A Comparative Study on Various Image Segmentation Techniques

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Abstract: **- Medical images(CT scans, MRI scans) play a vital role in diagnosing the disease. In order to diagnose the disease, medical images must be viewed clearly. So for clear visual appearance, medical images have been splitted into Region of Interest(RoI) and Non-Region of Interest(RoI) in which RoI must be visualized clearly for diagnosing the disease and to provide preventive measures. Therefore, to focus only on the RoI which is diagnostically important, segmentation is used. Segmentation is the most fundamental and important technique which is used to analyze images. The main aim of segmentation method is to simplify the complex problem into simpler ones by dividing the pixels based on the characteristics. After segmenting the image into regions, the pixel information can be stored and transmitted without any loss. Hence, there is a need for developing segmentation algorithms which consumes minimal time. In this work, existing segmentation methods such as edge-based segmentation, region-based segmentation, threshold-based segmentation, clustering-based segmentation have been analyzed based on the performance.**

Index Terms: **Segmentation, Medical image, Edge-based segmentation, Region-based segmentation, threshold-based segmentation, clustering-based segmentation**

I. INTRODUCTION

Computer Vision is an interdisciplinary field in which the automation of the task can be performed by extracting, analyzing and understanding useful information from an image or sequence of images. Image segmentation is a technique in which the images are segmented and processed individually. It is the process of partitioning the digital images into multiple segments which can be used to locate objects and boundaries. In other words, we can say that segmentation can also be used to extract the foreground from the background**.** Image segmentation is the prerequisite process before analyzing the images. In some cases, image de noising is performed before segmentation which is a challenging task. Selecting the most appropriate method on image segmentation is necessary to perform any task. Assigning pixel values to the correct segment is very important and it remains a tough task also. The number of segments to be made in the image depends on the size of the whole image which is to be segmented. Classifiers can be used inside the segmentation method which can be used to divide and analyze the images based on their structures. Segmentation has its own applications in measuring the size and shape of the image. Content-based image retrieval is one among them deals with the image segmentation.

II. SEGMENTATION

Feature extraction is an important task that can be performed in segmentation. It helps to obtain the information about various parameters of an image. Segmentation depends on the successful extraction of foreground from background in which the foreground has to be tackled for analysis. Segmentation can be broadly classified into two kinds namely contextual and non-contextual. Contextual segmentation deals by grouping of pixels according to some parameters or spatial relationship between the pixels. Non- contextual segmentation does not deal with the spatial relationship between the pixels rather grouping of pixels by its own property.

Mathematically, segmentation can be described as:If f(x, y) is an original image, then after segmentation, f1, f2, …, fn [2] are defined as disjoint sets which are segments of an image. Information of the whole image can be obtained from the segments as a whole through analysis and interpretation. New techniques were developed which are faster in execution and effective in its performance.

However, perfect segmentation is difficult to obtain due to under-segmentation and over-segmentation. Under-segmentation deals with the problem of grouping the pixels with different property under same class and over-segmentation works by grouping of pixels to different class which has similar property.

III. TECHNIQUES OF SEGMENTATION

Monochrome images are segmented based on two properties namely:

A. Discontinuity:

Discontinuity deals with the method of partitioning the image into segments based on abrupt changes in intensity. Edge detection is one of the method which uses discontinuity principle.

B. Similarity:

Similarity technique deals with the method of partitioning the image into segments based on predefined constraints. Algorithms like thresholding, region growing, region splitting and region merging comes under this category.

Segmentation techniques can be broadly categorized as follows:

1. Region-based methods

i. Region growing

ii. Region splitting and merging

a. Graph based segmentation

2. Thresholding

i. P-tile method

ii. Mean Value technique

iii. Edge maximization technique

iv. Optimal thresholding

3. Clustering techniques

i. k-means clustering

4. Edge detection-based methods 5.Morphological segmentation

5. Watershed algorithm

6. Matching

3.1 Region-Based Segmentation

Region-based segmentation methods are broadly classified into two groups [4]:

i. Region growing
ii. Region splitting and merging.

i) Region growing

Region growing deals with the process of grouping of pixels into larger areas depending on some predefined criteria [1–3, 5, 6]. Initially, seed points or reference points are determined. One or more seed points are possible in this method. Similar pixels reveal similar properties which can help to assign pixels at growing regions.

The algorithm is stated below:

a) Clusters of seed points are assigned as C1, C2, …, Cn with seed points named as s1, s2,…, sn.
b) Difference between the pixels and neighborhood pixels are calculated and are assigned to the clusters Cj.
c) Clusters are then reconstructed by calculating the difference between the seed points and neighborhood pixels.
d) These steps are repeated until all the pixels are allocated.

