International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 14 (2015) pp 34785-34791

Comparison of Image Segmentation Algorithms

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Abstract
Image segmentation techniques are very important in case of 3D modeling and other medical imaging applications. There are various segmentation algorithms and each one is best in its own way and can suit only a small range of applications. This paper provides an overall idea of various image segmentation algorithms with their pros and cons based on the domain or the range in which they are being implemented. Comparison has also been done by showing the experimental results.

Keywords- Image segmentation, Medical Imaging, Algorithm Comparison.

1. INTRODUCTION

An image is being processed using techniques such segmentation when you wish to observe only certain parts of an image. For instance in case of medical imaging such as MRI scan, an image is taken to observe particular parts of the body that has to be diagnosed. Image segmentation has various applications including medical imaging, object detection, machine vision, traffic control systems, recognition tasks, content-based image retrieval. Hence this technique is the one which is of great use in multiple fields.
Segmentation [1] partitions an image into distinct regions, each containing pixels with similar attributes. For meaningful and useful image analysis and interpretation, the regions should strongly relate to depicted objects or features of interest. Meaningful segmentation is the first step from low-level image processing by transforming a gray scale or color image into one or more other images to a high-level image description in terms of features, objects, and scenes. The success of image analysis depends on the reliability of segmentation, but an accurate partitioning of an image is generally a very challenging task.
There has been many segmentation algorithms which have emerged based on the need or application. The algorithms that are discussed in this paper are mean shift, region growing, Thresholding, Dynamic region merging, Similarity region merging, SVM, MRF, Clustering algorithms such as Fuzzy c-means, adaptive spatial fuzzy c-means, K-means, Adaptive fuzzy K-means, edge-based segmentation algorithms like Canny, Sobel, Prewitt, Robertsons, LoG, Zerocross.
In this paper we have taken images in simple background, complex background, bright as well as dark and segmented using various segmentation algorithms. The experimental results have been shown. Both general as well as specific category algorithms have been discussed and experimental results of specific algorithms have been shown.

The paper has been divided into the following sections. Section 2 describes the various image segmentation algorithms. Section 3 includes the experimental results of chosen algorithms which has been done using Matlab. Section 4 analyzes the algorithms based on various metrics and the experimental results that have been done. Section 5 gives the conclusion of the paper that has been discussed.

2. IMAGE SEGMENTATION ALGORITHMS

A. *Thresholding*

One of the most commonly used and oldest methods for segmentation of images. The processing includes the following steps:

- The region of the image has many grayscale ranges. Plot the histogram of images.
- The histogram consists of valleys and peaks.
- The peaks and valleys (region between the peaks) represent the regions and threshold values respectively.
- There are found to be two classes:
  - Values with intensity below threshold
  - Values with intensity above threshold

$$X(i,j) = \begin{cases} 0, n(i,j) < L \\ 1, n(i,j) \geq L \end{cases}$$

Here n(i,j) represents the pixel at the position (i,j). This method creates binary images from grayscale images. This method has been found to be used in mammography to classify tissue type as tumorous or abnormal and healthy or normal. The problem found in this is that noise and intensity inhomogeneity in MRI scanned images damages the image's histogram and intervenes the process of thresholding[2].

B. *Mean Shift*

This segmentation is a method of local homogenization that is very useful for reducing the visibility of shading or variations of tone in decentralized objects.

Three inputs are taken for mean shift which are:

1. A function for measuring distance between the pixels. It can either be Euclidean or Manhattan distance.
2. Radius r based on the function above which will be taken into account for calculation

3. Difference value using which we choose pixels within the radius r whose value lies within the difference. This is used for calculating the mean.

The benefit of this clustering is that there is no need to know the topology and that the segment can have any number of areas without connectivity for image that is bounded with a large consistency pixel by pixel. No early information about the count of the clusters is needed.
A major drawback here is speed. The time complexity of original mean shift is $O(N^2)$ where N refers to the pixels. This takes a lot of computation time especially for images with high-resolution [3].

