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Segmentation of Underwater Objects using CLAHE Enhancement and Thresholding with 3-class Fuzzy C-Means Clustering

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***Abstract*— Underwater images suffers from low illumination and poor contrast due to refractions of light rays and poor visibility. Therefore, underwater image segmentation and object extraction is a difficult task. This paper proposed an efficient and fast underwater image segmentation method using thresholding with class 3 fuzzy C-means clustering and CLAHE enhancement method. CLAHE enhancement method is used before image segmentation to improve the contrast and illumination of underwater image this in turn improves the segmentation performance significantly. The proposed method uses normally distributed pseudorandom numbers generator to initialize the fuzzy membership function. This modification improves the convergence rate of the standard FCM method. Results of the proposed object segmentation method are tested open the different kind of underwater images. It is found that entropy of segmented object is improved with the proposed method. Paper also compares the performance of FCM with different distance masers.**

***Keywords*— Underwater Image segmentation, Fuzzy C-mean Clustering, Thresholding, Entropy, Contrast enhancement.**

I. INTRODUCTION

With the technological growth it has become possible to acquire a large variety of underwater images deep inside the sea. This has permitted us to efficiently segment and comprehensively analyse the underwater images for identification and 3D visualization of sea objects. Underwater image segmentation is important for identification of sea objects like coral reefs, monitoring the underwater mountains, sea spices and plants. Segmentation methods does not perform equally well for all kinds of underwater images due to non uniform illumination. Therefore, researchers have developed various image segmentation methods [1, 7, 11, 14, and 16], which were designed for different types of underwater images. In uniform environment of underwater images, segmentation without losing the features of the objects is a challenging task. The underwater images usually have low contrast and fuzzy edges of objects under the influence of the imaging in poor visibility conditions.

But still very limited work [2, 5] is reported yet for fuzzy image segmentation for underwater images. There are various characteristic artifacts which make the fuzzy object segmentation more complicated for such images. These characteristic artifacts' include scattering, attenuation, and objects shadow. Therefore, underwater image segmentation is a most challenging task ever. Basically segmentation is a first stage of sea object classification and feature extraction [7] process as shown in Figure.1.

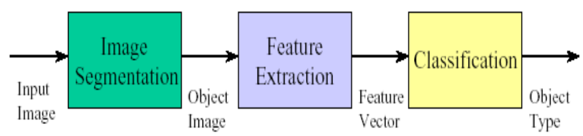

Figure 1 Basic segmentation process

Researchers have proposed many segmentation methods by using, global and local histogram thresholding [3 and 5], local region based image segmentations [10], region growing techniques, and NN based methods [8], edge detection based technique [12], and fuzzy based K-means and C-means clustering (FCM) algorithms [1, 16 and 17], But fully adaptive image segmentation is still a most challenging and bit fuzzy problem due to wide range of possible underwater imaging objects.

The thresholding based methods are widely used for many applications such as segmentation of see objects, defect detecting of underwater structures [7] and for automatic targets detection [2]. Thresholding based segmentation has proven to be effective for segmenting the well defined regions. Otsu's adaptive thresholding method is widely used from last five decades [3]. Although these methods work well for dark visible objects on bright backgrounds however, method is not efficient enough for segmenting all kind of underwater images. It may generate artifacts in the segmented image, mainly because it is pixel oriented. Therefore, new methods are needed to solve variety of underwater segmentation issues. It is also required to improve the efficiency of the thresholding based segmentation methods for such applications.

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This paper proposed an efficient method for segmenting the underwater image objects. The proposed method uses the FCM with 3 class thresholding approach for segmentation [1]. For improving the convergence rate of the conventional FCM method it is proposed to use the modified membership function by changing the procedure of initialization of fuzzy partition matrix. In addition, for improving the segmentation efficiency it is proposed to enhance the images before segmenting the objects, using method of contrast limited adaptive histogram equalization abbreviated as (CLAHE) [6]. Paper also compares performance of FCM using Euclidean distance to FCM with Chi square distances measures.

II. LITERATURE REVIEW

The segmentation techniques for underwater images can be distinguished by the methods used for the enhancement and object segmentation stages. Therefore the existing literature is also reviewed in two pass.

