Implementation of Enhancement Algorithms for Satellite Remote Sensing Images

A report on Miniproject on image processing(EC386)

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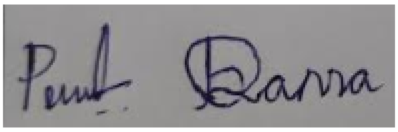
DECLARATION CERTIFICATE

We hereby declare that the mini project of Image Processing (EC-386) work entitled "Implementation of Enhancement Algorithms for Satellite Remote Sensing Images" which are being submitted to the National Institute of Technology, Karnataka, Surathkal, in partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology in Electronics Communication Engineering in the department of ELECTRONICS AND COMMUNICATION ENGINEERING is a bonafide report of the research work carried out by us. The material contained in this minor project has not been submitted to any other University or Institution for the award of any degree.



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1 Abstract

Enhancement algorithms are absolutely necessary for the visualization of both shadowed and bright image regions. Defining algorithms that permit to visualize them simultaneously without altering the image content is therefore extremely relevant for remote sensing applications. In this paper various image enhancement methods useful for remote sensing satellite images are implemented and tested with various input images giving a comparison between various methods to show which method to use for a given input image based on various parameters in Input images.

2 Introduction

The demand of high-quality remote sensing images is rapidly increasing due to the wide spread use of these images in various applications such as military, geosciences, agriculture, and astronomy. The undesirable environmental conditions reduce the contrast and the hidden details of the captured remote sensing images. Since contrast is an important quality factor in remote sensing images [1], therefore, contrast enhancement techniques are required for better information representation and visual perception. In general, the contrast enhancement methods can be divided into two categories, i.e., image spatial-domain methods and transform-domain methods. Among the image spatial-domain algorithms, the traditional histogram equalization (HE) [2] is the most widely used algorithm due to its simple and effective implementation. Transform-domain methods decompose an input image into different sub bands and enhance the contrast by modifying specific components. In, a singular value equalization method is proposed to adjust the image brightness. This method is further improved by combining with discrete wavelet transform in [1] to achieve better contrast enhancement results. In general, the satellite or remote sensing images usually present more than just one specific contrast problem. As can be observed in the examples displayed in Fig. 2, it is common to find images containing color cast and shadows or images presenting both shadows and fog. Contrast enhancement is one of the most important issues in image processing. Among all image processing techniques, it is the one that has the strongest impact on image quality. Many contrast enhancement techniques have therefore been proposed to improve image contrast. There are 3 different types of contrast enhancement techniques 1) Histogram - based methods. 2) Center - surround methods. 3) Gradient - Domain based methods.

3 Global Contrast Enhancement

Suppose an input remote sensing image X of size M × N with a dynamic range of [xmin, xmax], where xmin and xmax are the minimum and maximum elements of X, respectively. The goal is to produce an output global contrast enhanced image Yglobal with a new dynamic range of [ymin, ymax]. For example, $ymin = 0$ and $ymax = 255$ for 8-bit images. Since the traditional HE generates overenhanced results when there exist high peaks in the input histogram, the targeted distribution function for creating the output should be adjusted to avoid this problem. The overenhancement and saturation artifact problem can be effectively avoided by utilizing the smoothness and compression characteristics of the sigmoid function in finely regularizing the input histogram. Thus, a new distribution function f is generated as

$$f(k) = s(k)(1 + h(k)) \tag{1}$$

where h is the normalized input histogram; k = 1, . . .,K; and K is the number of the gray levels in the input image X. Sigmoid function s is modified as

$$s(k) = \frac{1}{1 + e^{(-k+1)}} - \frac{1}{2} \tag{2}$$

This modification assures the minimum of the enhanced image be equal to 0. Distribution function f is further normalized according to

$$f(k) = f(k) / \sum_{t=1}^{K} f(t) \tag{3}$$

and uniform distribution function F is computed by

$$F(k) = \sum_{t=1}^{k} f(t) \tag{4}$$

The new gray levels y(k) are computed by using F(k), ymin, and ymax

$$y(k) = F(k)(ymax - ymin) + ymin \tag{5}$$

Finally, the global contrast enhanced image Yglobal is obtained by adopting a standard lookup table-based HE procedure with new gray levels.

