DWT BASED SVD AND MORPHOLOGICAL GRADIENT FOR SATELLITE COLOR IMAGE ENHANCEMENT

By

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ABSTRACT

Digital image processing plays an important role in the analysis and interpretation of satellite image data. One of the most common degradations in satellite images is their poor contrast quality. Image enhancement technique help in improving the visibility of the image. This suggests the use of contrast enhancement methods as an attempt to modify the intensity distribution of the image. The main aim of this paper is to contrast and edge enhancements for digital satellite images using Discrete Wavelet Transform based Singular Value Decomposition and Morphological Gradient. The objective of the proposed method is that the input image is decomposed into different sub bands through DWT, estimating the singular value matrix of the low–low sub band image, and then, reconstructing the enhanced image by applying inverse DWT. To achieve a sharper color image, an intermediate stage for estimating the high-frequency sub bands is required. This is done by the success of threshold decomposition, gradient based operators are used to detect the locations of the edges, sharpen these detected edges. The results show the efficiency of proposed satellite image enhancement with color balances and not introducing unnecessarily artifacts. The proposed technique has been tested on satellite benchmark images. The quantitative (PSRN, MSE, RMSE, EME) and visual results show the efficiency of the proposed enhancement technique.

Keywords: Discrete Wavelet Transforms, Singular Value Decomposition, Morphological Gradient, Satellite Color Image Contrast Enhancement.

INTRODUCTON

Satellite images are used in many applications such as geoscience studies, astronomy, and geographical information systems. One of the most important quality factors in satellite images comes from its contrast. Contrast enhancement is frequently referred to as one of the most important issues in image processing. Contrast is created by the difference in luminance reflected from two adjacent surfaces. In visual perception, contrast is determined by the difference in the color and brightness of an object with other objects. A visual system is more sensitive to contrast than absolute luminance; therefore, it can perceive the world similarly regardless of the considerable changes in illumination conditions. If the contrast of an image is highly concentrated on a specific range, the information may be lost in those areas which are excessively and uniformly concentrated. The problem is to optimize the contrast of an image in order to represent all the information in the input image. There have been several techniques to overcome this issue [1]–[4], such as General Histogram Equalization (GHE), Local Histogram Equalization (LHE), Brightness Preserving Dynamic Histogram Equalization (BPDHE) [5] and the previously introduced Singular Value Equalization (SVE) [6]. In many image processing applications, the GHE technique is one of the simplest and most effective primitives for contrast enhancement [7], which attempts to produce an output histogram that is uniform [8]. One of the disadvantages of GHE is that the information laid on the histogram or Probability Distribution Function (PDF) of the image will be lost. Preserving the shape of the PDF of an image is of vital importance. Techniques such as SVE are preserving the general pattern of the PDF of an image.The 2-D wavelet decomposition of an image is performed by applying the 1-D discrete wavelet transform along the rows of the image first, and then the results are decomposed along the columns. This operation results in four decomposed sub band images referred to Low-Low (LL), Low-High (LH), High-Low (HL), and High-High (HH).The frequency components of those sub bands cover the full frequency spectrum of the original image. Theoretically, a filter bank shown in Figure 1 should operate on the image in order to generate different sub band frequency images. Figure 2 shows a sample low contrast arial image. Figure 3 shows different sub bands of a satellite image where the top left image is the LL sub band, and the bottom right image is the HH sub band Image contrast enhancement using the wavelets is a relatively new subject and recently many new algorithms have been proposed [9]. In this paper, the authors propose a contrast-enhancement technique using SVD of DWT low-frequency sub band image and the input low-contrast image. Inverse DWT (IDWT) has been applied to combine all these images to generate the final contrast-enhanced image. In order to achieve a sharper image, an intermediate stage is proposed for estimating the high-frequency sub bands by utilizing the Morphological gradient [12]. The classical morphological gradient operator for grayscale images is the difference between a dilation and an erosion [10]. Simple operators of this type are over-sensitive to image noise and some alternatives for practical morphological edge detection

