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UTILITY OF IMAGE PROCESSING ON MRI SCAN FOR EARLY DETECTION OF ALZHEIMER'S DISEASE

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Abstract: Alzheimer's disease (AD), an irreversible and progressive brain disease that gradually destroys memory and thinking skills to a critical extent, has become an increasing threat to quality of life of elderly. AD is the most common cause of dementia among older people. The paper discusses the utility of 2-dimensional image processing on MRI scans and estimating the possibility of an early detection of AD. Hippocampal atrophy is considered one of the strongest diagnostic tests for AD and T2 weighted MRIs would be used for the purpose. The paper discusses about the techniques such as K-means clustering algorithms and Volumetric analysis which aid the technical analysis to detect AD. The analysis is expected to improve by further correlation with the psychiatric results and could thus assist the doctors in detecting AD at an early stage and consequently help in improving patient management protocols.

Keywords*: Alzheimer's disease, image segmentation, atrophy, hippocampus, dementia, MRI*

Introduction

Alzheimer's disease is an irreversible, progressive brain disease that slowly destroys memory and thinking skills and in later stages intellectual abilities. In most people with Alzheimer's, visible symptoms first appear after age 60. Alzheimer's disease accounts for 50 to 80 percent of dementia cases. The damage to the brain in Alzheimer's begins a decade before the symptoms are noticeable. This continues to affect the hippocampus. The hippocampus is a major component of the human brain. It belongs to the limbic system and its most important functions are the consolidation of information from short-term memory to long-term memory and spatial navigation. Humans and other mammals have two hippocampi, one in each side of the brain. The hippocampus is a part of the cerebral cortex, and in primates is located in the medial temporal lobe, underneath the cortical surface. As more neurons die, affected brain regions begin to shrink. By the final stage of Alzheimer's, damage is widespread, and brain tissue has shrunk significantly.

Alzheimer's, if diagnosed early, can facilitate timely access to diagnosis and health care. The clinical indication for an earlier diagnosis would be that a critical period for some interventions may lie between the earliest point at which the diagnosis can be made and the time at which diagnosis is currently made. The interventions work better, when applied earlier, M. Prince et. al. (2011).

Current work in this area can be mainly divided into Neuropsychological markers and structural imaging markers. Another method is using Biomarkers but this method is not particularly popular as it is considered invasive. Neuropsychological markers broadly include 1) Community

based study and 2) Studies of individuals with Mild Cognitive Impairment (MCI) who are at risk of AD. In case of structural imaging, studies have shown that atrophy of the medial temporal lobe, including the hippocampus and entorhinal cortex are sensitive markers of AD, P. J. Nester et. al. (2004).

Currently, automated segmentation is difficult because hippocampus is a small and tightly folded elongate structure without any clear boundaries and due to this, many researches and radiologists still use manual sketching of the hippocampal area so as to be able to detect its volume. Using the manual tracing methods a large number of experiments have been conducted thereby confirming the accuracy of using atrophy of the medial temporal lobe. One such research, Yih-Yian Sitoh et. al. (2002), calculated mean cerebral volume, mean hippocampal volume and the normalized volume between the control subjects (healthy subjects) and the patients. Here, results have shown that hippocampal volume in early AD patients were 13.9% lower than in control subjects. When region segmentation and feature selection was tested on a group of people (including equal number of control subjects and AD patients) along with clinical results a high accuracy of 90% was achieved in the classification. But it is to be noted that this experiment included clinical results which is usually not available in the early stages of AD. Another experiment, Dong Hye Ye et. al. (2011), which involved manifold based learning techniques (automated), gave the following results: sensitivity- 94%, and accuracy 56.1%.

Along with the above, medical history and mental status evaluation is done by the psychologists as they recommend patients of AD for further brain study based on these tests. There are many standardized sets of tests which are used specifically for this purpose. Also, sets of questionnaires are asked to the relatives of those who are affected by Alzheimer's, Katie Palmer et. al. (2003).

In present context to notice atrophy in the brain, eyeballing of the MRI scan is the most popular method, but using this method it is mainly possible only to notice the atrophy at very advanced stages (if atrophy of the overall brain is being considered). In cases where the atrophy of only the medial temporal lobe is to be considered then it is possible to miss the shrinkage due to human error. In confirmed cases, functional MRIs (fMRI) are also carried out along with EEGs but most of these results only confirm the presence of Alzheimer's and not detect it.

K-means segmentation algorithm

Clustering analysis is the task of assigning a set of objects into groups (clusters) so that objects in the same cluster are more similar and to achieve this, K-means segmentation algorithm can be used. The problem is computationally difficult. However, there are efficient heuristic algorithms that are commonly employed and converge quickly to a local optimum. An iterative refinement approach is usually employed by the segmentation algorithms. K-means clustering tends to find clusters of comparable spatial extent.

