Analysis of Image Segmentation Methods Based on Performance Evaluation Parameters

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ABSTRACT

Image segmentation is an important technology for image processing which aims at partitioning the image into different homogeneous regions or clusters. Lots of general-purpose techniques and algorithms have been developed and widely applied in various application areas. However, evaluation of these segmentation algorithms has been highly subjective and a difficult task to judge its performance based on intuition. In this paper image segmentation using FCM, Region Growing and Watershed algorithms is performed and segmentation results of these techniques are analyzed based on four performance metrics GCE, PSNR, RI and VoI. This analysis provides an overview that on what parameters different image segmentation techniques can be evaluated at best.

Keywords: *FCM, Region Growing, Watershed, GCE, PSNR, RI, VoI.*

I. INTRODUCTION

Image segmentation is a technique of partitioning an image into several homogeneous segments or clusters based on measurements taken from the image. The output of image segmentation is a set of regions that combine to form the entire image. Some of the practical applications of image segmentation are: Content-based image retrieval, Machine vision, Medical imaging ,Recognition tasks, traffic control systems, video surveillance. Several general-purpose algorithms and techniques have been developed for image segmentation. There are various methods of image segmentation such as clustering based (FCM, K-means) methods, region based methods (region growing, region splitting, region merging), watershed, edge detection method, neural networks and thresholding.

In this work segmentation algorithms chosen for analysis are FCM (Fuzzy C-Means), Region Growing and Watershed. FCM is an unsupervised segmentation algorithm that is based on the idea of finding cluster centers by iteratively adjusting their position and evaluation of an objective function. The iterative optimization of the FCM algorithm is essentially a local searching method, which is used to minimize the distance among the image pixels in corresponding clusters and maximize the distance between cluster centers [1]. FCM algorithm has long been a popular image segmentation algorithm. Region growing is a simple region-based image segmentation method. In [2] region growing is a procedure that groups pixels or sub regions into larger regions based on predefined criteria for growth. The basic approach is to start with a set of "seed" points and from these grow regions by appending to each seed those neighboring pixels that have predefined properties similar to the seed.

Watershed transform is a powerful tool that is based on the object's boundary and finds local changes for image segmentation. According to [3] watershed segmentation method is based on watershed transform. This method aims to find catchment basins, which define border between two objects. If water falls into these basins, level of the water rises until neighbor basins share the same level. So output of the algorithm is a hierarchy of catchment basins. The key point is to find most discriminative basins, since most discriminative basins are the basins that separate two different objects . The performance evaluation parameters used here for evaluation of image segmentation quality are namely PSNR (Peak signal to noise ratio), RI (Rand Index), VoI (Variation of Information) and GCE (Global Consistency Error).

II. DESCRIPTION OF DIFFERENT IMAGE SEGMENTATION TECHNIQUES

2.1 Fuzzy C-Means (FCM) Algorithm

Input: image, cluster number.

Output: segmented image, cluster center and objective function [1].

1. Initialize the fuzzy cluster number, F and the cluster centers, c= {c1,…, cj,..cf}
   Set iteration time q=0;
2. while $\|W^{(q)} - W^{(q-1)}\| \geq €$ do
3. for j = 1 to F^{th} cluster do
4. for I =1 to N^{th} image pixel do
5. Calculate u_{ij} ,i.e. the membership of pixel x_i to the j^{th} cluster;
6. if $\| x_i - c_j \| = 0$ then
7. $u_{ij} = 1$;
8. reset other membership of pixel i to 0;
9. end if
10. end for
11. Update c_j (cluster center);
12. end for
13. Calculate objective function $W^{(q)}$;
14. q=q+1;
15. end while

The objective function is given as:

$$W^{(q)} = \sum_{j=1}^{F} \sum_{i=1}^{N} u_{ij}^{m} \left\| x_i - c_j \right\|^2 \qquad (2.1)$$

where N is the number of image pixels , u_{ij} is the membership of pixel x_i to the jth cluster, m is a constant that defines the fuzziness of the membership, $\|x_i - c_j\|$ is the Euclidean distance between x_i and c_j [1].
The membership function is defined as :

$$u_{ij} = \sum_{k=1}^{F} \left(\frac{\|x_i - c_j\|}{\|x_i - c_j\|} \right)^{-2/m-1} \qquad (2.2)$$

The value of m is manually set and mostly m=2.0 is used.
The cluster center in FCM algorithm is defined as:

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} x_i}{\sum_{i=1}^{N} u_{ij}^{m}} \qquad (2.3)$$

2.2 Region growing algorithm

Basic function of region growing algorithm is to segment the input image using n number of seed points. The basic steps followed in seeded based region growing technique includes two main points, firstly selection of initial seed point and secondly growing formula based on stopping criterion [5].

