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Image Enhancement using High Resolution Multispectral Satellite Imagery implemented by FCM Clustering Techniques

Mr. S Thirunavukkarasu
Research Scholar,
Dwaraka Doss Goverdhan Doss Vaishnav College,
Armbakkam, Chennai, India – 600 106.

Capt. Dr. S Santhosh Baboo
Associate Professor,
Dwaraka Doss Goverdhan Doss Vaishnav College,
Armbakkam, Chennai, India– 600 106.

Abstract—One of the most challenging problems for researchers in the field of remote sensing is image enhancement and its quality assessment. Several conventional contrast enhancement techniques adopt a global approach to enhance all the brightness level of the image. A very important issue in image quality assessment is image sharpness or brightness. Image Enhancement is usually difficult to enhance all land cover classes appearing in the satellite images. Because local contrast information and details may be lost in the dark and bright areas. In this paper a k-mean clustering image enhancement technique is developed to partition the imagery pixel values in to different degree of associates in order to recompense the neighboring brightness lost in the dark and bright regions.

Keywords— fuzzy, IQM, cluster, pixels, imagery, enhancemet

I. INTRODUCTION

The goal of image enhancement is to improve the quality of imagery, so that the processed imagery is improved than the original image for a set of objectives using ERDAS Imaging application [1]. With the development of remote sensing technology, the satellite can provide images with resolution of 1 or 2 meters. Although there are many feature detection algorithms developed for automatic purposes, manual interpretation and image visualization are still of basic importance for many areas of application. In general, raw satellite images have a relatively narrow range of brightness values; hence, contrast enhancement is frequently used to enhance the image for better interpretation and visualization. Several image enhancement algorithms have been proposed to improve the appearance of the imagery. One of the most generally used algorithms is Fuzzy C-mean (FCM) [1], FCM algorithms may be generally categorized into three classes. The first is spatial domain methods, in general work with local window algorithm. Each pixel on the imagery is enhanced with corresponding local contrast which is derived from designed filters [3].

The second transform based method; the method is using Fourier transform, 2D discrete cosine transform, or other transforms, in these transformation normally by transforming the images in to the frequency domain. Then different algorithms can be developed in to image enhancement. In generally the major reason of the approach is to enhance the shapes and decrease the noises of features on the frequency domain[5,6]. Finally, the histogram adjustment methods, are used to estimated the brightness and contrast of the image. The estimated values are dynamic range of the histogram, and mean value, respectively, thus an image could be enhanced by modifying the histogram with the above in sequence[4]. However, the conventional contrast enhancement method normally has difficulty in enhancing all land cover classes shown in the image. For example settlement regions normally appear brighter after contrast enhancement and forest area generally become darker. so, the usual contrast enhancement ends up with an image contain enough mid brightness contrast, while losing local brightness details in the dark and bright regions. In this study, a fuzzy C-Means based image enhancement method is developed to partition the image pixel value into various degrees of associates in order to compensate the local brightness lost in the dark and bright areas.

II. PROPOSED METHODOLOGY

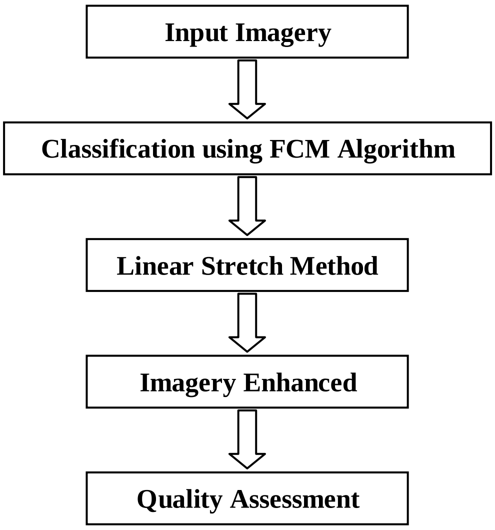


Figure 1. Research methodology

III. FUZZY C-MEAN ALGORITHM

Fuzzy C Means clustering techniques is mainly used for Satellite image fuzzy classification. In the fuzzy set logic algorithm is designed and developed based on k means clustering algorithm [10]. In this algorithm, each pixel can belong to more than one cluster by using Cluster Center Initializations and associated with each pixel is a set of membership levels, in the given strength of the associate between the each pixel in the present cluster. Fuzzy cluster is a process of assigning these membership levels, and then using them to assign each pixel to one or more cluster in its place. The clustering algorithm is performed with an iterative optimization of minimizing a fuzzy objective below equation (***J$_m$***)[7]. The Fuzzy C Mean technique allots pixels to each class by using fuzzy set memberships. Let X=(x1, x2,……,xn) denotes an image with n pixels to be segregated into c clusters, where xi represents multispectral imagery(features) data. The algorithm is an iterative optimization that minimizes the cost function defined the equation 1 as follows

