Watershed Segmentation of Brain MRI Image

A Project Report

Submitted By
OmsheNath
Under the Guidance of
Dr. K.Hemachandran
Abstract

Automated brain tumor detection from MRI images is one of the most challenging tasks in today’s modern Medical imaging research. Magnetic Resonance Images (MRI) are used to produce images of soft tissue of human body. It is used to analyze the human organs without the need for surgery. Automatic detection requires brain image segmentation, which is the process of partitioning the image into distinct regions, is one of the most important and challenging aspect of computer aided clinical diagnostic tools. Segmentation is used to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in MRI images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. The result of MRI image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image (edge detection). Each of the pixels in a region are similar with respect to some characteristic or computed property, such as color, intensity, or texture, in this paper various (existing) segmentation algorithm has been studied a and implemented using MATLAB.
CHAPTER 1

1.1 INTRODUCTION

Image Processing refers to the processing of visual information sources, such as images for some specific task, as per the application requirements. Image processing is the processing of images using mathematical operations by using any form of signal processing for which the input is an image, a series of images or a video, such as a photograph or a video frame. The output of the image processing may be either an image or a set of characteristics or parameters related to image. Digital image processing refers to the use of computer algorithms to perform image processing on digital images. Digital image processing has many advantages over analog image processing.

Image Segmentation

In image processing, segmentation is a basic problem in different fields for example, pattern recognition, scene analysis and image analysis. Image segmentation is the process of dividing images into regions according to its characteristic e.g., color and objects present in the images. These regions are sets of pixels and have some meaningful information about object. The result of image segmentation is in the form of images that are more meaningful, easier to understand and easier to analyze. In order to locate objects and boundaries in images feature extraction of object shape, optical density, and texture, surface visualization, image registration and compression image segmentation is used. Correct segmented results are very useful for the analysis, predication and diagnoses (Segmentation (image processing).

Medical images play vital role in assisting health care providers to access patients for diagnosis and treatment. Studying medical images depends mainly on the visual interpretation of the radiologists. However, this consumes time and usually subjective, depending on the experience of the radiologist. Consequently the use of computer-aided systems becomes very necessary to overcome these limitations. Artificial Intelligence methods such as digital image processing when combined with others like machine learning, fuzzy logic and pattern recognition are so valuable in Image techniques can be grouped under a general framework; Image Engineering (IE). This is comprised of three layers: image processing (lower layer), image analysis (middle layer), and image understanding (high layer).
MRI Images

MRI stands for Magnetic Resonance Imaging. It is one of the significant techniques for examining human body. Brain MRI images are useful in distinguishing and clarifying the neural architecture of the human brain. It scans and captures the internal soft tissue structure of the human body. It can be very useful in detecting diseases in the brain. It takes the images of the brain in the presence of a magnetic field and strong radio waves. Image segmentation is the first step and also one of the most critical tasks of MRI image analysis. Its objective is that of extracting information (represented by data) from an image via image segmentation, object representation, and feature measurement. Result of segmentation; obviously have considerable influence over the accuracy of feature measurement. The computerization of medical image segmentation plays an important role in medical imaging applications. It has found wide application in different areas such as diagnosis, localization of pathology, study of anatomical structure, treatment planning, and computer-integrated surgery. However, the variability and the complexity of the anatomical structures in the human body have resulted in medical image segmentation remaining a hard problem.
1.2 Objective

Marker Controlled Watershed Segmentation of Brain MRI Images
CHAPTER 2

IMAGE SEGMENTATION

Segmentation subdivides an image into its basic regions or objects. The level of detail to which the subdivision is carried depends on the problem being solved. That is interest in an application have been detected. The goal of image segmentation is to cluster pixels into salient image regions, i.e., regions corresponding to individual surfaces, objects, or natural parts of objects. Image is formed in the eye and in the camera by the amount of illumination reflected by an object. In computer vision, image processing is any form of signal processing for which the input is an image, such as photographs or frames of videos. The output of MRI image processing can be either an image or a set of characteristics or parameters related to image. The image processing techniques like image restoration, image enhancement, image segmentation etc.

![Segmentation types diagram]

**Figure 1. Various types of segmentation**
Image segmentation is an important yet still challenging problem in computer vision and image processing. In specific, it is an essential process for many applications such as object recognition, target tracking, content-based image retrieval and medical image processing, etc. Generally speaking, the goal of image segmentation is to partition an image into a certain number of pieces which have coherent features (color, texture, etc.) and in the meanwhile to group the meaningful pieces together for the convenience of perceiving.

