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A self-adaptive Contrast Enhancement Method Based on Gradient and Intensity Histogram for Remote Sensing Images

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Abstract. This paper proposes an efficient method to modify gradient and intensity histograms (GIH) for contrast enhancement, which plays an important role in remote sensing image processing and information extraction. First, a self-adaptive algorithm is used to flatten the shape of GIH of input image according to standard deviation of GIH. Then, the standard lookup table-based histogram equalization procedure is applied to get well enhanced image. Experimental results, using various remote sensing images, show that the proposed method generates enhanced images with more information and higher visual quality, compared with several conventional methods.

1. Introduction

Contrast enhancement (CE) plays a vital role in the image quality improvement for agriculture surveillance, military reconnaissance, and geoscience studies of remote sensing images [1]. Several circumstances may reduce contrast in remote sensing images, including undesirable weather conditions, lacking of sunlight, and old observational devices. Essentially, if the overall luminance is excessive or insufficient, the details of the image features will be lost.

To date, many techniques have been carried out on image contrast enhancement. The CE techniques can be divided into two categories: transform-domain and spatial-domain methods [2]. For transform-domain methods, the image can be decomposed into different sub-bands and the contrast enhanced by modifying specific components. However, most of these methods unfit for complex images and sometimes may bring artifacts. The image spatial-domain methods attempt to enhance image contrast by redistributing the probability density of gray levels. Histogram equalization (HE) is the most popular spatial-domain enhancement technique due to its easy, fast and effective implementation. However, it always generates excessive enhancement of the high histogram region and brings artifacts. Many methods have been presented to eliminate overenhancement in HE method, such as mean preserving bihistogram equalization (BBHE), brightness preserving histogram equalization with maximum entropy (BPHEME), entropy maximization histogram modification (EMHM) and flattest histogram specification with accurate brightness preservation (FHSABP) [3-6]. For the purpose of alleviating overenhancement and preserving important detail information, gradient and intensity histogram equalization (GIHE) based methods are applied to enhance contrast of image [4]. The GIH contains both gradient and intensity information of image. It can alleviate overenhancement existing in the traditional histogram equalization techniques. Nevertheless, these GIHE-based methods are still not enough to achieve satisfactory CE results for remote sensing images.

In this paper, we propose a novel method for remote sensing image enhancement which is an extension of GIHE. First, the method calculates a self-adaptive parameter to change the distribution of gradient and intensity histogram (GIH). Second, the modified GIH is used to enhance the contrast of the input image by applying the standard lookup table-based HE procedure. The experimental results have indicated that the proposed method can obtain promising results in statistical properties and visual assessments.

2. Proposed method

2.1 Observation.

In this part, we present the observation on image enhancement of the GIHE, then, give a conclusion for improvement of image enhancement.

Unlike traditional histogram, the GIH contains both gradient and intensity information of image. It can alleviate overenhancement existing in the traditional histogram based image enhancement techniques [4]. The GIH is defined by

$$GIH(k) = G(k) / sum(G)$$

(1)

where $k = 1, 2, ..., K$; K is the number of gray levels; G is gradient image calculate by gradient operator as proposed in [4], $G(k)$ is the sum of gradient value at the gray level k .

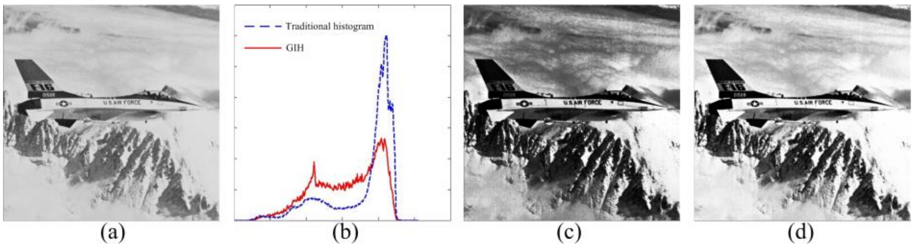


Fig.1 Illustration the difference of gradient and intensity histogram equalization and traditional histogram equalization of avion image: (a) the original image, (b) the corresponding traditional histogram and GIH, (c) image enhanced by histogram equalization (HE), (d) image enhanced by GIHE.

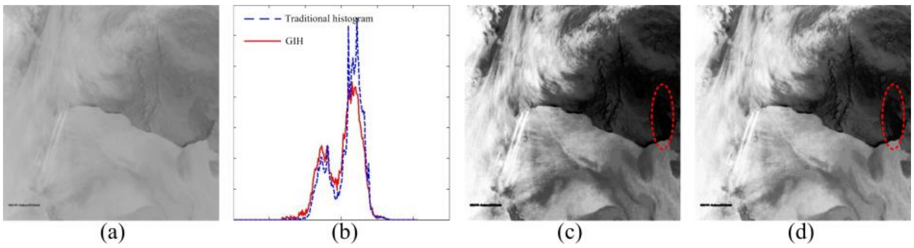


Fig.2 Illustration the difference of gradient and intensity histogram equalization and traditional histogram equalization of cloud image: (a) the original image, (b) the corresponding traditional histogram and GIH, (c) image enhanced by histogram equalization (HE), (d) image enhanced by GIHE.