$$\left.\begin{aligned} J_m &= \sum_{i=1}^{n}\sum_{j=1}^{c}\left(u_{ij}\right)^m \left\|x_j - v_i\right\|^2 \\ &\text{(or)} \\ J_m &= \sum_{i=1}^{n}\sum_{j=1}^{c}\left(u_{ij}\right)^m d^2\left(x_j, v_i\right) \end{aligned}\right\} \quad (1)$$

where u_{ik} = represent the membership value of ith cluster of jth pixel, x_j represent the vector of j^{th} pixel, V_i represent the center vector of i^{th} cluster, n is represent the number of pixels, c is represent the number of clusters, $\|.\|$ is represent the a norm metric, m is represent the fuzziness for each fuzzy membership, when m is close to 1, the algorithm is similar to k means clustering, $d^2(x_j,V_i)$ is represent the Euclidean distance between x_j and V_i

The membership (u_{ik}) is estimated by the distance between j^{th} pixel and center of i^{th} cluster, and is constrained as follows

$$\begin{cases} 0 \le u_{ij} \le 1 & \text{for all j} \\ \sum_{i=1}^{c} u_{ij} & \text{for all j} \\ 0 < \sum_{j=1}^{n} u_{ij} < n & \text{for all j} \end{cases} \quad (2)$$

where u_{ik} is represent the membership value of i^{th} cluster of j^{th} pixel, c represent the number of clusters, n represent the number of pixels

The center of cluster (V_i) and the membership value (u_{ik}) could be calculated by Equation 3 and Equation 4 are in that order.

$$vi = \frac{\sum_{i=1}^{n}\left(u_{ij}\right)^m x_k}{\sum_{j=1}^{n}\left(u_{ij}\right)^m}, 1 \le i \le c \quad (3)$$

$$u_{ij} = \left[\sum_{j=1}^{c}\left(\frac{d\left(x_k, v_i\right)}{d\left(x_k, v_j\right)}\right)^{\frac{2}{m-1}}\right]^{-1}, 1 \le i \le c, 1 \le k \le n \quad (4)$$

Therefore these equations of 3 and 4 by using ***Jm*** can be minimized by the iterations. Firstly, the iteration is to initialize a constant value of c. a fuzziness parameter m, a threshold ε of convergence, and an Initializations of Cluster Center for each pixel, then the computing u_{ik} and V_i using Equation 3 and Equation 4 respectively. The iteration stops, while the change in V_i between two iterations is smaller than ε. Finally, each pixel is classified into a combination of memberships of clusters.

IV. SIMPLE LINEAR STRETCH MODEL CONSTRUCTING

After the clustering process, the imagery is transformed in to association or membership level from gray level space [9]. The pixels in a data file that make up an imagery can contain any values are positive or negative integer, or floating point. While the imagery data are shown as brightness values for each pixel are displayed. In a data pixel with a bigger value is brighter than one with a smaller value. However, unlike the imagery data, screen pixels can be single 256 unique brightness values, varying as integer between 0 to 255. Clearly this limitation prevents the data from being displayed with brightness exactly equal to their real value. Stretching the image data refers to a method by which the data pixels are rescaled from their original values into a range that the monitor can display namely, into integer values between 0 to 255.

