Journal of Information Hiding and Multimedia Signal Processing ©2019 ISSN 2073-4212
Ubiquitous International Volume **10**, Number **4**, December **2019**

Enhancing Remote Sensing Image Contrast based on Combination of Fuzzy Logic and Local Approach

Trung Nguyen Tu*,Huy Ngo Hoang, Thoa Vu Van, Duc Dang Van, Anh Ha Trieu Phuong

Department of Information Technology, ThuyLoi University, 175 Tay Son, Hanoi, Vietnam
DienLuc University, Hanoi, Vietnam
Post and Telecommunications Institute of Technology, Hanoi, Vietnam
Vietnamese Academy of Science and Technology, Hanoi, Vietnam
Archimedes Academy, Hanoi, Vietnam
trungnt@tlu.edu.vn, huyngo3i@gmail.com, thoa236@gmail.com,
dvanduc@gmail.com, hatrieuphuonganh@gmail.com

Received August 2019; revised October 2019

Abstract. *The image enhancement methods are divided into 3 categories. These include histogram methods, fuzzy logic methods and optimal methods. Histogram based contrast enhancing methods modify histogram of images. Optimal methods are based on optimizing parameters. The fuzzy logic based image enhancement methods make image which quality is clearer than the traditional methods. However, these methods still use the global approach, therefore, it is difficult to enhance all land covered in remote sensing images. This paper proposes a new algorithm of enhancing the remote sensing images. This algorithm is based on combination of local approach and fuzzy logic.*

Keywords: Image enhancement, Fuzzy logic, Fuzzification, Defuzzification, Remote sensing images, Local approach

1. **Introduction.** Remote sensing images often have large size and high resolution. They can also contain noises. For noise reduction and image enhancement, we need to use methods to enhance the image quality. Quality Enhancement is a necessary step in image processing to complete some features of images. Noises in remote sensing images include common noises like color images and specific noises as mist, cloud For specific noises, we need specific methods of noise reduction such as removing cloud and mist using Mallat algorithm [3]. For common noises, we can use the common noise reduction methods such as noise filter, image smoothing, contrast enhancement, adjusting gray levels of images Many common contrast enhancement methods apply the global approach to enhance all brightness levels of images. However, it is difficult for the methods to enhance all land covered in remote sensing images because they can lose the local contrast information and details in bright and dark regions.

Image enhancement includes a variety of operations such as noise removal [4] [5], unblurring, and gray-level dynamic range modification. To improve the quality of the image and visual perception of human beings, a number of enhancement methods are to be applied [6], [7]. The image enhancement methods are divided into 3 categories including histogram, fuzzy logic and optimal methods [13]. Histogram based contrast enhancing methods focus on modifying histogram of images. Histogram specification and histogram equalization are commonly used as conventional contrast enhancement mothods. Optimal methods are based on optimizing parameters. The fuzzy logic based image enhancement methods make image which quality is clearer than the traditional methods.

Image enhancement techniques can be divided into two categories namely spatial domain and frequency domain methods [9]. The spatial domain method refers to aggregate of pixels composing an image, and they operate directly on the pixels of image. The frequency domain method refers to an aggregate of complex pixels resulting from taking the Fourier Transform and arises from the fact that this particular transform is composed of complex sinusoids. Due to the vast processing requirements, frequency-domain techniques are not widely used as spatial domain techniques. However, the enhancement in frequency domain is time-consuming process even with fast transformation technique, thus made it unsuitable for real time applications [10].

Fuzzy techniques are used for the enhancement of images. In [2] [8], the authors combine the fuzzy logic and the gray level adjusting formulas to enhance the contrast of images. The methods considered membership matrix and the gray level adjusting formulas to enhance contrast. However, the methods still use global approach, so they cannot solve the problem of traditional methods. In addition, the fuzzy image enhancing methods still select value of the upper, lower, and mean thresholds manually. Therefore, at no time does it select the good value, which may negatively affects the result of image enhancing. In [12], Cheng and partners proposed the algorithm of Contrast enhancement based on a novel homogeneity measurement. In this study, we propose a new algorithm of the image enhancement based on the local approach which combines the auto thresholds computing following each cluster, a gray level adjust model with using Fuzzy C-Means clustering algorithm.

