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A New Method for Satellite Image Security Using DWT-DCT Watermarking and AES Encryption

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ABSTRACT: With the large-scale research in space sciences and space 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. The researches and applications of applying digital watermarking to geo-information data are still very inadequate. Watermarking techniques developed for 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. Hence an efficient watermarking is necessary for satellite images. 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. The proposed method is more robust against different kinds of attacks and the watermarked image obtained is invisible. Satellite images have higher requirements in content security: it desires 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 peak signal to noise ratio (PSNR) and mean square error (MSE). The experimental results demonstrate the efficiency of the proposed scheme, which fulfills the strict requirements concerning alterations of satellite images.

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

I. INTRODUCTION

With the large-scale research and development in space sciences, space technologies, and network communication technologies, there is a great demand of satellite imagery security system for providing secure storage and transmission of satellite imagery over internet and/or shared network environment. 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. 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.

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Secure communication is when two entities are communicating and do not want a third party to listen in. For that they need to communicate in a way not susceptible to eavesdropping or 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].

A. Discrete wavelet Transform (DWT)

The basic idea of discrete wavelet transform (DWT) in image processing is to multi-differentiated decompose the image into sub-image of different spatial domain and independent frequency district. 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. The low-frequency district information also can be decomposed into sub-level frequency district information of LL2, HL2, LH2 and HH2. By doing this the original image can be decomposed for n level wavelet transformation. 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].

B. 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.A discrete cosine transform (DCT) expresses a sequence of finitely many data points in terms of a sum of cosine functions oscillating at different frequencies. The use of cosine rather than sine functions is critical in these applications: for compression, it turns out that cosine functions are much more efficient (as described below, fewer functions are needed to approximate a typical signal), whereas for differential equations the cosines express a particular choice of boundary conditions.

II. 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.

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A. 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.

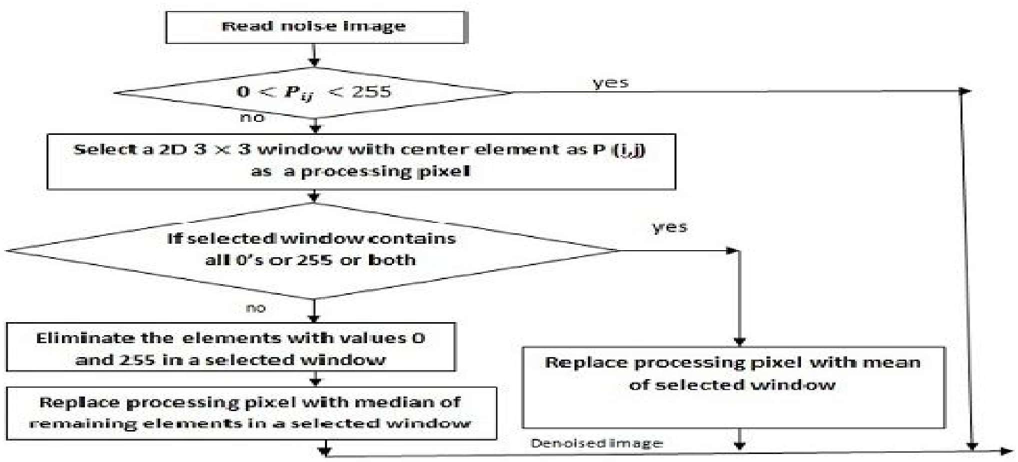

Fig.2.1 Flow chart of MDBUTMF algorithm

B. Watermark embedding

- Input color satellite image
- Remove impulse noise by using Modified decision based unsymmetric trimmed median filter (MDBUTMF) algorithm
- Convert RGB image to HSV image [3] and convert HSV to Hue, Saturation and Value
- 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

$$I_w = I + k \times W$$

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

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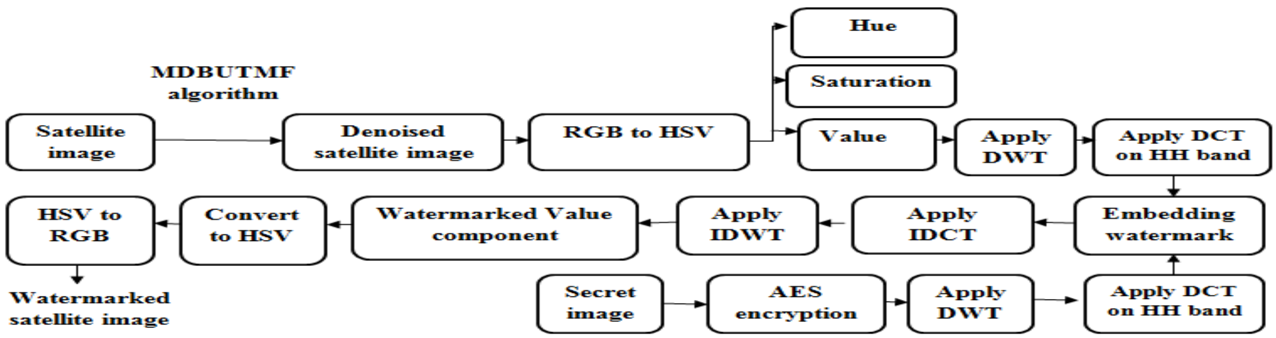

