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Mathematical Morphology Based Hippocampus Segmentation for the Detection of Alzheimer's Disease (AD)

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ABSTRACT

Alzheimer's disease (AD) is a neurodegenerative disorder and is estimated to be the third leading cause of death after heart disease and cancer. It is the most common form of dementia caused due to brain shrinkage. This progressive disorder gradually increases in cognitive impairment, characteristic degenerative pathology and brain atrophy. Structural Magnetic Resonance Imaging (sMRI) noninvasively examines the changes in contrast and detail resolution of soft tissues, which provide the early detection of AD. In the transition to AD, a patient goes through the stages of normal aging (NM), and mild cognitive impairment (MCI).In the proposed work the components of the MRI brain images will be segmented after doing some pre-processing techniques.

Key words: Alzheimer's disease, mild cognitive impairment, MRI, Segmentation

1. INTRODUCTION

Machine Learning and Medical Imaging presents state-of-the-art machine learning methods in medical image analysis. Advances in both imaging and computers have synergistically led to a rapid rise in the potential use of artificial intelligence in various radiological imaging tasks, such as risk assessment, detection, diagnosis, prognosis, and therapy response, as well as in multi-omics disease discovery. In the Medical Imaging part leading research groups around the world present a wide spectrum of machine learning methods with application to different medical imaging modalities, clinical domains, and organs. The targeted organs span the lung, liver, brain, and prostate etc. The guidelines for the diagnosis of Alzheimer's disease emphasize the role that can be played by using various biomarkers. These include measures from magnetic resonance imaging(MRI)[4][6], positron emission tomography (PET), cerebrospinal fluid (CSF) protein profiles as well as analysis of genetic risk profiles though these are expensive and difficult to scale to large numbers of assessments. There is no single test that can show whether a person has or does not have Alzheimer's disease. Diagnosing Alzheimer's requires careful medical evaluation.

1.1 Motivation

According to the Alzheimer's Association's 2015 report an estimated 5.3 million US citizens have Alzheimer's disease [2]. While 5.1 million of these are aged more than 65 years, approximately 200,000 are aged less than 65 years and have what is called younger onset of Alzheimer's disease as shown figure 1. By the middle of this century, the number of people living with AD in the United States is projected to grow by nearly 10 million, fuelled in large part by the aging baby boom generation. Today, someone in the USA develops AD every 67 seconds. By 2050, one new case of AD is expected to develop every 33 seconds, resulting in nearly 1 million new cases per year, and the estimated prevalence is expected to range from 11 million to 16 million. In 2013, official death certificates in the United States recorded 84,767 deaths from AD, making AD the sixth leading cause of death in the United States and the fifth leading cause of death in Americans aged 65 years or greater. Between 2000 and 2013, deaths resulting from heart disease, stroke and prostate cancer decreased by 14%, 23% and 11%, respectively, whereas deaths from AD increased by 71%.

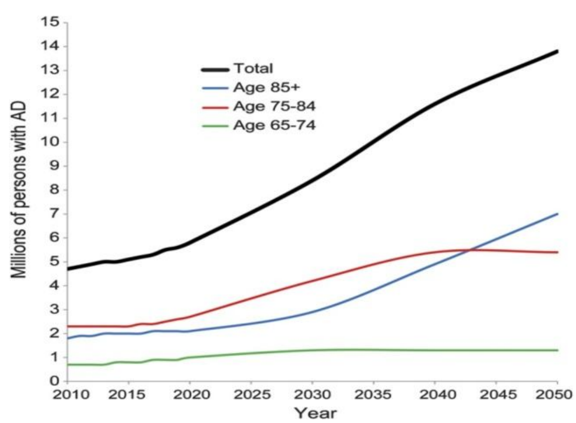


Figure 1: Estimated number of people with Alzheimer disease (AD) in the United States in 2010 and projections through 2050

Only 1-in-4 people with Alzheimer's disease have been diagnosed, according to Alzheimer's disease International. Alzheimer's and dementia is most common in Western Europe and while no definitive cure for Alzheimer's disease is available, suffering can be lessened by compassionate skilled post-diagnosis support. Alzheimer's disease is a serious personal, medical and social problem. Recent research indicates early and accurate diagnosis as the key to effectively coping with it. Even when the disease is diagnosed correctly, monitoring the progression of the disease over time is costly. Treatment is thought to be most effective when it is started before significant downstream damage occurs, i.e. before clinical diagnosis of Alzheimer's Disease, at the earlier stage of mild cognitive impairment [1](MCI) or even earlier.

2. OBJECTIVES

The aim is to automatically segment the hippocampus from MRI brain images after skull stripping and contrast enhancement. The three sensitive structural features of AD are hippocampal atrophy, ventricle enlargement and cortex shrinkage [7].Among them the structural features of Hippocampal atrophy [5] has analyzed.