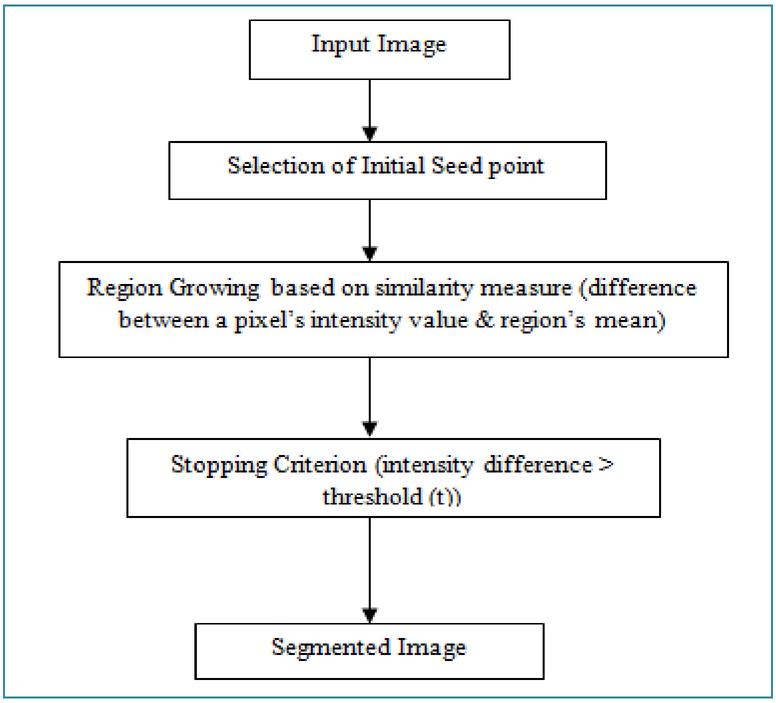


Figure1. Flow chart of Region Growing algorithm.

2.3 Watershed Algorithm

In this paper Marker-Controlled Watershed Segmentation algorithm is presented. The steps involved in this algorithm are: Firstly we compute a segmentation function, then compute foreground markers, after that we compute background markers and then modify the segmentation function so it only has minima at the foreground and background marker locations, finally compute the watershed transform of the modified segmentation function [4].

2.4 GCE (Global Consistency Error)

The Global Consistency Error (GCE) measures the extent to which one segmentation can be viewed as a refinement of the other. Segmentations which are related are considered to be consistent, since they could represent the same image segmented at different scales. The formula for GCE is as follows,

$$GCE = \frac{1}{n}\min\{\textstyle\sum_i E(s1, s2, pi), \sum_i E(s2, s1, pi)\} \qquad (2.4)$$

where, segmentation error measure takes two segmentations S1 and S2 as input, and produces a real valued output in the range [0::1] where zero signifies no error. For a given pixel pi consider the segments in S1 and S2 that contain that pixel [6].

2.5 PSNR (Peak Signal to Noise Ratio)

PSNR represents region homogeneity of the final partitioning. The higher the value of PSNR the better is segmentation. PSNR in decibels (dB) is computed by using [7]:

$$PSNR = 10\log_{10}\left(\frac{255^2}{MAE}\right) \qquad (2.5)$$

MAE is the mean absolute error of the segmented image computed as follows

$$MAE = \frac{1}{MN}\sum\sum |F(i, j) - f(i, j)| \qquad (2.6)$$

F (i, j) - segmented image, f (i, j) - source image that contains M by N pixels.