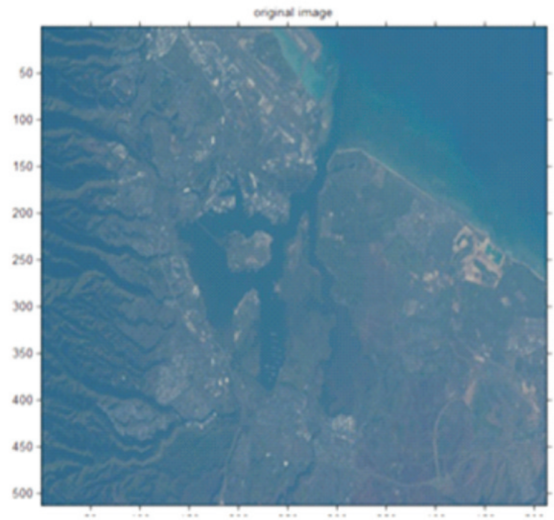

Figure 2. Low Contrast Arial Image

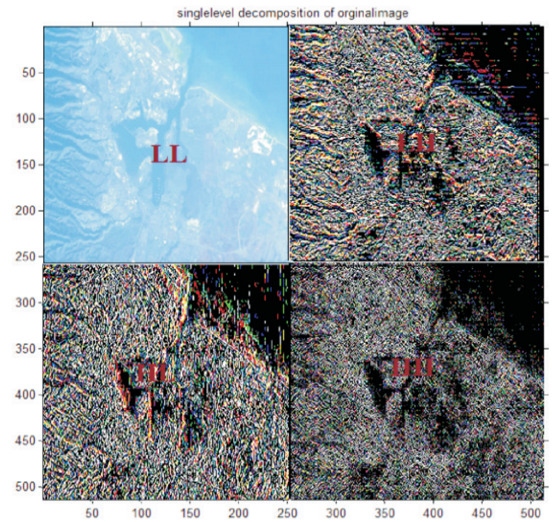

Figure 3. Sub bands of an Arial image using DWT

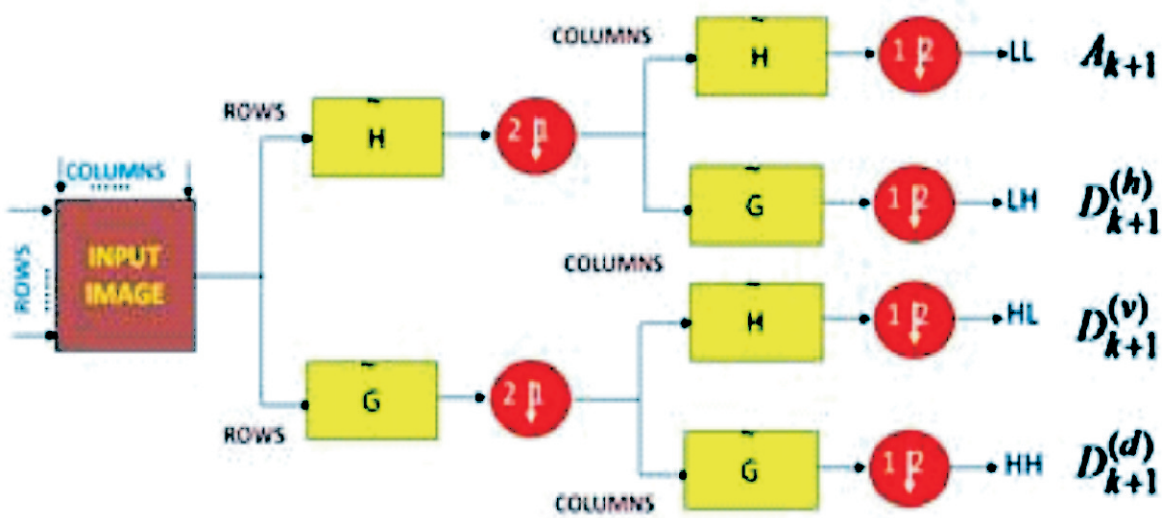

Figure 1. Block diagram of DWT filter banks of level-1

were proposed by Lee [11].

The paper is organized as follows. Section 1 introduces the proposed Satellite Color Image Enhancement using DWT based SVD and Morphological Gradient. Section 2 discusses the qualitative and quantitative results of the proposed method. Conclusions are given in the final section.