The remaining sections of this report are presented as follows: Section II introduces a short overview of remote sensing and remote sensing images. Section III presents the algorithms of image enhancement based on fuzzy logic and the one of Cheng. Section IV shows the algorithm of remote sensing enhancement based on global approach. Experiments and accessments are presented in section V. Section VI is the conclusion of the article.

2. A Short Overview of Remote Sensing and Remote Sensing Images.

According to [11], remote sensing is science branch remote gathering the information on the Earth surface, including sensing and taking energy released, processing, analyzing data and applying the information after analysis. Besides, most of receiving systems and remote sensing images processing include seven-step process like figure 1.

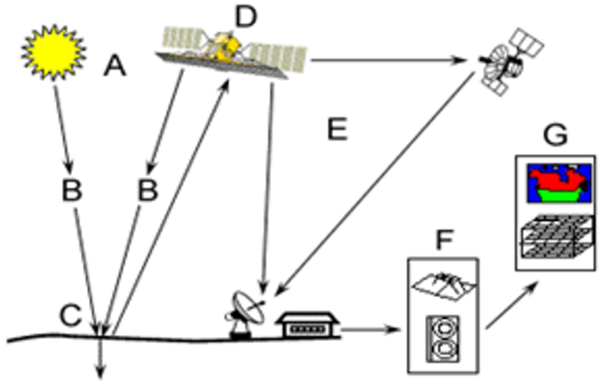

Figure 1. Process of gathering and processing remote sensing images [11]

In figure 1, A is energy source or bright source, B is radiance and atmosphere, C is interactive with destination object, D is energy gathered by sensor, E is energy transmission, reception and processing, F is interpretation and analysis, G is application. Remote sensing images have features: image channel, space resolution, spectrum resolution, radiant resolution and time resolution. There are many different types of remote sensing images/satellites such as weather sensing satellites (GOES, NOAA, AVHRR), ground observation satellites (Landsat, SPOT) Remote sensing images are applied in agriculture, forestry, geology, hydrography One of concrete applications is classifying land cover, building maps on the special subject in each field.

3. Enhancing Images based on Fuzzy Logic and of Cheng.

3.1. Image enhancement based on fuzzy logic.

3.1.1. *Overview of image enhancement based on fuzzy logic.* Fuzzy image enhancement is based on gray level mapping into a fuzzy plane, using a membership transformation function [2]. The aim is to generate an image of higher contrast than the original image by giving a larger weight to the gray levels that are closer to the mean gray level of the image than to those that are farther from the mean. In recent years, many researchers have applied the fuzzy set theory to develop new techniques for contrast improvement. An image I with its size of M x N and L gray levels can be considered as an array of fuzzy singletons, each having a value of membership denoting its degree of brightness relative to some brightness levels. For an image I, we can write in the notation of fuzzy sets:

$$I = \cup_{mn} \mu_{mn}/g_{mn} \tag{1}$$

Where: m=1,2,...,M n= 1,2,...,N g_{mn} is the intensity of $(m,n)^{th}$ is membership value. The membership function characterizes a suitable property of image (e.g. edginess, darkness, textural property) and can be defined globally for the whole image or locally for its segments. Some researchers have recently applied the concept of fuzziness to develop new algorithms for image enhancement. The principle of fuzzy enhancement scheme is illustrated in Figure 2.

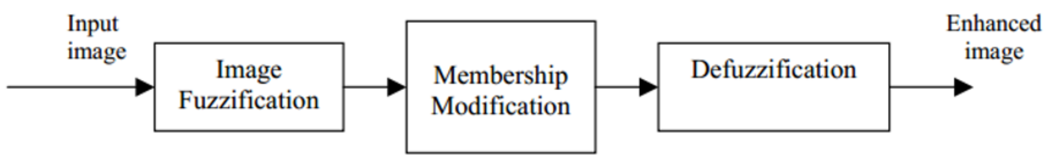

FIGURE 2. The Main Principles of Fuzzy Image Enhancement [2]

In the subsection 3.2 and 3.3, the article presents the algorithm of fuzzy image enhancement by using intensification operators and Hyperbol.