2.6 RI (Rand Index)

The Rand index (RI) between test and ground-truth segmentations S and G is given by the sum of the number of pairs of pixels that have the same label in S and G and those that have different labels in both segmentations, divided by the total number of pairs of pixels [8]. In [9] the RI is given as:

$$RI = \frac{a+b}{a+b+c+d} = [\binom{n}{2}[0.5\{\Sigma_i(\Sigma_j n_{ij})^2 + \Sigma_j(\Sigma_i n_{ij})\}^2 - \Sigma\Sigma n_{ij}^2]] \Big/ \binom{n}{2} \qquad (2.7)$$

where, a, the number of pairs of elements in S that are in the same set in U and in the same set in V ; b, the number of pairs of elements in S that are in different sets in U and in different sets in V; c, the number of pairs of elements in S that are in the same set in U and in different sets in V; d, the number of pairs of elements in S that are in different sets in U and in the same set in V. n_{ij} is the number of objects in the ith cluster in U and jth cluster in V, and $\binom{n}{2}$ is the binomial coefficient, which gives the number of distinct pairs found in a set of n objects.

2.7 VoI (Variation of Information)

The Variation of Information (VoI) metric defines the distance between two segmentations as the average conditional entropy of a segmentation given the other, and thus roughly measures the amount of randomness in a segmentation which cannot be explained by the other [5]. Lower the VoI value better is the result. In [10] VoI is defined as:

$$\mathrm{VI}(c, c') = \mathrm{H}(c) + \mathrm{H}(c') - 2\mathrm{I}(c, c') \qquad (2.8)$$

where, H(c) and $\mathrm{H}(c')$ are the entropies associated with cluster c and c'; $\mathrm{I}(c, c')$ is the mutual information between the associated random variables.

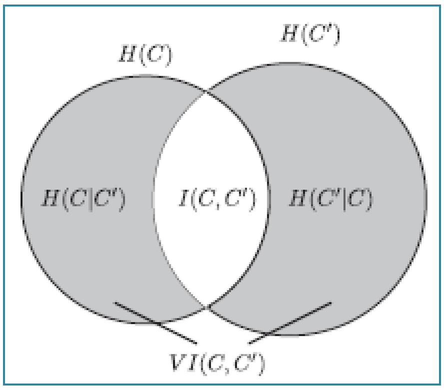


Figure2. The variation of information and related quantities

III. IMPLEMENTATION DETAILS AND RESULT ANALYSIS

The three image segmentation algorithms discussed in this paper are implemented in MATLAB (R2010a) and their results are evaluated using four quantitative performance metrics namely, GCE, PSNR, RI and VoI.

For better segmentation results the values of PSNR (Peak Signal to Noise Ratio) and RI (Rand Index) should be higher and on the other hand the values of GCE (Global Consistency Error) and VoI (Variation of Information) should be low. The image segmentation algorithms in this paper are applied to natural images from BSD database, where test and ground-truth images are used to calculate GCE, RI and VoI values [11]. The results of segmentations performed by three different algorithms are described below taking three natural images flower, airplane and kid. Four performance metrics are then calculated separately for each algorithm and performance analysis is done.