A. Review of contrast enhancement methods

The underwater images are usually of low contrast due to poor visibility. Thus contrast enhancement methods are widely used to improve the contrast of these images. Researchers have explained various contrast enhancement techniques including region growing based methods [10], wavelength compensation [13], linear contrast stretching and brightness preserving histogram equalization [14] etc. John *et al.* [13] have proposed a new systematic method for enhancing the underwater images by using dehazing algorithm to compensate various attenuation discrepancies along the light paths. They have taken consideration of the influence of possible presence of an artificial light source. They have compared the background and foreground lights for deciding whether the artificial source is needed or not. But the method demands the accurate estimation of the light source luminance distribution and method also seems computationally complex. Jyoti *et al.* [14] have used brightness preserving histogram equalization with maximum entropy (BPHEME) method for enhancing the underwater mages. Method was based on the histogram processing. Hitam *et al* [9] used CLAHE method for enhancing underwater images using RGB and HSV spaces.

Etaa D. Pisano *et al.* [4] have proposed a method named contrast limited adaptive histogram equalization (CLAHE) for enhancing the image quality. Letter on many researchers used CLAHE as tool for contrast enhancement as [5, 6, and 9].

Antonis Daskalakis *et.al*, [6] under their research has investigate on an efficient CLAHE based, spot adaptive image segmentation Method for improuvant on microarray gènes quantification. There team found that this method improved the display of spots and emphasized on the spots depiction.

B. Review of segmentation methods

Rahesh *et al.* [5] have used CLAHE enhancement and histogram based global thresholding methods for underwater image segmentation. The CLAHE method is implemented on gray images in spatial domain. The efficiency of the method depends upon the manual selection of global threshold. Yan et al. [16] have explained the different underwater image segmentation including Fuzzy enhancement, and fractional segmentation method.

G. Padmavathi [17] has proposed a fuzzy c means clustering method using thresholding for underwater image segmentation. They have compared the standard fuzzy c means clustering algorithms with proposed method for underwater images. Quantitative and statistical measures have been used for evaluating the nonlinear image region segmentation, such as the discrete entropy, gray level energy, But clustering is less effective for large number of diagnosis images with non uniform brightness conditions such as in underwater images. Therefore, thresholding is widely used for improving the efficiency of the conventional FCM method.

Wang, Shilong *et al.* [2] have presented a fast underwater optical image segmentation algorithm using a histogram weighted FCM algorithm improved by particle swarm optimization (PSO). This underwater image segmentation was fast and effective fuzzy C-means algorithm. But method was mathematically complex Shi-long *et al*. [15] has implemented an adaptive fuzzy c-means algorithm using spatial neighbourhood for segmenting the marine images.

Radhika *et al*. [1] have proposed a method of the segmentation of dark areas in SAR images to detect the oil spill. They have used FCM with 3 class thresholding method which performs efficiently. Guanglei *et al.* [19] have proposed the automated method of segmenting the Drosophila RANi Fluorescence cellular images using thresholding with 3 class FCM deformable models. Since then this concept was used by many researcher for various applications like medical image segmentation. Jafar *et al*. [18] have compared the FCM based on various distance measures like Chebyshev and Chi-square distances.

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Since FCM clustering methods does not work well for non uniform brightness underwater images thus there is always a scope to improve their efficiency.

III. PROPOSED METHOD

This paper proposes an underwater object segmentation method which is a combination of the CLAHE enhancement method [6], with the FCM based clustering with thresholding [1]. Proposed method is first enhances the contrast of underwater image using the CLAHE, this improves the performance of the segmentation under the noisy and non uniform illuminations environments. In the second step efficient method of thresholding with 3-class fuzzy c means clustering is used to segment the dark areas. By modifying the initialization process of membership function the performance of the standard FCM method is improved. Usually the method of FCM with thresholding generates logical (back and white) images. In the proposed method the as an improvement FCM based logical output is used to extract the colour segment from the original image by masking. The block diagram of the segmentation method is given in the Figure 2. Every block is sequentially explained in the remaining paper.

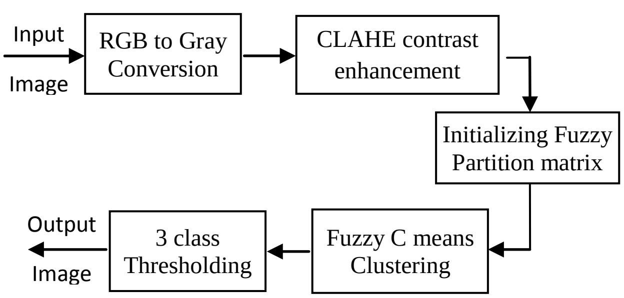

Figure 2 Block diagram of proposed method

IV. CLAHE ENHANCEMENT ALGORITHM

In this paper images are converted to gray images and then equalized in spatial domain. Basic algorithm for enhancing the contextual image regions by using the CLAHE technique [4, 5, and 6] is described below;

Step 1: First the input color image is transformed to gray image using Rgb2gray function. The transformed image is a intensity image..

