 | Volume 3 | Article 25 .

[7] Simon S. Keller1 & Neil Roberts2, Measurement of brain volume using MRI:software, techniques, choices and prerequisites, Journal of Anthropological Sciences the JASs is published by the Istituto Italiano di Antropologia www.isita-org.com Vol. 87 (2009), pp. 127-151.

[8] Robyn Honea, B.Sc. Tim J. Crow, M.B., Ph.D.,Dick Passingham, Ph.D.Clare E. Mackay, Ph.D.,Regional Deficits in Brain Volume in Schizophrenia:A Meta-Analysis of Voxel-Based Morphometry Studies, Am J Psychiatry 2005; 162:2233–2245.

[9] Hidetaka Arimura, Taiki Magome , Yasuo Yamashita and Daisuke Yamamoto2, Computer-Aided Diagnosis Systems for Brain Diseases in Magnetic Resonance Images, www.mdpi.com/journal/algorithms Algorithms 2009, 2, 925-952; doi:10.3390/a2030925.

[10] Thomas Bittera, Johanna Brüderlea, Hilmar Gudziola, Hartmut Peter Burmeisterb,Christian Gaserc, Orlando Guntinas-Lichius, Gray and white matter reduction in hyposmic subjects — A voxel-based morphometry study, 2010 Elsevier B.V. doi:10.1016/j.brainres.2010.06.003.

[11] R.S. Desikan, H.J. Cabral,B. Fischl,C.R.G. Guttmann,D. Blacker,B.T. Hyman, M.S. Albert,R.J. Killiany, Temporoparietal MR Imaging Measures of Atrophy in Subjects with Mild Cognitive Impairment That Predict Subsequent Diagnosis of Alzheimer Disease, AJNR Am J Neuroradiol 30:532–38 _ Mar 2009 _ www.ajnr.org.

[12] Badreddine Bencherif, MD; Martin J. Stumpf, MA; Jonathan M. Links, PhD; and James J. Frost, MD, PhD, Application of MRI-Based Partial-Volume Correction to the Analysis of PET Images of _-Opioid Receptors Using Statistical Parametric Mapping, THE JOURNAL OF NUCLEAR MEDICINE • Vol. 45 • No. 3 • March 2004,402-408.