A combined approach of using DWT-DCT watermarking and AES encryption to improve the security of satellite images

Naida.H.Nazmudeen[1], Jismi.K[2]

[1]Kerala University, Muslim Association college of Engineering,
Venjaramoodu, Trivandrum District, Kerala
naidanizam9@gmail.com

[2]Kerala University, Muslim Association college of Engineering,
Venjaramoodu, Trivandrum District, Kerala
jis.ansal@gmail.com

Abstract: *With the large-scale research in space sciences and technologies, there is a great demand of satellite image security system for providing secure storage and transmission of satellite images. As the demand to protect the sensitive and valuable data from satellites has increased and hence proposed a new method for satellite image security by combining DWT-DCT watermarking and AES encryption. Watermarking techniques developed for normal multimedia data cannot be directly applied to the satellite images because here the analytic integrity of the data, rather than perceptual quality, is of primary importance. To improve performance, combine discrete wavelet transform (DWT) with another equally powerful transform; the discrete cosine transform (DCT). The combined DWT-DCT watermarking algorithm's imperceptibility was better than the performance of the DWT approach. Modified decision based unsymmetrical trimmed median filter (MDBUTMF) algorithm is proposed for the restoration of satellite images that are highly corrupted by salt and pepper noise. Satellite images desire not only the watermarking for copyright protection but also encryption during storage and transmission for preventing information leakage. Hence this paper investigates the security and performance level of joint DWT-DCT watermarking and Advanced Encryption Standard (AES) for satellite imagery. Theoretical analysis can be done by calculating PSNR and MSE. The experimental results demonstrate the efficiency of the proposed scheme, which fulfils the strict requirements concerning alterations of satellite images.*

Keywords: Satellite images, Watermarking, DWT, DCT, AES encryption, MDBUTMF algorithm, PSNR and MSE.

1. Introduction

With the large-scale research and development in space sciences and technologies, there is a great demand of satellite imagery security system, for providing secure storage and transmission of satellite imagery over internet. This brings new challenges to protect sensitive and critical satellite imagery from unauthorized access and illegal use in order to keep the storage and transmission process secure and reliable [1]. Watermarking can be used to protect the copyright of satellite images. Digital watermarking for satellite imagery is the process of embedding visible or invisible information into the digital imagery which may be used to verify its authenticity or the identity of its owners. The embedded information can be the trademark, script, image chip, or any kind of digital information generated from the original images.

Secure communication is when two parties are communicating and do not want a third party to listen in. For that they need to communicate in a way not susceptible to interception. Secure communication includes means by which people can share information with varying degrees of certainty that third parties cannot intercept what was said. Watermarking techniques developed for multimedia data cannot be directly applied to the satellite images because the analytic integrity of the data, rather than perceptual quality, is of primary importance.

Hence satellite images needs efficient watermarking techniques. Satellite image watermarking along with encryption technique can be used for secret satellite communication [2].

This paper presents a new method for satellite image security improvement using DWT-DCT watermarking and AES encryption. By using the proposed method security of satellite images can be improved to a greater extend when compared to the previous works. Encryption technique is also used along with watermarking to enhance the secrecy of secret image.

The paper is constructed as follows. The background review is described in section 2. The proposed method in section 3 includes noise removal, watermark embedding, watermark extraction and AES encryption. Simulation results are discussed in section 4. Performance analysis is done in this section. Conclusion is presented in section 5.

2. Background review

Within the field of watermarking, satellite image watermarking particularly has attracted lot of attention in the research community.

2.1 Existing methods

There are several existing methods for satellite image watermarking. Some of them are explained below.

2.1.1. Digital Watermarking Of Satellite Images Using Secured Spread Spectrum Technique:

This paper [4] provides spread spectrum watermarking of the satellite image by choosing a region of interest and embedding the watermark in the same. The reason for choosing a region of interest is an area which contains important information and must be sent through media without any distortions and attacks. A particular region is chosen as ROI. The disadvantage of this method is visible watermark and it is used to maliciously trace users of an anonymous communication networks. In detection process get an idea about the watermark signal, can easily change the data.

