

# MRI Brain Image Segmentation using Machine Learning Techniques

Anusree P S<sup>1</sup>, Reshma Reghunath<sup>2</sup>, Saritha K S<sup>3</sup>, Ani Sunny<sup>4</sup>

<sup>1,2,3</sup>Student, Dept. of Computer Science & Engineering, Mar Athanasius College of Engineering, Kothamangalam, India

<sup>4</sup>Assistant Professor, Dept. of Computer Science & Engineering, Mar Athanasius College of Engineering, Kothamangalam, India

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**Abstract** – Magnetic Resonance Imaging (MRI) has been widely used in medical field now a days. Its non-invasive and good soft tissue contrast makes it useful for detecting abnormal tissues like tumors or lesions. Due to the recent advancement in machine learning, various methods have been proposed to improve MRI image processing and analysis. Medical interpretation by human expert is always prone to errors and may vary according to individual. Image segmentation is an important step that helps in image interpretation. In this paper, we are presenting five machine learning methods for image segmentation. Analysis is done based on comparison with a ground image.

**Key Words:** MRI, Mean Square Error, Structural Similarity, Image segmentation, Brain image

## 1. INTRODUCTION

Machine learning is the core of artificial intelligence. It has been widely applied in many fields, such as computer aided disease diagnosis, bioinformatics, and computer vision. Now a day, due to increase in image acquisition devices, medical data is huge. Hence there is a demand for extensive effort by human experts that is subjective and prone to error. But machine learning has provided robust tools for the detection, classification and quantification of patterns in medical images. Even though much deep learning architectures are developed for medical image analysis, their performance may vary depending on the type of input data and treatment requirement.

Brain tumor segmentation is an important task in medical image processing. Early diagnosis is very important for improving treatment possibilities. Manual segmentation is difficult and time consuming task since large amount of MRI images are generated in clinical routine. Hence, there is a need for automatic image segmentation. In order to find the optimal method of MRI image segmentation and analysis, we are considering a set of machine learning methods. Segmented images are compared with a ground truth image for analysis.

### 1.1 MRI

Magnetic Resonance Imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body. It is widely used

in hospitals and clinics for medical diagnosis. The person is positioned within an MRI scanner that forms a strong magnetic field around the area to be imaged. The hydrogen atoms in tissues containing water molecules get excited and emit a radio frequency signal, which is measured by receiving coil. The contrast between various tissues is determined by the rate at which excited atom returns to the equilibrium state.

Magnetic resonance imaging has been applied in neuroscience research that focuses on neurodegenerative diseases such as Alzheimer's disease (AD) and Parkinson's disease (PD) in clinical hospitals and research institutes.

Each tissue returns to its equilibrium state after excitation by the independent relaxation processes of T1 (spin-lattice; that is, magnetization in the same direction as the static magnetic field) and T2 (spin-spin; transverse to the static magnetic field). To create a T1-weighted image, magnetization is allowed to recover before measuring the MR signal by changing the repetition time (TR). This image weighting is useful for assessing the cerebral cortex, identifying fatty tissue, characterizing focal liver lesions and in general for obtaining morphological information, as well as for post-contrast imaging. To create a T2-weighted image, magnetization is allowed to decay before measuring the MR signal by changing the echo time (TE). This image weighting is useful for detecting edema and inflammation, revealing white matter lesions and assessing zonal anatomy in the prostate and uterus.

### 1.2 Brain tumor

A brain tumor is an abnormal growth of cells inside brain or skull. Tumors can be primary (grow from brain tissue itself) or secondary (cancer from elsewhere the body spread to brain). Treatment options vary depending on the tumor type, size and location. Treatment goals may be curative or focus on relieving symptoms. Many of the 120 types of brain tumors can be successfully treated. New therapies are improving the life span and quality of life for many people. Normal cells grow in a controlled manner as new cells replace old or damaged ones. For reasons not fully understood, tumor cells reproduce uncontrollably. Primary tumor can be benign or malignant. Benign tumor does not invade surrounding brain tissue and they grow in a well circumscribed fashion. Malignant tumors grow quickly,

invade normal brain and spread to other parts of the neuroaxis.

## 2. IMAGE SEGMENTATION

Image segmentation is the process of subdividing an image. The goal is to simplify the representation into something that is easier to analyze. It is used to locate boundaries and objects in images. The result of segmentation is a set of segments that collectively cover the entire image. Pixels in a region are similar to one another and dissimilar to those in other region. Automatic tissue segmentation in MRI images is of great importance in modern medical research and clinical routines. In MRI brain images, one of the most common image segmentation is the segmentation of Gray matter, White matter and Cerebrospinal Fluid.

Brain tumor segmentation methods can be classified as manual methods, semiautomatic methods and fully automatic methods based on the level of user interaction required [2].