C. ***Clustering***

Clustering is a method of grouping similar features, characteristic or attribute. This uses two approaches:

- Supervised
- Unsupervised

In the former approach, the clustering criterion is given by the user. While in the latter, the criterion is examined by the clustering system.
Clustering-based image segmentation techniques:

i. K-means Clustering:

This is an unsupervised approach [4] which includes the following steps:

1. The clusters are chosen either randomly or based on a condition
2. The clusters are generated and the centre of the cluster is found out
3. Each pixel in the pixel is assigned a cluster based on which pixel is at minimal distance from the centre of the cluster
4. The centre of cluster is found again by finding the average of the pixels in a cluster
5. The steps 2 and 3 are repeated until convergence is achieved

The plus here is that the computational speed increases as the k decreasesIn case that the clusters are globular, the output is a clenched cluster than a hierarchical cluster
Drawback here is that it fails to work for clusters which are non-globular. With fixed number of clusters predicting the value of k becomes tedious.

ii. Fuzzy C-means Clustering

This technique comes under unsupervised clustering. An image can in general be classified into various features. The FCM algorithm [5] classifies the image into clusters by grouping the data points which are similar in the feature space. This is done by reducing the cost function in iteration which depends on the distance between the pixels and centre of the cluster in that feature.
An advantage of FCM is that it is better when compared with K-means. Also, unlike K-means, a pixel can belong to more than one cluster.
Disadvantage is the sensitivity to the initialization condition of the centre of cluster and number of the cluster. Also the computational time is huge.

iii. Fuzzy K-means

Each object in the fuzzy clustering has some degree of belongingness to the cluster .So, the objects that are present on the edge of the cluster are different from the objects that are present in the centroid i.e. objects on edge have lesser degree than the objects in the centre. In the fuzzy c-means, the centroid of a cluster is the mean of all objects present in the cluster, measured by their degree of belonging of points to the cluster.
Fuzzy K-means is better than K-means as it gives better results with increase in the fuzzy factor. It takes lesser computation time. This is a soft clustering as pixels can belong to more than one cluster. The distance measure is found to be more reliable than K-means.
The drawback here is that the pixel assignment is user-defined cut-off. Thus selecting the right cut-off is a challenge. Finding the patterns depends on the dataset properties as it may not be able to find patterns even if the centroids were initiated with unidentified patterns.

iv. Adaptive Fuzzy K-means

In adaptive fuzzy K-means [6]first is the assignment of the member to the centre based on Euclidean distance and then the concept of fuzziness is applied. Next step is belongingness, which is used to find the relationship between the centres and to check if the criteria have been met.Based on the level of this belongingness, the degree of being a member is updated. The centres are again recalculated on the basis of the membership function.
This method provides a better flexible clustering which is an advantage.
Disadvantage is that it is found to be sensitive to noises.

D. ***Region-growing***

This uses region-based segmentation [7], which finds the region to be segmented directly. Steps include:

- First is the selection of initial seed points.
- Looks at the neighbour pixels of initial seed points and decides if the pixels can be added to the region

This method can be used in many applications involving delineation of structures which are like tumours.
Noise can be the reason for causing holes in the image and also disconnected regions which are a drawback in this algorithm.

E. ***Markov Random Field***

This is a statistical model [8] than a segmentation method. This produces spatial interactions between the nearby pixels. It implements spatial correlation in to the process of segmentation in which the reconstruction of image is done by combining the local characteristics that is combined with the data that is given. In the field of medical imaging, the pixels come under the same class as their neighbours has been brought into the picture which concludes that any anatomical

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 14 (2015) pp 34785-34791

structure has less probability of coming under MRF if it consists of only one pixel.

MRF is found to be robust to noise and the segmentation is smoother which makes this algorithm advantageous.

Difficulty is observed in selecting parameters which demand the strength of spatial interactions. High levels of certain parameters can make the image extra smooth leading to loss in intricate information. This method requires intensive algorithms with huge computations. These are some of the difficulties in MRF.

F. Dynamic Region Merging

This method is initiated from a group of regions [9] that has been segmented keeping in mind that a region will give better details than a data point can give. This greatly improves the efficiency in computing.

The benefits of this method are as following. Firstly, than pixels regions are found to give more information in describing the object's nature. The number of regions is definitely lesser than the number of pixels. This naturally gears up the process.

The drawbacks here are as follows: Difficulty has been found in the selection of threshold as the regions are merged if the neighbour regions are above the pre-set threshold. Lower threshold will result in merging of regions into the background. Higher threshold results in incompleteness in the process of merging. The stopping condition for this algorithm is found to be tedious.

G. Similarity Region Merging

To group similar regions initial segmentation [10] has to be done.Markers which are strokes used in order to obtain the location, background and region of the object. Initial segmentation is done using the mean shift and then the contour of the object is taken and the non- marker regions are marked as either object or as background.

The time complexity is found to be better than dynamic region merging.In this method, the way in which the image is merged is seen at every step.