3.1.2. *Fuzzy image enhancement with intensification Operator.* This method uses the intensification operator [8] to reduce the fuzziness of the image which results in an increase of image contrast. The algorithm is described as follows:

Step 1: Setting the parameters F_e, F_d, g_{max} of membership function

$$F_e = 2 \tag{2}$$

$$F_d = \frac{g_{max} - g_{mn}}{0.5^{-1/F_e} - 1} \tag{3}$$

Step 2: Define the membership function

$$\mu_{mn} = G(g_{mn}) = [1 + \frac{g_{max} - g_{mn}}{F_d}]^{-F_e} \tag{4}$$

Step 3: Modify the membership values

$$\begin{cases} 2[\mu_{mn}]^2 & 0 \leq \mu_{mn} \leq 0.5 \\ 1 - 2[1 - \mu_{mn}]^2 & 0.5 \leq \mu_{mn} \leq 1 \end{cases} \tag{5}$$

Step 4: Generatenew gray-levels

$$g'_{mn} = G^{-1}\left(\mu'_{mn}\right) = g_{mn} - F_d\left(\left(\mu'_{mn}\right)^{\frac{-1}{F_e}} - 1\right) \tag{6}$$

3.1.3. *Fuzzy image enhancement with Hyperbol Operator.* Algorithm of Fuzzy image enhancement with Hyperbol Operator is described in [2]. Due to the nonlinear human brightness perception, this algorithm modifies the membership values of gray levels by a logarithmic function. The algorithm can be formulated as follows:

Step 1: Setting the shape of membership function.

Step 2: Setting the value of the fuzzifier β.

Step 3: Calculation of membership values μ_{mn}.

Step 4: Modification of the membership values by β.

Step 5: Generation of new gray levels, as described below.

The choice of the membership function is very important, as the membership function characterize a certain property of the image (edginess, darkness, textual property). In this algorithm the shape of membership function is set as a triangular to characterize the hedges, and the value of fuzzifier β as a linguistic hedge such that: $\beta = -0.75 + \mu 1.5$. Then by calculating the membership values μ_{mn} and modifying the membership values by β. Generate new gray levels values g_{mn} by following equation:

$$g'_{mn} = \left(\frac{(L-1)}{e^{-1} - 1}\right)\left(e^{-\mu_{mn} - g^{\beta}_{mn} - 1}\right) \tag{7}$$

3.2. **Enhancement algorithm of Cheng.** The proposed contrast enhancement algorithm of Cheng [12] is as follows:

Step 1. Compute the non-homogeneity value for each pixel (i,j) as:

$$\psi_{ij} = 1 - \beta_{ij} \tag{8}$$

where

$$\beta_{ij} = \beta\left(g_{ij}, w_{ij}\right) = \frac{HO_{ij}}{HO_{max}} \tag{9}$$

Step 2. Compute the mean non-homogeneity gray value σ_{ij} for window w_{ij} with center at pixel (i,j) as

$$\sigma_{ij} = \frac{\sum_{p=i-\frac{(d-1)}{2}}^{i+\frac{(d-1)}{2}} \sum_{q=j-\frac{(d-1)}{2}}^{j+\frac{(d-1)}{2}} (g_{pq} * \psi_{pq})}{\sum_{p=i-\frac{(d-1)}{2}}^{i+\frac{(d-1)}{2}} \sum_{q=j-\frac{(d-1)}{2}}^{j+\frac{(d-1)}{2}} \psi_{pq}} \tag{10}$$

where: $0 \leq i \leq M-1$, $0 \leq j \leq N-1$ and g_{pq} is the gray level of the pixel (p,q).

Step 3. Evaluate the contrast associated with pixel (i,j), and it can be calculated as

$$C_{ij} = \frac{|g_{ij} - \sigma_{ij}|}{g_{ij} + \sigma_{ij}} \tag{11}$$

Step 4. Transform the contrast C_{ij} to C'_{ij}

$$C'_{ij} = C_{ij}^{\xi'{ij}} \tag{12}$$

$$C_{ij}^{\xi'{ij}} = \xi_{ij}^{t} \tag{13}$$

where ξ_{ij} is the contrast amplification constant of pixel (i,j). It significantly affects the degree of the contrast enhancement, and it is related to the contrast of the given pixel. In Eq. (12), $0 \leq t \leq 1$.

$$\xi_{min} = \frac{g_k - g_1}{g_{max} - g_1}\xi_{ij} = \xi_{min} + \frac{\xi_{max} - \xi_{min}}{\beta_{max} - \beta_{min}} * (\beta_{ij} - \beta_{min}) \tag{14}$$