Watershed segmentation is a morphological based method of image segmentation. The gradient magnitude of an image is considered as a topographic surface for the watershed transformation. Watershed lines can be found by different ways. The complete division of the image through watershed transformation relies mostly on a good estimation of image gradients. The result of the watershed transform is degraded by the background noise and produces the over-segmentation. Also, under segmentation is produced by low-contrast edges generate small magnitude gradients, causing distinct regions to be erroneously merged.

In order to reduce the deficiencies of watershed, many preprocessing techniques are proposed by the different researchers for example Jung and Scharcanski (2005) presents a robust watershed segmentation using wavelets where wavelets technique is used to denoise the image. Bieniek and Moga (2000) present an efficient watershed algorithm based on connected components. Hamarneh and Li (2009) have proposed a method of watershed segmentation using prior shape and appearance knowledge to improve the segmentation results etc. But most of the techniques previously proposed consider the over segmentation problems and focus on the denoising of the image. The image low contrast and under segmentation problem is not yet addressed by most of the researchers.

The proposed technique focuses on the solution of under segmentation problem of low contrast images by applying preprocessing on the input image. The technique for preprocessing on the images is Random Walk. It is probabilistic approach used to enhance the image contrast in the way image is degraded.

The division of this paper is as follows, in section 2 some related work is given which describes the previous research about the remedy of watershed issues. In section 3, some basic information about watershed and random walk is given. In section 4, the proposed technique is discussed. In section 5, results are given. In section 6, the conclusion and future plane is given.
CHAPTER 3

IMAGE THRESHOLDING

Threshold is one of the widely methods used for image segmentation. It is useful in discriminating foreground from the background. By selecting an adequate threshold value $T$, the gray level image can be converted to binary image. The binary image should contain all of the essential information about the position and shape of the objects of interest (foreground). The benefit of obtaining first a binary image is that it decreases the complexity of the data and simplifies the process of recognition and classification. The most common way to change a gray-level image to a binary image is to select a single threshold value ($T$). Then all the gray level values below this $T$ will be classified as black ($0$), and those above $T$ will be white ($1$). The segmentation problem becomes one of selecting the correct value for the threshold $T$. A common method used to select $T$ is by analyzing the histograms of the type of images that want to be segmented.

The ideal case is when the histogram presents only two dominant modes and a clear valley (bimodal). In this case the value of $T$ is selected as the valley point between the two modes. In real applications histograms are more complex, with many peaks and not clear valleys, and it is not always easy to select the value of $T$ [9].

A. Iterative Method for Finding $T$

1. Estimate value of $T$ (start with mean)
2. Divide histogram into two regions, $R_1$ and $R_2$ using $T$
3. Calculate the mean intensity values $\mu_1$ and $\mu_2$ in regions $R_1$ and $R_2$
4. Select a new threshold $T = (\mu_1 + \mu_2)/2$
5. Repeat 2-4 until the mean values $\mu_1$ and $\mu_2$ do not change in successive iterations

Thresholding techniques identify a region based on the pixels with similar intensity values. This technique provides boundaries in images that contain solid objects on a contrast background [3]. Thresholding technique gives a binary output image from a gray scale image. This method of segmentation applies a single fixed criterion to all pixels in the image.
3.1 Global Thresholding
Suppose the histogram of an image $f(x, y)$ is composed of light objects on a dark background. The pixel intensity levels of the object and the background are grouped into two dominant modes. In global thresholding, a threshold value $T$ is selected in such a way that it separates the object and the background. The condition for selecting $T$ is given as follows:

$$g(x,y)= 1 \text{ if } f(x,y)>T$$
$$g(x,y)= 0 \text{ if } f(x,y)\leq T$$

Equation (1) has no indication on selecting the threshold value $T$. The threshold $T$ separates the object from the dark background. Any point $(x,y)$ for which $f(x, y) \geq T$ is called an object point. After Thresholding operation, the image is segmented as follows: Pixels labeled 1 corresponds to object whereas pixels labeled 0 corresponds to the background. In global Thresholding, the threshold value $T$ depends only on gray levels of $f(x, y)$.