Step 2: Gray image is sub-divided into small bins of 8X8 called as tiles..

Step 3: Clip limit is selected for histogram equalization

Step 4: Histogram is calculated for each bin individually.

Step 5: For contrast enhancement histogram of each region is transformed in such a way that its height did not exceed the selected clip limit

Basically segmentation requires the flat histogram thus uniform distribution is used for enhancement in this paper. The mathematical expression for transformed gray levels for CLAHE method with uniform distribution can be given as

$$g = [g_{\max} - g_{\min}] * P(f) + g_{\min} \tag{1}$$

Where $g_{max}$is maximum pixel value, $g_{min}$is the minimum pixel value. Where, g is computed pixel value and $P(f)$ is the Cumulative probability distribution. The flow chart of the method is given in Figure 3.

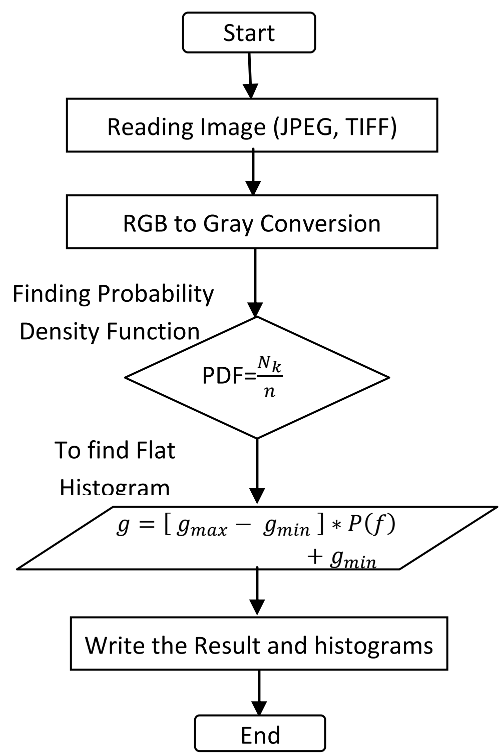

Figure 3 Data Flow of CLAHE Method

The difference $g_{max} - g_{min}$represents the contrast of the image. Since CLAHE method is basically designed for maximum entropy of image therefore, it is widely used for enhancement in imaging applications.

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V. FUZZY C MEANS CLUSTERING WITH THRESHOLDING

The proposed clustering technique is a combination of fuzzy algorithm, C-means clustering and thresholding algorithm [1]. The main goal of the clustering is to divide an input image into number of clusters. The FCM alone is sensitive to presence of the noise and is less effective for the medical images with non uniform illuminations. Therefore, in this paper contrast enhancement and thresholding is combined with the FCM, to improve its efficiency.

The standard FCM method divides the input image into cn numbers of clusters with each cluster is having different centre or centroids. The each data point in the particular dataset belongs to every cluster to a certain degree of extant. For example, consider a certain data point that lies closer to the centre of the cluster, it will have a high degree of belonging or membership to that cluster and the data point which lies far away from the cluster centre it will have a lower degree of belonging or membership to that cluster.

The step wise proposed fuzzy C means clustering method is as follows;

1. Initialize the number of clusters $Nc \geq 2$, number of data points N. and the minimum desired improvement I_{min}. Define the random initial fuzzy partition matrix Uin, and its exponent Exp.
2. The initial fuzzy membership function is given as;

$$mf = Uin * Exp \tag{2}$$

3. Basically the objective function represents the distance from cluster centre to any given data point weighted by membership grades of that data point's. Calculate the objective cost function for FCM as;

$$f_m(U,C,D) = \sum_{i=1}^{cn}\sum_{j}^{N} M_{ik}^{E} d_{ik}^{2} \tag{3}$$

Where, U is the given set of the fuzzy partition matrix, $C = [V_1, V_2, V_3, \ldots\ldots V_{cn}]$ is the vector of the clusters canters. D= $[x_1, x_2, x_3, \ldots\ldots x_N] \sqsubseteq R^p$ is the image data set of the p dimensional vector space. Where, M_{ik} is the degree of membership corresponding to the data x_k in the i^{th} cluster, E is the exponent of member ship function.