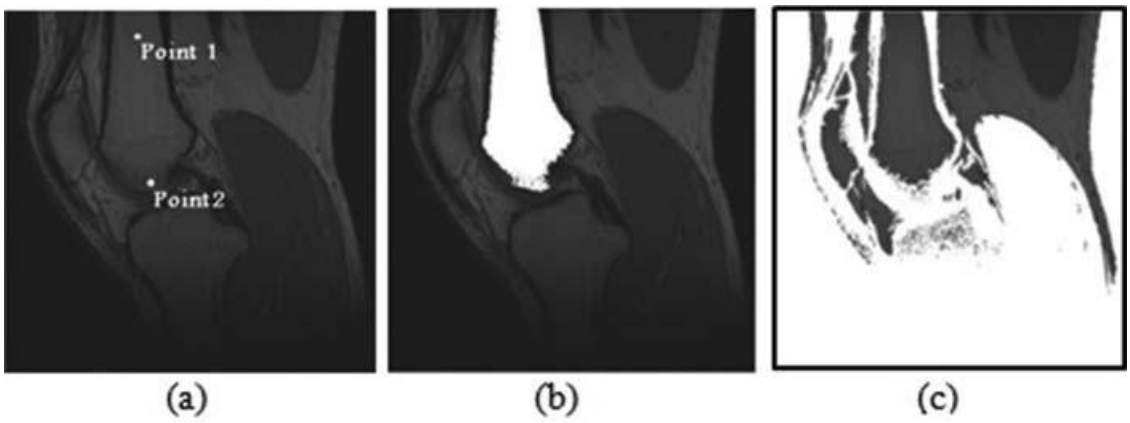

Fig 1. Performing region growing method on MR images a)Original images with two seed points b)Region growing for seed point 1 c)Region growing for seed point 2[13]

Disadvantage:

i. Determining seed point is a difficult task.
ii. It takes more time to complete the task.

ii. Region splitting and merging

Homogeneity property of an image can be differentiated by this method. Quad tree concept has been used for this method. Non-homogeneous regions are divided into square sub-regions as nodes of a quad tree. Further, non-homogenous regions are sub- divided into four parts. Homogeneity measure can be calculated for some regions which are grouped into a single region.(Fig. 1).