Global Thresholding technique will not produce the desired output when pixels from different segments overlap in terms of intensities [3]. The overlapping of intensities may be caused due to (a) noise (b) variation in illumination across the image. In the first case, minimum-error method can be used to estimate the underlying cluster parameters and the threshold is chosen to minimize the classification error. Variable Thresholding technique is used for the latter case. Global Thresholding is popular due to simplicity and easy implementation.

3.2 Local Thresholding
Global Thresholding method is not suitable whenever the background illumination is uneven. In local Thresholding technique, the threshold value $T$ depends on gray levels of $f(x, y)$ and some local image properties of neighboring pixels such as mean or variance.

The threshold operation with a locally varying threshold function $T(x, y)$ is given by

$$g(x,y)= 1 \text{ if } f(x,y)>T(x,y)$$
$$g(x,y)= 0 \text{ if } f(x,y)\leq T(x,y)$$

$f_0(x, y)$ is the morphological opening of $f$, and the constant $T_0$ is the result of function $\text{graythresh}$ applied to $f_0$. Local Thresholding is superior to the global threshold method in the
case of poorly illuminated images.

3.3 Adaptive Thresholding

Adaptive Thresholding technique is used when images are captured under unknown lightning condition and it is required to segment a lighter foreground object from its background or whenever the background gray level is not constant and object contrast varies within an image. This technique allows the threshold value $T$ to change based on the slowly varying function of position in the image or on local neighboring hood statistics. Threshold $T$ depends on the spatial coordinated $(x, y)$ themselves.

3.4 Threshold Selection

The key parameter in image segmentation using Thresholding technique is the choice of selecting threshold value $T$. In case of manual Thresholding method, the threshold value $T$ can be selected by the user with the help of image histogram. This method is generally accomplished by a tool that allows the user to select the threshold value $T$ based on choice. In case of automatic threshold selection method, the value of $T$ can be chosen based on histogram, clustering, variance, means etc.
CHAPTER 4

FORMATION OF AN MRI IMAGE

In this first section we describe the process of formation of MRI to understand the model that will be used later and to be able to identify limitations. We were inspired by various documents explaining the physics of MRI, it seemed necessary to develop the implementation of the model we will use later in our paper.

This chapter introduces the basic concepts necessary to understand this work. At first we present some elements of the central nervous system anatomy, to clarify the vocabulary and concepts that are then used in a second step, we briefly introduce the physical principles of magnetic resonance imaging in emphasis particularly on the difficulties arising from this acquisition technique.

4.1 Elements of Cerebral Anatomy

This first section presents some basics of brain anatomy. It defines key terms and concepts to better understand what is seen with brain imaging. The central nervous system consists of the spinal cord located in the spinal canal, and brain. In what follows we describe the anatomy of the latter, including the components of interest in this study.

Figure 2. - The image (a) shows the brain consisting of the brain, cerebellum and brainstem. Image (b) shows a histological section of the brain showing the three main subjects of the brain.

4.2. The Main Substances in the Brain

Besides the presence of cerebral veins, tissues using walls, or many small structures such as glands, brain mainly contains three substances (Figure 2): a. The cerebrospinal fluid
(CSF) (or cerebrospinal fluid, CSF) is the fluid that bathes the brain and cerebellum. It is a transparent substance made up of 99% water with an average volume of 150ml, it is absorbed by the cerebral venous system and continually renewed. b. Gray matter (GM) (or gray) corresponds to the cell bodies of neurons with their dense network of dendrites. c. White matter (WM) (or white matter) corresponds to the myelin sheath covering the axons of neurons to accelerate conduction. The myelinated axons are assembled into bundles to establish connections between groups of neurons.

4.3. Observation of the Brain

The observation of two-dimensional slices of the brain can be performed in several angles. Thus, there are three anatomical axes to make cuts (Figure 3).

1. Axial: These cuts are virtually identical to a horizontal plane. In magnetic resonance imaging, they correspond to a plane perpendicular to the axis of the main magnetic field.
2. Sagittal: These cuts are taken in planes parallel to the inter-hemispheric. These lateral views of the brain.
3. Coronal: These are cut perpendicular to the axial slices. They correspond to views from the front of the brain.

Figure 3: three cutting axes for viewing of the brain.
Chapter 5

Implementation of Watershed Segmentation

This section gives some basic information about Watershed segmentation and Random Walk method. The proposed system is based on the enhanced watershed segmentation technique rather than conventional watershed segmentation technique. This segmentation is defined as marker controlled watershed segmentation.