4 Local Detail Enhancement

In order to enhance both the global contrast and the local details in the remote sensing images, the DCT coefficients of the previous global enhanced image are further adjusted. For the 2-D image, 2-D DCT [2] is adopted to obtain the coefficients. The 2-D DCT coefficients D of size M × N are computed by

$$D(h,w) = c_h c_w \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} Y_{global}(i,j) \cos \frac{\pi(2i+1)h}{2M} \cos \frac{\pi(2j+1)w}{2N} \tag{6}$$

where $0 \le i$, $h \le M-1$, $0 \le j$, and $w \le N-1$. ch and cw are computed by

$$c_h = \begin{cases} \sqrt{\frac{1}{M}}, & h = 0 \\ \sqrt{\frac{2}{M}}, & 1 \le h \le M-1 \end{cases}$$

$$c_w = \begin{cases} \sqrt{\frac{1}{N}}, & w = 0 \\ \sqrt{\frac{2}{N}}, & 1 \le w \le N-1. \end{cases}$$

Note that lower absolute values of D represent the lower energy components, i.e., details and textures, and vice versa. Moreover, D(0, 0) is the largest energy component that represents the mean value of the image. To emphasize the local details, low energy parts should be adjusted, whereas high energy parts should be maintained to avoid any significant change. Based on this analysis, a thresholding algorithm is designed to properly adjust coefficients D by

$$D'(h,w) = \begin{cases} D(h,w), & \text{if } |D(h,w)| > 0.01 \times D(0,0) \\ \alpha D(h,w), & \text{otherwise} \end{cases}$$

where $\alpha > 1$ is the parameter that controls the level of local detail enhancement. Based on the observation of our enhanced results of over 100 images, 0.01 is an appropriate empirical value to separate high and low energy parts. However, a large value of α may result in overenhancement. Thus, a simple automatic parameter setting for α is introduced as

$$\alpha = 1 + \sqrt{\frac{std(Y_{global}) - std(X)}{2^B - 1}} \tag{7}$$

where B is the image bit depth, and std(Yglobal) and std(X) are the standard deviations of the previously enhanced image Yglobal and the input image X, respectively. The larger the difference between std(Yglobal) and std(X) is, the higher local details enhancement is achieved. Lastly, the final enhanced output image Yfinal is obtained by using the inverse 2-D DCT transform [2] of D'.

5 Histogram - Based Methods

TABLE I
HISTOGRAM-BASED METHODS

Name	Description	Advantages	Disadvantages
Simplest Color Balance (SCB, [14])	$T_{SCB}(u) = \frac{u-u_{min}}{u_{max}-u_{min}}$, $\#\{\mathbf{x} : u(\mathbf{x}) \leq u_{min}\} = s_1\%$ of N, $\#\{\mathbf{x} : u(\mathbf{x}) \geq u_{max}\} = s_2\%$ of N	Good results in satellite images, with small clipping percentages.	Saturation can create flat white regions or flat black regions that may look unnatural. Parameters: s_1 and s_2 (clipping percentages).
Histogram Equalization (HE)	$T_{HE}(u) = F(u)$, $F(l) = \frac{\#\{\mathbf{x}:\ u(\mathbf{x}) \leq l\}}{N}$	Increases the global contrast. No parameters	Excessively reveals noise and quantization.
Piecewise Equalization (PE, [15])	$T_{PE}(u) = F_{k'}(u), \quad l_{k'} \leq u \leq l_{k'+1}$ $F_k(l) = z_k + m_k(l - l_k)$, $k = 0, 1, \ldots, M$ $z_k = k/M$, $l_k = F^{-1}(z_k)$, $m_k = \max(s_{min}, \min(s_{max}, \frac{z_{k+1}-z_k}{l_{k+1}-l_k}))$,	Limits the SNR, local degradation, and color attenuation.	Slope too small, contrast reduction Slope too large, noise amplification. Parameters: M, s_{min}, s_{max}.
Ideal Gamma (IG)	$T_{IG}(u) = \left(\frac{u-u_{min}}{u_{max}-u_{min}}\right)^{\gamma}$, γ s.t. $\frac{1}{N}\sum_{\mathbf{x}} u(\mathbf{x})^{\gamma} - 0.5 = 0$,	Simple. No parameters.	Poor enhancement in some images. Saturation of bright regions.

