## Enhanced Satellite Image Clarity Using Stationary Wavelet Transform and Singular Value Decomposition

# 1 Gaddam Anjali Kumari, 2Aswani Lalitha, 3Raju Thommandru, 4Gangolu Rajesh

# 1,4Asst. Professor, Dept. of ECE, Chalapathi Institute of Technology, Guntur, AP, India.

**2,3Assoc. Professor, Dept. of ECE, Chalapathi Institute of Technology, Guntur, AP, India.**

**ABSTRACT: Image processing encompasses a wide range of tasks, including compression, feature extraction, and classification. Digital sensors produce a "raw" image, which is essentially a matrix of digital values, where each value indicates the brightness or gray intensity of a pixel. The goal of image enhancement is to reveal hidden details and emphasize key features within an image. Among the critical attributes of any image are resolution and contrast. While resolution defines the clarity of image detail, the human visual system is particularly sensitive to variations in contrast.This paper introduces a technique for contrast and resolution enhancement of satellite images using Stationary Wavelet Transform (SWT) and Singular Value Decomposition (SVD). Satellite imagery finds applications across various fields such as meteorology, oceanography, agriculture, forestry, geology, education, and defense. SWT's translational invariance aids in detecting edge features accurately. The proposed approach decomposes the input image into four frequency sub-bands using Discrete Wavelet Transform (DWT). The high-frequency sub-bands are then refined through interpolation and enhancement using a difference image derived from the input.Additionally, a modified singular value matrix is computed from the LL sub-band of both the histogram-equalized and original images to achieve brightness enhancement. Experimental results demonstrate that the proposed method outperforms traditional and state-of-the-art image enhancement techniques.**

**KEYWORDS: Stationary Wavelet Transform (SWT), Discrete Wavelet Transform (DWT), Singular Value Decomposition (SVD), Satellite Imagery, LL Sub-band, Image Enhancement.**

## INTRODUCTION

The fast advance of technologies and the prevalence of imaging devices, billions of digital images are being created every day. Due to undesirable light source,

unfavourable weather or failure of the imaging device itself, the contrast and tone of the captured image may not always be satisfactory [1]. Satellite images are used in many applications such as geo-scientific studies, astronomy, and geographical information systems. One of the most important quality factors in satellite image comes from its Contrast. The processing of digital satellite images have different scientific and need based applications in the field of agriculture, geology forestry, biodiversity, construction, regional planning, education, intelligence, warfare etc. Digital satellite images are subject to a wide variety of distortions which may result in visual quality degradations. Therefore, image enhancement is often required for both the aesthetic and pragmatic purposes [2]. The ultimate goal of image enhancement techniques is to improve the visual information of a degraded image in a subjective process.

Image enhancement is among the simplest and most appealing areas of digital image processing. The idea behind enhancement is to bring out the details in the image that are obscured [3] and also to highlight certain features of interest in an image. Image resolution is always a key feature of all kinds of image. Resolution of an image is an important issue in all image and video processing application like, feature extraction, video resolution enhancement and satellite image resolution enhancement. Resolution enhancement is always being associated with interpolation technique. Visual system is more sensitive

to contrast. Contrast of an image is determined by its dynamic range, which is defined as the ratio between brightest and the darkest pixel intensities [4].

Image enhancement divided into two widespread categories one is spatial domain method and another one is frequency domain method. The term spatial domain refers to the image plane itself, which directly deal with the image matrix and in frequency domain processing is done by modifying the Fourier transform of an image. Enhancement techniques based on various combinations of methods from these two categories are not unusual. When an image is processed for visual perception, the viewer is the ultimate judge of how accurate a particular method works, but here along with visual basis paper also check the results on qualitative scale measurements.

While discussing the subparts of the main composed work which is such as, resolution and contrast of an image these two factors are always important issues in many image processing applications. Due to interpolation of an image the number of pixels in a digital image increases and its applications are widely used in many image processing applications, such as image resolution enhancement, multiple description coding and facial reconstruction. Many techniques have been developed to increases the resolution image enhancement by interpolation. Wavelets are also playing a significant role in many image processing applications. The 2-D discrete wavelet transform of an image is performed by applying the 1-D discrete wavelet transform (DWT) along the rows first, and then along the columns [5]. This operation gives results in four decomposed sub band images named as low-low (LL), low-high (LH), high-low (HL) and highhigh (HH). The frequency components of these sub bands enclose the

full frequency spectrum of the original image.

1. **LITERATURE SURVEY** Corina Nafornita, Alexandru Isar, Teodor Dehelean, et. al. [6] discusses the enhancement of multilooks Synthetic- aperture radar (SAR) images for the purpose of wave detection. The method is based on improving the contrast in the dual tree complex wavelet domain, while performing denoising simultaneously. We describe the particularities of Sentinel-1 Strip map multilooks ground range detected images with high resolution and present the advantages of the proposed SAR image enhancement method. Simulation results and comparisons with state of the art contrast enhancement and denoising methods highlight the benefits of the proposed solution. Wen Zhang, Zhiyuan Zhang, Zhen Huang, et. al. [7] proposes an intelligent extraction method for farmland irrigation and drainage system based on domestic high resolution satellite GF-2 images, which has considered both spectral features and geometry features of farmland irrigation and drainage system, and could be divided into four parts as: image scale converting, spectral model for canal identification, data extraction by spatial features and breakpoint connecting with morphology. This paper chose the Sanhulianjiang reservoir irrigation area to be experimental area, which is located in Hubei's Jiayu County. The comparison shows the accuracy of this method is credible; it could satisfy the needs as large-scale, fast extraction for irrigation and drainage system, which has huge potential in agriculture and water conservancy fields.