Manual segmentation requires the radiologist to use the multi-modality information presented by the MRI images along with anatomical and physiological knowledge gained through training and experience. Apart from being a time consuming task, manual segmentation is also radiologist dependent and segmentation results are subject to large intra and inter rater variability. However, manual segmentations are widely used to evaluate the results of semi-automatic and fully automatic methods. Semi-automatic methods require interaction of the user for three main purposes; initialization, intervention or feedback response and evaluation. Semi-automatic brain tumor segmentation methods are less time consuming than manual methods and can obtain efficient results; they are still prone to intra and inter rater/user variability. In fully automatic brain tumor segmentation methods no user interaction is required. Mainly, artificial intelligence and prior knowledge are combined to solve the segmentation problem.

### 2.1 K Means Clustering

Clustering is the division of data into groups of similar objects. Each group consists of objects that are similar between themselves and dissimilar to objects of other groups. From the machine learning perspective, Clustering can be viewed as an unsupervised learning concept. Unsupervised machine learning means that clustering does not depend on different types of clusters depending on the predefined classes and training examples while classifying the data objects. Numerous methods have been proposed for clustering. The most popular clustering method is K-Means clustering algorithm.

This algorithm is more prominent for clustering massive data rapidly and efficiently. So, the image processing techniques especially the segmentation of images may be implemented by K-Means clustering algorithm. K-means

clustering is a method of vector quantization, originally from signal processing, that is popular for cluster analysis in data mining. K-means clustering aims to partition  $n$  observations into  $k$  clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster. But the final clustering result of the K-Means clustering algorithm greatly depends on the selection of the initial centroids, which are selected randomly and the number of clusters are manually initialized. Since, the initial cluster centers are selected arbitrarily, K-Means algorithm does not promise to produce consistent clustering results. Efficiency of the original K Means algorithm heavily relies on the selection of initial centroids.

### 2.2 Fuzzy C Means

The aim of FCM is to find cluster centers (centroids) that minimize dissimilarity functions. In order to accommodate the fuzzy partitioning technique, the membership matrix ( $U$ ) is randomly initialized. In the first step, the algorithm selects the initial cluster centers. Then, in later steps after several iterations of the algorithm, the final result converges to actual cluster center. Therefore a good set of initial cluster is achieved and it is very important for an FCM algorithm. If a good set of initial cluster centers is chosen, the algorithm make less iterations to find the actual cluster centers. The Fuzzy C-Means algorithm is an iterative algorithm that finds clusters in data and which uses the concept of fuzzy membership. Instead of assigning a pixel to a single cluster, each pixel will have different membership values on each cluster.

### 2.3 Watershed

A grey-level image may be seen as a topographic relief, where the grey level of a pixel is interpreted as its altitude in the relief. A drop of water falling on a topographic relief flows along a path to finally reach a local minimum. Intuitively, the watershed of a relief corresponds to the limits of the adjacent catchment basins of the drops of water. In image processing, different watershed lines may be computed. In graphs, some may be defined on the nodes, on the edges, or hybrid lines on both nodes and edges. Watersheds may also be defined in the continuous domain.

There are also many different algorithms to compute watersheds. If we consider a plain surface with places having few drenches and then if we spill water in it then we can easily understand that it will fill the deeper gradient first then the lighter gradient. This is how the watershed transformation came into existence. For a gray scale image black is considered to be the deepest gradient and lighter gradients are considered as we move through gray sheds toward white. Since it is highly sensitive to local minima and a watershed is created, if we have an image with noise, this will influence the segmentation. To get accurate results erosion and dilation is performed on segmented image.

## 2.4 Random Walker

Random walk is defined as discrete random motion in which a particle repeatedly moves a fixed distance up, down, east, west, north or south [3]. This is also a region growing based image segmentation method based on random walk of a particle. In this method the initial position at which a particle is initially present is known as seed point. After calculation of the seed point from second stage this stage starts from the seed point. The region is grown until the result is obtained. Movement from one position to another is based on the probability calculation.

## 2.5 Thresholding

Thresholding is the simplest method of image segmentation. From a gray scale image, thresholding can be used to create binary images. The key of this method is to select the threshold value. In image processing, thresholding is used to split an image into smaller segments, or junks, using at least one color or gray scale value to define their boundary. The advantage of obtaining first a binary image is that it reduces the complexity of the data and simplifies the process of recognition and classification. The most common way to convert a gray level image to a binary image is to select a single threshold value (T).