1. Proposed Enhancement Method

As it was mentioned before, contrast enhancement is an important application in satellite imaging. There are two significant parts of the proposed method. The first one is the use of Discrete Wavelet Transform based SVD. The singular value matrix obtained by SVD contains the illumination information. Therefore, changing the singular values will directly affect the illumination of the image; hence, the other information in the image will not be changed. The former section explained that the illumination information is embedded in the LL subband. The edges are concentrated in the other subbands (i.e., LH, HL, and HH). Hence, separating the high-frequency subbands and applying the illumination enhancement in the LL subband only will protect the edge information from possible degradation. The second important aspect of this work is the application of morphological gradient Morphological gradient operations are used to enhance the intensity variations in satellite image, and these variations are to be the edges of objects. After reconstructing the final image by using IDWT, the resultant image will not only be enhanced with respect to illumination but also will be sharper. Figure 4 shows the general procedure of the proposed technique.

1.1 Discrete Wavelet Transform Based SVD

A combination of Singular Value Decomposition and Discrete Wavelet Transform is used for the contrast enhancement. The Singular Value Decomposition factorizes the image matrices and the singular value matrix contains the intensity information. Therefore changing the singular value will directly affect the illumination of the image. In the proposed technique, Discrete Wavelet Transform is applied on the input image and it decomposes into four sub band images

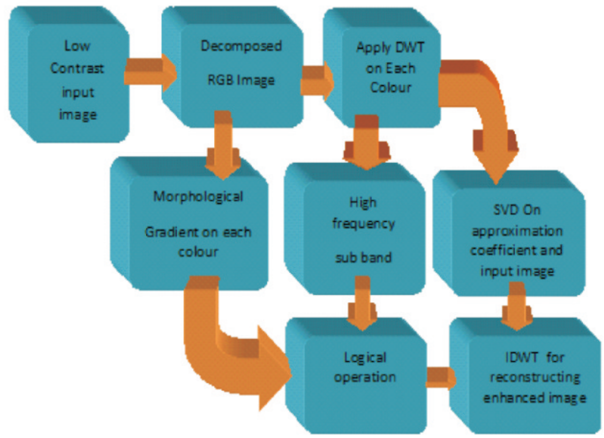

Figure 4. Block Diagram of the Proposed Image Enhancement Method

(LL,LH,HL,HH). The LL sub band image contains all illumination information. So manipulating the LL sub band gives the enhancement in contrast. Singular Value Decomposition is applied on LL subband and the input image. The correction coefficient for the singular value matrix of input image I and LL sub band is calculated by using the following equations,

$$\xi = \frac{\max(\Sigma_{(I)}(\mu=0, var=1))}{\max(\Sigma_{LL})} \quad (1)$$

where $\Sigma_{(I)}$ is singular value matrix of input image and Σ_{LL} is the LL singular value matrix of the input image. The new $\overline{\Sigma}_{LL1}$ singular value matrix is given as,

$$\overline{\Sigma}_{LL1} = \xi \Sigma_{LL} \quad (2)$$

Where $\overline{\Sigma}_{LL1}$ is referred as the Singular Value Matrix of the equalized image. Using $\overline{\Sigma}_{LL1}$, a new equalized LL sub image matrix is formed. The new equalized LL sub image, LL1 is given by the equation,

$$LL1 = U_{LL} \overline{\Sigma}_{LL1} V_{LL}^T \quad (3)$$

1.2 Morphological Gradient

Morphological gradients are operations enhancing variations of pixel intensity in a given neighborhood. In order to do this, three different combinations of operation were used.

- Arithmetic difference between an extensive operation and an anti-extensive operation.
- Arithmetic difference between an extensive operation and an original function.

- Arithmetic difference between original function and an extensive operation.

The morphological gradient in the discrete case has the arithmetic difference between the dilated and the eroded of the image with the elementary structuring element B of the considered grid.

$$G(f)= \delta_B (f)- \varepsilon_B (f) \quad (4)$$

In the above equation G(f) represents the maximum variation of the gray level intensities within an elementary neighborhood rather than a local slope. Flat 3X3 structuring elements for gray scale images are created using Strel in the same way as for binary images. Dilation, erosion is most often performed using flat structuring elements. Dilation and erosion can be combined to achieve a variety of effects. In this paper, subtracting an eroded image from its dilated version produces a morphological gradient which is a measure of local gray-level variation in the image. The resultant image is the morphological gradient of the original image has edge enhancement characteristics. In the proposed method, first the RGB Low contrast images are read. Then, decompose the RGB and apply the morphological gradient for detection of edges. To reach the high sharpen image, these edge information is added with high frequency sub bands obtain by DWT of original image. The illumination enhancement SVD on LL sub band only will protect the edge information from possible degradation. IDWT is used to reconstructed the proposed enhanced image.