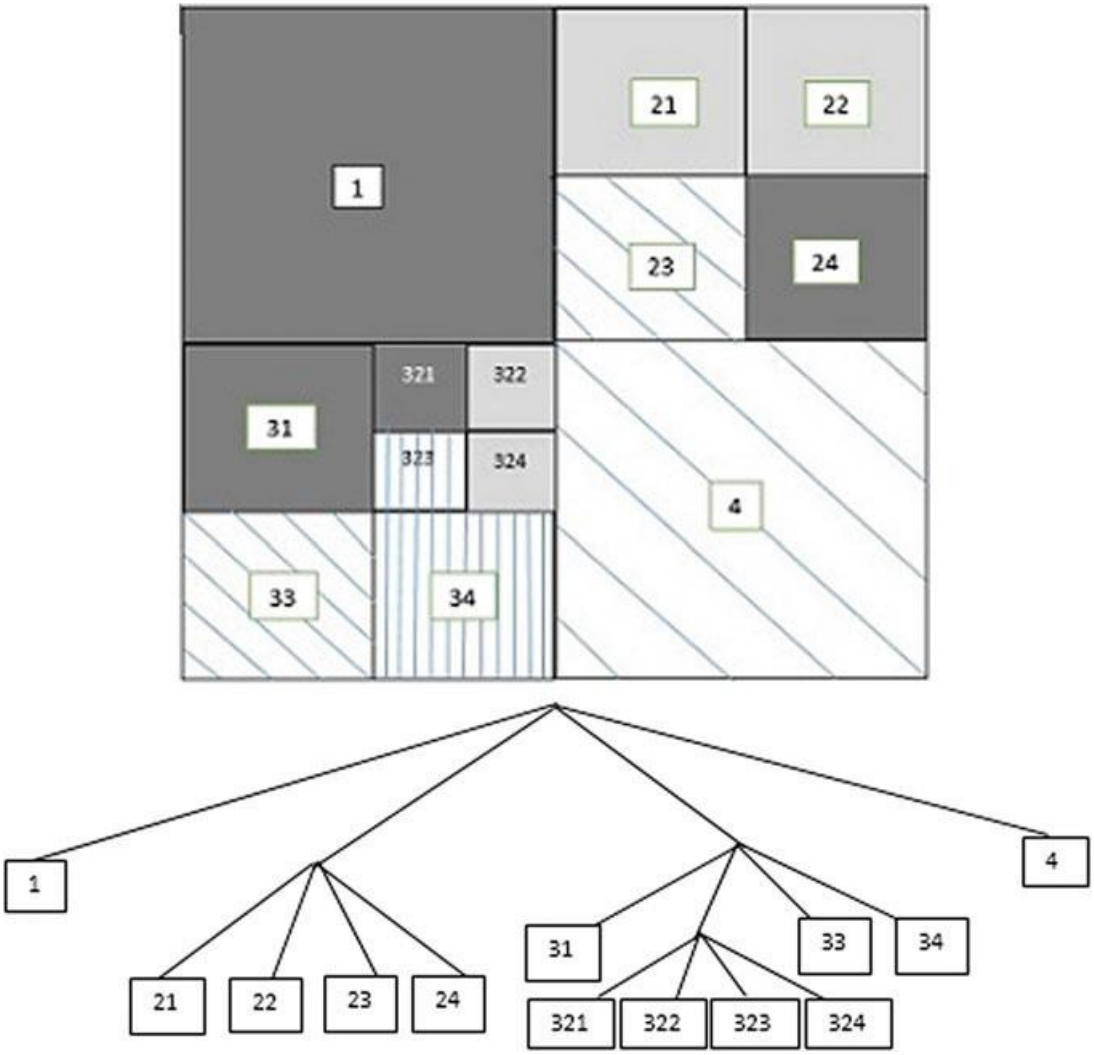

Fig 1. Quad Tree Segmentation

ii. a) Graph based segmentation:

In practical applications, graph based methods for image segmentation has good features. It explicitly organizes the image elements into mathematically sound structures, and makes the formulation of the problem more flexible and the computation more efficient.[15].

Let G = (V, E) be a graph where V ={ v1 ,..., vn } is a set of vertices corresponding to the image elements, which might represent pixels or regions in the Euclidean space. E is a set of edges connecting certain pairs of neighboring vertices. Each edge (vi,vj) ∈ E has a corresponding weight w(vi,vj) which measures a certain quantity based on the property between the two vertices connected by that edge. In the case of image segmentation, the elements in V are pixels and the weight of an edge is some measure of the dissimilarity between the two pixels connected by that edge (e.g., the difference in intensity, color, motion, location or some other local attributes). An image can be partitioned into mutually exclusive components, such that each component A is a connected graph G = (V, E), where V′⊆ V, E′⊆ E and E' contains only edges built from the nodes of V'. In other words, nonempty sets A1, …, Ak form a partition of the graph G if Ai∩Aj =φ (i,j∈ {1, 2, …, k}, i≠j) and A1∪…∪Ak=G. The graph based methods are categorized into five classes :

i) Minimal spanning tree based methods
ii) Graph cut based methods with cost functions,
iii) Graph cut based methods on Markov random field models
iv) Shortest path based methods

Using the definition of graph theory, the degree of dissimilarity between two components can be computed in the form of a graph cut. Graph cut formalism is well suited for segmentation of images. A cut is a subset of edges by which the graph G will be partitioned into two disjoint sets A and B and the cut value is usually defined as: where u and v refer to the vertices in the two different components[15]. The cost

function is defined in terms of boundary and region properties of the segments. These properties can be viewed as soft constraints for segmentation.

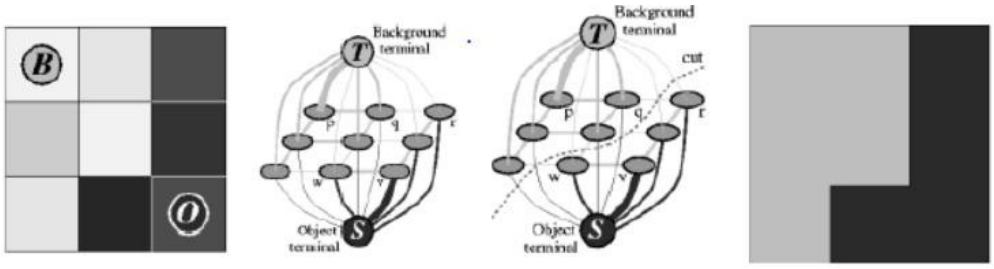

Fig 2. Graph cut segmentation [15]

Consider an image as shown in the above fig 2. Using the object and background seeds create a graph with two terminals as shown in 2(b) and by using the edge weights, boundary terms of cost function and positions of seeds in the image separate two terminals by computing optimal minimum cut 2(c). This cut would give the segmentation result as shown in 2(d).