Step 5. The modified gray value g'_{ij} corresponding to the original gray value g_{ij} of the pixel (i,j) can be obtained by using the transformed contrast:

$$g'_{ij} = \sigma_{ij} x \frac{(1 - C'_{ij})}{(1 + C'_{ij})} \qquad if \qquad g_{ij} \leq \sigma_{ij} \tag{15}$$

or

$$g'_{ij} = \sigma_{ij} x \frac{(1 + C'_{ij})}{(1 - C'_{ij})} \qquad otherwise \tag{16}$$

Step 6. Repeat Step 1-5 for all pixels

3.3. **Disadvantages of the image enhancement algorithms based on fuzzy logic and the one of Cheng.** With a description of the fuzzy image enhancement method as above, we have the following comments:

Firstly, the fuzzy image enhancement algorithms use global approach, so advantages of this method are only adding a membership matrix to images. Therefore, this method is still difficult to enhance all land covered in remote sensing images because the local contrast information and details can still be lost in bright and dark regions.

Secondly, although the fuzzy image enhancement methods and Chengs methods can increase the contrast, they cannot change the brightness. Therefore, the enhancement is quite inefficient in images that are too bright or too dark.

Thirdly, like the traditional methods, the fuzzy image enhancement methods and Chengs methods only perform with a spectral channel. With multi-spectral images as color images RGB or remote sensing images, algorithm is performed on each channel. Suppose, having a pixel P with gray levels correspond to the channels as $\left((g_1^P, g_2^P, g_3^P)\right)$. So, gray values g_1^P, g_2^P, g_3^P have relation of the same pixel. When performing fuzzy image enhancement algorithm follow each channel, this relation is not covered. Therefore, each gray value in set $\left((g_1^P, g_2^P, g_3^P)\right)$ is enhanced independently so it is hard to ensure the above spectral relation of new gray values after enhancing. Therefore, color of objects in output image cannot be conserved. To overcome the above disadvantages, we propose a new remote sensing enhancement method based on the local approach according to cluster. Accordingly, gray levels are enhanced to follow each cluster. The algorithm of remote sensing image enhancement based on local approach is presented in section 4.

4. **Local based Remote Sensing Image Enhancement.**

4.1. **The algorithm of Local based Remote Sensing Image Enhancement.** The main steps of algorithm of Local based Remote Sensing Image Enhancement (LoRSIE) using FCM clustering algorithm are listed in table 1.

TABLE 1. Processing of LoRSIEK.

Step	Task
1	Localizating remote sensing image based on clustering algorithm KMeans
2	Constructing model of adjusting gray level in accordance with cluster
3	Calculating automatic thresholds in accordance with each cluster
4	Generating enhanced image based on the gray adjusting from cluster

4.1.1. *Localizing remote sensing image based on clustering algorithm Fuzzy C-Means.* Fuzzy c-Means clustering algorithm [1] of fuzzy segmentation is widely used.

4.1.2. *Constructing model of adjusting gray level in accordance with cluster.* In this subsection, we will construct function of gray level adjusting to enhance in accordance with each cluster. This function is constructed from the following gray level Stretch fomula:

$$g^{'} = 255 * \frac{g - min}{max - min} \tag{17}$$

The function of gray level Stretching in accordance with each cluster is stated as follows:

$$T_i\left(g, lower_{V_i}, upper_{V_i}\right) = 255 * \frac{g - lower_{V_i}}{upwer_{V_i} - lower_{V_i}} \tag{18}$$

Where: min : minimum value, max : maximum value, $lower_{V_i}$: lower bounds of cluster, $upwer_{V_i}$: upper bounds of cluster, g : original gray value, $g^{'}$: new gray value. With the above way, we constructed the function of gray level adjusting from gray level stretching operator. By the same way, we can construct the functions of gray level adjusting from Hyperbol, Intensification operators In this study, we construct the functions of gray level adjusting from gray level Stretching and Hyperbol operators in accordance with each cluster and they are listed in table 2.

TABLE 2. The functions of gray level adjusting in accordance with each cluster.