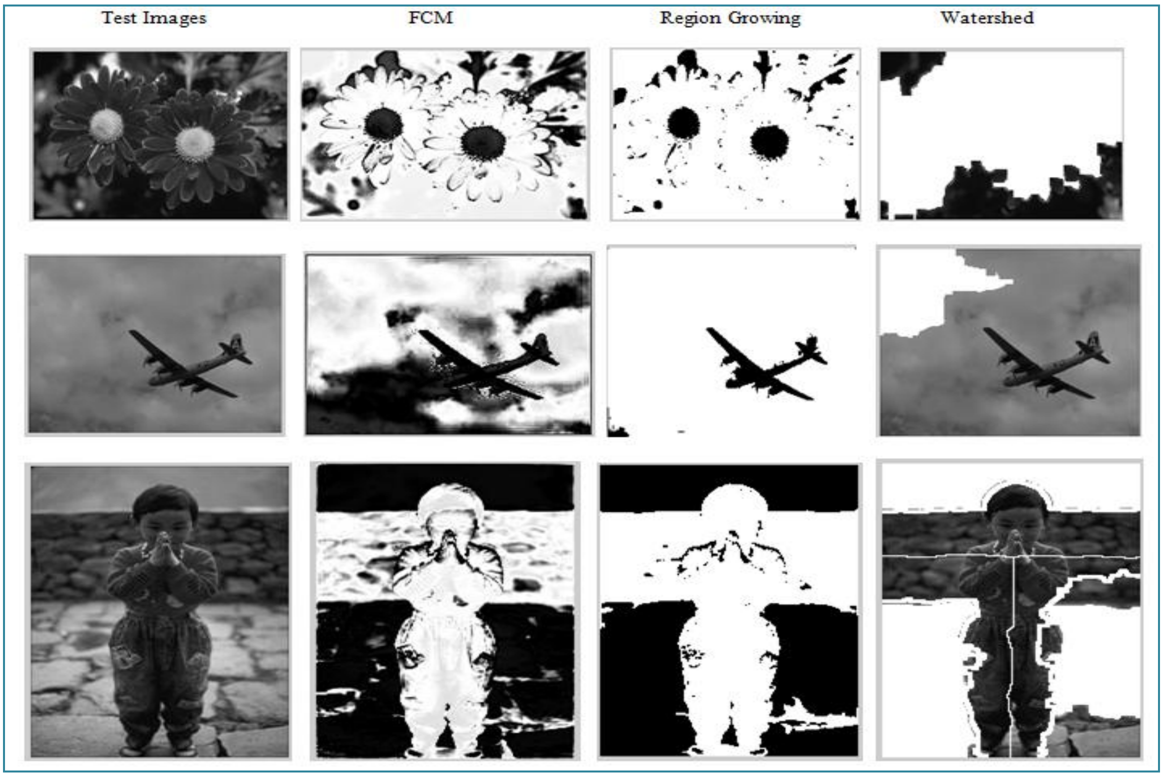


Figure 3. Segmentation results of FCM, Region Growing and Watershed algorithms performed on three natural images Flower, Airplane and Kid.

Table1. PSNR, RI, VoI and GCE values calculated for FCM algorithm

Test Image	PSNR	RI	VoI	GCE
Flower	17.1785	0.9367	0.2079	0
Airplane	12.6525	0.9566	0.1536	0
Kid	13.8960	0.9496	0.1732	0

Table 2. PSNR, RI, VoI and GCE values calculated for Region Growing algorithm

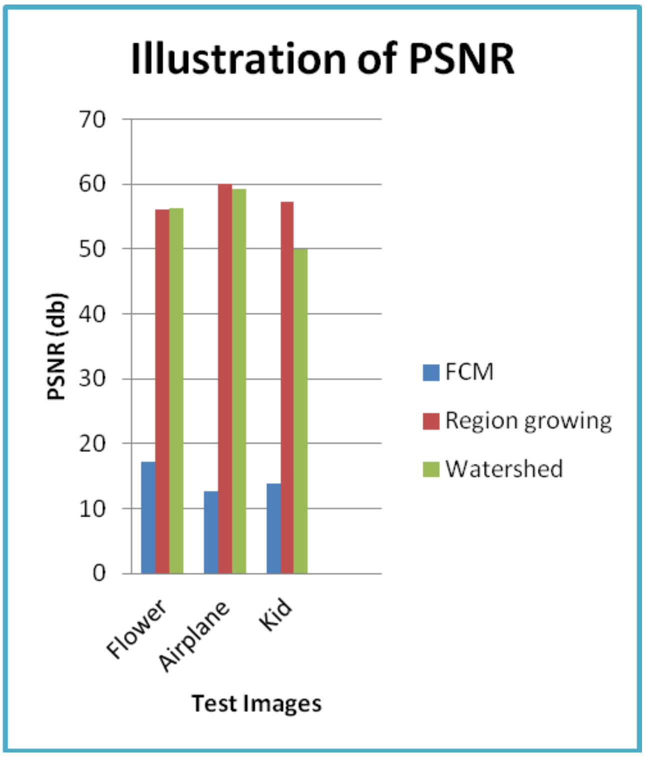
Test Image	PSNR	RI	VoI	GCE
Flower	56.0955	0.7690	0.6987	0.0633
Airplane	60.0042	0.8710	0.4581	0.0429
Kid	57.2841	0.5001	1.1724	0.0504

Table 3. PSNR, RI, VoI and GCE values calculated for Watershed algorithm

Test Image	PSNR	RI	VoI	GCE
Flower	56.2281	0.9367	0.2079	0
Airplane	59.3651	0.9566	0.1536	0
Kid	46.9179	0.3208	2.1163	0.0501

Table 4. Comparative analysis of FCM, Region growing and Watershed algorithm on three images (average value of parameters), bold values represent highest, italic second highest value.