H. Segmentation using Support Vector Machines

This method [11] classifies the classes using a surface which is a hyper plane in order to increase the margin between them to maximum. Support vector machines use the Structural Risk Minimization principle that reduces the error that happens in a decision function. By maintaining a balanced relationship between the machine capacity and the accuracy that has been attained on the training data, it produces the best generalization performance.

This method provides a radical solution and also provides an excellent out-of sample generalization.

Extra time is taken for training. Transparency is found to be less in the results.

I. Edge-based Segmentation

The edge [12] in an image is the change in image intensity due to discontinuity in the intensity of the image. There are three steps in the process of edge detection a) filtering b) enhancement and c) detection

a) Filtering: Images can contain noises. Filtering is done as there is an interchange in the noise detection and the strength of the edge

b) Enhancement: Highlights pixels which have changes in intensity is computed by finding the magnitude of the slope

c) Detection: Not all pixels that have non-zero slope values are edges. This detection is done to find which pixels are edges

Some of the edge detection techniques are LoG, Canny, Prewitt, Sobel, Roberts, Zero-cross.

3. EXPERIMENTAL RESULTS

To visualize the algorithms in a better way experiments has been conducted in segmentation using MATLAB and results has been shown. The challenge of segmentation is that the same technique will not be suitable for images of different kind. Here the data set is chosen in such a way that images with simple background, complex background, bright light as well as dim light are all put together and segmentation is done by various methods. By seeing the results one can clearly see the challenge involved in choosing an algorithm for a particular domain or range of images. Fig 3.1 shows the original dataset on which the segmentation has been done.

Fig 3.1: Original Image

Fig 3.2: Thresholding

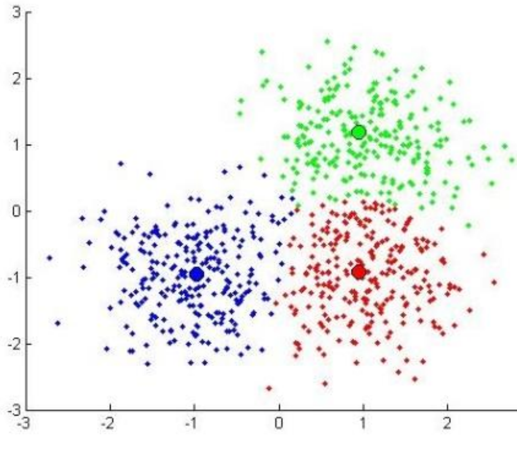

Fig 3.3: Mean Shiftlocal Homogenization is Clearly Shown - no shifting

A. Region Merging

Meaningful regions may not be uniform: surface properties of a solid body will vary in brightness or color dependent on the existence of slowly varying gradients due to lighting conditions. Lighting effects or curvature affect the appearance, Regional segmentation works best with binary data as the limited range of values lead to more uniform regions. (fig.3.4)

Fig 3.4: Region Merging

B. Edge-based Segmentation

Missing to detect existing edges, Detecting edges where it does not exist and Positioning of the detected edge shifted from its true location in a dynamic background and changing light condition is clearly shown in Fig 3.5