Fig. 2.2 Watermark embedding

C. 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

$$I = I_w - k \times W$$

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)

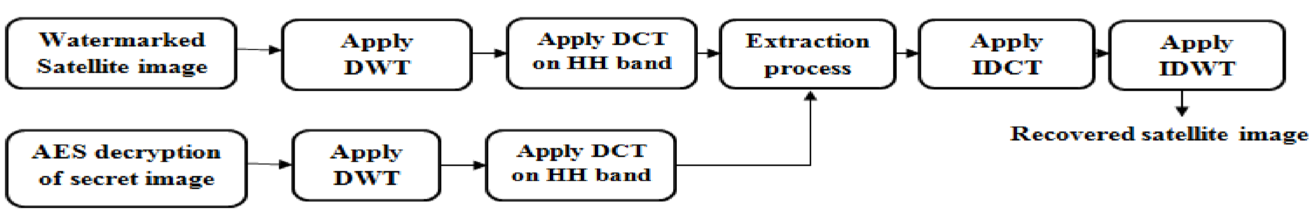

Fig. 2.3 Watermark extraction

D. 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 noise ratio (PSNR) and mean square error (MSE) [11]. MSE is computed pixel-by-pixel by adding up the squared differences of all the pixels and dividing by the total pixel count.

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

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.

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$$PSNR = 10log_{10}\frac{255^2}{MSE}$$

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

E. 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.

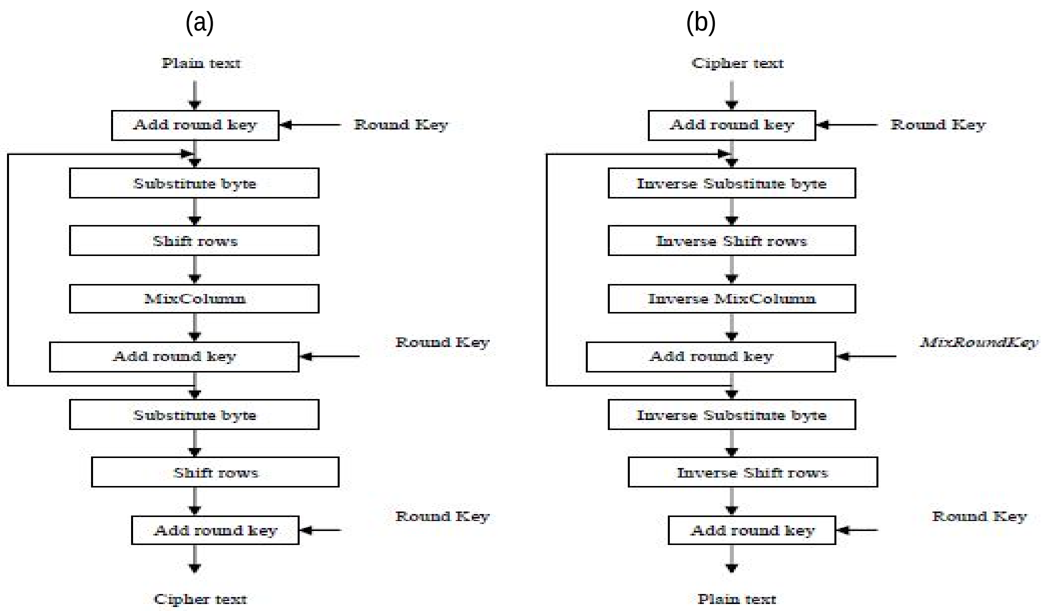

Fig. 2.4. (a) AES encryption, (b) Decryption

III 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).

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(a) (b)

Fig.3.1. (a) Noisy image (b) Denoised image

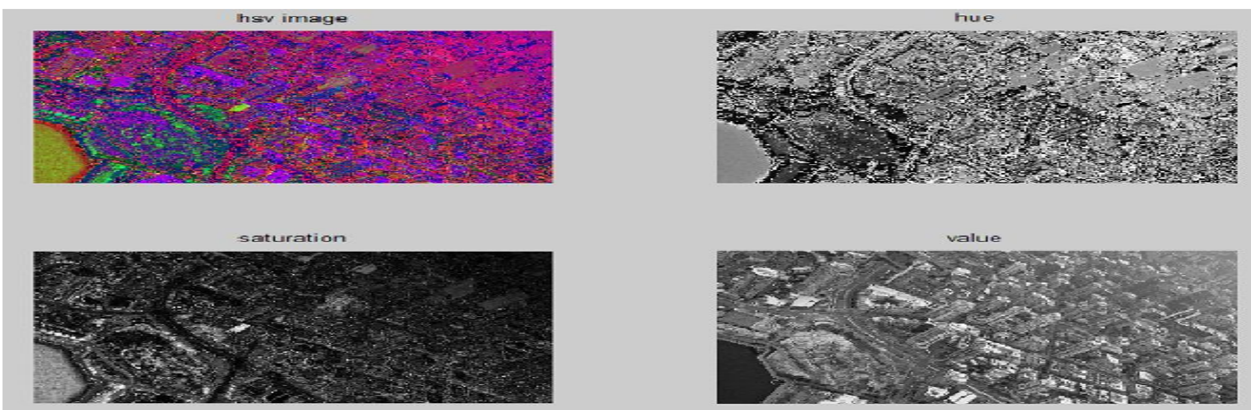

Fig.3.2. HSV images

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.