Where, d_{ik} is the distance measure between object and cluster canters defined as squared Euclidean distance.

$$d_{ik}(x_k, V_i) = \|x_k - V_i\|^2 \tag{4}$$

Method calculates the distance matrix using the Euclidean distance between each row in centre and each row in data, and returns a distance matrix out of size M by N, where M and N are row dimensions of centre and data, respectively, and gives the output as distance between centre and data. Therefore equation (2) may be written as;

$$= \sum_{i=1}^{cn}\sum_{j}^{N} M_{ik}^{E} \|x_k - V_i\|^2 \tag{5}$$

4. Calculate the cluster canter corresponding to the current membership function as;

$$V_i = \frac{mf * D}{\sum_{k=1}^{N} u_{ik}} \tag{6}$$

5. Compute the new membership function M_{ik}^{n} as;

$$M_{ik}^{n} = \frac{1}{d_{ik}^{\frac{2}{E-1}}} \tag{7}$$

Then FCM iteratively updates the cluster centres and the membership grades for each data point based on minimizing the objective function f_m. This means that, above mention procedure is iteratively repeated until the following condition is satisfied.

$$f_m(n) - f_m(n-1) < I_{\min} \tag{8}$$

A. Modified Fuzzy Partition Matrix

For initial estimate of fuzzy partition matrix U, the uniform random generator is used commonly. But in proposed method for boosting up the iterations the pseudo random generator with normal distribution is used. It generates the higher initial estimate for fuzzy partition matrix as shown in Figure 4.

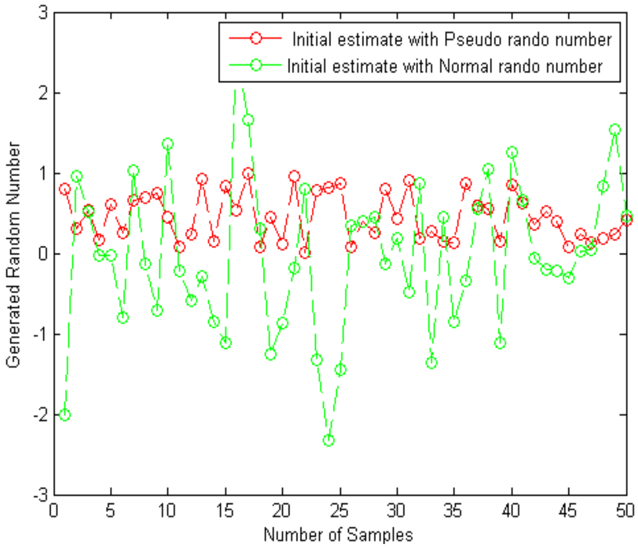


Figure 4 Comparison of the Random number generators

B. Fuzzy Threshold selection

Here fuzzy c means clustering is used based on thresholding. It works better than the standard Ostu method [3]. Fuzzy c means clustering the segmented part cannot be seen clearly. For that reasons, thresholding is applied to extract the segmented image portion. The threshold is calculated by taking the mean of maximum in the class with the smallest canter and the minimum in the class with the middle canter [1] as per the distance matrix. This can be thought as a trade-off between the local and the global features. The for the input choice *ch* fuzzy threshold are given as;

If switch = 0

$$L\,Th_1 = \frac{max\big((label = 1)\big) + min\big(D(label = 2)\big)}{2} \quad (9)$$

If switch = 1

$$LTh_2 = \frac{max\big(D(label = 2)\big) + min\big(D(label = 3)\big)}{2} \quad (10)$$

Thus the proposed FCM method generates the two output images correspond to the each threshold level L, and their performance is compared with the standard Otsu threshold method [3].

VI. FUZZY C MEANS CLUSTERING WITH THRESHOLDING

This section presents some of our experimental results for the work done on proposed medical image segmentation method.

Proposed method uses the combination of Contrast limited adaptive histogram equalization (CLAHE) method and the Fuzzy C mean clustering based on three level thresholding.