3. LIMITATIONS OF EXISTING WORKS

There have been several attempts to solve the problem of automatic brain segmentation [3] from MR images. However only a handful of them were fully automatic which are based on active contour model and Bayesian approach. The problem is still challenging. Some semi automatic approaches also exist for segmentation. Histogram-based thresholding and morphological operations are sensitive to small data variations and it is difficult to find the optimum morphology size for separating the brain tissues from the non-brain tissues. In some cases Histogram analysis approach is not producing good skull stripping result when the image is affected with various image artifacts.

4. PROPOSED METHOD

The basic experiment design and the corresponding processing steps have been illustrated below. Data used in this work were obtained from the Alzheimer's disease NeuroImaging Initiative database (ADNI) .In the proposed work MR Images are taken for the study. The methodology and different steps in the proposed system are described in figure 2.

Figure 2: Dataflow diagram of proposed system

4.1 Image Acquisition

The MRI image acquired by ADNI is taken as a series for preprocessing and further segmentation. All the images taken for the experiment are of T1 weighted sagittal orientation images. The data are collected from patients whose age ranges from 70 to 90.

4.2 Image pre-processing

The pre-processing technique will help to identify the brain atrophy with more clarity. In preprocessing I have done the noise removal and contrast enhancement. Here in MRI brain images noise removal is the removal of unwanted skull part from the brain images. Skull stripping and contrast enhancement is done with the help of morphological operations. The preprocessing steps are described in figure 3.

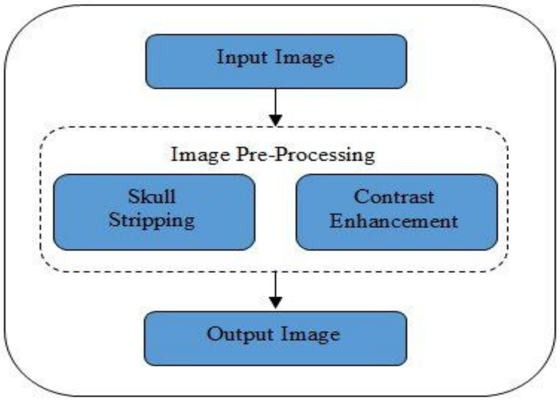


Figure 3: Preprocessing steps

4.2.1 Contrast Enhancement

MR images are low contrast images. For diagnosing purpose, the minute details in the image must be visible. That is, the contrast of the image must be enhanced. In this work we proposed a simple method for MRI brain image enhancement using the technology of mathematical morphology. Mathematical morphology is a tool for extracting image components that are useful in the representation and description of region, shape such as boundaries, skeletons, and convex hull. Erosion and Dilation are the fundamental morphological operations, which are used to define the closing and opening operations.

Dilation is used for expanding an element A by using structuring element B.Dilation of A by B in Z.

Erosion is used for shrinking of element A by using element B.Erosion for Sets A and B in Z.

Opening
First erode A by B, and then dilate the result by B .In other words, opening is the unification of all B objects entirely contained in A.

Closing
First dilate A by B, and then erode the result by B .In other words, closing is the group of points, which the intersection of object B around them with object A which is not empty.

Opening smoothes contours of an image and eliminates thin protrusions. Closing smoothes sections of contours but fuses narrow breaks, eliminates small holes and fills gaps in contours. These operations are dual to each other. These operations are can be applied few times, but has effect only once.Structuring Element (SE) is a small set or sub images used to probe an image under study for properties of interest. Different types of structuring elements are available for morphological processing like square, line, disc, ball etc... Working of contrast enhancement is shown in the algorithm.1

Algorithm.1: Morphology based contrast enhancement of MR brain images.

Step 1: Read the MR Image, A, of brain.
Step 2: Find the complement, B of the image A.
B = Ac = (L-1) - A, Where L is the maximum possible intensity value.
Step3: Apply Closing operation with a disk structuring element, SE1. C = B ꞩ SE1
Step 4: Find the complement, D of the resultant image, C.
D= Cc = (L-1) -C
Step 5: Find the difference between original image, A and resultant image, D obtained from step 4.
A diff = A- D
Step 6: Add A diff obtained from step 5 with the original image, A.
A enhanced = A + A diff

For enhancement, after complementation and closing operation find the difference with the original image. The result is an image with edges and high intensity values. If we add this image with the original, the result is an enhanced image C

4.2.2 Skull Stripping

Skull stripping is a major phase in MRI brain imaging applications and it refers to the removal of the brain's non-cerebral tissues. The main problem in skull-stripping is the segmentation of the non-cerebral and the intracranial tissues due to their homogeneity intensities. Numerous techniques were applied in the studies of skull stripping; most common are region growing and mathematical morphology. The proposed system performs skull stripping using mathematical morphology as given in algorithm 2.

Algorithm 2: Morphology based skull stripping of MR brain images.