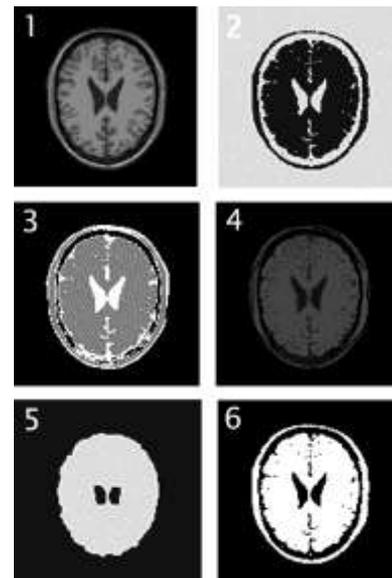
The input to a thresholding operation is typically a gray scale or color image. In the simplest implementation, the output is a binary image representing the segmentation. Black pixels correspond to background and white pixels correspond to foreground (or vice versa). This method of segmentation applies a single fixed criterion to all pixels in the image simultaneously. Otsu method is used to overcome the drawback of iterative thresholding i.e. calculating the mean after each step. In this method identify the optimal threshold by making use of histogram of the image. Otsu's method is aimed in finding the optimal value for the global threshold.

## 2.6 Data sets

A number of online neuroscience databases are available which provide information regarding gene expression, neurons, macroscopic brain structure, and neurological or psychiatric disorders. Some databases contain descriptive and numerical data, some to brain function; others offer access to 'raw' imaging data, such as post-mortem brain sections or 3D MRI and fMRI images. Some focus on the human brain, others on non-human. For our purpose we have considered datasets from BraTS (Brain Tumor Segmentation) from Kaggle.

## 2.7 Output

The outputs obtained for each algorithm are the segmented images of the input brain image.



**Fig -1:** (1) Normal brain image, (2) K Means, (3) Fuzzy C-Means, (4) Watershed, (5) Random walker, (6) Thresholding.

## 3. PERFORMANCE EVALUATION

Segmenting an image is an important step in many computer vision applications. With the emergence and development of various segmentation algorithms, the evaluation of perceptual correctness on the segmentation output becomes a demanding task. Generally, evaluation methods are classified into two broad category named as, subjective and objective [5].

Subjective method is an evaluation based on human visual inspection which is biased, time consuming and expensive. However, it is expensive, time consuming and often impractical in real-world applications.

As an alternative, the objective evaluation methods, which aim to predict the segmentation quality accurately and automatically, are much more expected. It is further classified into two groups as analytical method and empirical method. Most of the segmentation methods are evaluated based on empirical method which is an indirect method of evaluation. Goodness evaluation method and discrepancy evaluation method are the two major classification of empirical method based on the use of reference or ground truth or gold standard image. Discrepancy evaluation method also known as supervised or relative evaluation methods evaluate the performance of segmentation algorithms by analyzing the similarity between segmentation algorithm applied output image and the ground truth image.

In our analysis, a set of machine learning methods are used for segmentation and an MRI brain image is given as input. The result of each algorithm is compared with corresponding ground truth for the input in order to find the

most efficient method [6]. Best method is selected on the basis of mean square error value and structural similarity index. Larger the structural similarity and smaller the mean square error better the segmentation results.

The Structural similarity [7] based image quality assessment method, is motivated from the observation that natural image signals are highly “structured,” meaning that the signal samples have strong dependencies amongst themselves, especially when they are spatially proximate. These dependencies carry important information about the structure of the objects in the visual scene. For our purpose, we have used Mean Square Error and Structural Similarity Index. Mean Square Error (MSE) is calculated using the equation given below (Equ. 3.1).

$$MSE = \frac{1}{MN} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i, j) - K(i, j)]^2 \tag{Equ. 3.1}$$

Similarly, Structural similarity [7] is calculated as follows (Equ. 3.2).

$$SSIM(x, y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\mu_x^2 + \mu_y^2 + c_2)} \tag{Equ. 3.2}$$

The parameters include the (x, y) location of the N x N window in each image, the mean of the pixel intensities in the x and y direction ( $\mu$ ), the variance of intensities in the x and y direction ( $\sigma$ ), along with the covariance(c).

SSIM is used to compare two windows rather than the entire image as in MSE. Doing this leads to a more robust approach that is able to account for changes in the structure of the image, rather than just the perceived change. Unlike MSE, the SSIM value can vary between -1 and 1, where 1 indicates perfect similarity.

The result of analysis is given in Table-1. Out of five algorithms we have considered for our analysis, Fuzzy C Means and Watershed algorithms were found to have near similarities with the ground truth. Thresholding, being the basic one was having larger MSE when compared to the others.

**Table -1:** Performance evaluation

Method	MSE	SSIM
K Means	9205.56	0.36
Fuzzy C Means	9058.92	0.46
Watershed	4853.59	0.41
Random Walker	6256.14	0.14
Thesholding	10346.4	0.30

#### 4. CONCLUSION

Segmentation can be done by supervised and unsupervised techniques. The main disadvantage of the supervised segmentation methods is that they do not consider the neighborhood information and sensitive to noise. Due to the presence of noise and intensity variations in the image, these segmentation methods could not produce accurate segmentation results. Also, the computational complexity of these segmentation methods is high and contrast level of these methods is too low. The unsupervised segmentation is performed without requiring any manual support and depending upon the image features. From the analysis we have done it is understood that Fuzzy C Means and Watershed algorithm have much better accuracy compared to others.

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