The algorithm is composed of the following steps:

1. K points are randomly placed in the image and they represent initial centroids for initiating the algorithm.
2. Isolate the image into objects and assign each object to the nearest centroid.
3. The positions of the K centroids are calculated.
4. Repeat steps 2 and 3 until the mean square error reduces below a set threshold.

Methodology

MRI scans of 25 volunteers referred to the Department of Radiology, Kasturba Medical College, Mangalore, by Department of Psychiatry, Department of Neurology and Department of Geriatrics were studied. Cases involving stroke, brain tumors, physical brain damage and those not willing to give consent for study were excluded from the study. The subjects included 16 men and 9 women aged between 16 to 83 years (Mean - 48.32

years; Standard deviation - 16.27 years). They were neurologically intact and had no systemic disease. MRI imaging was performed using a 1.5-T MRI machine. T2 tirm flair MRI images were acquired for each subject along the axial plane. The MRI scans are captured at regular intervals known as slice thickness which is dependent on the MRI machine being used. Smaller slice thickness gives greater accuracy and greater details for image processing. Each set of axial scans used here contained 22- 26 slices of 6.5mm slice thickness. On these scans, clustering and segmentation algorithms were used with K=8 and K=10 to calculate grey and white matter volume of the brain and to isolate the hippocampus in particular slices of the MRI respectively.

In case of grey and white matter volume measurement, initially the MRI scans were processed using an averaging filter to remove noise from the image, following which boundary detection and dilation methods were used in deleting the cranium from the image. This is done as inclusion of the cranium has shown disparity in results when segmentation algorithms were run on the image. Fig. 1 and Fig. 5 show axial MRI scans of two samples. Fig. 2 and Fig. 6 show the MRI scans post segmentation of the same samples. Following this, the k-means algorithm was run on all the slices of the scan and masks are created such that the segments containing the grey and white matter were isolated. Fig.3 and Fig.7 depict effect of masking on the segmented image to calculate brain volume in case of the two samples. Fig.4 and Fig.8 depict masking on slices 13-16 of the segmented image to calculate grey matter volume. Using the acquired results, the area of each cluster was found in each slice. Using the area calculated by the algorithm and the slice thickness, the volume of the grey matter and white matter can be calculated using the trapezoidal rule. The volume estimation algorithm was implemented on 25 samples and Table 1 presents results of 4 typical samples.

The following can be inferred from the 4 cases given in Table I:

Sample 1 – Comparing the estimated volume to that of the reference, it can be easily observed that the patient has a 'healthy' brain with no signs of dementia or AD.
Sample 2 - Comparing the estimated volume to that of the reference, it can be easily observed that the patient has a 'healthy' brain with no signs of dementia or AD.
Sample 3 – There is small reduction in the grey matter of the patient's brain. Comparing the estimated volume to that of the reference, it can be easily observed that the patient has 'atrophy through age' symptoms but no definite signs of dementia or AD.
Sample 4 – There is a huge reduction in the grey matter of the patient's brain. Comparing the estimated volume to that of the reference, it can be easily observed that the patient has AD.

Hippocampal isolation is essential to find the hippocampal volume. For this, first the slices in the axial MRI where the hippocampus is visible are isolated (slices 10 to 15 in a 22 slice MRI). Following that, the region in which the hippocampii are most likely to be found is selected and the noise is removed with the help of averaging filters. The image is further improved by contrast stretching. The hippocampus is visible as the brightest region in the image. This property is further exploited by segmentation of the image with K=10 and the resulting image has the hippocampus clearly isolated. This helps in not only isolating the hippocampus in the slice but also to further estimate the area covered by it. Fig.9 shows the steps of hippocampal isolation.

Conclusion

The work presented in this paper describes an approach of using image processing and image segmentation to help in utilisation of MRI scans to aid in the early detection of Alzheimer's. This has mainly been done by combining the two parameters- brain volume measurement (to estimate atrophy) and hippocampal isolation (hippocampal atrophy characterises AD). To do so, axial brain

scans of high contrast were processed and the results of the brain volume measurement were in correlation with standard average volumes. The grey matter volume in the AD patient was significantly lesser than average grey matter volume of a healthy individual, thereby validating the results. In case of hippocampus isolation, the isolation algorithm has been successfully implemented making it easier to identify the atrophy in case of an AD patient. The above progress has greatly reduced the manual intervention in measuring the above statistics. Future work in this direction will focus on further isolation of the hippocampus to estimate its volume, which in addition to the brain volume measurement will prove to be an important and much more accurate marker in the early detection of Alzheimer's. The number of people with AD is growing significantly each year hence techniques are needed to battle this grave disease and curb its growth. We hope that our work will be a contribution in the direction of better management of AD patients and thereby helping society.