Advantage

It requires no discretization by virtue of purely combinatorial operators and thus incur no discretization errors.

3.2 Thresholding

Thresholding is the process of segmenting the objects from background. An input image f(x,y) is segmented into output binary image g(x,y) using the following condition[3]:

g(x,y)=1, f(x,y)>T

=0,f(x,y)<T

If f(x, y) >T, then the pixel is an object pixel, otherwise, it is a background pixel. Threshold detection methods can be worked out in local as adaptive threshold procedure, or multiple thresholds as global procedure, where there is a single threshold for the whole image.

There are several thresholding techniques such as:

1. P-tile method,
2. Mean value technique,
3. Edge maximization technique (EMT),
4. Optimal thresholding.

i. P-tile method

P-tile method uses the working principle of gray level histogram. It is assumed that the objects are brighter than the background which occupies particular percentage (P%) of the image area. Threshold is then mapped at P% of the gray level which is computed at gray level.

ii. Mean value technique

Mean value of the pixels are computed and fixed as threshold values. This is suitable only in the case where approximately half of the pixels belongs to objects and other half belongs to background.

iii. Edge Maximization Technique (EMT)

This technique is used where there are several homogeneous regions or where there is change in illuminations between background and objects. This technique has a drawback that the portions of the objects and background may be merged.

iv. Optimal thresholding

This method is based on the fact that the histogram is made up of Gaussian distribution curves which are overlapped[2]. The intersection point is chosen as threshold which is given as minimum probability of maxima of two distributions.

Disadvantage

Knowledge about object and background details must be known in advance for proceeding with this method(Fig. 2).

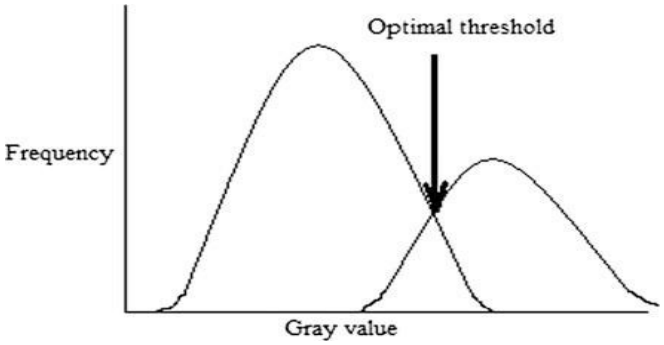

Fig 2. Optimal Threshold

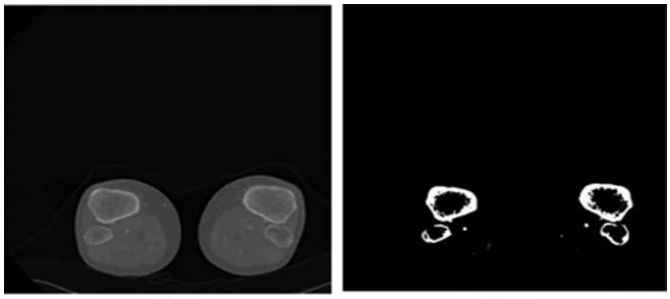

Fig.3 Applying threshold on CT image. a) Original CT image b) Extracting bone using thresholding method[13]

3.3 Clustering Techniques

Grouping the contents of an image into patterns with common properties or attributes is the main objective of clustering technique. K-means clustering is the most commonly used clustering algorithm[6,7]. The whole image is partitioned into k clusters.

Clustering procedure is as follows:

a. Desired number of clusters have to be selected and the center of the clusters has to be pointed out arbitrarily.
b. Assign each pixel to the cluster which is close to the respective pixels.
c. Re-compute the cluster centers by averaging the pixels in the center.
d. Steps are repeated until all the pixels are assigned and none of centre changes.