Commonly, a simple linear stretch model is designed to smoothly enhance each cluster sketching in one of the image enhancement techniques which can be used to improve or locally adjust the imagery element. So that it is better to view the dark and bright portion of the image. A linear stretch type is used so that the stretched data values maintain the same relationship to each other as the original data. Each pixel comprises various combinations of memberships. The linear stretch algorithm is performed using the following steps

a. The histogram of each cluster is generated by counting the corresponding membership value of each pixel instead of frequency which is generally used. Thus, the count of each bin of the histogram is floating number, but the sum of floating counts of each histogram is still equal to the number of pixels of the image.

b. In the stretch model is used the corresponding floating histogram as a construct base for each cluster by using the following equation ***SI(g)***

$$SI(g) = \frac{g - b_{i,l}}{b_{i,u} - b_{i,l}}\,\mathrm{X}\left(L - l\right) \quad (5)$$

where ***SI(g)*** = stretched gray value, ***g*** is represent the original gray value, ***L*** is represent the number of gray level, $b_{i,u}$ is represent the upper boundary for stretching of i^{th} cluster, $b_{i,l}$ is represent the lower boundary for stretching of i^{th} cluster

The upper boundary (b_i,u) and the lower boundary (b_i,l) are determined by two proportion parameters of p_u and p_l, as shown in Equation 6

$$\begin{aligned} b_{i,l} &= h_i^{-1}\left(p_1 \mathrm{X} \sum_{g=0}^{L-1} h_i\left(g\right)\right), \\ b_{i,l} &= h_i^{-1}\left(\left(1 - p_u\right)\mathrm{X}\sum_{g=0}^{L-1} h_i\left(g\right)\right) \end{aligned} \quad (6)$$

where *hi(g)* is represent the distribution function of i^{th} cluster *pu, pl* is represent the proportion parameters.

V. DEFUZZIFICATION

Defuzzification is the process of producing a quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees. It is typically needed in fuzzy control systems. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets [15].

The main objective of the process is to infer and apply decision rules to assigning full membership of the fuzzy regions to the target land cover classes. General defuzzification techniques include max membership principle, centroid method, and weighted average method and mean max membership [8]. A simple method of defuzzification - not exploiting feature analysis uses a logical union operator like the fuzzy t-conorm MAX operator [8]. There are two defuzzification operators that can be utilized in geographic data of nominal scale. As described briefly in the following membership index and confusion index. After the stretch model of each cluster is built, the image could be transformed back to the gray level space. According to the stretch model of each cluster using Equation 5, gray values of the original image could be enhanced to various values [14]. These enhanced values are then weighted with corresponding membership values using Equation 7. In order to prevent over-saturation of the pixel value, the result of the enhancement is constrained by using Equation 8.

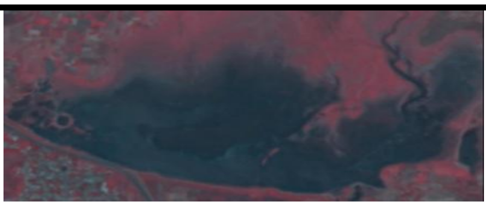
$$m'(g) = \sum u_{ij} \times m_i(g) \qquad (7)$$

$$0 \le m'(g) \le L - l \qquad (8)$$

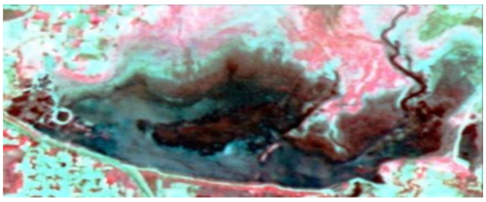
where u_{ik} is represented to membership value of i^{th} cluster of j^{th} pixel, g is represented to original gray value of pixel j, L is represented to number of gray level, $mi(g)$ is represented to mapping function of i^{th} cluster.

VI. EXPERIMENTAL RESULTS

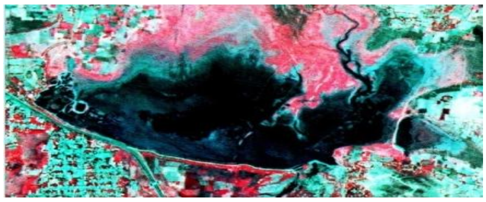
The proposed algorithm is tested with a PAN and LISS III Merged data by using ERDAS Imaging application. There are different land cover classes appearing on the imagery, including water body, settlement areas, and river body. In the satellite imagery resolution is 23 meter and the size of the imagery is 3000×2300 pixels. In Fuzzy C-Mean step, the number of cluster (c) is given by 5 and the fuzziness (m) is given by a value of 2 for purposes of efficient computation. Furthermore, proportion parameters (pu) and (pl), are both given by 0.015 to build the stretch model of each cluster.