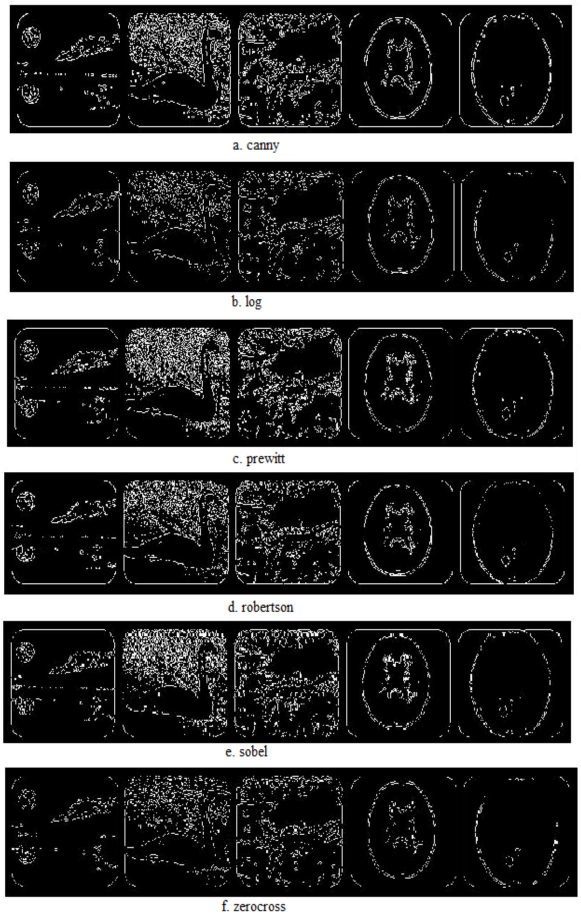

Fig 3.5: Edge- based Segmentation

C. Fuzzy C-means and Spatial Fuzzy C-means

The spatial function modifies the membership function of a pixel according to the membership statistics of its neighbourhood. Both sFCM techniques reduce the number of spurious blobs, and the segmented images are more homogeneous. The sFCM algorithm with a higher parameter shows a better smoothing effect. The possible disadvantages of using higher spatial weighting are the blurring of some of the finer details. However, this is difficult to judge from the results. Shown in Fig 3.6, fig 3.7

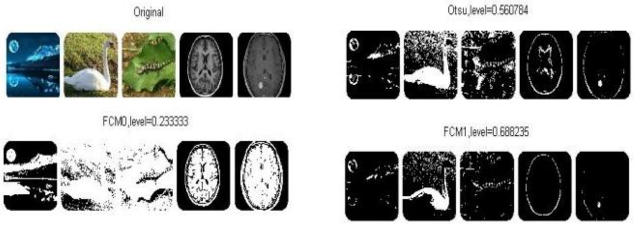

Fig 3.6: Fuzzy C-Means

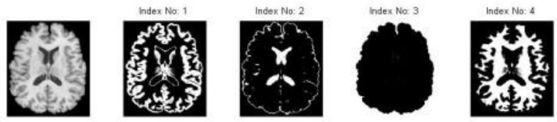

Fig 3.7: Spatial Fuzzy C-means

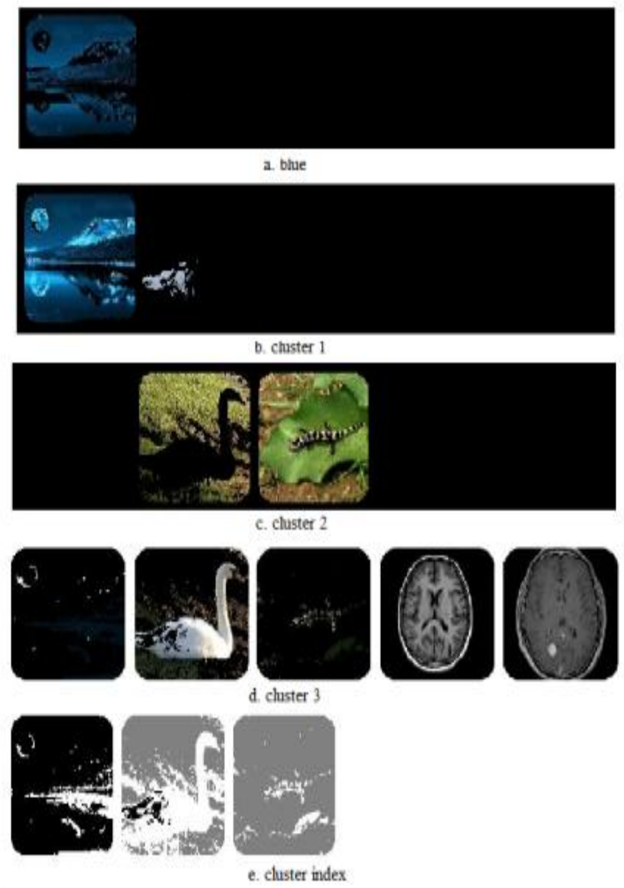

Fig 3.8: K-means clustering the colour based segments are clearly visible in the result

4. ANALYSIS OF ALGORITHMS

Based on certain metrics segmentation algorithms are compared to each other by which it is easier to choose which algorithm will be more effective for a particular purpose. Based on Pixel value (Number of pixels missing) and Volume, performance evaluation goes in increasing order for cluster, region growing and threshold techniques. Adaptive fuzzy k-means (AFKM) can give better performance of segmentation technique when compared to the conventional method of FCM both in terms of quantity as well as quality. Based on running time and size of the image Similarity Region Merging runs faster than the Dynamic region merging technique for a fixed size of the image. Based on Dice Ratio, Overlap ratio and Jaccardcoefficient , for same noise level and different values of intensity non-uniformity, adaptive spatial fuzzy c-means segmentation method give better result in segmentation of brain tissue. Both FCM and SFCM techniques reduce the number of spurious blobs, and the segmented images are more homogeneous. The FCM algorithm with a higher parameter shows a better smoothing effect. Comparison of commonly used segmentation algorithms are listed below.