(a) (b) (c)

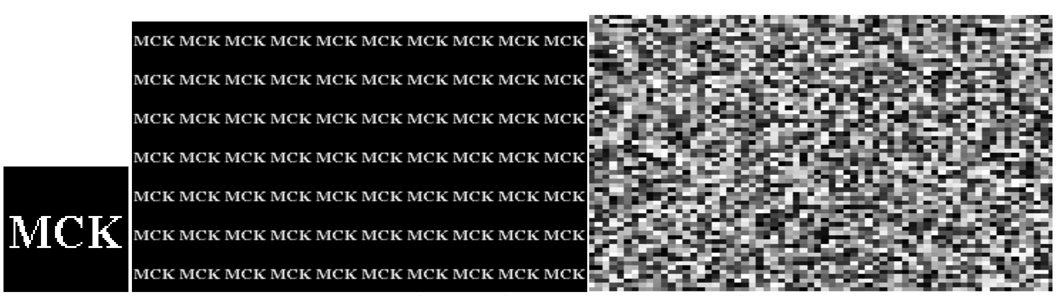

Fig.3.3 (a) Secret image, (b) Resized secret image (c) Encrypted secret image

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.

(a) (b)

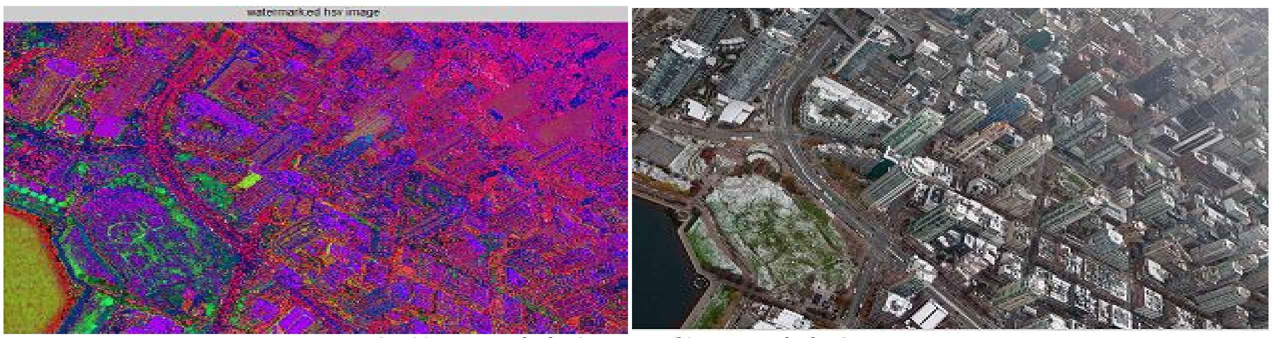

Fig.3.4 (a) Watermarked HSV image, (b) Watermarked RGB image

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.

Images	PSNR in dB (DWT)	PSNR in dB (DWT and DCT)	MSE (DWT)	MSE (DWT and DCT)
1	54.587	65.718	0.226	0.0174
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

Fig.3.5 Values of MSE and PSNR

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.

(a) (b)

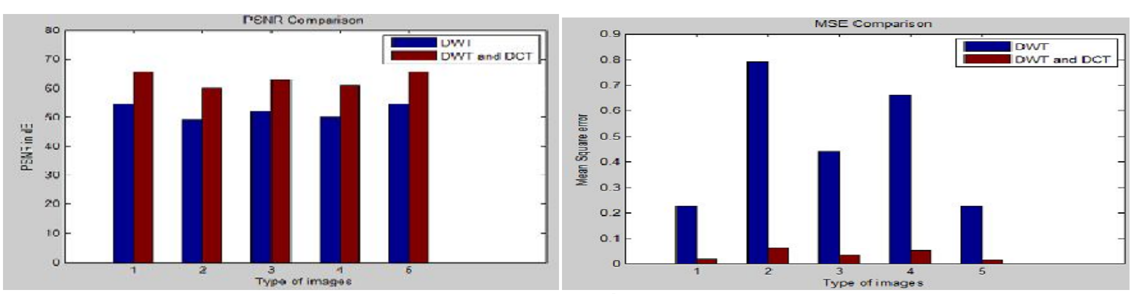

Fig.3.6 (a) PSNR comparison, (b) MSE comparison

V. CONCLUSION

The proposed satellite image watermarking system not only can keep the image quality well, but also can be robust against many image processing operations of filer, sharp enhancing, adding noise etc. This algorithm has strong capability of

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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.

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