Name	Adjusting fomula $T_i\left(g\right)$
Gray level Stretch	$255 * \frac{g - lower_{V_i}}{upwer_{V_i} - lower_{V_i}}$
Hyperbolization	$\left(\frac{255}{e^{-1}-1}\right)\left(e^{-\mu^2(g)} - 1\right)$

Where:

$$\mu = \begin{cases} 0 & g \le lower_{V_i} \\ \frac{g - lower_{V_i}}{uper_{V_i} - lower_{V_i}} & lower_{V_i} \le g \le upper_{V_i} \\ 1 & upper_{V_i} \le g \le 255 \end{cases} \tag{19}$$

Values of the thresholds $upper_{V_i}$ and $lower_{V_i}$ are calculated automatically in accordance with each cluster V_i as described in next subsection.

4.1.3. *Calculating automatic thresholds in accordance with each cluster.* Suppose, $d(g)$ is called the distributed function of the g gray level following each cluster. $d(g)$ and the parameters: V_i, $upper_{V_i}$, $lower_{V_i}$ is showed in Figure 3. The thresholds upper and lower is determined by selecting so that area of subregion between the graphs of V_i, $upper_{V_i}$, $lower_{V_i}$, the distributed function $d(g)$ and horizontal axis equalize 95/100 area of region built by graph of the distributed function $d(g)$ and horizontal axis (crossover bar region).

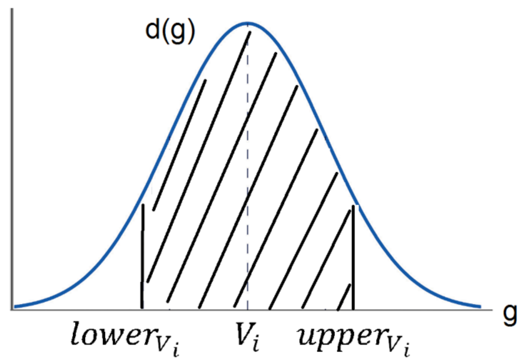

FIGURE 3. Distributed function and thresholds following each cluster.

4.1.4. *Generating enhanced image using the gray level model which adjusted in accordance with cluster.* Based on the model of adjusting gray level in accordance with cluster that constructed in subsection 4.1.2, each input gray value is changed into new values corresponding to the cluster. This function has general format as follows: $g \mapsto g' = T(g)$. Wherein,

$$T(g) = \sum_{i=1}^{c} \mu_i T_i \left(g, lower_{V_i}, upwer_{V_i}\right), 0 \le T(g) \le 255 \tag{20}$$

4.2. **Upgrading the algorithm to multi-spectral images.** We know that FCM algorithm clusters the objects which are vectors having many components. So, FCM algorithm performs well to multi-spectral images as color images RGB. Therefore, the algorithm LaRSIE is applied to the multi-spectral remote sensing images, called LoRSIE for multi-spectral images (LoRSIEMI), as follows:

Step 1: *Localizating input image.* After clustering procedure is executed, each pixel $P\left(g_1^P, g_2^P, g_3^P\right)$ belong to a cluster. We can consider this is feature of the same pixel relation of the set $\left(g_1^P, g_2^P, g_3^P\right)$. Thus, overcoming the third disadvantage in subsection 3.4.

Step 2: *Constructing gray adjust model.* This step is similar as described in subsection 4.1.2.

Step 3: *Calculating automatic thresholds.* The thresholds $lower_{V_i}^k$ and $upwer_{V_i}^k$ are calculated automatic in accordance with each cluster V_i and each channel k.

Step 4: *Generating enhanced image.* With each pixel P, we have:

$$T(g) = \sum_{i=1}^{c} \mu_i T_i (g, lower_{V_i}, upper_{V_i}), 0 \leq T(g) \leq 255 \tag{21}$$

Where: g_k^P : original gray value belong to kth of pixel P. $upper_{V_i}^k$: upper bounds of cluster belong to k^{th} channel. $lower_{V_i}^k$: lower bounds of cluster belong to k^{th} channel. V_i : center of cluster i^{th}. Each center V_i includes set (V_i^1, V_i^2, V_i^3)