	FCM	Region Growing	Watershed
PSNR	14.5757	**57.7946**	*54.1704*
RI	**0.9477**	*0.7134*	0.7380
VoI	**0.1782**	*0.7764*	0.8259
GCE	**0**	0.0522	*0.0167*



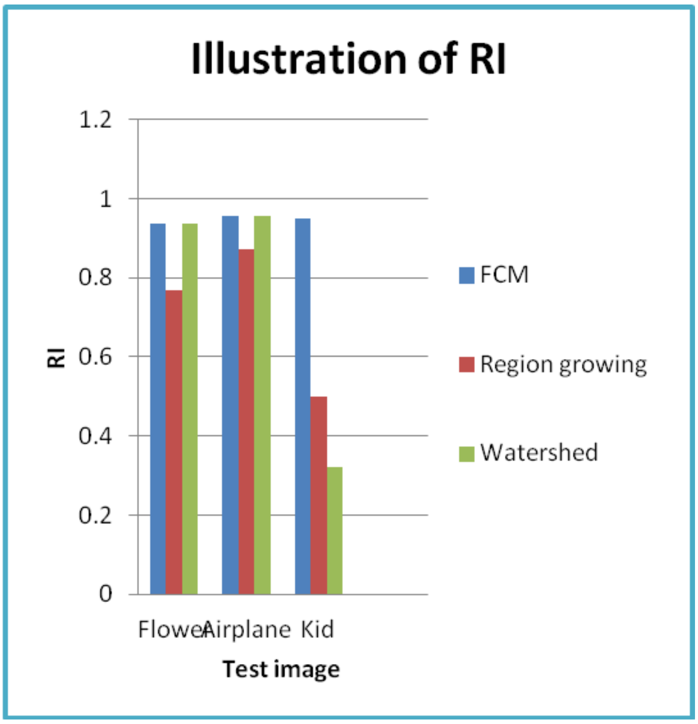
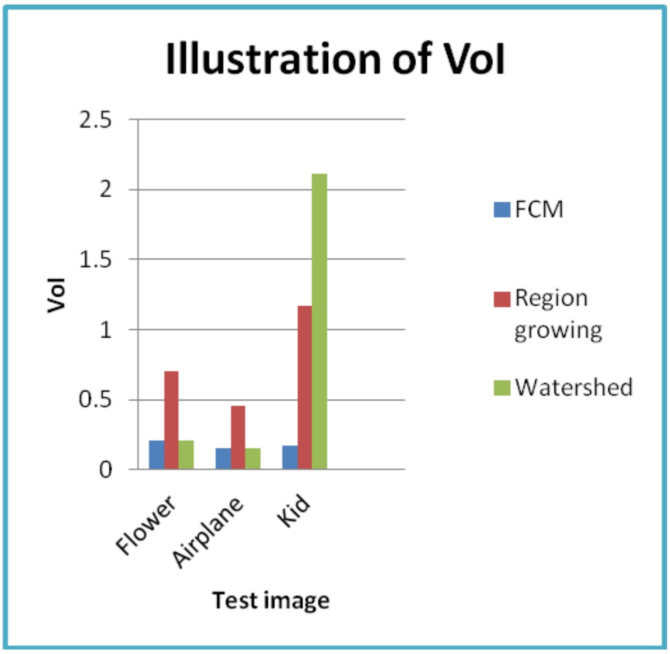


Figure4. Illustration of PSNR and RI values for FCM, Region growing and Watershed algorithm