Figure 1: Histogram - Based Methods

6 Center - Surround Based Methods

TABLE II
CENTER/SURROUND METHODS

Name	Description	Advantages	Disadvantages
Multi-Scale Retinex (MSR, [25])	$T_{MSR}(u(\mathbf{x})) = \sum_{k=1}^{K} w_k \left[\log u(\mathbf{x}) - \right.$ $\left. - \log((G_{\sigma_k} * u)(\mathbf{x}))\right]$, $G_{\sigma_k}(\mathbf{x}) = C_k \exp[-(\|\mathbf{x}\|^2)/2\sigma_k^2]$	Well-known and very used method. In general, good results.	Arbitrary bounds in the solution. Possible halo effects. Excessive parameters. Parameters: K, ω_k and σ_k, for every k.
Other retinex kernels [22]	$T_{Rkernel}(u(\mathbf{x})) =$ $\log(u(\mathbf{x})) - \log((u * F)(\mathbf{x}))$		
Land Kernel (MSRKLAND)	$F_{\text{land}}(\mathbf{x}) = \frac{1}{\|\mathbf{x}\|^2}$	Scale invariant, faithful to the original method. No parameters.	Is not integrable. Possible halo effects. Saturation of bright zones.
ACE Kernel (MSRKACE)	$F_{\text{ACE}}(\mathbf{x}) = \frac{1}{\|\mathbf{x}\|}$	No parameters. Good color rendition.	Is not integrable. Possible halo effects.
New Kernel (MSRNK)	$F_{\text{new}}(\mathbf{x}) = C\frac{G_{\sigma_2}(\mathbf{x}) - G_{\sigma_1}(\mathbf{x})}{\|\mathbf{x}\|^2}$, $\|\mathbf{x}\| \neq 0$ $F_{\text{new}}(\mathbf{x}) = C\frac{\sigma_1^{-2} - \sigma_2^{-2}}{2}$, $\|\mathbf{x}\| = 0$ $\sigma_i = a^{s_i}$, $i = 1, 2$	Integrable. The parameters allow to adjust the level of contrast.	Possible halo effects. Parameters: s_1, s_2 and a.
Local Color Correction (LCC, [23])	$T_{LCC}(u(\mathbf{x})) = (u(\mathbf{x}))^{2^{\frac{0.5 - M(\mathbf{x})}{0.5}}}$, $M(\mathbf{x}) = (G_r * (1 - I))(\mathbf{x})$.	Allows simultaneous shadow and highlight adjustment.	Possible halo effects. Parameter: r.
Automatic Color Enhancement (ACE, [24])	$T_{ACE}(u(\mathbf{x})) = \frac{R(\mathbf{x}) - R_{min}}{R_{max} - R_{min}}$, $R(\mathbf{x}) = \sum_{\mathbf{y} \in \Omega - \mathbf{x}} \frac{s_\alpha(u(\mathbf{x}) - u(\mathbf{y}))}{\|\mathbf{x} - \mathbf{y}\|}$, $s_\alpha(t) = \min(\max(\alpha t, -1), 1)$, $\alpha > 1$.	The enhancement process is consistent with perception. Local method.	Excessive enhancement for certain values of the parameter. Parameter: α.

Figure 2: Center/Surround - Based Methods

7 Gradient - Domain Methods

TABLE III
GRADIENT-DOMAIN METHODS

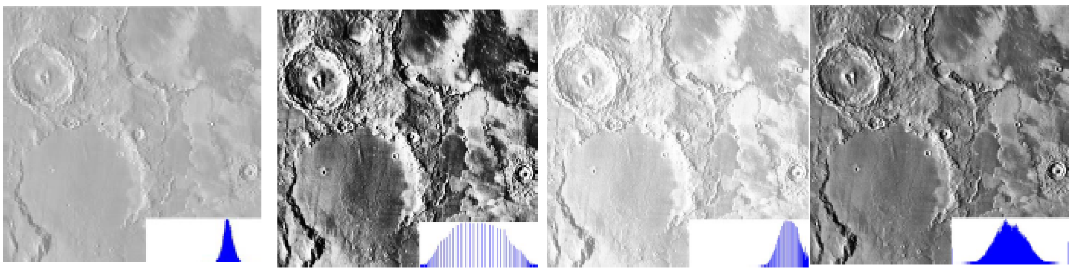
Name	Description	Advantages	Disadvantages
Global contrast enhancement (SCE_global, [27])	$\mathbf{V} = \|\nabla u\|^{\alpha - 1} \nabla u$	Global method.	Poor enhancement in some images. Parameter: α.
Selective contrast enhancement (SCE_dark, [28])	$\mathbf{V} = \begin{cases} a\nabla u & \text{in } D \\ \nabla u & \text{otherwise} \end{cases}$, $D = \{\mathbf{x} \in \Omega;\ I(\mathbf{x}) \leq T\}$	Well adapted to images with back light or strong shadows. Reveals details in shadows.	"Manual" selection of the dark zone. Parameters: a and T.