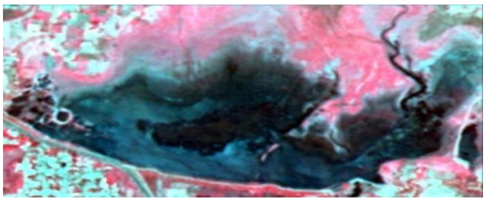
(a) Water Body original Image



(b) Proposed Image



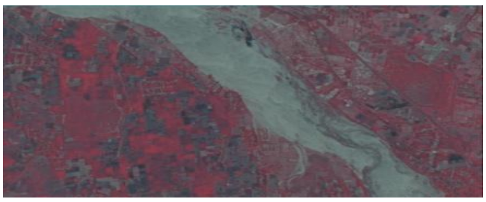
(c) Histogram Equalization



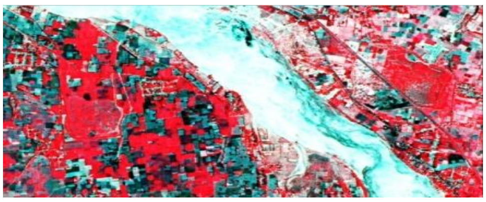
(d) Linear contrast stretch

Figure 2. Water body

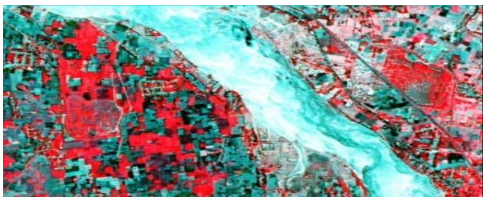
Figure 2 shows the original image and enhanced images using conventional methods and the proposed method. The original image obviously appears that the brightness is dark and the contrast is low. By using the conventional enhancement methods, the gray values with extremely dark or bright are visibly over saturated. As Figure 2 shows, the proposed method provides better visualization in color and details than other methods. Figure 3 and 4 are explaining the relationship of the enlarged imagery of Settlement region, river body in the same way. In these areas, the predictable enhancement methods tend to lose the tiny details of the imagery, as the proposed method can give an additional details and better contrast in the imagery



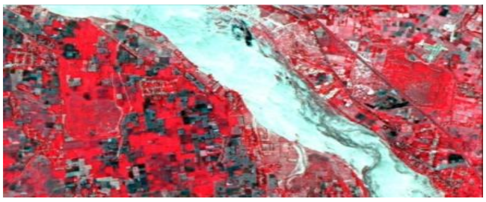
(a) River Body original Image



(b) Proposed Image

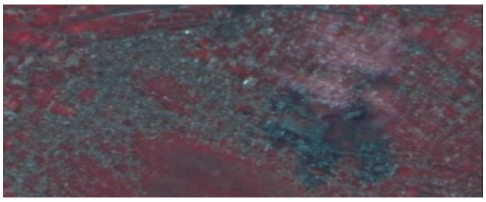


(c) Histogram Equalization

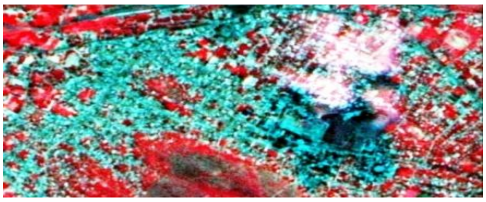


(d) Linear contrast stretch

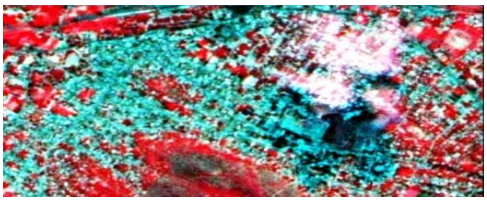
Figure 3. River Body



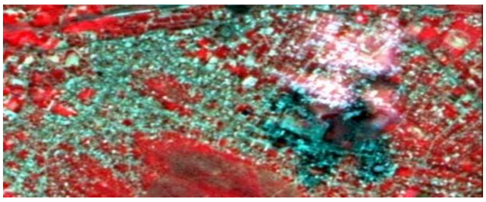
(a) Settlement region Original Image



(b) Proposed Image



(c) Histogram Equalization



(d) Linear contrast stretch

Figure 4. Settlement Region

VII. QUALITY ASSESSMENT

As shown in Figure 2, 3, 4, and 5, the proposed method provides significantly better contrast and details for human visual perception than the conventional enhancement methods. However, the visual performance of the contrast enhancement approach is difficult to evaluate and compare with different methods objectively. Hence, a metric index is required to estimate the result. In this study, two indices, entropy and Image Quality Measure, are used to evaluate the results.

