Satellite Image Enhancement

Deepali M. Bongulwar

Kolhan University, Department of ECE, RVS College of Engineering and Technology, Jamshedpur,831005,India

ABSTRACT

To propose a satellite image contrast enhancement technique based on the discrete wavelet transform (DWT) and singular value decomposition (SVD).In this technique DWT decomposes the input low contrast satellite image into four frequency sub bands referred to as low-low (LL), high-low (HL). Low-high (LH), high-high (HH) and estimates the singular value matrix of the low-low sub band image. The singular value matrix represents the intensity information of the given image and any change on the singular values change the intensity of the input image. After reconstructing the final image by using inverse dwt, the resultant image will not only be enhanced with respect to illumination but also will be sharper with good contrast. This technique is compared with conventional image equalization technique such as general histogram equalization (GHE). The visual and quantitative results suggest that the proposed DWT and SVD method clearly out performs the GHE method.

Keywords: Contrast enhancement, discrete wavelet transform (DWT), singular value decomposition (SVD).

1. Introduction

Satellite images are used in many applications such asgeoscience studies, astronomy and geographical information systems. One of the most important quality factors in satellite images comes from its contrast. Contrast enhancements 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. Our visual system is more sensitive to contrast than absolute luminance; therefore, we 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.Histogram equalization (HE) has been the most popular approach to enhance the contrast in various application areas.HE-based methods cannot, however, maintain average brightness level, which may result in either under or oversaturation in the processed image. The problem is to optimize the contrast of an image in order to represent all the information in the input image.

The aim of this project is to enhance the contrast of the satellite image using Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD). In this, two techniques are discussed, DWT and SVD and GHE. While comparing these techniques, the visual and quantitative results suggest that the proposed DWT and SVD method clearly out performs the GHE method. Demirel*et al.*have also proposed a modified HE method which is based on the singular-value decomposition of the LL sub band of the discrete wavelet transform (DWT). In spite of the improved contrast of the image, this method tends to distort image details in low- and high-intensity regions.

In remote sensing images, the common artifacts caused by existing contrast enhancement methods, such as drifting brightness, saturation, and distorted details; need to be minimized because pieces of important information are widespread throughout the image in the sense of both spatial locations and intensity levels. For this reason, enhancement algorithms for satellite images not only improve the contrast but also minimize pixel distortion in the low- and high-intensity regions. To achieve this goal, we present a contrast enhancement method for remote sensing images using dominant brightness level analysis and adaptive intensity transformation. More specifically, the proposed contrast enhancement algorithm first performs the DWT to decompose the input image into a set of band-limited components, called HH, HL, LH, and LL sub bands. Because the LL sub band has the illumination information, the log-average luminance is computed in the LL sub band for computing the dominant brightness level of the input image. The LL sub band is decomposed into low-, middle-, and high-intensity layers according to the dominant brightness level. The adaptive intensity transfer function is computed in three decomposed layers using the dominant brightness level, the knee transfer function, and the gamma adjustment function.

2. Singular Value Decomposition

In this paper, a technique based on the singular value decomposition (SVD) and discrete wavelet transform (DWT) has been proposed for enhancement of low-contrast satellite images. SVD technique is based on a theorem from linear algebra which says that a rectangular matrix A, that can be broken down into the product of three matrices, as follows: (i) an orthogonal matrix U_A, (ii) a diagonal matrix $\sum_A$ and (iii) the transpose of an orthogonal matrix V_A. The singular- value-based image equalization (SVE) technique is based on equalizing the singular value matrix obtained by singular value decomposition (SVD). SVD of an image, which can be interpreted as a matrix, is written as follows:

$$A = U_A \sum_A V_A^T \quad (1)$$

Where U_A and V_A are orthogonal square matrices and Σ_A matrix contains singular values on its main diagonal. The singular value matrix represents the intensity information of input image and any change on the singular values change the intensity of the input image. The main advantage of using SVD for image equalization, $\Sigma_A$contains the intensity information of the image. In the case of singular value decomposition the ratio of the highest singular value of the generated normalized matrix, with mean zero and variance of one, over a particular image can be calculated using the equation as:

$$\xi = \frac{max(\sum_{\bar{A}}(\mu=0, var=1)}{max(\sum A)} \qquad (2)$$

By using this coefficient to regenerate an equalized image using

$$\sum_{equalized} = U_A\, (\xi \sum_A)\, V_A^T \qquad (3)$$

Where,equalized Ais used to denote the equalized image. The equalization of an image is used to remove the problem of the illumination.