2.1.2. Satellite image watermarking using LSB manipulation algorithm:

The simplest spatial-domain image watermarking technique is to embed a watermark in the least significant bits (LSB) of some randomly selected pixels [5]. Disadvantages of this method are the watermark can be destroyed if the image is low-pass filtered, Security level is very less, Least robust.

2.1.3. Watermarking based on the scale-space feature points:

Here proposed a novel algorithm that the digital watermark was embedded into the photogrammetric images, and the robustness of the embedded digital watermark and the impact on photogrammetric image quality are evaluated. Disadvantages are if suffers from the changes of rotation or scaling attack, the pixel sequence changes, results in failure of watermark extraction affects image matching, image classification and image measurements[6].

2.2 Discrete wavelet transform (DWT)

The basic idea of discrete wavelet transform (DWT) in image processing is to multi-differentiated decompose the image into sub-images of independent frequency district and different spatial domain . Then transform the coefficient of sub-image. After the original image has been DWT transformed, it is decomposed into 4 frequency districts which is one low-frequency district (LL) and three high-frequency districts (LH,HL,HH). If the information of low-frequency district is DWT transformed, the sub-level frequency district information will be obtained. A two-dimensional image after three-times DWT decomposed can be shown as Fig.1. Where, L represents low-pass filter, H represents high-pass filter. An original image can be decomposed of frequency districts of HL1, LH1, HH1. An image can be decomposed into a pyramidal structure, with various band information: low-low frequency band LL, low-high frequency band LH, high-low frequency band HL, high- high frequency band HH [1].
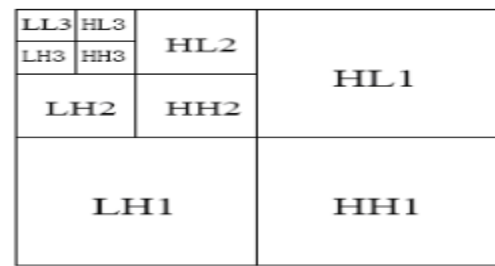

Figure 1: Sketch Map of Image DWT Decomposed

The signal is passed through a series of high pass filters to analyze the high frequencies, and it is passed through a series of low pass filters to analyze the low frequencies. Filters of different cutoff frequencies are used to analyze the signal at different resolutions. Let us suppose that x[n] is the original signal, spanning a frequency band of 0 to π rad/s. The original signal x[n] is first passed through a half-band high-pass filter g[n] and a low-pass filter h[n]. After the filtering, half of the samples can be eliminated according to the Nyquists rule, since the signal now has the highest frequency of π /2 radians instead of π. The signal can therefore be sub-sampled by 2, simply by discarding every second sample [11]. This constitutes one level of decomposition and can mathematically be expressed as follows:

$$y_{high}[k] = \sum_n x[k]\, g[2k - n] \qquad (1)$$

$$y_{low}[k] = \sum_n x[k]\, h[2k - n] \qquad (2)$$

where $y_{high}[k]$ and $y_{low}[k]$ are the outputs of the high-pass and low-pass filters, respectively, after sub-sampling by 2. The analysis and synthesis filters are identical to each other, except for a time reversal. Therefore, the reconstruction formula becomes (for each layer).

$$x[n] = \sum_n \big(y_{high}[k]g[-n + 2k] \\ + y_{low}[k]h[-n + 2k] \big) \quad (3)$$

2.3 Discrete cosine transform (DCT)

The DCT transforms a signal from a spatial representation into a frequency representation [2]. Lower frequency are more obvious in an image than higher frequency so if we transform an image into its frequency component and throw away a lot of higher frequency coefficients, we can reduce the amount of data needed to describe the image without sacrificing too much image quality. The discrete cosine transform (DCT) is closely related to the discrete Fourier transform. It is a separable linear transformation; that is, the two-dimensional transform is equivalent to a one- dimensional DCT performed along a single dimension followed by a one-dimensional DCT in the other dimension. With an input image, x, the DCT coefficients for the transformed output image, y, are computed according to equation shown below. In the equation, x, is the input image having N$\times$ M pixels, x (m, n) is the intensity of the pixel in row m and column n of the image, and y (u, v) is the DCT coefficient in row u and column v of the DCT matrix [14].