4.3. Large-sized remote sensing image enhancement, LaSRSIE.

4.3.1. *Disadvantages of FCM over large-sized remote sensing image.* The FCM algorithm [1] cannot perform for large size images such as remote sensing images. FCM algorithm process to cluster directly input image. It is not sure that this can be executed with large size remote sensing images. The fuzzy clustering has problem when being executing large size images which are remote sensing images with high resolution. The problem is due the member matrix μ. According to formula 4 (section 2.A.1), size of μ is computed as following:

$$Size_\mu = c.n.8(Byte) \tag{22}$$

Where, c is cluster count, n is pixel count of image. Supposing we have an image with size $2048 * 2048$, we need segment to 20 clusters. Then, $Size_\mu$ is $2048 * 2048 * 20 * 8(B) = 640(MB)$. This matrix is stored in RAM. In this case, we need RAM 1GB to store the matrix. However, if we want to segment to 40 clusters, $Size_\mu$ is $1280(MB) > 1024(MB) = 1GB$. It means if we have only RAM 1GB then it will not contain enough elements of the matrix. Then, to execute FCM algorithm, we must increase RAM. If the size of image is $16000 * 16000$, cluster count c = 20, $Size_\mu$ is $16000 * 16000 * 20 * 8(B) = 640(MB) = 39062.5(MB)$ about 39(GB). With the above image size and the above cluster count, even with largest size RAM at the moment, PC (personal computer) cannot also contain the matrix, which leads to the fact that FCM unable to executed if this matrix is stored in RAM. Therefore, we can think of using hard disk to store this. However, then, even with the common color images, executing time of FCM is very low. With remote sensing, this time can be up to day unit. Therefore, it is not effective. The above analysis explains the reason why FCM [1] has problems with large size images that are specific remote sensing images.

4.3.2. *The Large Size Remote Sensing Image Enhancement (LaSRSIE) algorithm.* In this part, we propose the algorithm called Large Size Remote Sensing Image Enhancement (LaSRSIE). The diagram of the algorithm is illustrated in Fig. 4.

According to the diagram, the algorithm is performed as follows: Firstly, the first image is lowered the size from the size of using Wavelet propitious change to smaller size that is selected for approximately minimum image. Selected approximately minimum image enhancement uses LaRSIE algorithm. Next, using enhanced approximate image instead of approximately minimum image and carrying out the contrary change by using Wavelet propitious change in order to get enhanced image that corresponds to original image.

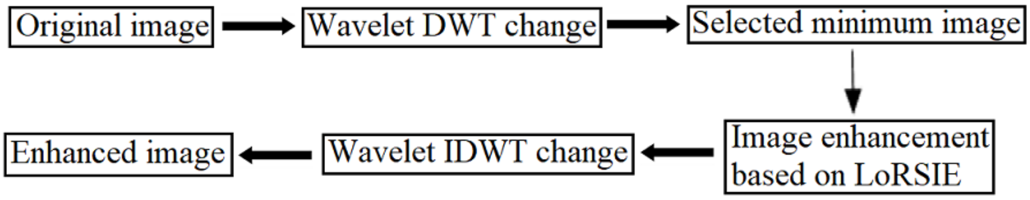

FIGURE 4. The diagram of LaSRSIE.

5. **Experiments.** We test the proposed algorithm and compare to the fuzzy algorithm. Data set used for experiments includes 3 types. The first, Landsat ETM+ images are taken in Hoa Binh area in 2001, including 11 pictures about districts and 1 picture about Hoa Binh province. Landsat ETM+ image includes 7 channels: Indigo, Green-red, Red, Near infrared, Medium infrared, Heat infrared, Medium infrared. The second, SPOT images, including 4 channels: Green, Red, Near infrared, Infrared, which are about Hoa Binh and Son La areas with 21 pictures in 2003 and 14 pictures in 2008. In there, SPOT images with high resolution The third, Quickbird images, including 4 channels: Blue, Green, Red and Near infrared, which are downloaded from model data on website: http://opticks.org. Because of the limited scope of the paper, the authors present experiments with different four input images. Results of the proposed method are compared with results of the fuzzy method and result of the recent research of Cheng, in 2003 [12]. To measure the quality of the original and enhanced images, we use the linear index of fuzziness γ [2][8]. Wherein:

$$\gamma = \frac{2}{MN} \sum_{M} \sum_{N} min\left(\mu_{mn}, 1 - \mu_{mn}\right) \tag{23}$$

The index of fuzziness was defined by Kaufmann [8].The index of fuzziness, for instance, reflects the ambiguity in an image by measuring the distance between its fuzzy property plane and the nearest ordinary plane. This index can be regarded as a degree of difficulty in deciding whether a pixel should be treated as black (dark) or white (bright). The value of the index of fuzziness is smaller, the contrast of image is greater. In Experiments, input images are clustered into 15 clusters.