4.1.Clustering vs Region growing

There are missing of more number of pixels in the clustering, when compared to the threshold method and the region growing method. Missing of pixels is due to the noise interference and this lead to the holes in the segmented image [13].InRegion growing you have to select seed points and then the local area around the seed is analysed in order to know if the neighbour pixels should have the same label but it can be used for precise image segmentation. On the other hand there are many clustering techniques (k-means, hierarchical clustering, density clustering, etc.). Clustering algorithms don't ask to input seed points because they are based on unsupervised learning and it can be used for coarse image segmentation.

4.2. Region growing vs Thresholding

Region growing method gives better output, when
compared to the thresholding method in identifying the abnormality. Region growing clearly extracts the abnormal tissue volume. But it requires manual interaction to select the seed point. One seed point used to extract the region of interest because abnormal part has unique property when compared to the background. At the same time if given proper threshold value thresholding method gives more appropriate results than clustering as well as region growing techniques [13].

4.3. Adaptive Fuzzy K-means vs Fuzzy C- means Segmentation

Based on qualitative analysis, quality of image that is obtained by conventional FCM is not perfect compared to the AFKM method. The main drawback of FCM method is it over segment the image which leads to image become too bright. But using AFKM, it can segment the image clearly and the Region of interest is sharper. Based on quantitative analysis by following evaluating functions of Liu and Yang[14] AFKM method is proved to give better results when compared to FCM. [15][16][17]. Therefore AFKM method yields a much sharper and clearer image than FCM method of segmentation.

4.4. Similarity Region Merging vs Dynamic Region Merging

The similarity merging method starts from the Initial marker regions and all the non-marker regions will be gradually labeled as either object region or background region so this method of merging is better than dynamic region merging as the time taken iscomparatively less. In similarity region merging at each step we are able to see how the segments in the image are getting merged. Dynamic region merging is a slow process and the results obtained with it are also not very consistent. Therefore the similarity region merging method is better in terms of time taken and the quality of the results[18].

4.5. AdaptiveSpatial Fuzzy C-means vs Markov Random Field

The difficulty that is observed in selecting parameters in Markov Random field will demand the strength of spatial interactions. High levels of certain parameters can make the image extra smooth leading to loss in intricate information. This method requires intensive algorithms with huge computations. These are some of the difficulties in MRF. In Adaptive Spatial Fuzzy C Means method there is no complexity like this and hence produces higher quality results than that of the Markov Random Field. Based on Quantitative analysis using Dice ratio, Jacccard Coefficient, overlap ratio Adaptive Spatial Fuzzy C Means method is proved to be more efficient than Markov Random Field for same noise level[19].

4.6. Adaptive Spatial Fuzzy C-means vs Fuzzy Connectedness

The Image Segmentation frame work based on Fuzzy Connectedness effectively captures the "hanging togetherness" of image elements specified by their strength of fuzzy connectedness. Fuzzy Connectedness defines how the image elements hang together spatially in spite of their gradation of intensities. The fuzzy Connectedness framework is resistant to some degree of intensity non - uniformity artifact in MRI. But the segmentation methods tend to be affected by severe intensity non - uniformity in MRI. Thus some complex intensity non - uniformity correction method is required to improve the accuracy of fuzzy connectedness method.For different values of intensity non-uniformity, adaptive spatial fuzzy c-means segmentation method give better result in segmentation of brain tissue than that of the fuzzy connectedness method [19].

5. CONCLUSION

For any Image processing techniques segmentation plays a vital role and choosing the appropriate segmentation technique is of prime importance. In this his paper we discussed about various segmentation techniques and their strength in a range of applications. After the analysis of many algorithms using the metrics and also with the experimental results, it is found that in clustering segmentation, mean shift gives good results. When fuzzy C-means and K-means are compared, fuzzy C-means produces better results than K-means. Among the edge detection techniques, canny is found to be the best when compared with LoG, Prewitt and Sobel K-Nearest Neighbor segmentation method is an efficient method for brain tumor detection when compared to other methods. This K-NN method offers an automated and fully reproducible approach that accurate and applicable on standard clinical MRI images[20].

