A Modified SVD-DCT Method for Enhancement of Low Contrast Satellite Images

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Abstract:
During the last decade, several techniques are proposed for contrast enhancement of a low-contrast satellite images. In this a new technique has been proposed based on the Singular Value Decomposition (SVD) and Discrete Cosine Transform (DCT). The proposed technique modified SVD-DCT converts the image into the SVD-DCT domain after normalizing the singular value matrix. Then the modified image is reconstructed by using inverse DCT. In the enhancement procedure Adaptive Histogram Equalization (AHE) has been used.. The perceptual and quantitative results of the proposed modified SVD-DCT method clearly indicates increased efficiency and flexibility over the exiting methods such as Linear Contrast Stretching technique, GHE technique, DWT-SVD technique, DWT technique, De-correlation Stretching technique, Gamma Correction method based techniques.

Keywords: Adaptive Histogram Equalization (AHE), Contrast enhancement, Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD).

1. Introduction

Satellite images are used in many applications such as geosciences studies, astronomy and geographical information systems. One of the problem occurs in satellite images while capturing image with a huge amount of distance, is the dark light and contrast of image.

Suppose, if an image has been taken in very dark or a very bright situation, the information may be lost in those areas which are excessively and uniformly dark or bright. Satellite images are low contrast and dark images, which has complete information but is not visible. The problem is how the contrast of an image can be improved from the input satellite images.

Image contrast enhancement is one of the most important issues in low-level image processing. Its purpose is to improve the quality of low contrast images. There have been several techniques to overcome this issue for the contrast analysis of satellite image such as General Histogram Equalization (GHE), Gamma correction and Linear contrast stretching. These techniques are very simple and effective for the contrast enhancement. But these techniques are not efficient as the information laid on the histogram of the image, which is totally lost.

The proposed technique based on the singular value decomposition (SVD) and discrete cosine transform (DCT) has been proposed for enhancement of low-contrast satellite images. In the enhancement procedure **A**daptive **H**istogram **E**qualization (AHE) has been used.

The enhancement mapping cannot improve image contrast satisfactorily since the contrast of an object is interfered by the whole image. Naturally, it is difficult to find enhance the whole image. AHE stretches the local contrast to improve the visibility of satellite images, while preserving information as it is. For this purpose, we are using **A**daptive **H**istogram **E**qualization (AHE). Here unlike **G**eneral **H**istogram **E**qualization (GHE), AHE operates on small data regions rather than the entire image. It is therefore suitable for improving the local contrast of an image and bringing out more detail [1]. The result shows that visibility improvement of specific objects is successfully enhanced using SVD-DCT method by incorporating AHE.

2. Proposed Methodology

Satellite images are low contrast and dark images, which has complete information but is not visible. The problem is how the contrast of an image can be improved from the input satellite images.

For this reason, we propose a new contrast enhancement. Basically two parts involve in the enhancement of the satellite images. The first one is **S**ingular **V**alue **D**ecomposition (**SVD)** and second one is **D**iscrete **C**osine **T**ransform (**DCT)**. The result shows that visibility improvement of specific objects is successfully enhanced using SVD-DCT method by incorporating AHE.

2.1 Adaptive Histogram Equalization:

Adaptive histogram equalization (AHE) is a computer image processing technique used to improve contrast in images. It differs from ordinary histogram equalization in the respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image. It is therefore suitable for improving the local contrast of an image and bringing out more detail.

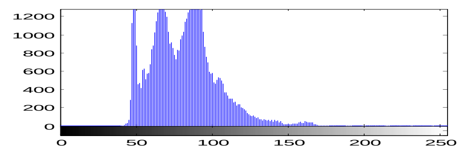
Ordinary histogram equalization uses the same transformation derived from the image histogram to transform all pixels. This works well when the distribution of pixel values is similar throughout the image. However, when the image contains regions that are significantly lighter or darker than most of the image, the contrast in those regions will not be sufficiently enhanced.

Adaptive histogram equalization (AHE) improves on this by transforming each pixel with a transformation function derived from a neighborhood region.

Adaptive histogram equalization is an extension to traditional Histogram Equalization technique. It enhances the contrast of images by transforming the values in the intensity image using contrast-limited adaptive histogram equalization (CLAHE).Unlike Histogram equalization, it operates on small data regions (tiles), rather than the entire image. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the specified histogram. The neighboring tiles are then combined using bilinear interpolation in order to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited in order to avoid amplifying the noise which might be present in the image.

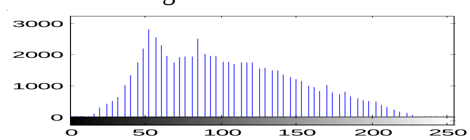
Adaptive histogram equalization of an original image and its histogram as shown in below figure 2.1

2.1.1: original



2.1.2: histogram

2.1.3: Adaptive equalized image



2.1.4: histogram equalization

Fig 2.1: Adaptive equalized image and its histogram

2.2 singular Value Decomposition (SVD)

SVD is based on a theorem from linear algebra which says that a rectangular matrix A, which is a product of three matrices that is (i) an orthogonal matrix UA, (ii) a diagonal matrix ΣA and (iii) the transpose of an orthogonal matrix VA. 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, can be interpreted as a matrix, is written as follows:

$$A = U_A \Sigma_A V^T{}_A \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where *UA* and *VA* are orthogonal square matrices and ΣA matrix contains singular values on its main diagonal [1].