$$y(u,v) = \sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\alpha_m \alpha_n \sum_{x=0}^{M-1}\sum_{y=0}^{N-} \left\{ x(m,n)cos\frac{(2m+1)u\pi}{2M}cos\frac{(2n+1)u\pi}{2N} \right\} \ (4)$$

Where

$$\alpha_u = \begin{cases} \dfrac{1}{\sqrt{2}}, & for\ u = 0 \\ 1, & for\ u = 1,2..N-1 \end{cases}$$

$$\alpha_v = \begin{cases} \dfrac{1}{\sqrt{2}}, & for\ v = 0 \\ 1, & for\ v = 1,2..N-1 \end{cases}$$

3. Proposed method for satellite image security

This paper proposes a method to improve satellite image security by combining DWT-DCT watermarking and AES encryption. Here proposes an algorithm for satellite image watermarking based on Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) [1]. To improve performance, combine discrete wavelet transform (DWT) with another equally powerful transform; the discrete cosine transform (DCT). The combined DWT-DCT watermarking algorithm's imperceptibility was better than the performance of the DWT approach. For watermarking, the preferred color model must be HSV (Hue, Saturation and Value) rather than RGB because it is the most closely related color model with Human Visual System [3]. Salt and pepper noise of input color satellite image can be removed by using MDBUTMF algorithm. Watermarked satellite image is obtained by implementing watermark embedding process. Original satellite image and secret image can be recovered back by using extraction process. The simulation results show that this algorithm is invisible and has good robustness for some common image processing operations.

3.1 Algorithm for noise removal using MDBUTMF algorithm

A modified decision based unsymmetrical trimmed median filter (MDBUTMF) algorithm is proposed here for the restoration of satellite images that are highly corrupted by salt and pepper noise. The proposed algorithm replaces the noisy pixel by trimmed median value when other pixel values, 0's and 255's are present in the selected window and when all the pixel values are 0's and 255's then the noise pixel is replaced by mean value of all the elements present in the selected window [7]. Flow chart is as shown below.

3.2 Algorithm for watermark embedding

- Input color satellite image
- Remove impulse noise by using Modified decision based unsymmetric trimmed median filter (MDBUTMF) algorithm
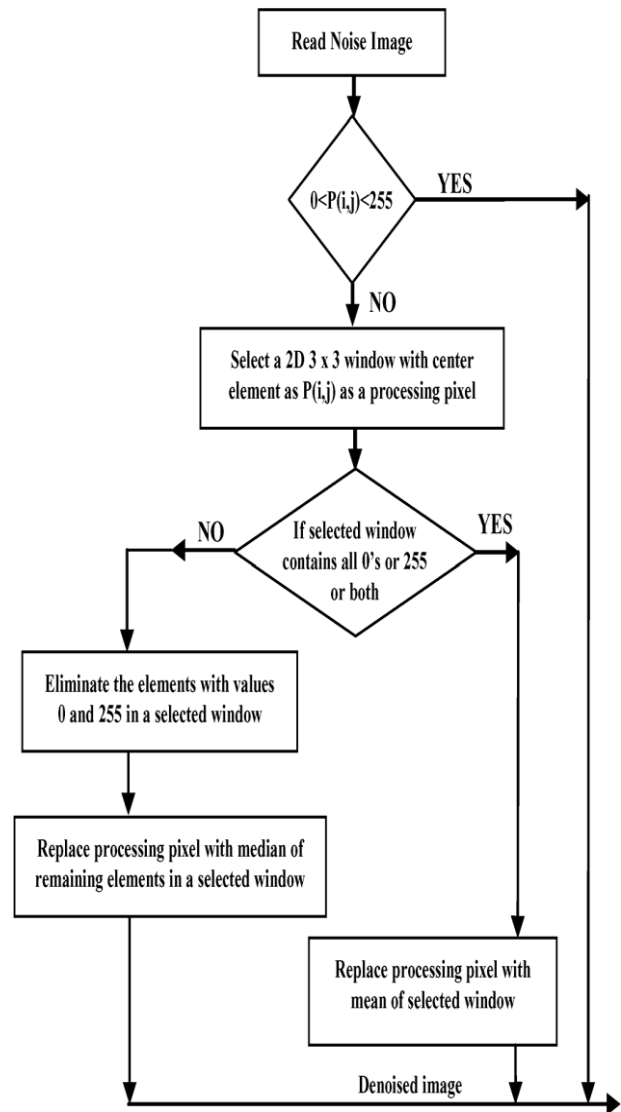
Figure 2: Flow chart of MDBUTMF algorithm