There is no single method which can be considered good for all type of images or all methods equally good for a particular type of image. Opting a single technique or method would not provide better optimized results, based on the need. Algorithms are used in group or modified with some changes or some pre-processing techniques are followed before segmenting it with known algorithms. Due to all above factors, image segmentation still remains a challenge in image processing and computer vision.

References

[1] https://www.cs.auckland.ac.nz/courses/compsci773s1c/lectures/ImageProcessing-html/topic3.htm

[2] Salem Saleh Al-amri, N.V. Kalyankar, "Image Segmentation by Using Threshold Techniques", Journal of Computing, Volume 2, Issue 5, May 2010

[3] D. Comaniciu and P. Meer, "Mean shift: A robust approach toward feature space analysis", IEEE Trans. Pattern Anal. Machine Intell, Volume 24, No 603–619, 2002.

[4] Tapas Kanungo, Senior Member, IEEE, David M. Mount, Member, "An Efficient k-Means Clustering Algorithm: Analysis and Implementation", IEEE Transactions on Pattern Analysis and Machine Intelligence, Volume 24, No. 7, July 2002

[5] ArchanaLala, Jitendra Kumar Gupta, "Implementation of K-means Clustering and Fuzzy C-means Algorithm for Brain Tumor Segmentation", International Journal of Computer Engineering & Science, Volume 3, Issue 1, pp. 27-33, Sept 2013.

[6] Sulaiman, S.N., "Adaptive fuzzy-K-means clustering algorithm for image segmentation", Consumer Electronics, IEEE Transactions, Volume 56 , Issue 4, November 2010.

[7] ShilpaKamdi, R.K.Krishna, "Image Segmentation and Region Growing Algorithm", International Journal of Computer Technology and Electronics Engineering (IJCTEE) Volume 2, Issue 1, April 2006.

[8] Huawu Deng, David A. Clausi, "Unsupervised image segmentation using a simple MRF model with a new implementation scheme", Volume 37, Issue 2, April 2004.

[9] Lei Zhang, David Zhang, "Automatic Image Segmentation by Dynamic Region Merging", Image Processing, IEEE Transactions, Volume:20 , Issue: 12, Dec 2011.

[10] LahouaouiLalaoui, TayebMohamadi, "A comparative study of Image Region-Based Segmentation Algorithms", Volume 4, No. 6, 2013.

[11] An-Min Zou, Zeng-GuangHou, Min Tan, "Support Vector Machines (SVM) for Color Image Segmentation with Applications to Mobile Robot Localization Problems", Advances in Intelligent Computing Lecture Notes in Computer Science Volume 3645, pp 443-452, 2005.

[12] N. Senthilkumaran, R. Rajesh, "Edge Detection Techniques for Image Segmentation – A Survey of Soft Computing Approaches", International Journal of Recent Trends in Engineering, Vol. 1, No. 2, May 2009.

[13] Manoj Kumar V, Sumithra M G, **"**Performance comparison on medical image segmentation algorithms", International Journal of Image Processing and Vision Sciences, Volume 1, Issue 3, April 2012.

[14] Y. H. Yang. J.Liu, "Multiresolution color image segmentation," IEEE Transaction on Pattern Analysis and Machine Intelligence, vol. 16, pp. 689-700, 1994.

[15] M. V. Kumar, and. Sumitra. M. G, "An improved clustering Based Segmentation Algorithm For Brain MRI," vol. 2, p. 126, 2013.
[16] J. Sheng-Yi and L. Xia, "A Hybrid Clustering Algorithm," in Fuzzy Systems and Knowledge Discovery, 2009. FSKD '09. Sixth International Conference on, 2009, pp. 366-370.
[17] Arushi Chhabra, Ankit Gupta, “Comparison of Image SegmentationAlgorithms”, International Journal of Emerging Trends and Technology in Computer Science, Volume 2, Issue 3, May –June 2013.
[18] S. N. Sulaiman and N. A. M. Isa, "Adaptive fuzzy-K-means clustering algorithm for image segmentation," Consumer Electronics, IEEE Transactions on, vol. 56, pp. 2661-2668, 2010.
[19] Ritu Agrawal, Manisha Sharma, “Review of Segmentation Methods for Brain Tissue with Magnetic Resonance Images”, I.J. Computer Network and Information Security, Volume 4,pp: 55-62, 2014.
[20] D. Manju, Dr. M. Seetha, “Comparison Study of Segmentation Techniques for Brain Tumour Detection”, International Journal of Computer Science and Mobile Computing, Vol.2 Issue. 11, November- 2013.