Basic enhancement occurs due to scaling of singular values of the DCT coefficients. 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, *ΣA* 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:

$$\xi = \frac{\max(\Sigma N\ (\mu=0, var=1))}{\max(\Sigma A)} \ldots\ldots\ldots\ldots \quad (2)$$

By using this coefficient to regenerate an equalized image using:

$$E\ equalized_A = U_A(\xi \Sigma_A)V^T{}_A \ldots\ldots\ldots\ldots \quad (3)$$

Where E *equalized A* is used to denote the equalized image. The equalization of an image is used to remove the problem of the illumination.

2.3 Discrete Cosine Transform (DCT)

The DCT transforms or converts a signal from spatial domain into a frequency domain. DCT is real-valued and provides a better approximation of a signal with few coefficients. This approach reduces the size of the normal equations by discarding higher frequency DCT coefficients.

Important structural information is present in the low frequency DCT coefficients. Hence, separating the high-frequency DCT coefficient and applying the illumination enhancement in the low–frequency DCT coefficient, it will collect and cover the edge information from satellite images. The enhanced image is reconstructed by using inverse DCT and it will be sharper with good contrast [1].

In the proposed technique, initially the input satellite image 'A' for processed by AHE to generate $\hat{A}$. After getting this, both of these images are transformed by DCT into the lower frequency DCT coefficient and higher–frequency DCT coefficient. Then, the correction coefficient for the singular value matrix can be calculated by using:

$$\xi = \frac{max(\sum \bar{D})}{max(\sum D)} \text{.............................} \quad (4)$$

Where $(\sum \bar{D})$ is the lower-frequency coefficient singular matrix of the satellite input image, and $(\sum D)$ is the lower-frequency coefficient singular matrix of the satellite output image of the Adaptive Histogram Equalization (AHE).

The new satellite image (D) is determined by:

$$(\sum \bar{D}) = \xi(\sum D) \text{..............................} \quad (5)$$

$$\bar{D} = U_D \sum \bar{D} \, V_D \text{...........................} \quad (6)$$

$\bar{D}$ is the lower DCT frequency component of the original image that is reconstructed by applying the inverse operation (IDCT) to produce equalized image is

$$\bar{A} = IDCT(\bar{D}) \text{.............................} \quad (7)$$

The performance of this method is measured in terms of following significant parameters:

$$Mean(\mu) = \frac{1}{MN} \sum_{x=1}^{M-1} \sum_{y=1}^{N-1} I(x,y) \text{............} \quad (8)$$

$$standard\ deviation(\sigma) = \sqrt{\frac{1}{MN} \sum_{x=1}^{M-1} \sum_{y=1}^{N-1} \{I(x,y) - \mu\}^2} \text{...........} (9)$$

Mean (μ) is the average of all intensity value. It denotes average brightness of the image, where as standard deviation 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.

2.4. Flow Chart:

The following flowchart shows the proposed scheme:

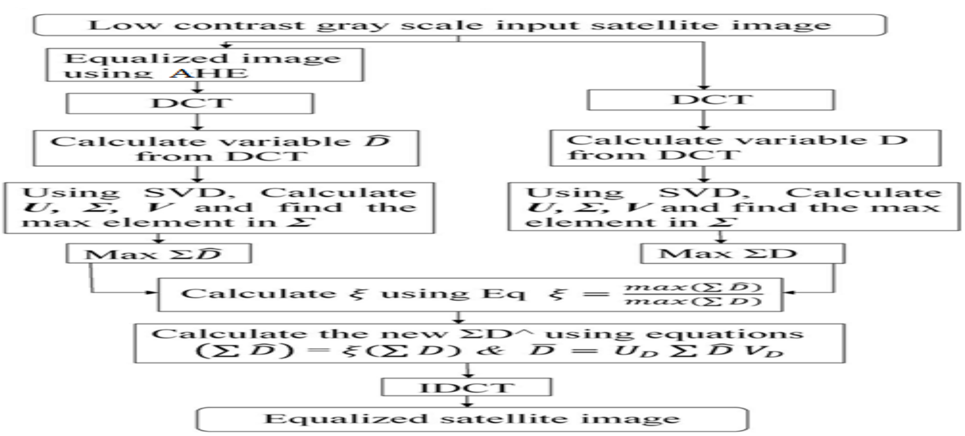


Fig 2.2 Flow chart of the proposed methodology

3. Results

The performance of this method is measured in terms of following significant parameters:

$$Mean(\mu) = \frac{1}{MN}\sum_{x=1}^{M-1}\sum_{y=1}^{N-1} I(x,y) \qquad \ldots\ldots\ldots\ldots (8)$$

$$standard\ deviation(\sigma) = \sqrt{\frac{1}{MN}\sum_{x=1}^{M-1}\sum_{y=1}^{N-1}\{I(x,y)-\mu\}^2} \qquad \ldots\ldots\ldots\ldots (9)$$

Mean (μ) is the average of all intensity value. It denotes **average brightness of the image**, where as standard deviation 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 [3].