5.1 Watershed Segmentation

Watershed transformation is a morphological based tool for image segmentation. In grey scale mathematical morphology the watershed transformation for image segmentation is originally proposed by Digabel and Lantuejoul (1977) and later improved by Li et. al. (2003). The watershed transform can be classified as a region-based segmentation approach.

![Figure 1: Illustration of immersion process of watershed transforms. (CB is for catchment basins)](image)

The idea of watershed can be view as a landscape immersed in a lake; catchment basins will be filled up with water starting at each local minimum. Dams must be built where the water coming from different catchment basins may be meeting in order to avoid the merging of catchment basins. The water shed lines are defined by the catchment basins divided by the dam at the highest level where the water can reach in the landscape. As a result, watershed lines can separate individual catchment basins in the landscape. The idea is described in Figure 1 which describes the flooding or rain falling process of watershed algorithm (Hsiieh, 2006).
The process of rain falling is described in Figure 2.

![Figure 2: Illustrations of flooding (rain-falling) process of watershed transform.](image)

Watershed segmentation is used to separate touching objects in an image. The watershed transform is often applied to this problem. The watershed transform finds "catchment basins" and "watershed ridge lines" in an image by treating it as a surface where light pixels are high and dark pixels are low.

Segmentation using the watershed transforms works well if you can identify, or "mark," foreground objects and background locations. Marker-controlled watershed segmentation follows this basic procedure:

1. Compute a segmentation function. This is an image whose dark regions are the objects you are trying to segment.
2. Compute foreground markers. These are connected blobs of pixels within each of the objects.
3. Compute background markers. These are pixels that are not part of any object.
4. Modify the segmentation function so that it only has minima at the foreground and background marker locations.
5. Compute the watershed transform of the modified segmentation function.
Advantages of Watershed Segmentation

- Watershed Segmentation is basically simple and intuitive method.
- It is fast and can be parallelized with almost linear speedup.
- It produces the complete division of the image even if the contrast is poor.
- Avoids the need of contour joining.
- The resulting boundaries of a given object forms closed and connected regions where as other edge-based techniques forms disconnected boundaries.
- The boundaries of the resulting regions always corresponds to contours which appear in the image as obvious contours of objects. This is in contrast to split and merge methods where the first splitting is often a simple. Regular sectioning of the image of the image loading, sometimes results to unstable results.
- The union of all regions forms the entire image region.

5.2 Marker Controlled Watershed Algorithm:

After image enhancement by using random walk process. The marker controlled watershed algorithm is applied on the image. The marker controlled watershed transform is mainly for the problems where adjacent objects are there in an image and we have to separate them using image processing operations. This approach deals with catchment basins and watershed ridge lines in an image by assuming it as a surface where light pixels are low. In the initial step we have to convert a 3D color image into gray scale and compute the gradient magnitude as the segmentation function where gradient is highest at the borders of the object and generally low inside the object. We will then use the internal marker to distinguish the foreground of adjacent objects. The background of the image will then be segregated from the foreground objects using the external markers. Finally we will aggregate the computed result of the watershed transform and examine the final image. The detailed algorithm is the following:

Step 1: Read in the Color Image and Convert it to Grayscale
Step 2: Use the Gradient Magnitude as the Segmentation Function
Step 3: Mark the Foreground Objects
Step 4: Compute Background Markers  
Step 5: Compute the Watershed Transform of the Segmented Function  
Step 6: Visualize the Result

5.3 Segmentation Technique  
The image segmentation system here is able to segment the 2-D images with minimum drawbacks of over segmentation and under segmentation. Before the segmentation algorithm is performed on the acquired images a preprocessing step by using random walk is performed in order to reduce the segmentation drawbacks. The steps of the proposed system are shown in Figure 3.

![Figure 3: process for image segmentation](image)

5.4 Image Acquisition  
In the step of implementation an image for analysis is acquired. The image can be taken through different sources e.g., camera. Image can have different drawbacks due to the camera fault, poor positioning of the camera, and the object of interest is out of focus. All these drawbacks create difficulty in image analysis especially in image segmentation.
5.5 Literature Survey

Erikson (2005) proposes two different techniques of performing preprocessing of an image to improve segmentation results. The methods use the grey level thickness of the objects, in order to find the resulting image. The first method proposed by the author is RW, uses the random walk of a particle to a random position, the position is defined in the neighborhood of the particle. The resulting image through this method holds the number of times the particle visits a pixel. The second method is Iterative Procedure (IP) scans the image iteratively and calculates the expected value of the same number, instead of randomization to find the number of visits. The methods proposed in this paper are independent of the segmentation method and can therefore be used as a preprocessing step for other segmentation methods as well.