Figure 3: Gradient Domain - Based Methods

8 Training And Implementation Details

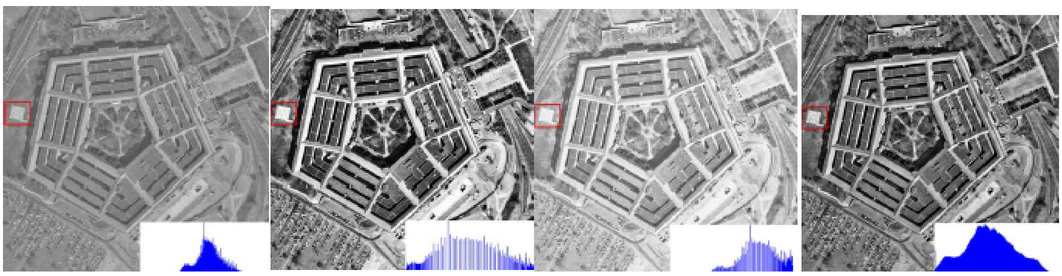
All the necessary algorithms were coded in Python Programming Language in Local machine. For some algorithms due to large computation power requirement for example the discrete cosine transform (DCT) algorithm was implemented in C++ Programming Language because of faster execution time.

9 Output images for Global Contrast Enhancement and Local detail Enhancement algorithm



(a) Image1 input **(b)** Image1 HE **(c)** Image1 AGCWD **(d)** Image1 Proposed Method

Figure 4: Comparison of Enhancement techniques for Image 1



(a) Image2 input **(b)** Image2 HE **(c)** Image2 AGCWD **(d)** Image2 Proposed Method

Figure 5: Comparison of Enhancement techniques for image 2

10 Output Images for Histogram, Center/Surround, Gradient - Domain based methods.

(a) Image3 input **(b)** Image3 HE **(c)** Image3 MSR **(d)** Image3 LCC

Figure 6: Comparison of Enhancement techniques for Image 3

(a) Image4 input **(b)** Image4 HE **(c)** Image4 MSR **(d)** Image4 LCC

Figure 7: Comparison of Enhancement techniques for image 4

11 Simulation Results and Discussion

The above techniques were implemented and tested with various input images and corresponding output images for some of the useful input images are shown in the paper. Histogram based methods take a lesser computational time than Center/Surround based methods and is useful when there is not much peak in the input histogram. While Center/Surround based methods takes more computational time but give more promising results when input images have a peak in the histogram.

12 Conclusion

Many of the Contrast Enhancement techniques were implemented and tested with sample input images and the output images were compared with that of other enhancement techniques. After simulation with various enhancement techniques with some input satellite remote sensing images, Histogram Equalization technique is simple but not effective the image is over enhanced if there is a peak in the histogram. Improvement of the HE with Global Contrast Enhancement and Local Detail Enhancement is capable of generating enhanced remote sensing images not only with high global contrast but also with rich local details without introducing artifacts. Moreover, the proposed method has a satisfactory computation time, which is suitable for enhancement of both remote sensing and ordinary images but it does not consider the Noise issue. The other Histogram and Center/Surround based methods implemented are MSR, LCC, Simplest Color Balance (SCB), Piecewise Equalization (PE). Among these methods Center/Surround based methods gives much less artifacts while the Histogram based methods over enhance the images. Among the Center/Surround based methods implemented MSR and LCC gives promising results which can be seen in the output images for some of the sample input images.

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