The contrast enhancement of GIHE is positive correlation with the height of the histogram, which is similar to histogram equalization. Hence, the gray scales of the high histogram region are extended to a larger range. Fig. 1 shows the difference of gradient and intensity histogram equalization and traditional histogram equalization of avion image. As shown in Fig. 1(c), some details of the dark parts of the white snow areas and the sign of “F-16” are lost by applying the HE procedure. Compared with the traditional histogram, the explanate GIH can alleviate overenhancement (Fig. 1(d)), the avion image is visual pleasant. Moreover, since GIH contains structure information of an image, it makes the enhanced image with more clear details. Fig. 2 shows the difference of gradient and intensity histogram equalization and traditional histogram equalization of cloud image. As shown in Fig. 2(c) and Fig. 2(d), details in the ellipse areas are lost by applying the HE and GIHE procedure, due to that the GIH and the traditional histogram have the similar high histogram region. In despite of overenhancement of GIHE, it still has more pleasant visual presentation and more details than the HE.

As described above, we can conclude that GIH has more detail information than the traditional histogram, which is suit for remote sensing image enhancement in keeping important structural information of geo-objects. However, we need to pay attention to that if GIH has high peaks, the GIHE method cannot avoid overenhancement.

2.2 GIH-Based Self-Adaptive Contrast Enhancement.

Since image quality of GIHE is related to the distribution of GIH, there is no universal procedure to alleviate high peaks in GIH. According to the observation, we propose a measure to change the distribution of GIH, as follow

$$GIH_f(k) = GIH(k)^p \tag{2}$$

$GIH_f(k)$ is the modified GIH, p is the parameter to modify the GIH, the value of p is from 0 to 1. If p is equal to 0, the equalization procedure based on modified GIH is similar to linear enhancement; if p is equal to 1, the equalization procedure is the GIHE. Then the $GIH_f(k)$ is normalized by

$$GIH_f(k) \leftarrow GIH_f(k) \Big/ \sum_{g=1}^{K} GIH_f(g) \tag{3}$$

and uniform cumulative distribution function F is calculated by

$$F(k) = \sum_{g=1}^{k} GIH_f(g) \tag{4}$$

The mapping function is defined by

$$y_f(k) = \lfloor F(k)(y_u - y_d) + y_d \rfloor \tag{5}$$

y_f is the final enhanced image, y_u and y_d are the max and min values of the output image.

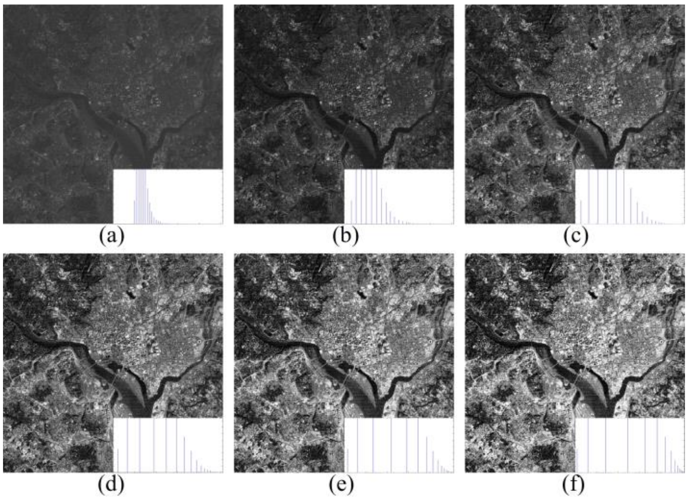


Fig. 3(a) Input Landsat image. Enhanced image by different p values: (b) $p = 0.1$, (c) $p = 0.3$, (d) $p = 0.5$, (e) $p = 0.7$, (f) $p = 0.9$.

Fig. 3 shows the enhanced images with different p values. As p value increased, the degree of enhancement is increasingly stronger. It's shown that the enhanced image of Fig. 3(c) is visually pleasant with no artifacts. However, large values of p lead to overenhancement phenomenon and visually unpleasant results, as illustrated in Fig. 3(d)-(f). Conversely, as shown in Fig. 3(b), a low value of p leads to underenhancement. According to illustration of Fig. 3, it concluded that the appropriate p value is the key point to get satisfactory enhanced image. In the image enhancement processing, it is time consuming to set the appropriate p value, thus, a simple automatic parameter is crucial for the contrast enhancement. There, the self-adaptive parameter p based on standard deviation is introduced as

$$p = e^{stdh} - 0.7 \tag{6}$$

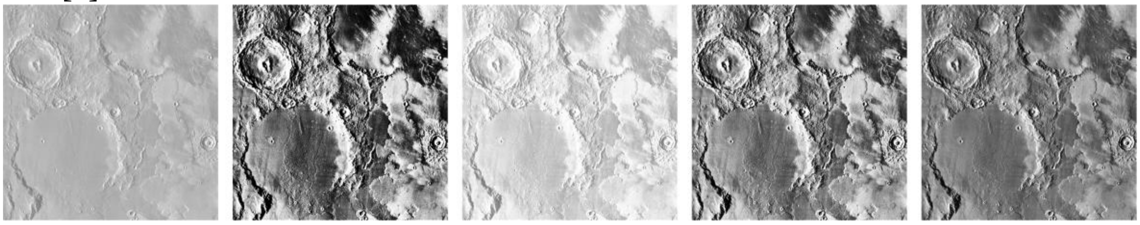
The $stdh$ is defined as

$$stdh = std(GIH) \big/ (2^B - 1) \tag{7}$$

where B is the image bit depth, $std(*)$ is used to calculate the standard deviation. According to the formula (6), the larger standard deviation of GIH is, the higher enhancement is produced.