5.1. **Expriment 1.** In experiment 1, original image is a LANSAT image about the Kim Boi district, belong to Hoa binh province. Results is shown in figure 5 and table 3.

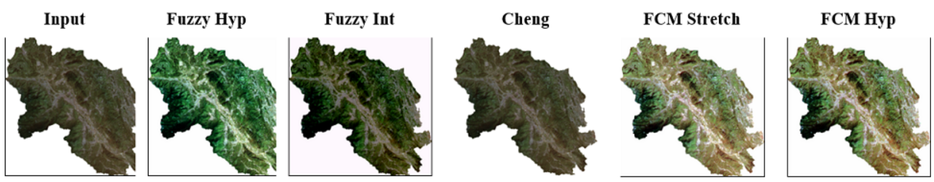

FIGURE 5. Enhancing images with the methods.

5.2. **Expriment 2.** In experiment 1, original image is a LANSAT image about the Lac Thuy district, belong to Hoa binh province. Results is shown in figure 6 and table 4.

5.3. **Expriment 3.** In experiment 3, original image is a SPOT image.Results is shown in figure 7 and table 5

Table 3. Compare Fuzzy Index of enhanced images by the methods.

Band	Fuzzy Hyp	Fuzzy Int	Cheng	FCM Stretch	FCM Hyp
1	0.38	0.43	0.32	0.27	0.30
2	0.31	0.45	0.35	0.24	0.26
3	0.38	0.39	0.36	0.34	0.36

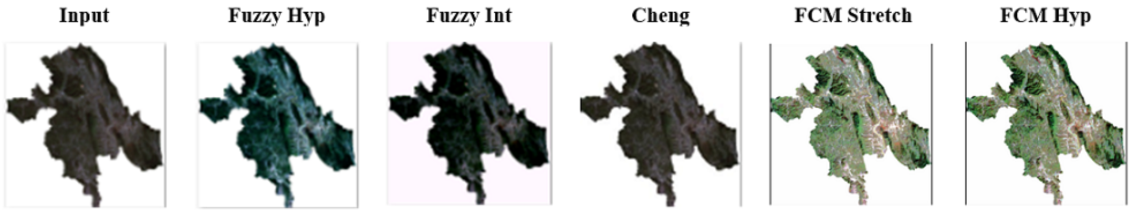

Figure 6. Enhancing images with the methods.

Table 4. Compare Fuzzy Index of enhanced images by the methods.

Band	Fuzzy Hyp	Fuzzy Int	Cheng	FCM Stretch	FCM Hyp
1	0.28	0.28	0.20	0.12	0.15
2	0.27	0.30	0.25	0.07	0.09
3	0.27	0.28	0.23	0.19	0.23

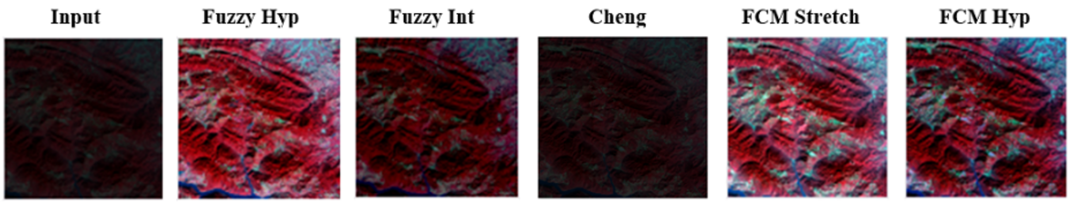

Figure 7. Enhancing images with the methods.

5.4. **Expriment 4.** In experiment 4, original image is a Quickbird image.Results is shown in figure 8 and table 6.

Comment: Figure 5, 6, 7, 8 includes input and result images which are enhanced by using the fuzzy method with the intensification and hyperbolization operators and the proposed method with the stretch and hyperbolization operators. Visually, in tables 5 and 6, we see that the enhanced images of fuzzy method do not conserve color correlation, especially with hyperbolization operator. The enhanced images of Cheng almost make the brightness change a bit. However, in table 7, The enhanced image of Cheng is bad. While result images of proposed method still conserve color correlation and prominent than original image and the brightness changes obviously. In table 3, 4, 5, 6, through comparing fuzzy index of images, we see that γ of result images of the proposed method are smaller than γ of result images of the fuzzy method. This insists that quality of enhanced images of proposed method is higher than quality of enhanced images of fuzzy method.