Beucher (1991) proposed a method for image segmentation based on the mathematical morphology. The process of image segmentation is divides into two approaches, boundary based and region based. Watershed segmentation is a region based approach and uses to detect the pixel and region similarities. Basic tools for the watershed transformation are given and watershed transformation is applied on the gray tone images by using flooding process. The problem of over segmentation is remedied by using marker controlled watershed segmentation. Another approach, called hierarchical segmentation, is proposed. This approach is particularly efficient for defining levels of segmentation starting from a graph representation of the images based on the mosaic image transform.

Hsieh, Han, Wu, Chuangc, and Fana (2006) proposed a novel approach for small object detection by using watershed-based transformation. In this paper, the small moving objects are detected from the image. In order to improve the detection results from the previous techniques a noise removal technique is first applied to the image which removes the noise from the image and improve the image quality. The proposed detection system includes two main modules, first one is region of interest (ROI) locating and the other is contour extraction. After noise removal accurate ROI can be located. In contour extraction process, a rough candidate object in the images can be detected by applying some differencing technique on two contagious image frames.
from the image and improve the image quality. The proposed detection system includes two main modules, first one is region of interest (ROI) locating and the other is contour extraction. After noise removal accurate ROI can be located. In contour extraction process, a rough candidate object in the images can be detected by applying some differencing technique on two contiguous image frames. In this paper, in order to find the best results for contour extraction, a watershed-based technique along with the region matching technique is applied.

Hamarneh and Li (2007) propose a method for image segmentation consist of watershed segmentation using prior shape and appearance knowledge. Watershed segmentation is a common technique for image segmentation but has problems of over segmentation and sensitivity to noise. The proposed method has two stages, first is training stage and the other is segmentation stage. In training stage, a prior shape and appearance knowledge model is developed by using ‘shape histogram’ and image intensity statistics. The segmentation stage is an automatic iterative procedure and consists of four steps: classical watershed transformation, improved k-means clustering, shape alignment, and refinement. The issues of watershed are remedied by this method, as over segmentation problem is handled by clustering and noise effect can be removed by mean intensity of each segment. The limitation of k-mean clustering algorithm affects the proposed methods result and a failure case is reported.

Other researchers also proposed different method to remedy the problem of watershed. Li, Elmoataz, Fadili, and Ruan, S. (2003) proposed an improved image segmentation approach based on level set and mathematical morphology. The gradient magnitude of the smoothed image is input to the watershed transformation, the result of watershed is used for rough approximation of the desired contour in the image, and guide for the initial location of the seed points used in the following level set method. This method combines the advantages of both the methods and finds best contoured.

In this paper, Techniques such as Thresholding, the region growing, statistical models, active control models and clustering have been used for image segmentation. Because of the complex intensity distribution in medical images, Thresholding becomes a difficult task and often fails. In the region growing method, Thresholding is combined with connectivity.

Fuzzy C – means is a popular method for medical image segmentation but it only considers image intensity thereby producing unsatisfactory results in noisy images. A bunch of algorithms are proposed to make FCM robust against noise and in homogeneity but it’s
still not perfect.

Accurate estimation of the probability density function (PDF) is essential in probabilistic classification. Nonparametric approach does not make any assumption in obtaining the parameters of PDF thereby making it accurate but expensive. In parametric approaches, a function is assumed to be a PDF function. It is easy to implement but sometimes lacks accuracy and does not match real data distribution.

Segmentation for brain with anatomical deviations: The main challenge lies in segmentation of brain with anatomical deviation like tumor with different shape, size, location and intensities. The tumor not only changes the part of brain which tumor exists but also sometimes it influences shape and intensities of other structures of the brain. Thus the existence of such anatomical deviation makes use of prior information about intensity and spatial distribution challenging.

Segmentation of the tumor, its surrounding edema and other structures of the brain is very important for treatment and surgical planning. Some methods for brain tumor segmentation can be found in and. FFT based Segmentation for brain: Noises present in the medical images are multiplicative noises and reductions of these noises are difficult task. The anatomical details should not be destroyed by the denoising process from clinical point of view. Spectral leakage has the effect of the frequency analysis of finite-length signals or finite-length segments of infinite signals.