A. Image database

Figure 5 shows the data base of four distinct original underwater images. All these images are taken from different ocean environments. The image in Figure 5(b) and 5(d) are btaken respectively from two different islands in Terengganu, Malaysia namely Bidong Island and Redang Island [8]. Image in Figure 5(a) is a standard sea plnat image with a uniform background.

a) Sea_plant image

b) Bidong Island 2

c) Bubble_vision_2 image

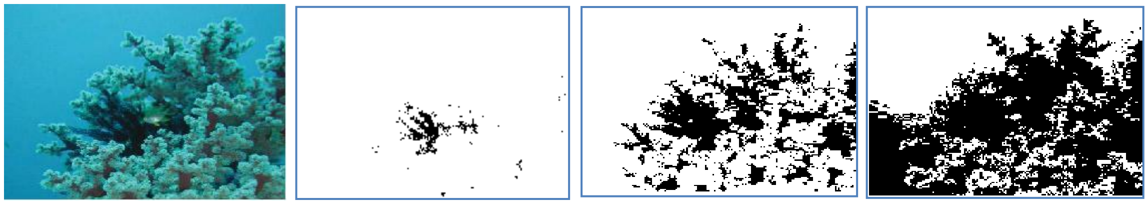
d) Redang_Island_2

Figure 5 Input image dataset

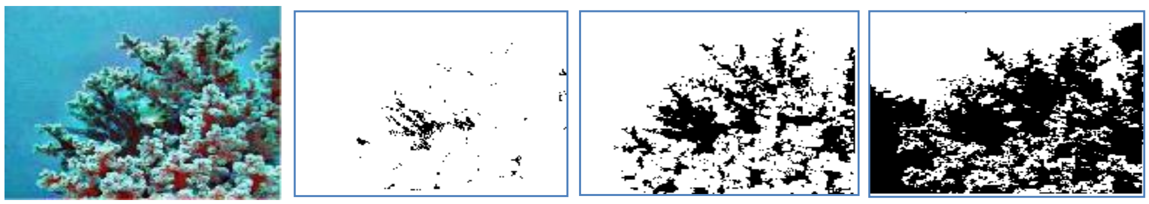
The Bubble_vision_2 image [13] Figure 5(c) is a part of an underwater footage available at the Youtube website taken by the Bubble Vision Comp1any. These images have different objects and background with unique features. Due to underwater environment Images having poor contrast.

b) Performance Comparison

Results comparison of the standard 3 class FCM thresholding method with the Otsu thresholding is presented in Figure 6 (a-d) for sea plant image. The corresponding results of the proposed FCM method with contrast enhancement are presented in Figure 6 (e-h) It can be seen, that proposed method improves the threshold level significantly, thus contains the more information. The segmentation results for Redang Island 2 image is shown in the Figure 7. It can be observed that the objects at the see floor see clearly visible by the proposed FCM method along with CLAHE enhancement.

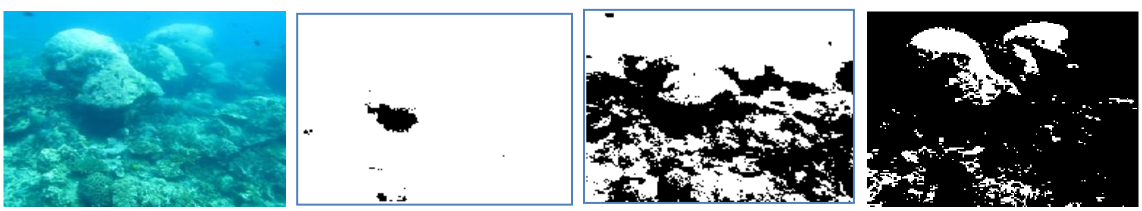


a) Original image b) With Otsu method level =0.384314 c) FCM0 level0=0.299197 d) FCM1 level=0.471888

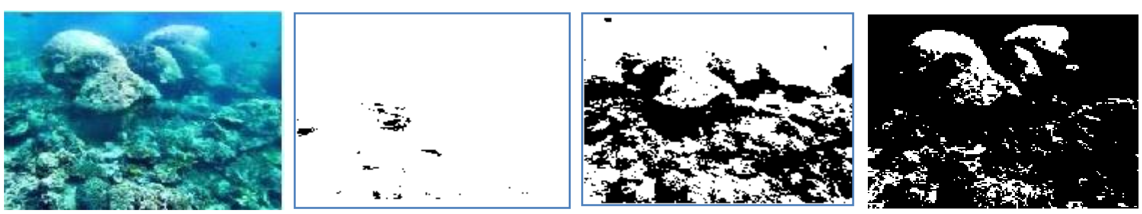


e) CLAHE image f) With Otsu method level =0.403922 g) FCM0 leel0=0.324071 h) FCM1 level=0.515936