- Convert RGB image to HSV image [3] and convert HSV to Hue, Saturation and Value components
- Apply DWT on satellite image to decompose into Sub-bands LL, HL, LH and HH and apply DCT on HH band
- Select a secret image and perform AES encryption
- Make the size of the encrypted secret image equal to original image
- Apply DWT on secret image and apply DCT on HH band of secret image
- Embedding equation

$$I_w = I + k \times W \qquad (5)$$

  I - DCT transformed matrix of satellite image
  W - DCT transformed matrix of secret image
  k - Embedding strength varies from 0 to 1
  I_w - embedded matrix
- Apply inverse DCT to produce HH* and inverse DWT to LL, HL, LH and HH*
- Watermarked (Value) image is obtained. Now concatenate H,S,V back to HSV
- Convert back to RGB satellite image. Then watermarked satellite image is obtained

3.3 Algorithm for watermark extraction

- Apply DWT on watermarked satellite image and apply DCT on HH band
- Do AES decryption of secret image and perform DWT on secret image
- Apply DCT on HH band of secret image
- Extraction process

$$I = I_w - k \times W \qquad (6)$$

I_w - DCT transformed matrix of watermarked satellite image

W - DCT transformed matrix of secret image

I - recovered matrix

- Apply inverse DCT to produce HH* and inverse DWT to LL, HL, LH and HH*
- Recover secret image and original satellite image
- Theoretical evaluation - Calculate Mean square error (MSE) and Peak signal to noise ratio (PSNR)

3.4 Theoretical analysis

For the testing of the proposed algorithm following measures are used for assessment of quality of image and watermark. Image quality is theoretically measured using peak signal to n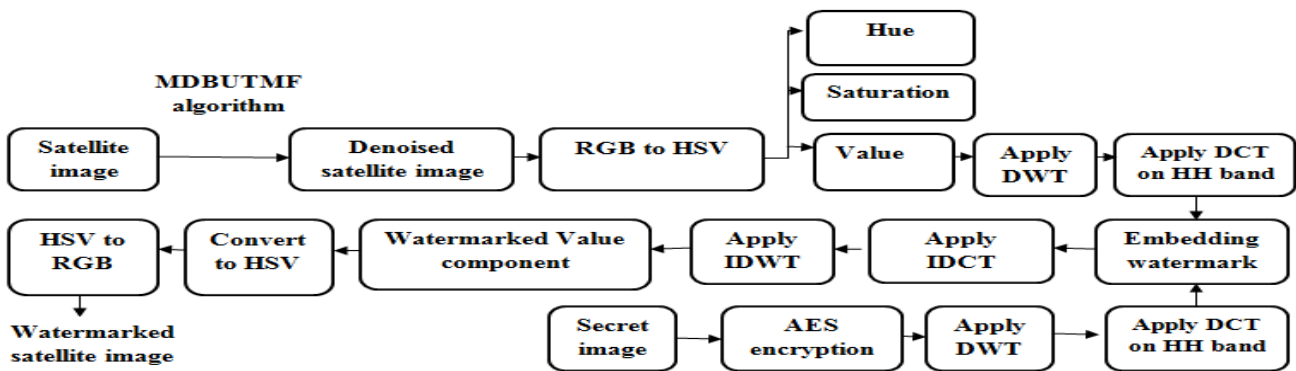oise ratio (PSNR) and mean square error (MSE) [7]. MSE is computed pixel-by-pixel by adding up the squared differences of all the pixels and dividing by the total pixel count.