Jun Wang, Xiucheng Yang, Xuebin Qin, Xin Ye, Qiming Qin, et. al. [8] presents a new approach for rapid automatic building extraction from very high resolution (VHR) optical satellite imagery. The proposed method conducts building extraction based on distinctive image

primitives such as lines and line intersections. The optimized framework consists of three stages: First, a developed edge-preserving bilateral filter. Second, a state-of-the-art line segment detector. Finally, we present a graph search-based perceptual grouping approach. Extensive experiments performed on VHR optical QuickBird imageries justify the effectiveness and robustness of the proposed linear-time procedure with an overall accuracy of 80.9% and completeness of 87.3%.

Vasileios Syrris, Stefano Ferri, Daniele Ehrlich, Martino Pesaresi, et. al. [9] presents Image Enhancement and Feature Extraction Based on Low- Resolution Satellite Data. The purpose of this study is to investigate the sensitivity of contrast-based textural measurements and morphological characteristics. In the existence of a low-resolution reference layer, we apply supervised learning that indirectly reduces the uncertainty and improves the quality of the reference layer. Based on the new class label assignments, the image histogram is adjusted suitably for the computation of contrast-based textural/morphological features. Experimental results demonstrate that spectral band combination is the key factor that conditions the contrast of grayscale images.

M. Priyadarshini, R. Sasikala, R. Meenakumari, et. al. [10] presents new satellite image resolution and contrast enhancement technique based on DWT (Discrete wavelet transform), Stationary Wavelet Transform (SWT) and BPDHE (Brightness Preserving Dynamic Histogram Equalization) has been proposed. The BPDHE is used to enhance the contrast of the image. The contrast is enhanced by using Brightness Preserving Dynamic Histogram Equalization. The proposed method enhances the resolution and contrast of the low resolution and contrast image. The quantitative metrics

are measured to show that the proposed method is superior to the conventional method.

## CONTRAST AND RESOLUTION ENHANCEMENT FOR SATELLITE

**IMAGES**

The block diagram of Stationary Wavelet Transform (SWT) and Singular Value Decomposition (SVD) based Contrast and Resolution Enhancement for Satellite Images is represented in below Fig. 1.

Low contrast Satellite Image

Decomposition of RGB Image

DWT

DWT

SWT

Apply SVD for LL sub-band

Estimate new LL band

IDWT

High Resolution and Brightness image

**Fig. 1: BLOCK DIAGRAM OF CONTRAST AND RESOLUTION ENHANCEMENT MODEL**

The purpose of this work is to enhance the resolution and contrast of satellite images using SVD (Singular Value Decomposition) and DWT (Discrete Wavelet Transform). The DWT technique divided the input image into four subband images and different operations performed on different sub bands. Interpolation

method is used here for the resolution enhancement of the satellite image whereas the SVD technique enhances the contrast of the satellite image. Then this work gives more refinement in the output image when it is compared with the input image.

Down sampling in each of the DWT sub bands causes information loss in the respective sub bands. That is why SWT is employed to minimize this loss. Stationary wavelet transform is translational invariant, which helps to identify the image edge features. The interpolated high frequency sub bands and the SWT high frequency sub bands have the same size which means they can be added with each other. The new corrected high frequency sub bands can be interpolated further for higher enlargement. Also it is known that in the wavelet domain, the low resolution image is obtained by low pass filtering of the high resolution image.

The wavelet decomposition of an image is done row by row and then column by column. DWT provides multi resolution representation of image and can efficiently implemented using digital filters. Image itself is considered as two dimensional signal. Thus in DWT process the image will be subdivided into four sub bands. The four sub images are obtained when the image is by low-pass filtered by rows and then by columns which is named as LL sub band image then the next sub band is obtained by low-pass filtering of the rows and high-pass filtering of the columns is named as LH sub band image. The one which is obtained by high-pass filtering of the rows and low-pass filtering of the columns is named as HL subband image. The sub image which is obtained by high pass filtering of the rows and columns is named as the HH sub band image.

Consider the LL sub band image among the four sub band images of image A and image B then apply SVD on the LL sub

band of both the images. The singular value decomposition of an a×b real or complex matrix M is a factorization form. Singular Value Decomposition method can transform matrix A into USVT product which allows us to refactoring of a digital image into three matrices. The using of singular values of such refactoring allows us to represent the image with a smaller set of values, which can preserve useful features of the original image, but use less storage space in the memory.