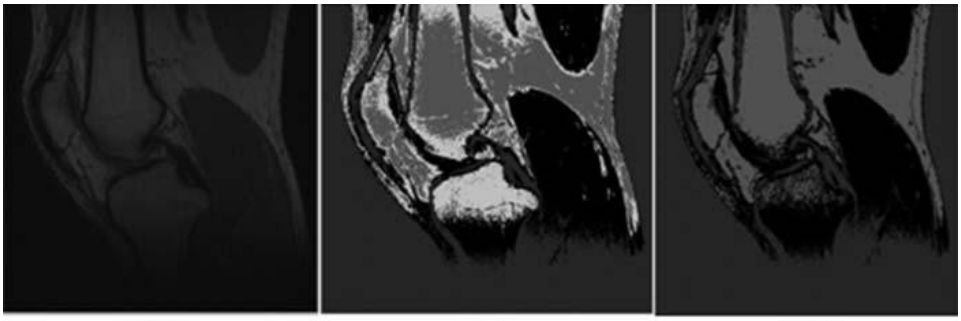

Fig.4 Performing k-means on the MRI of the knee bone a)Original image b)Performing k-means with k=4 c)Performing k-means with k=3 [13]

Disadvantage:

It does not lead to an optimal solution.

3.4 Edge Detection-Based Methods

Finding boundaries on discontinuities on an image is a very difficult task. Hence, Edge-based segmentation find the boundaries on images based on discontinuities in attributes like texture, gray levels, color, etc. [8–10]. Problem arises when there are gaps on edges. It can be solved using Hough Transform.

Various edge detectors are:

i. Sobel edge detector
ii. Prewitt detector
iii. Roberts cross edge detector
iv. Log of Gaussian (LoG) detector
v. Canny edge detector,
vi. Kirsch detector,
vii. Laplacian edge detector.

Below are the results of MATLAB simulation for various edge detectors (Fig. 3).

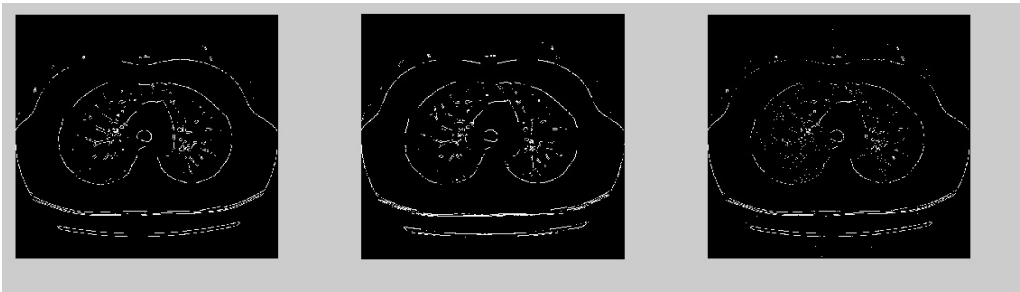

Fig 3(a).Edge Detection by Roberts operator [14]

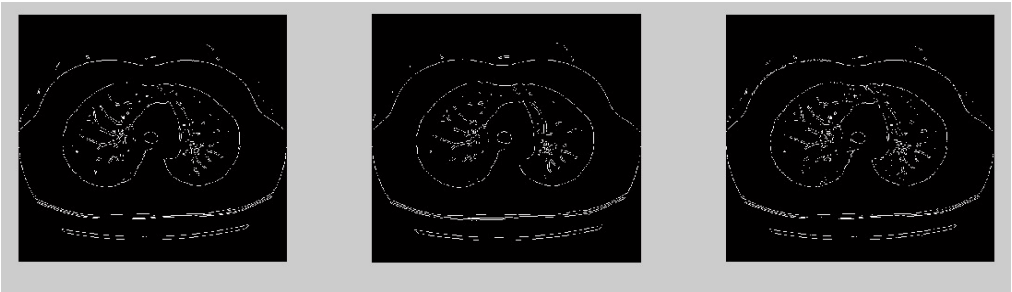

Fig 3(b).Edge Detection by Prewitt operator [14]

Fig 3(c) Edge Detection by Sobel operator [14]

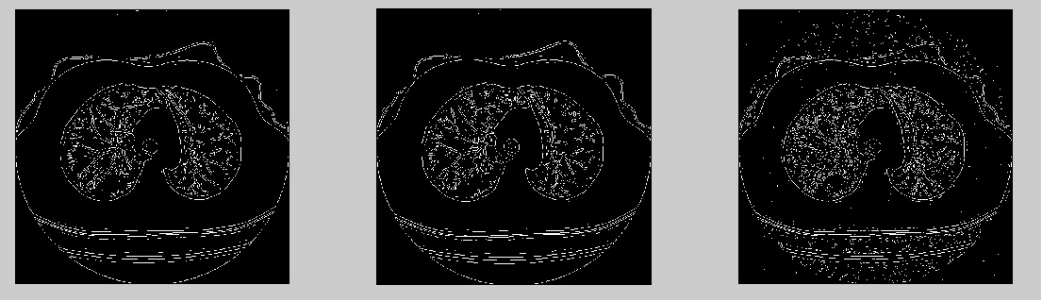

Fig 3(d) Edge Detection by LOG operator [14]