Singular value decomposition (SVD) can be calculated mainly by the three mutually compatible points of view. On the one hand, we can view it as a method for transforming World Academy of Science, Engineering and Technology 55 2011 36 correlated variables into a set of uncorrelated ones that better expose the various relationships among the original data items. At the same time, SVD is a method for identifying and ordering the dimensions along which data points exhibit the most variation. This ties in to the third way of viewing SVD, which is that once we have identified where the most variation is present, then it is possible to find the best approximation of the original data points using fewer dimensions

Hence SVD can be seen as a method for data reduction and mostly for feature extraction as well as for the enhancement of the low contrast images. Following are the basic ideas behind SVD taking a high dimensional, highly variable set of data points and reducing it to a lower dimensional space that exposes the substructure of the original data more clearly and orders it from most variation to the least.

3. Discrete Wavelet Transform

The discrete wavelet transform which is based on the sub band coding is found to yield a fast computation of wavelet transform. It is easy to implement and reduces the computation time and resource required. The foundations of DWT go back to 1976 when techniques to decompose discrete time signals were devised. Similar work was done in speech signal coding which was named as sub band coding.

In 1983, a technique similar to sub band coding was named pyramidal coding. Later many improvements were made to these coding schemes which resulted in efficient multi-resolution analysis schemes.

LL	LH
HL	HH

Figure 1: Result of 2-D DWT

This operation results in four decomposed sub band images based on DWT referred to as low– low (LL), low–high (LH), high–low (HL), and high–high (HH). This techniquedecompose the images into four frequency sub-bands by using DWT and estimate the singular value matrix of the low-low sub-band image.

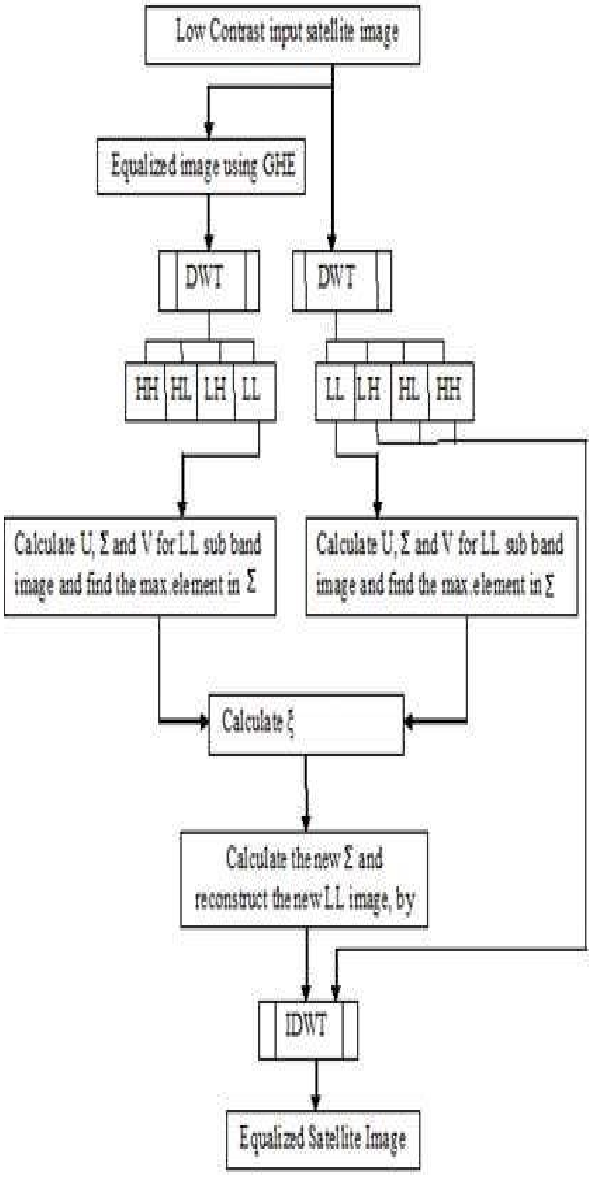

Figure 2: Flow Chart for the proposed Technique

4. Algorithm

Step1: In the very first step, a low contrast input satellite image has been taken for analysis
Step2: Equalize the satellite image using general histogram equalization technique.
Step3: After equalization, compute the discrete wavelet transform for the contrast enhancement.
Step4: DWT of an image decomposed four sub band images referred to as (LL, LH, HL, and HH)
Step5: calculate U, ∑ and V for LL sub band image
Step6: calculate ξ using the following equation

$$\xi = \max(\sum_{LL\bar{A}})/\max(\sum_{LLA})$$

Where $\sum_{LLA}$ is the LL singular value matrix of the input image and $\sum_{LL\bar{A}}$ is the LL singular value matrix of the output image.