After that the transformation factor by which new enhanced LL sub band is formed. On the other hand for the need of sharper image because the image is get blurred due to interpolation which get by the frequency sub bands of input image those modified by an intermediate stage in which difference image is added in them, difference image is the image which get by subtracting the input image with interpolated LL sub band image.

Then the output is combined by resizing the new SVD enhanced LL sub band to the size of interpolated estimated other three sub bands estimated LH, HL, HH by applying IDWT (Inverse DWT) technique and obtained the final resolution and contrast enhanced image.

## RESULT ANALYSIS

The proposed technique has been examined on several different satellite images. In order to display the superiority of the proposed method over the conventional techniques visually, we show the result images which we get from different equalization methods such as General Histogram Equalization (GHE), Local Histogram Equalization (LHE), Singular Value Equalization (SVE) and enhanced images obtained by the proposed technique. The superiority of proposed method is estimated by using Peak signal- to-noise ratio (PSNR), root mean square error (RMSE) and mean square error (MSE).

The enhancement is measured in terms of MSE (Mean square error), PSNR (Peak signal to noise ratio) and RMSE (Root mean square error) values of both input and output images. An increase in PSNR value indicates good quality of the image as compared to the input image and low value of RMSE, MSE indicates there are fewer errors in the output image as compared to input image. These values are calculated for the qualitative analysis.

## Mean Square Error (MSE):

MSE is the cumulative squared error between the compressed and the original image. A lower value of MSE means lesser error, and it has the inverse relation with PSNR.

B2

PSNR = 10. log10 (MSE) … . . (3)

Where, B is the maximum fluctuation in the input image.

Table 1 is showing the comparison between the proposed Stationary Wavelet Transform (SWT) and Singular Value Decomposition (SVD) based Contrast and Resolution Enhancement, GHE, LHE and SVE. Fig. 2 shows the Graphical representation of MSE parameter and Fig.

3 shows the graphical representation of PSNR and RMSE values.

**Table 1: COMPARATIVE ANALYSIS OF PERFORMANCE PARAMETERS**

M N

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Paramet ers** | **GHE** | **LHE** | **SVE** | **SWT & SVD****based enhance ment** |
| MSE | 10156. | 1734. | 9215. | 412.51 |
|  | 21 | 76 | 46 |  |
| PSNR | 8.21 | 16.43 | 8.99 | 23.21 |
| RMSE | 108.03 | 41.86 | 96.11 | 20.31 |

1

MSE(i1, i2) =

∑ ∑ [i1(x, y) − i2(x, y)]2 … . . (1)

NM

x=1 y=1

Where, i1(𝑥, 𝑦) is the original image and i2(𝑥, 𝑦) is the reconstructed image and M, N are the dimensions of the image.

**Root mean square error (RMSE):** Clearly, RMSE is the square root of MSE, hence it can be calculated by the following:

M N **MSE**

1

RMSE = √

∑ ∑ [i1(x, y) − i2(x, y)]2 … (2)

NM

x=1 y=1

12000

10000

8000

6000

**Peak Signal-to-Noise Ratio (PSNR):** PSNR is used to measure the quality of compression images. It is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation.

4000

2000

0

**Techniques**

This ratio is often used as a quality measurement between the original and compressed image. The higher PSNR gives better quality of the compressed or reconstructed image.

**Fig. 2: COMPARATIVE ANALYSIS IN TERMS OF MSE**

120

100

80

60

40

20

0

**Techniques**

PSNR

RMSE

**Fig. 3: COMPARATIVE ANALYSIS IN TERMS OF PSNR AND RMSE**

If we are taking the input image cameraman in Fig. 4 image as some noise should be occur. Similarly Fig. 5 is the final resolution and contrast enhanced image.



**Fig. 4: INPUT IMAGE**



**Fig. 5: OUTPUT IMAGE**

It is clear that the enhanced image using proposed technique is sharper and brighter than the other techniques.

## CONCLUSION

This paper presents a **contrast and resolution enhancement method** for satellite images, leveraging **Stationary Wavelet Transform (SWT)** and **Singular Value Decomposition (SVD).** In image processing, **resolution** and **contrast** are crucial attributes. While resolution captures the level of detail in an image, the human visual system is particularly responsive to contrast. The **Discrete Wavelet Transform (DWT)** offers a multi-resolution image representation and can be efficiently executed using digital filters. **SWT**, which maintains translational invariance, is particularly effective in detecting image edge features. The **SVD method** improves image contrast by adjusting the singular values in the transformed image domain.In this approach, **DWT** decomposes the input image into frequency sub-bands: the **LL sub-band** (representing low-frequency components) and the **HL, LH, and HH sub-bands** (representing high-frequency components). Resolution enhancement focuses on refining the high-frequency sub-bands (HL, LH, HH), while contrast enhancement targets the LL sub-band.The proposed method was evaluated on multiple test images, and the results—measured in terms **of PSNR, MSE, RMSE**, and visual quality—demonstrated its superiority over conventional and contemporary techniques. The enhanced images produced by this method are noticeably sharper and brighter, confirming the effectiveness of the approach.

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