The results for the enhancement of satellite images are given. The proposed method is compared with other existing methods such as Linear Contrast Stretching technique, GHE technique, DWT-SVD technique, DWT technique, De-correlation Stretching technique, and Gamma Correction method shown in figure3.1. The visual and quantitative result shows that the proposed method has increased efficiency and flexibility.

The resultant images for the enhancement of satellite images are given below fig 3.1, the following resultant images of DCT-SVD gives the better contrast as well as high image quality. The images are:

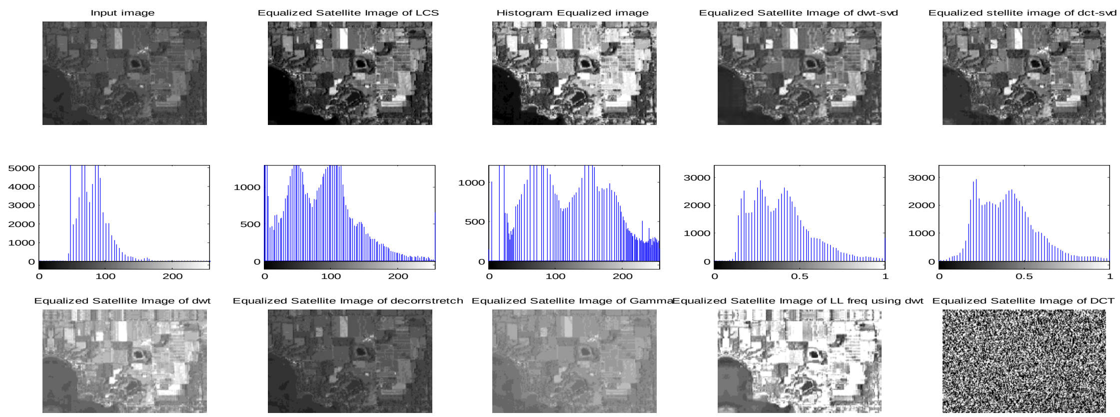


Fig 3.1: Various resultant images using existing techniques and proposed technique

The quality of the visual results indicates that the proposed technique is sharper and brighter than existing technique as compared. After obtaining mean and standard deviation, it is found that the proposed algorithm gives better results in comparison with the existing techniques. Mean (μ) represent the intensity of the image and the standard deviation represent (σ) the contrast present in the images. The proposed DCT method represents the better contrast as well as better brightness with appropriate contrast. However, the estimated mean (μ) and standard deviation (σ) in Fig 3.1 of the proposed method covers a good range of gray level and this is the cause of the better illumination. Therefore the observation of the proposed DCT gives the better result. In order to exhibit the superiority of the proposed methodology three different images have been taken for analysis. The singular values denote luminance of each image layer after decomposition using DCT methodology.

The **Mean** (μ) & **standard deviation** (σ) values are given below for analysis of this result. Here we can observe that the proposed method DCT-SVD gives better contrast as well as better brightness.

	Mean(µ)	Standard deviation(□)
Input image	80.1919	22.0798
DWT image	158.5717	42.1936
De-correlation Stretch Tech.	80.1919	22.0798
Gamma correction	102.1564	43.7705
LCS image	82.5653	53.7372
GHE image	129.2727	42.8887
DWT-SVD image	102.1848	46.4943
Proposed DCT-SVD image	**103.4778**	**48.0550**

Table1: Comparison of the results between different proposed methodology and already existing techniques.

4. Conclusion

In this paper, a new technique has been proposed based on the **S**ingular **V**alue **D**ecomposition (SVD) and **D**iscrete **C**osine **T**ransform (DCT) that means SVD-DCT domain for enhancement of low-contrast satellite images. The basic enhancement occurs due to scaling of singular values of the DCT coefficients. Performance of this technique has been compared with existing contrast enhancement techniques like histogram equalization, gamma correction and DWT-SVD based techniques.

From the above experimental results, it can be concluded that the proposed algorithm is effective in naturally enhancing low contrast images and the visibility improvement of specific objects compared to other existing methods. The results show that the proposed technique gives better performance in terms of contrast (variance) as well as brightness (mean) of the enhanced image as compared to the other existing techniques. Thus, this technique can be considered suitable for enhancement of low contrast satellite image.

5. Future Scope

Image enhancement of low contrast satellite images using discrete cosine transform and singular value decomposition can be implemented by using Adaptive histogram equalization is extended to color images. In case of grayscale images, DCT-SVD can be replaced by contrast stretching method and de-correlation stretch methods.

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