The methodology of proposed method can be summarized in the following steps.

1. Read low contrast image and separate RGB colours.
2. Decompose each colour using DWT.
3. Apply SVD on approximation coefficient and input image.
4. Morphological gradient is used to detect the edge information.
5. Obtain detected edge information is added to high frequency sub band.
6. IDWT is used to reconstruct the enhanced image.

Experimental results demonstrate that the detected edge improved the visibility and perceptibility of images. Figures 5-8 show that a satellite low contrast images and high contrast images which are enhanced by the proposed technique. Not only visual comparison but also quantitative comparisons are confirming the superiority of proposed method. Peak Signal to Noise Ratio (PSNR), Root Mean Square Error (RMSE), and Enhancement Performance Measure (EME) have been implemented in order to obtain some quantitative results. PSNR can be obtained by using the following formula [10],

$$PSNR = 10\log_{10}\left[\frac{R^2}{MSE}\right] \quad (5)$$

where R is the maximum fluctuation in the input image (255 is here as the images are represented by 8 bit); MSE is representing input image I1(m,n) and proposed enhance image I2(m,n) which can be obtained by the following formula:

$$MSE = \frac{\sum_{m,n}[I1(m,n)-I2(m,n)]^2}{M*N} \quad (6)$$

where M and N are the size of the images. Clearly, RMSE is the square root of MSE, hence it can be calculated by the following:

$$RMSE = \sqrt{\frac{\sum_{m,n}[I1\ (m,n)-I2(m,n)]^2}{M*N}} \quad (7)$$

The concept of local intensity measurement is based on Weber law, which argued that the human visual interpretation depends on the ratio of light intensity values f(x, y) and f (x, y)+∂f (x, y). This quantitative measure is useful in choosing enhancement methods, parameters in parametric enhancement methods. Let the image be split into k1k2 blocks W_{k1}(l, j). For a given class {ϕ} of orthogonal transforms, Enhancement Performance Measure (EME) is calculated as,

$$EME = \min_{\emptyset\in\{\emptyset\}}(EME(\emptyset)) \quad (8)$$

$$EME = \min_{\emptyset\in\{\emptyset\}}\left[\frac{1}{k1k2}\quad \sum\sum 20\log\frac{I^W_{max;k,l}\quad(\emptyset) - \ I^W_{min;k,l}\quad(\emptyset)}{I^W_{max;k,l}\quad(\emptyset) + \ I^W_{min;k,l}\quad(\emptyset)}\right] \quad (9)$$

where, $I^W_{max;k,l}$ $(\emptyset)$ and $I^W_{min;k,l}$ $(\emptyset)$ are respectively maximum and minimum of the image X (n1, n2) inside the block $W_{k,l}$ (i,j), after processing the block by φ transform based enhancement algorithm. The block size chosen is 3 by 3. In order to show the improvement obtained by the proposed satellite image, contrast enhancement from information content point of view and the entropy of enhanced images have been calculated. By means of calculating, PSNR, MSR, RMSE, EME, with proposed enhanced images using above equations. Table 1 is showing the proposed method qualitative results. The quality of the visual result indicated that high contrast images as shown in Figures 5-8. The quantitative result in Table 1 has PSNR, RMSE, MSE, EME which indicates the superiority of the proposed technique.

2. Results and Discussions

The main objective of this work finds applications in many fields mainly where the satellite images are used. Satellite images have many applications in meteorology, agriculture, geology, forestry, landscape, biodiversity conservation, regional planning, education, intelligence and warfare. The contrast enhancement of satellite