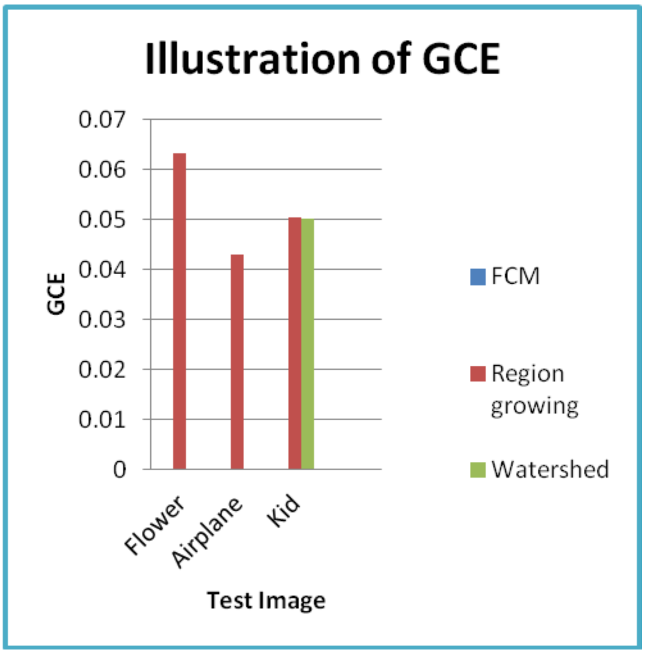


Figure5. Illustration of VoI and GCE values for FCM, Region growing and Watershed algorithm

IV. CONCLUSION

Three image segmentation algorithms namely FCM, region growing and watershed are discussed and their segmentation results are evaluated using four quantitative measures. Comparative analysis shows that region growing algorithm has more de-noising capability with highest PSNR value. Measures suitable for evaluating FCM algorithm are Rand Index (RI), VoI and GCE, where GCE (Global Consistency Error) for FCM is zero indicating better segmentation result. Also PSNR is suitable for evaluating Watershed algorithm. Thus, different image segmentation algorithm can be evaluated with suitable performance metric based on its application.

REFERENCES

[1] Tan .S. K., Lim .H.W, Isa .M.N (2013), "Novel initialization scheme for Fuzzy C-Means algorithm on color image segmentation", Applied Soft Computing 13, 1832-1852.

[2] R.C. Gonzalez, R.E. Woods (2011), "Digital Image Processing", Third Edition, ISBN 978-81-317-2695-2.

[3] T. Berber, A. Alpkocak, P. Balci , O. Dicle (2013), "Breast mass contour segmentation algorithm in digital mammograms", Computer methods and programs in Biomedicine 110, pages 150–159.

[4] M. A. Hamdi (2011), "Modified Algorithm marker-controller watershed transform for Image segmentation Based on Curvelet Threshold", Canadian Journal on Image Processing and Computer Vision Vol.2 No.8.

[5] Jianping et al. (2005), "Seeded region growing: an extensive and comparative study", Pattern Recognition 26, 1139-1156.

[6] B. Sathya and R. Manavalan (2011), "Image Segmentation by Clustering Methods: Performance Analysis", International Journal of Computer Application, 0975-8887.

[7] Sowmya. B. and Rani Sheela. B. (2011), "Colour image segmentation using fuzzy clustering techniques and competitive neural network", Applied Soft Computing 11, pages 3170–3178.

[8] Arbela, X.P. ez, M. Maire, C. Fowlkes, J. Malik (2011), Contour detection and hierarchical image segmentation, IEEE Transactions on Pattern Analysis and Machine Intelligence 33, pages 898–916.

[9] W. Liu, B. Wang, J. Glassey, E. Martin, J. Zhao (2009), "A novel methodology for finding the regulation on gene expression data", Progress in Natural Science 19, pages 267–272.

[10] M. Meila (2007), "Comparing clusterings—an information based distance", Journal of Multivariate Analysis 98, 873 – 895.

[11] D. Martin, C. Fowlkes, D. Tal and J. Malik (2001), "A Database of Human Segmented Natural Images and its Application to Evaluating Segmentation Algorithms and Measuring Ecological Statistics", Proc. 8th Int'l Conf. Computer Vision, Vol. 2, pages 416-423.