$$MSE = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} \left(W_{ij} - W'_{ij}\right)^2 \quad (7)$$

where m×n is the size of the image, W_{ij} is the original watermark pixel and W'_{ij} is the extracted watermark pixel in i^{th} row and j^{th} column. Lower the value of MSE lower the error and better picture quality. As a measure of the quality of a watermarked image, the PSNR is typically used[11].

$$PSNR = 10 log_{10} \frac{255^2}{MSE} \quad (8)$$

Its unit is db. And the bigger the PSNR value is, the better the watermark conceals.
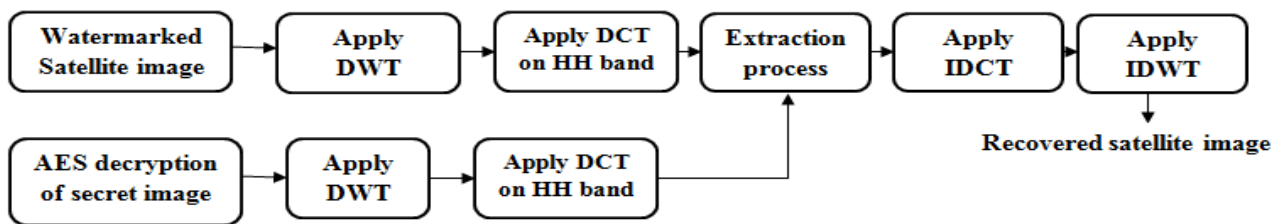

Figure 3: Watermark embedding

Figure 4: Watermark extraction

3.4 Advanced Encryption Standard (AES)

To protect satellite images some cryptographic techniques are used. To provide high security Advanced Encryption Standard (AES) is used which is approved by NIST. AES is a block cipher. AES is used in different application since it provides simplicity, flexibility, easiness of implementation and high throughput [8].

The AES algorithm is a symmetric-key cipher, in which both the sender and the receiver use a single key for encryption and decryption. The data block length is fixed to be 128 bits, while the key length can be 128, 192, or 256 bits, respectively. In addition, the AES algorithm is an iterative algorithm. Each iteration can be called a round, and the total number of rounds is 10, 12, or 14, when the key length is 128, 192, or 256 bits, respectively. The 128-bit data block is divided into 16 bytes. These bytes are mapped to a 4×4 array called the State, and all the internal operations of the AES algorithm are performed on the State. Each round in AES, except the final round, consists of four transformations: Sub-Bytes, Shift-Rows, Mix-Columns, and Add-Round-Key. The final round does not have the Mix-Columns transformation. The decryption flow is simply the reverse of the encryption flow and each operation is the inverse of the corresponding one in the encryption process [8].
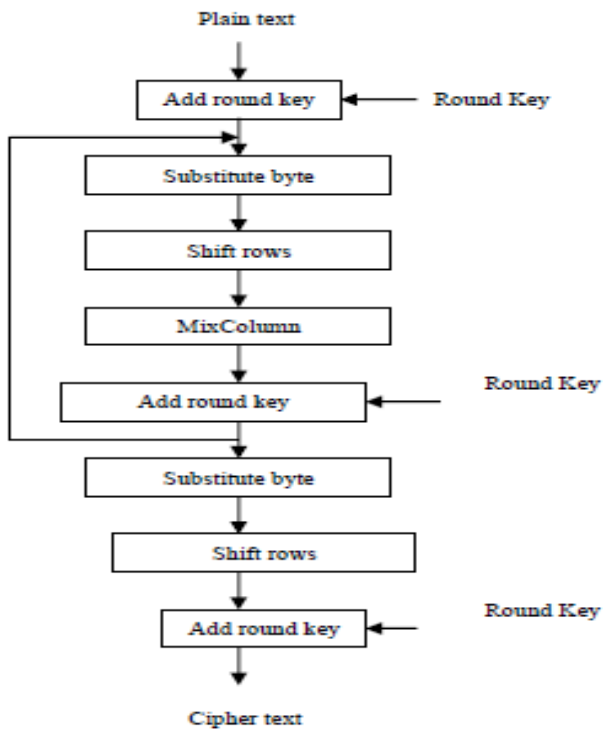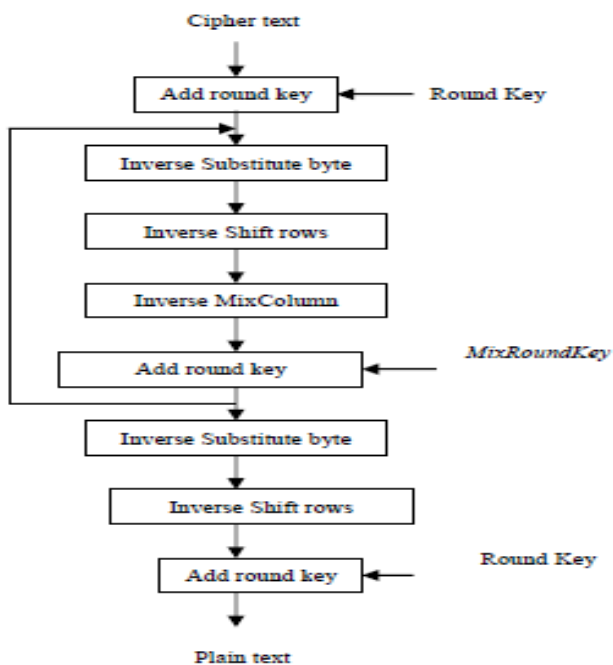
Figure 5: AES encryption