Fig 3(e) Edge Detection by Canny operator [14]

3.5 Morphological Segmentation Watershed algorithm

Topographical integration technique is used in this method. Intensity levels and height of the terrain determines the catchment basins and mountains. A hole in its minimum level is provided where water spillage fills the catchment. When the water level rises, basins are allowed to be merged. Dams are built to avoid the spillage[5, 11]. These dams are considered as boundaries in region based segmentation.

Disadvantage: Over-segmentation is a main problem in this method.

3.6 Matching

A template on Region of interest (object) is placed over the image locations till the object is found [2]. The template is overlapped on the image to compare with the gray values of the template. When all gray values are found, the object has been detected

The comparative study of the different segmentation techniques is shown in Table 1. [18]

Parameter	**Watershed algorithm**	**Edge-based**	**Region based**	**Threshold Technique**	**k-means clustering**
Spatial relationship between pixels	Exists	Does not exist	Exists	Does not exists	Exists
Immunity in noise	More immunity	Less immune	More immune to noise than edge-based	Less immune	Noisy data cannot be handled easily
Speed	Moderate	Moderate	Slow	Fast	Slow
Accuracy rate	Over segmentation exists	Accurate	Accurate	Not very accurate	Moderate accuracy

IV. RESULT ANALYSIS

Threshold methods, Region growing and clustering methods have

been applied for normal brain and MRI.

- In clustering methods, number of iterations decides the running time. Performance of clustering methods are not very good and hence it needs improvement in pre- processing and region-growing process.
- Accurate thresholding method performance is better than the clustering method.
- Region grrowing method results are intermediate between the thresholding and clustering.

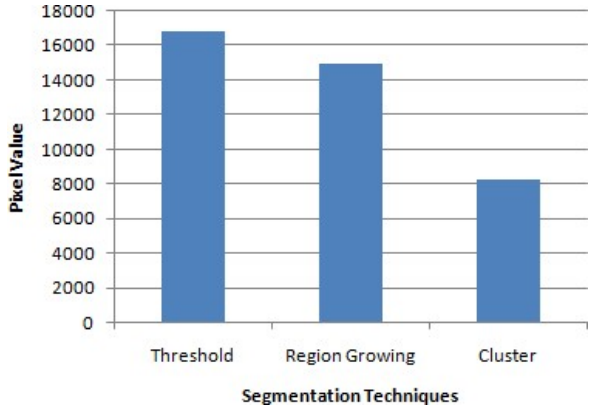

Fig.4. Performance Evaluation of segmentation methods on normal brain [16]

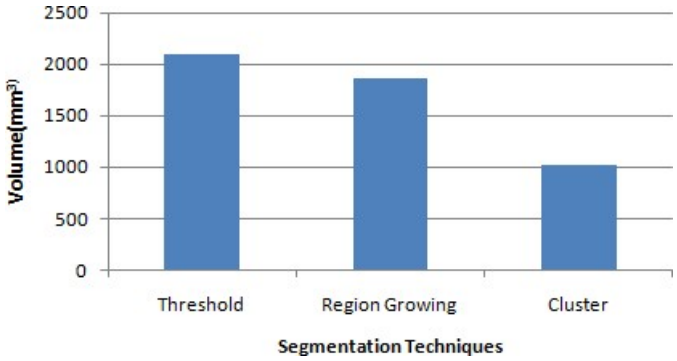

Fig.4. Performance Evaluation of segmentation methods on MRI brain [16]

The complexity of the segmentation methods can be tabulated as follows, [17]

METHOD	ADVANTAGE	SEGMENTATION EFFECT
Pixel Based Segmentation	More Complexity	Normal
Edge Based Segmentation	Average Complexity	Average
Graph Based Segmentation	Very Low Complexity	Good

V. CONCLUSION

In this paper, a number of image segmentation techniques have been studied, which are utilized by the field of computer vision. Segmentation is widely used in many fields such as image database lookup, editing of the image, optical character recognition, object recognition, terrain classification in satellite image and medical images. Recently, neural, fuzzy, graph cut techniques [6, 12] have also been employed for segmentation. Out of all methods, graph cut methods have been found more effective in medical images

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