6. **Conclusions.** In this study, we proposed new algorithms of enhancing contrast of remote sensing images LoRSIE-FCM and LoSRSIEMI based on local approach. LoRSIE-FCM includes 4 steps. The first, input image is localizated by algorithm FCM. Then,

Table 5. Compare Fuzzy Index of enhanced images by the methods.

Band	Fuzzy Hyp	Fuzzy Int	Cheng	FCM Stretch	FCM Hyp
1	0.72	0.60	0.64	0.20	0.33
2	0.87	0.84	0.49	0.33	0.51
3	0.85	0.81	0.59	0.22	0.41

Figure 8. Enhancing images with the methods.

Table 6. Compare Fuzzy Index of enhanced images by the methods.

Band	Fuzzy Hyp	Fuzzy Int	Cheng	FCM Stretch	FCM Hyp
1	0.69	0.64	0.63	0.41	0.52
2	0.70	0.67	0.64	0.48	0.54
3	0.68	0.65	0.59	0.36	0.57

modifying the gray level adjust formula to to fit each cluster. Next, thresholds are calculated automatic in accordance with each cluster. Finally, Generating enhanced image by the gray level model which adjusted in accordance with each cluster. LoSRSIEMI is upgrated for the multi-spectral remote sensing images. Test results showed that proposed methods new images which have higher quality than fuzzy method and method of Cheng.

Acknowledgment. This work is partially supported by Department of Information Technology, Thuy Loi University and Institute of Information Technology, Vietnamese Academy of Science and Technology. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

REFERENCES

[1] J.C. Bezdek, R. Ehrlich, W.Full, FCM: the fuzzy c-Means clustering algorithm, *Computers and Geosciences*, vol. 10, no. 2-3, pp. 191-203, 1984.

[2] A.E. Hasanien, A, Badr, A comparative study on digital mamography enhancement algorithms based on fuzzy theory, *Studies in Informatics and Control*, vol.12, no.1, March 2003.

[3] Zhu Xifang, Wu Feng, An improved approach to remove cloud and mist from remote sensing images based on mallat algorithm, *International Symposium on Photoelectronic Detection and Imaging*, Beijing 2007.

[4] G. Sudhavani, G.Madhuri, P. Venkateswara Rao and K. Satya Prasad, Removing of gaussian noise from color images by varying size of fuzzy filter, *International Journal of Computer applications*, vol. 72, No. 17, pp. 09751-8887, June 2013.

[5] [G. Sudhavani, G. Madhuri, P. Venkateswara Tao and Dr. K. Satya Prasad, Additive noise removal for color images using fuzzy filters, *International Journal of Computer Science, Engineering Applications (IJCSEA)*, vol. 3, No. 3, June 2013.

[6] Byoung-Woo Yoon, Woo-Jin Song, Image contrast enhancement based on the generalized histogram, *Journal of Electronic Imaging*, vol. 16, no. 3, 033005 July-Sep 2007.

[7] Dr. H. Mamatha Devi, S. Somorjeet Singh, Th. Tangkeshwar Singh, O. Imocha Singh, A new easy method of enhancement of low contrast image using spatial domain, *International Journal of Computer Applications*, vol. 40, no. 1, February 2012.

[8] G.Sudhavani, M.Srilakshmi, P.Venkateswara Rao, Comparison of fuzzy contrast enhancement techniques, *International Journal of Computer Applications*, vol. 95, no.22, pp. 0975-8887, June 2014.

[9] R. Maini and H. Aggarwa, A comprehensive review of image enhancement techniques, *Journal of Computing*, vol. 2, no. 3, March 2010.

[10] K. Hasikin and N. Ashidi Mat Isa, Enhancement of the low contrast image using fuzzy set theory, *14th International Conference on Modeling and Simulation IEEE*, 2012.

[11] Canada Center for Remote Sensing, *Fundamentals of Remote Sensing*, http://www.ccrs.nrcan.gc.ca, 2008.

[12] H.D. Cheng M. Xue, X.J. Shi, Contrast enhancement based on a novel homogeneity measurement, *Pattern Recognition*, vol. 36, no. 11, pp. 2687-2697, 2003.

[13] Adlin Sharo T, Kumudha Raimond, A Survey on Color Image Enhancement Techniques, *IOSR Journal of Engineering (IOSRJEN)*, vol. 3, no. 2, Feb. 2013.