Figure 6: AES encryption

4. 4. Simulation results

Input noisy color satellite image. A modified decision based unsymmetrical trimmed median filter (MDBUTMF) algorithm is used for the restoration of satellite gray scale, and color images that are highly corrupted by salt and pepper noise. Convert denoised RGB satellite image to HSV image. Convert HSV image to Hue (H), Saturation(S) and Value (V) components. Next select a secret image (watermark image).

Make the size of this secret image equal to that of the original satellite image. Do AES encryption of secret image. Apply watermark embedding process. Watermarked satellite image (Value component) is obtained. Concatenate Hue, Saturation and Value components back to watermarked HSV image. Convert this HSV satellite image back to RGB satellite image. Obtained watermarked satellite image.

Do inverse operation for discrete cosine transform (DCT) and discrete wavelet transform (DWT). Perform AES decryption of satellite image. Recover secret image and original satellite image back. Theoretical evaluation can be done by calculating Mean square error (MSE) and Peak signal to noise ratio (PSNR). Image quality is theoretically measured using peak signal to noise ratio (PSNR) and mean square error (MSE).Values of MSE and PSNR using the proposed method is as shown in the table.
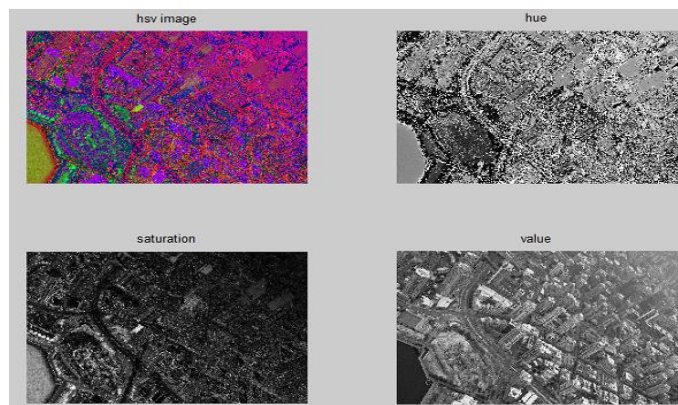

Figure 7: (a) Noisy image (b) Denoised image
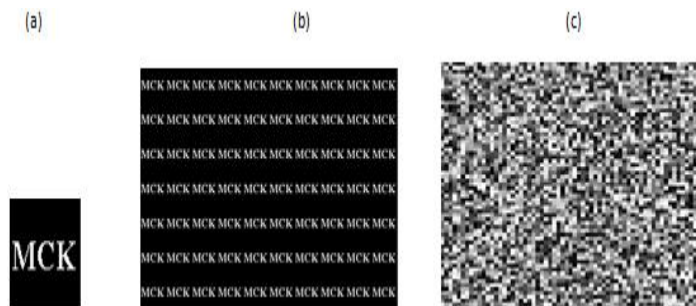