A. *Shannon Entropy*

Shannon Entropy (or information entropy) is a method to measure the uncertainty of the information. Assume there are n events in the sample space, the probability of each event is pi (i= 1, 2, …, n), each pi is equal or greater than zero, and the sum of pi is defined to be 1. Therefore, a function H could be defined to measure the uncertainty of the sample space [13]. For image processing, n is given by the number of gray level. Then the H could be described as Eq.9. From the values of the entropy, it appears that the information of the image is richer when entropy is higher. Since the test data is multispectral image, the entropy in this study is calculated by averaging all bands. The entropy results are shown in Table 1. Entropy of the image enhanced by the proposed method is 5.071 which is higher than the values of images enhanced by the conventional methods.

$$H = -\sum_{i=0}^{L-1} P_i \ln(P_i) \tag{9}$$

where L is represented number of gray level, P_i is represented probability of level i in the histogram

B. *Image Quality Measure*

The proposed a method to measure the quality of natural scene based on human visual system. The algorithm performs as the following steps. First, the image is transformed to power spectrum using Fourier transform. Second, the power spectrum is normalized by brightness and size of the image. Third, a vision filter is used to incorporate with the human visual system model. Moreover, the system needs a noise filter to control the noise of the image and a directional scale factor to treat the images obliquely acquired [11]. Finally, the measure is obtained from the power spectrum weighted by the above processes. Equation10 shows the Image Quality Measure index. It appears that the image quality seems better when Image Quality Measure index is higher.

Table I also shows the Image Quality Measure index's of the images enhanced by the proposed method and the conventional methods. The comparison indicates that the image enhanced by the proposed method can obtain higher Image Quality Measure index and accordingly, better quality than the conventional methods

$$IQM = \frac{1}{I^2} \sum_{\theta=-180^0}^{180^0} \sum_{\rho=0.01}^{0.5} S(\theta_1) W(\rho) A^2(T\rho) P(\rho,\theta) \tag{10}$$

where I^2 is represented to image size, $S(\theta_1)$ is represented to directional image scale parameter, $W(\rho)$ is represented to modified Wiener noise filter, $A^2(T\rho)$ is represented to modulation transfer function of human visual system, $P(\rho, \theta)$ is represented to brightness normalized image power spectrum, ρ,θ is represented to spatial frequency in polar coordinates

Most conventional contrast enhancement algorithms usually fail to provide detailed contrast information in the dark and bright areas of remotely sensed images. This study proposed a fuzzy-based approach to enhance all the contrast and brightness details of the image. The test results indicate that the proposed method could provide better contrast image than the conventional enhancement methods in terms of visual looks and image details. Moreover, two image quality indices are used to evaluate the performance of the enhancement technique.

Table: 1 Algorithm Analysis

Index	Algorithm Analysis		
	Histogram Equalization	***Simple Linear Contrast Stretch***	***Proposed Method (FCM)***
IQM	4.30*10-3	2.92*10-3	4.72*10-3
Entropy	4.049	4.039	5.571

The comparison shows that the proposed method can produce better measurements than the conventional enhancement techniques. However, the stretch method used to enhance each cluster in this study is generated by a linear model with stretch parameters given by experience. In future work, the linear stretch model would be modified and constructed automatically with an optimization procedure in order to provide the image enhancement more feasible and efficient.

VIII.CONCLUSION

The test results derived from the proposed method could provide better contrast image than the conventional enhancement methods in terms of visual looks and image details. Moreover, two image quality indices were used to evaluate the performance of the enhancement technique. The stretch method used to enhance each cluster in this study is generated by a linear model with stretch parameters given by experience. The accuracy was derived by using IQM and the result is achieved as $4.72*10^{-3}$. Most conventional contrast enhancement algorithms usually fail to provide detailed contrast information in the dark and bright areas of remotely sensed images. This study proposed a fuzzy-based approach to enhance all the contrast and brightness details of the image.

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