Acknowledgements

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References

[1] Dong Hye Ye, Kilian M. Pohl and Christos Davatzikos (2011), Semi-Supervised Pattern Classification: Application to Structural MRI of Alzheimer's Disease, IEEE International Workshop on Pattern Recognition in Neuro Imaging, Seoul, Korea, May 16-18

[2] Katie Palmer, et. al. (2003), Detection of Alzheimer's disease and dementia in the preclinical phase: population based cohort study, Basic Medical Journal, Volume 326 (7383)

[3] Martin Prince, Renata Bryce and Cleusa Ferri (2011). The benefits of early diagnosis and intervention, World Alzheimer Report, 2011, Alzheimer's Disease International

[4] Peter J Nestor, Philip Scheltens, John R Hodges, (2004) Advances in the Early detection of Alzheimer's disease, Nature Reviews Neuroscience

[5] Yih-Yian Sitoh, Jagannathan Karthik, et al. (2002) Cerebral and Hippocampal Volumetry in Early Alzheimer's Disease, International Conference on Neural Information Processing (ICONIP'OZ-2002), Singapore, Vol. 3

Table 1 Results obtained by implementing the volume estimation algorithm on the samples

Sample No.	Age	Sex	Grey matter (in cc)	White matter (in cc)	Total (in cc)	Comments
1	35	F	543	519	1062	Healthy patient
2	35	M	560	592	1152	Healthy patient
3	68	M	447	533	980	Atrophy through age
4	78	F	312	498	810	Confirmed AD case

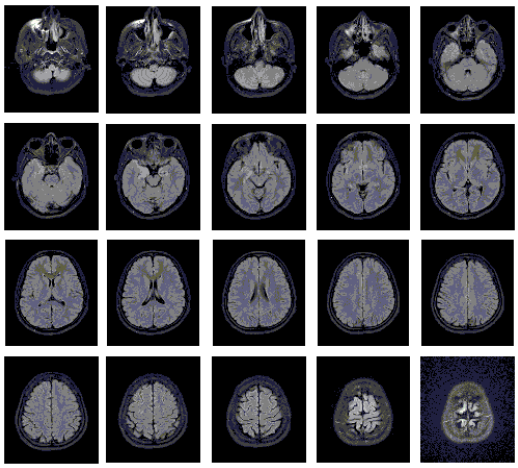

Fig. 1 Axial MRI scans of 35 year old female healthy subject (Sample 1)

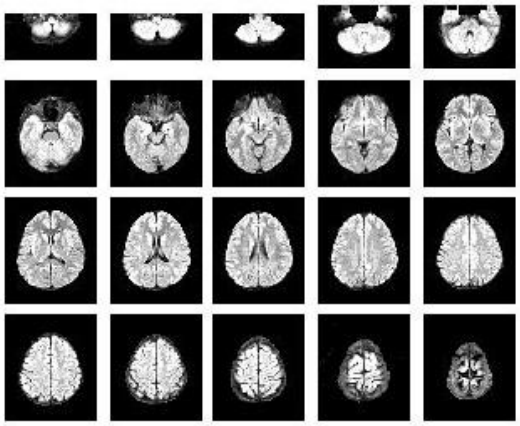

Fig. 2 MRI scans post segmentation (Sample 1)

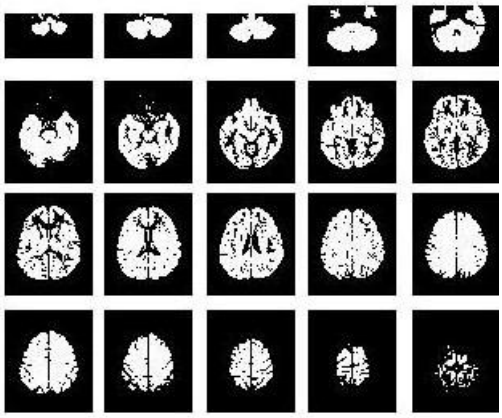

Fig. 3 Masking on the segmented image so as to calculate brain volume (Sample 1)

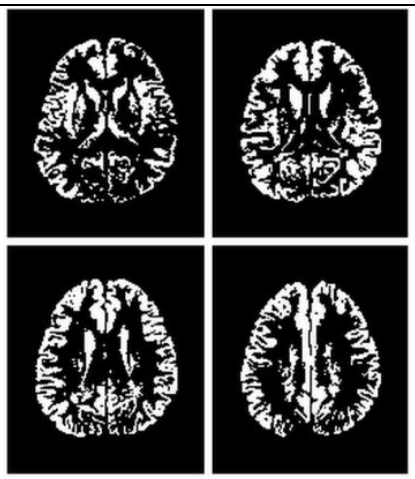

Fig. 4 Masking shown on slices 13-16 of the segmented image so as to calculate grey matter volume (Sample 1)