In brain the tumor itself, comprising a necrotic (dead) part and an active part, the edema or swelling in the nearby brain. As all tumor do not have a clear boundary between active and necrotic parts there is need to define a clear boundary between edema and brain tissues. It shows that some energy has leaked out of the original signal spectrum into other frequencies. A radix-4 FFT recursively partitions a DFT into four quarter-length DFTs of groups of every fourth time sample. The total computational cost reduced by these shorter FFTs outputs which are reused for computing the output.

5.7 Morphological Operation
Morphology is a broad set image processing operations that process images based on shapes. Morphological operations apply a structuring element to an input image, creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel of the input image with its
Two basic Morphological operations in Image Processing are-

**Dilation and Erosion** –
Dilation adds pixels to the boundaries of the object in an image. The number of pixel added is based on the structuring element that we use. In Dilation, the value of output pixel is the maximum of all the neighborhood pixel value. For a binary image, if the value of input pixel is 1 then the value of the output pixel is 1.

Dilation is represented by the following operations-

\[ \text{Dilation} = A + B \]

Erosion removes pixels from the boundaries of the object. The number of pixel removed from the object is based on the structuring element that we use. In Erosion operation, the value of output pixel is minimum of all the neighboring pixel value of the input image. In a binary image if the value of any input pixel is 0, then the value of the output pixel is 0.

Erosion is represented by the following operation-

\[ \text{Erosion} = A - B \]

**Image Reconstruction**

Image Reconstruction techniques are used to create 2-D or 3-D images from 1-D projections. These techniques are common for basic image modalities such as CT, MRI and PET. It is very useful in MRI techniques it can give us a clear picture in case of data collected at a very short amount of time.

**Opening and Closing Operation of an Image**

Opening and Closing operation are two kinds of image morphological operations that are based on basic image morphological operations that is –dilation and erosion. Opening serves as a basic workhouse for morphological noise removal. It removes small
objects from foreground (dark pixels) and places them in the background. Opening can find things into which a specific structuring element fits.

Closing removes small holes in the foreground, changing small islands of background into foreground. These can be used to find specific shapes in an object.

5.8 Result Analysis

The designed algorithm has been tested on MRI brain images. Results indicate that the segmentation is very clear for the images where the region of interest is enhanced.

The segmented images with the pre-processing using random walk have less chances of over or under segmentation. The difference between the segmentation using random walk and without using random walk as a preprocessing step is given. This shows the improvement in the segmentation results. The time complexity of the algorithm is $O(10n)$. 
Chapter 6

Conclusion

This section describes the conclusion of the proposed system and the future work, which defines how to future expand this research.

The goal of image segmentation process is to identify the segments of the image according to the image characteristic e.g., image color, objects shape etc. The simplified working of the image segmentation system is stated here. The most important step is the image acquisition. Any deficiency during the image acquisition can cause many problems in the result. The image used in this process is taken from image library. The input images are of low contrast. This segmentation process deals with the problem caused by these low contrast images by applying a preprocessing step using random walk. This step enhances the contrast of the input image so that the gradient of the image is strong enough to properly segment the image by using the watershed. After preprocessing step the gradient of the image is finding by converting the input image to grey scale. And this gradient of image is used as the input the image. The results show the improvement in the segmentation results using random walk.

The system will examined only one image at a time. This system can be very helpful for the segmentation of the images which are used in different fields of life. And the image analysis process can be facilitated by this system. The research content of this system was segmentation and image enhancement.
Chapter 7

Future work

In the paper the 2-D random walk is used with marker controlled watershed segmentation for the enhancement of the 2-D images this work can be expanded by using 3-D random walk process on the image. The work can be expanded to the 3-D images too.
Appendix A

References


[22] Osher, S., and Sethian, J. A, Fronts Propagating with Curvature- Dependent Speed:


Appendix B

Screenshots

Screenshot before loading of an Image
Screenshots after loading of a Test Image
Screenshot after loading a Brain MRI Image
Screenshot showing Brain Tumour segmentation of Brain MRI Image
Watershed Segmentation of Brain MRI Image

.. Original Image
.. Grayscale Image
.. Gradient magnitude
.. Watershed Segmentation
.. Opening Image
.. Opening by reconstruction
.. Opening by closing

Entropy after Laplacian of Gaussian: 0.374736