Step7: calculate the new ∑ and reconstruct the new LL image by using the IDWT.The LL image is composed by

$$\sum_{LL\bar{A}} = \xi \sum_{LLA}$$

$$LL_{\bar{A}} = U_{LLA} \sum_{LL\bar{A}} V_{LLA}$$

Now $LL_{\bar{A}}$,LH_A, HL_A and HH_A sub band images of the original image are recombined by applying IDWT to generate the resultant equalized image.

Step8: Equalized satellite image obtained is

$$\bar{A} = IDWT\ (LL_{\bar{A}}, LH_A, HL_A, HH_A)$$

The proposed method has been used for enhancement of the several satellite images. Different satellite images are included to demonstrate the usefulness of this algorithm. The performance of this method is measured in terms of following significant parameters

$$\text{Mean } (\mu) = \sum_{x=1}^{M-1} \sum_{y=1}^{N-1} I(x, y)$$

$$\text{Standard deviation}(\sigma) = \sqrt{\sum_{x=1}^{y=M-1} \sum_{y=1}^{N-1} \{I(x, y - \mu\}^2}$$

Mean (μ) is the average of all intensity value. It denotes average brightness of the image; whereas standard deviation (σ) is the deviation of the intensity values about mean. It denotes average contrast of the image. Here I(x, y) is the intensity value of the pixel (x, y), and (M, N) are the dimension of the image.

Image Enhancement

For performance evaluation, we used the measurement of enhancement by entropy (EME), which is computed as

$$\text{EME} = \frac{1}{K1K2} \sum_{l=1}^{K2} \sum_{k=1}^{K1} \frac{I_{max}(k,l)}{I_{min}(k,l)+c} \ln \frac{I_{\max}(k,l)}{I_{min}(k,l)+c}$$

Where $k1k2$ represents the total number of blocks in an image, $I_{max}(k, l)$ represents the maximum value of the block, $I_{min}(k, l)$ represents the minimum value of the block, and c represents a small constant to avoid dividing by zero.

5. Result

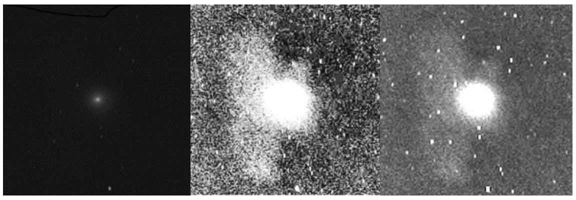

Figure 3: (a) (b) (c)
(a)Original Low Contrast Image from Satellite Imaging Corporation
(b)Equalized Image by GHE (c)Equalized Image using proposed method(SVD-DWT)

Table 1: MEAN AND STANDARD DEVIATION

Input Image Mean (μ) Standard Deviation (σ)	**μ=142.025 σ=1.0525e+003**
GHE Image Mean (μ) Standard Deviation (σ)	**μ=102.652 σ=917.6582**
DWT-SVD Image Mean (μ) Standard Deviation (σ)	**μ=120.5720 σ=3.8521e+003**

Experimental results demonstrate that the proposedalgorithm can enhance the low-contrast satellite images and is suitable for various imaging devices.But,takes more processing time to enhance the low contrast satellite images.

6. Conclusion

In this paper, a Satellite image contrast enhancement technique based on DWT and SVD has been proposed. This technique decomposed the input image into the DWT sub bands, and after updating the singular value matrix of the LL sub band, it reconstructed the image by using IDWT. The proposed technique was compared with GHE technique for visual and quantitative performance evaluation. The quantitative results supports the visual results that the quality and information content of the equalized images are better preserved through the proposed DWT and SVD technique over GHE technique.

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Author

Mrs. Deepali M. Bongulwar, received her B.E. and M.E. degree in Electronics Engineering and Electronics Engineering (Specialization in Computer Technology) in 1997 and 1999 respectively from Shri Guru Gobind Singh ji College of Engineering and Technology, Nanded, India. She worked at Shivajirao Jondhale College of Engineering, Dombivali(E),Mumbai University. She is now in Kolhan University in Department of ECE at RVS College of Engineering and Technology, Jamshedpur, Jharkhand, India.