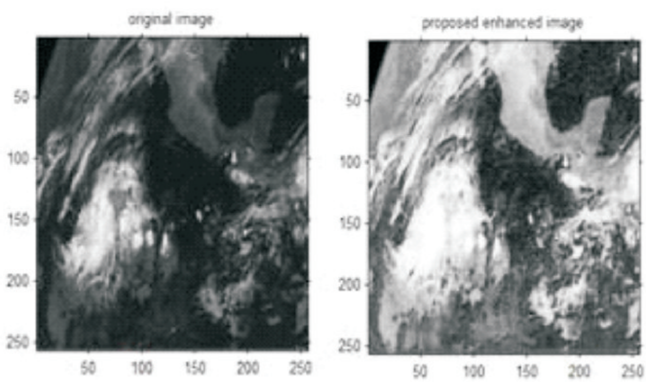

Figure 5. Low Contrast Original Arial Image and the Proposed Enhanced Image

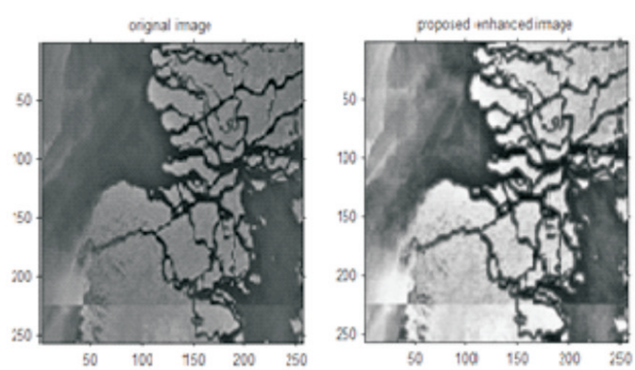

Figure 6. Low Contrast Original Arial Image and the Proposed Enhanced Image

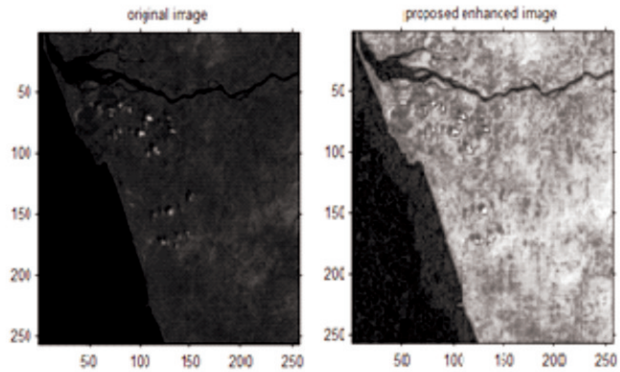

Figure 7. Low Contrast Original Arial Image and the Propose Enhanced Image

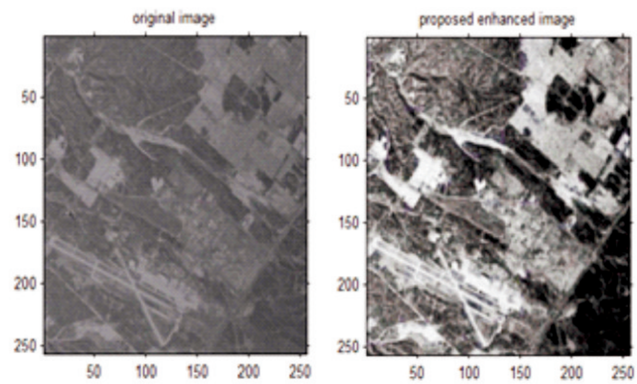

Figure 8. Low Contrast Original Arial Image and the Proposed Enhanced Image

Figure Quality	Figure 5	Figure 6	Figure 7	Figure 8
PSNR	46.1895	38.7500	55.7430	29.0419
MSE	1.5636	8.6711	0.1733	81.0763
RMSE	1.2505	2.9447	0.4163	9.0042
EME	6.3703	5.9544	3.9645	7.1158

Table 1. PSNR (db), MSE, RMSE, EME Results when compared with Original Images and Proposed Enhanced Images

images as a result of this work leads to improvement in all the above fields is given. The images tested in the proposed method, and the quality of the visual result indicated that high contrast are shown in Figures 5-8. The quantitative result in Table 1 represent PSNR, RMSE, MSE, EME values that indicates the superiority of the proposed technique. It is clear that, the resultant image, is sharper than the other techniques using the proposed technique.

Conclusion

In this paper, a new satellite image contrast enhancement technique, Discrete wavelet Transforms

Based SVD and Morphological Gradient was proposed. The proposed technique decomposed the input image into the sub bands using DWT. By using singular value matrix, a new equalized LL sub band for contrast enhancement and Morphological gradient operations are used to enhanced intensity variations in satellite image After reconstructing the final image by using IDWT, the resultant image will not only be enhanced with respect to illumination but also will be sharper. The visual results in the Figures 5-8 show that both the contrast and edge information are enhanced without adding unnecessary data.

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