Figure 8: HSV images

Figure 9: (a) Secret image, (b) Resized secret image (c) Encrypted secret image

Compare PSNR values of watermarking using DWT alone and by using the combination of DWT and DCT. Compare MSE values of watermarking using DWT alone and by using the combination of DWT and DCT. Processing time required is very less. In the proposed method 0.87 seconds is required for processing.

By using the proposed method invisible watermark is obtained so that the purpose of the image must not be violated. When compared to the traditional work satellite image security is more in the proposed method. This can be theoretically analyzed by checking the values of MSE and PSNR. MSE value is less and PSNR value is more when compared to the previous work. This shows the improved security level of satellite images.

Figure 10: (a) Watermarked HSV image, (b) Watermarked RGB images

Table 1: Values of MSE and PSNR

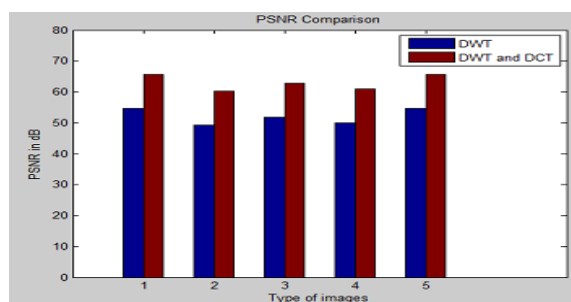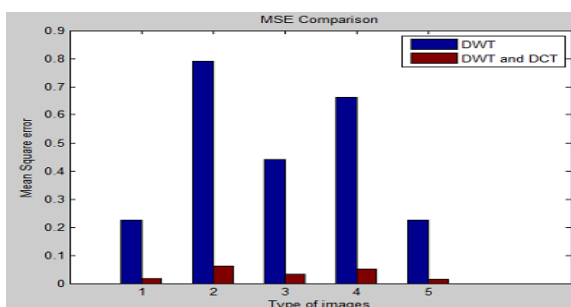| Images	PSNR in dB (DWT)	PSNR in dB (DWT and DCT)	MSE (DWT)	MSE (DWT and DCT)
1	54.587	65.718	0.226	0.014
2	49.1492	60.2774	0.7910	0.0610
3	51.6985	62.8290	0.4398	0.0339
4	49.9267	61.0418	0.6613	0.0512
5	54.5870	65.63	0.2261	0.014

Figure 11: PSNR comparison

Figure 12: MSE comparison

5. Conclusion and Future Work

The proposed satellite image watermarking system not only can keep the image quality well, but also can be robust against many image processing operations like filtering, sharp enhancing, adding noise etc. This algorithm has strong capability of embedding signal and anti-attack. Platform used is Matlab. The comparability of the recovered watermark with the original watermark can quantitatively analyze by using peak signal to noise ratio (PSNR) and mean square error (MSE). Combination of DCT and DWT techniques can be used to improve the PSNR. Combined DWT-DCT watermarking along with AES encryption provide more security for satellite images.

As the future work some post processing operations such as image restoration and correlation can be used to further improve the watermark recognition process and hence can increase the success rate against different types of image attacks.

Acknowledgement

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Author Profile

Naida.H.Nazmudeen took her B-Tech from University of Kerala with her major as Electronics and Communication engineering. She is currently pursuing her Masters in Microwave Engineering from University of Kerala. Her focus areas include image processing, neural network, network security and communication systems.

Jismi.K obtained B-Tech degree from IHRD under Cochin University of Science and technology, Kerala in 2004 and M-Tech in VLSI Design form Electronics and Communications Engineering Department Amrita Vishwavidyapeetham University in 2010. She is presently working as Associate Professor in Department of ECE, MACE, Trivandrum, Kerala. Her current research interests are in the field of VLSI design, testing and cryptography.