Step 1: Read the image, G.
Step 2: Binarize the image using Otsu's method.
Step3: Find the largest connected component, C1 from the binarized image, G bin.
Step 4: Dilate, C1 with a 3x3 square structuring element, SE2.
Step 5: Erosion inside the brain region
Step 6: Fill the holes in the resultant image.
Step 7: Segment the image region from the original image (G) to obtain the skull stripped image (G new)

4.3 Segmentation

Segmentation will be done to segment the Region of interest (ROI) by applying region growing technique.

4.3.1. Morphology based Segmentation

Binary images may contain countless defects. In some circumstances binary regions constructed by simple thresholding are buckled by noise and textures. Morphology is a vast extent of image processing operations that modifies the images based on shapes. It is considered to be one of the data processing methods useful in image processing. It has many applications like texture analysis, noise elimination, boundary extraction etc. Morphological image processing follows the goal of eliminating all these defects and maintaining structure of image. Morphological operations are confident only on the associated ordering of pixel values, rather than their numerical values, so they are focused more on binary images, but it can also be applied to grayscale images such that their light transfer functions are unknown and thus their absolute pixel values are not taken into consideration. Morphological techniques verify the image with a small template called structuring element. This structuring element is applied to all possible locations of the input image and generates the same size output. In this technique the output image pixel values are based on similar pixels of input image with its neighbors. This operation produces a new binary image in which if test is successful it will have non-zero pixel value at that location in the input image. There are various structuring element like diamond shaped, square shaped, cross shaped etc. The base of the morphological operation is dilation, erosion, opening, closing expressed in logical AND, OR notation and described by set analysis. Dilation adds pixels while erosion removes the pixels at boundaries of the objects. This removal or adding of pixels depends on the structuring element used for segmenting the image.

The proposed work uses simple algorithm to create foreground and background markers using morphological image reconstructions. We used erosion-based gray-scale reconstruction followed by dilation-based gray-scale reconstruction to trace the foreground objects .Calculating the regional maxima of these reconstructed images is done to get smooth edge foreground objects. The background markers are created by calculating the Euclidean distance of binary version of above superimposed image. The gradient image is modified by morphological reconstruction with foreground and background markers.

Algorithm 3: Morphology based segmentation

Step 1: Read the MRI image and convert it to gray-scale.
Step 2: Develop gradient images using appropriate edge detection function.
Step 3: Mark the foreground objects using morphology
Step 4: Calculating the regional maxima and minima to obtain the good forward markers.
Step 5: Superimpose the foreground marker image on the original image.

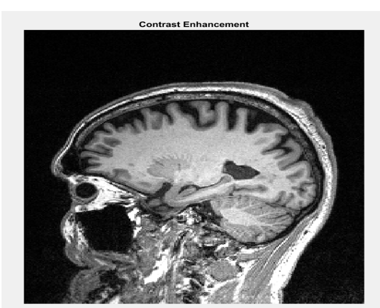
Step 6: Clean the edges of the markers using edge reconstruction.
Step 7: Compute the background markers.
Step 8: Compute the watershed transform of the function.

5. CONCLUSION

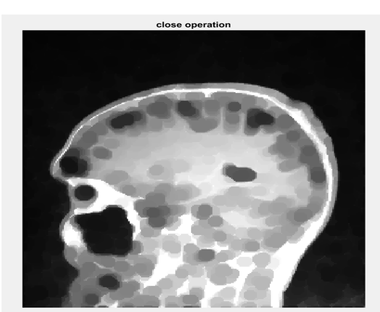
Image segmentation is an important step in many medical applications involving 3D visualization, computer-aided diagnosis, measurements, and registration. This proposed work has provided a brief introduction to the fundamental concepts of MRI segmentation of the human brain and methods that are commonly used. Before segmentation, preprocessing steps necessary to prepare images for MRI segmentation have been described. The most important steps include contrast enhancement and skull stripping. Due to the rapid development of medical image modalities, new application-specific segmentation problems are emerging and new methods are continuously explored and introduced. Selection of the most appropriate technique for a given application is a difficult task. In many cases, a combination of several techniques may be necessary to obtain the segmentation goal.

APPENDIX

Input Image

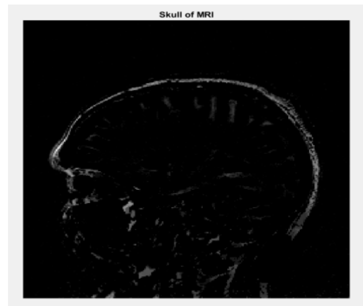


Contrast enhanced Image



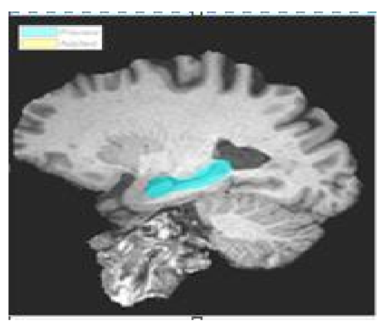
Close Operation

Open Operation



Skull Extraction

Skull Stripped Image



Segmented Image

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