3. Results and Discussion.

To evaluate the performance of the proposed method, various remote sensing images were used for test even though only three pictures are shown in Figs. 4-6(a). Three well known image CE methods based on histogram modification are used for comparison, including traditional GHE [2], AGCWD [7], BP-GIHE [8].

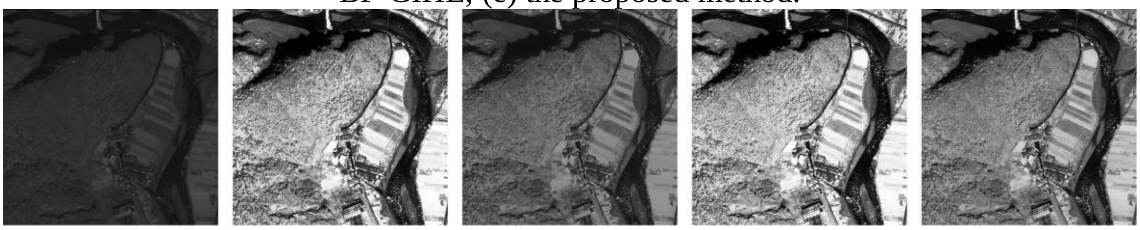


(a) (b) (c) (d) (e)

Fig. 4 (a) Original Mars image. contrast-enhanced images by using (b) GHE, (c) AGCWD, (d) BP-GIHE, (e) the proposed method.

(a) (b) (c) (d) (e)

Fig. 5 (a) Original Island image. contrast-enhanced images by using (b) GHE, (c) AGCWD, (d) BP-GIHE, (e) the proposed method.



(a) (b) (c) (d) (e)

Fig. 6 (a) Original Hill image. contrast-enhanced images by using (b) GHE, (c) AGCWD, (d) BP-GIHE, (e) the proposed method.

Figs. 4-6 show the enhancement results of GHE, AGCWD, BP-GIHE and the proposed method. As shown in Figs. 4–6(b), the results of the traditional GHE algorithm show over enhancement phenomenon. This is because it simply change histogram based on gray level probability, which would lead to over stretching at the region of high peak histogram. The AGCWD method has produced saturation artifacts in bright regions, particularly in Figs. 4(c) and 5(c). The BP-GIHE has better performance than GHE and AGCWD in visual display. However, in spindrift region of Figs. 5(d), the contrast is reduced and some details are lost. The enhanced results of Figs. 4-6(e) demonstrate the proposed method has achieved visual pleasant enhanced results with reasonable high contrast and abundant local details. For example, the local details in spindrift region of Figs. 5(e) are much clear than the other three methods.

In order to present the enhancement quality, the discrete entropy (E) is applied to measure information of the enhanced image [2], which is defined by

$$E = -\sum_{k=1}^{K} h(k)\log_2 h(k) \tag{8}$$

where $h(k)$ is the probability of the pixel value k in the histogram. The enhanced image with higher value of E indicates it has more useful information [2]. As shown in Table I, the original images have the highest E values. The images enhanced by the four methods have the lower values than the original images. The reason is that the gray levels of enhanced images are reduced during the enhancement processing. Although the original pictures the highest E value, there is not enough useful information in the pictures because of its low contrast. Conversely, the proposed method is providing natural enhanced images with the second best E values. It proves that the proposed method has better performance for providing more useful information compared with other three methods.

Table 1 Quantitative Measurement Results of E

	Input	GHE	AGCWD	BP-GIHE	Proposed
Mars	5.8262	5.3684	5.6574	5.7424	5.8234
Island	6.0199	5.2041	5.7813	5.9092	5.9955
Hill	5.5869	5.3037	5.5525	5.5213	5.5865
Mean Value	5.8110	5.2921	5.6637	5.7243	5.8018

4. Conclusion

In this paper, a self-adaptive remote sensing image enhancement method based on GIH has been proposed. The proposed method calculated the GIH using the gradient to replace the probability of each gray level. This can preserve the structural information of geo-objects. Then a self-adaptive parameter, determined by standard deviation of GIH, was used to alter the GIH to a flat model. After GIH alter, the standard lookup table-based HE procedure was applied to change the gray level of the input image to get final enhanced results. The method was compared with the GHE, AGCWD and BP-GIHE. Qualitative and quantitative assessments both indicate that the proposed method is more effective than the compared state-of-the-art methods.

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