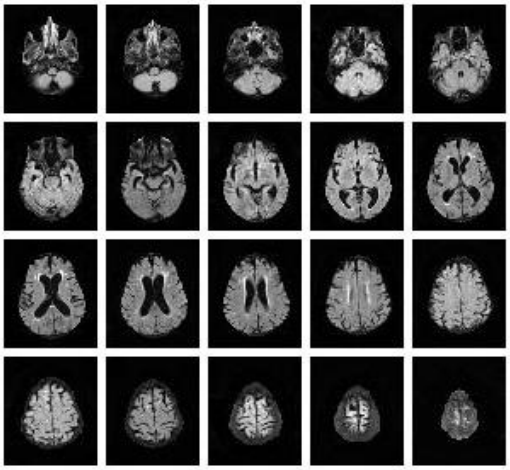

Fig. 5 Axial MRI scans of a 35 year old female healthy subject (Sample 4)

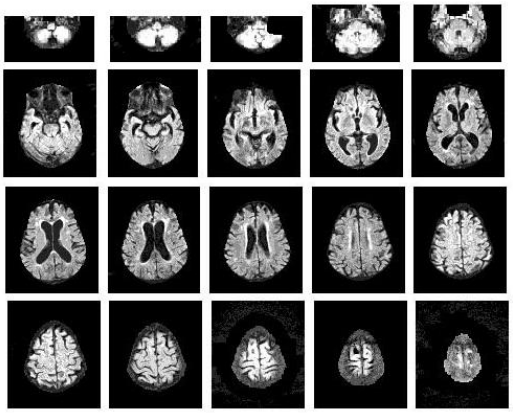

Fig. 6 MRI scans post segmentation (Sample 4)

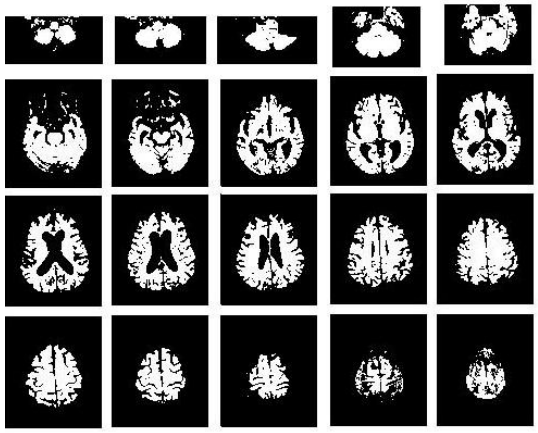

Fig. 7 Masking on the segmented image so as to calculate brain volume (Sample 4)

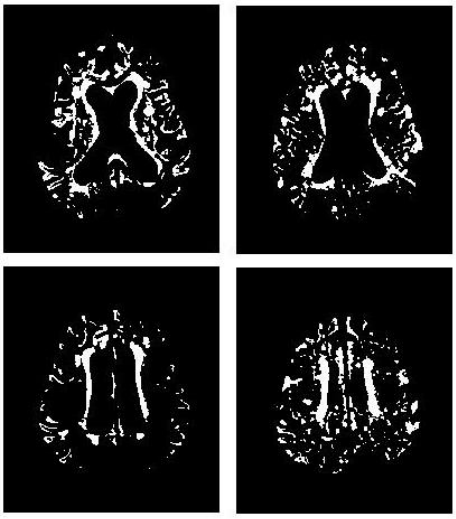

Fig. 8 Masking shown on slices 13-16 of the segmented image so as to calculate grey matter volume (Sample 4)

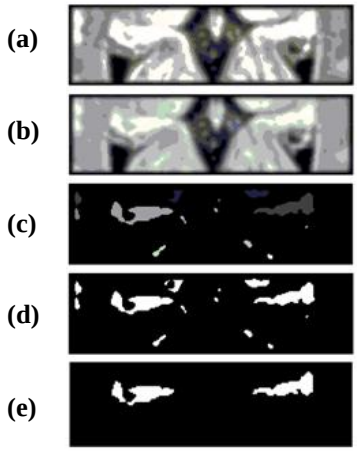

Fig.9 Steps of hippocampal isolation
a) Region of interest isolation
b) Segmentation
c) Binary Image
d) Bounded regions separation
e) Hippocampal isolation