Figure 6 Result of standard method of FCM with 3 class thresholding for See plant image. Top row is without enhancement, and Bottom row is with CLAHE Enhancement



a) Original image b) With Otsu method level =0.39412 c) FCM0 level0=0.34153 d) FCM1 level=0.57651



e) CLAHE image f) With Otsu method level =0.40980 g) FCM0 leel0=0.35101 d) FCM1 level=0.59343

Figure 7 Results of the proposed FCM method with 3 class thresholding for Redang Island image 2, Top row is without enhancement, and Bottom row is with CLAHE Enhancement

Table 1
The Level Threshold For Fcm With And Without Clahe Image Enhancement

Images	Threshold. without CLAHE			Threshold with CLAHE		
	Otsu	FCM0	FCM1	Otsu	FCM0	FCM1
See_Plant	0.38431	0.29919	0.47188	0.40392	0.32470	0.51593
Redang_Island_2	0.39412	0.34153	0.57651	0.40980	0.35101	0.59343
Bidong_island_2	0.68431	0.52164	0.78138	0.65098	0.48170	0.77032
Bubble_vision_image	0.48039	0.38520	0.65051	0.48823	0.39371	0.64009

Table 1 explains that threshold levels with 3 class FCM and with proposed modified FCM and CLAHE enhancement. It can be seen that threshold is improved with CLAHE enhancement.

The Table 2 shows that the use of normal pseudo random generation minimizes the number of iterations required for optimized objective function without changing threshold levels.

Table shows the results for average of 20 Simulations. Since the initial value of objective function is randomly generated thus the number of iterations is different every time the simulation is run. Therefore Figure 10 presents the comparison of iteration count for 10 individual simulations. It is observed from the both of these Figures that proposed FCM with normal random generator reduces the iteration count thus converges faster.

Table 2
The Number Of Iterations For Two Random Number Generations

Images	Iterations with Uniform Pseudo random initialization	Iterations with Normal Pseudo random initialization
See_Plant	40	38
Redang_Island_2	28	25
Bidong_island_2	26	23
Bubble_vision_image	34	32

The Table 3 shows the comparison of the segmentation with Euclidean distance and Chi square distances [18]. It is observed from the Table 3, that FCM with Euclidean distance performs better in terms of number of iterations except for Bone ankle X-ray image.

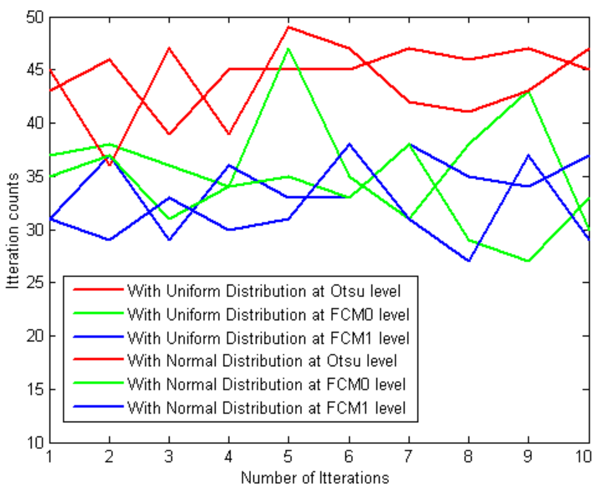


Figure 10 Number of iteration count for FCM with different random number generator for Redang _Island_2 image.

VII. Conclusion

Efficient underwater image segmentation method is proposed using the CLAHE method with the Fuzzy 111C mean clustering based on three level thresholding.

Table 3
Comparison Of The Iteration Count For Fcm With Diffrent Distance Measures

Properties	With Chi Square Distance	With Euclidean distance
See_Plant	78	25
Redang_Island_2	45	32
Bidong_island_2	62	27
Bubble_vision_image	74	34

As a modification the normal pseudorandom generator is used, which improves convergence rate for the almost all images except for image with less numbers of gray levels. The performance of the proposed method is compared with the FCM using Chi Square distance measure. It is observed that Chi square method needs more iterations than the proposed Euclidean distance measure. The proposed method improves the threshold level at the lesser computation cost. In future the performance of the different objective functions can be compared for FCM and C-mean may compare with k-Means clustering and the can be used for setting the exponent of partition adaptively.

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