DWT-SVD Based Image Watermarking Method Using Arnold Key

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ABSTRACT *Watermarking is a technique to hide data and embedded inside an image to show authenticity or proof of ownership. Various watermarking techniques and the utility of Wavelets in the decomposition and embedding of watermark in image with various methods of wavelet transform are proposed in this paper.*

2. Introduction

Digital Image Watermarking is a technique which provide solution for Copyright, image authentication and other issues Watermarking deals with decomposing original image called Cover image using some wavelet Transforms[1] and embedding watermark into one of the sub band (LL,LH,HL,HH) the obtained image is called watermarked image (Stego Image) this image have transmitted through Channel Where various noise Affect watermarked Image [2],[3],[4].At receivers Side embedded watermark has extracted from watermarked image[5].For watermark embedding Discrete Wavelet Transform(DWT) has used, DWT is a Wavelet Transform which use Dydic Filters to decompose M×N Image in to N-Levels, we can embed watermark into one of the sub band, For Extraction of Watermark Inverse Discrete Wavelet Transform (IDWT) is used[6] Analysis of Image has based on Performance Parameters like Signal to Noise Ratio (SNR) of original & watermarked Image[7] Peak signal to Noise ratio(PSNR) & WPSNR are some other factors to analyze Performance[8][9][15]. Various Image compression techniques has described in[10],[12].Bi orthogonal wavelet has used to analyze watermarking [15].Various attacks on watermarked image like Gaussian Noise attack, salt& pepper attack, JPEG Compression ,speckle attack[11][16][17][18][19][20] etc.

3. Discrete Wavelet transform (DWT)

Discrete Wavelet transform (DWT) is a mathematical tool for hierarchically decomposing an image. It is useful for processing of non-stationary signals. The transform is based on small waves, called wavelets, of varying frequency and limited duration. Wavelet transform provides both frequency and spatial description of an image. Unlike conventional Fourier transform, temporal information is retained in this transformation process. Wavelets are created by translations and dilations of a fixed function called mother wavelet. This section analyses suitability of DWT for image watermarking and gives advantages of using DWT as against other transforms. For 2-D images, applying DWT corresponds to processing the image by 2-D filters in each dimension. The filters divide the input image into four non-overlapping multi-resolution sub-bands LL1,LH1, HL1 and HH1. The sub-band LL1 represents the coarse-scale DWT coefficients while the sub-bands LH1, HL1 and HH1 represent the fine-scale of DWT coefficients. To obtain the next coarser scale of wavelet coefficients, the sub-band LL1 is further processed until some final scale N is reached. When N is reached we will have 3N+1 sub-bands consisting of the multi-resolution sub-bands LL_N and LH_x, HL_x and HH_x where x ranges from 1 until N. Due to its excellent spatio-frequency localization properties, the DWT is very suitable to identify the areas in the host image where a watermark can be embedded effectively. In general most of the image energy is concentrated at the lower frequency sub-bands LLx and therefore embedding watermarks in these sub-bands may degrade the image significantly.Embedding in the low frequency sub-bands, however, could increase robustness significantly. On the other hand, the high frequency sub-bands HHx include the edges and textures of the image and the human eye is not generally sensitive to changes in such sub-bands. This allows the watermark to be embedded without being perceived by the human eye.

a. Characteristics of DWT

The wavelet transform decomposes the image into three spatial directions, i.e. horizontal, vertical and diagonal. Hence wavelets reflect the anisotropic properties of HVS more precisely. Fig. 1 shows DWT decomposition of an image using three level pyramids.
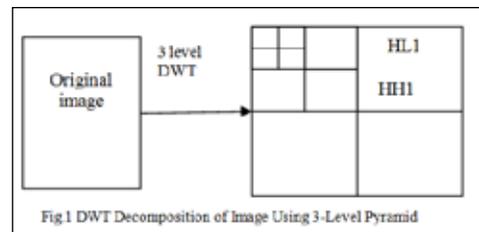

Fig.1 DWT Decomposition of Image Using 3-Level Pyramid

1. Wavelet Transform is computationally efficient and can be implemented by using simple filter convolution.
2. With multi-resolution analysis, image can be represented at more than one resolution level. Wavelets allow image to be described in terms of coarse overall shape and details ranging from broad to narrow.
3. Magnitude of DWT coefficients is larger in the lowest bands (LL) at each level of decomposition and is smaller for other bands (HH, LH, HL).
4. The larger the magnitude of wavelet coefficient, the more significant it is.
5. Watermark detection at lower resolutions is computationally effective because at every successive resolution level, less no. of frequency bands are involved.
6. High resolution sub bands help to easily locate edge and textures patterns in an image.

b. Advantages of DWT

The suitability of wavelet transform for image watermarking can be considered because of following reasons.

1. Wavelet transform can accurately model HVS than other transforms like Discrete Fourier Transform (DFT) [6] or Discrete Cosine Transform (DCT) [7, 8]. This allows higher energy watermarks in regions where HVS is less sensitive. Embedding watermark in these regions allow us to increase robustness of watermark, with no much degradation of image quality.
2. Wavelet coded image is a multi-resolution description of image. Hence an image can be shown at different levels of resolution and can be sequentially processed from low resolution to high resolution. The advantage of such approach is that the features of an image that might go undetected at one resolution may be easy to spot at another.
3. Visual artefacts introduced by wavelet coded images are less evident compared to DCT because wavelet transform doesn't decompose image into blocks for processing. At high compression ratios, blocking artefacts are noticeable in DCT as against wavelet transformed images.
4. DFT and DCT are full frame transform. Hence, any change in

the transform coefficients affects entire image except if DCT is implemented using a block based approach. However DWT has spatial frequency locality. It means it will affect the image locally, if watermark is embedded.

5. Another advantage is that current image compression standard JPEG 2000 is based on wavelet transform.

4. Singular Value Decomposition (SVD)

Singular Value Decomposition (SVD) is said to be a significant topic in linear algebra by many renowned mathematicians. SVD has many practical and theoretical values; special feature of SVD is that it can be performed on any real (m, n) matrix.Every real (or complex) m×n matrix A can be decomposed into two orthogonal (or Unitary) matrices U and V and a diagonal matrix S. The entries in this diagonal matrix are called the singular values of the matrix A. This decomposition is called Singular Value Decomposition of A and can be expressed as

$$A = USV'$$

Where r is the rank of the matrix A and hence r=min (m, n). The first r columns of V are the right singular vectors and the first r columns of U are the left singular vectors. These singular values (σ_i) are such that it satisfies $\sigma1 \geq \sigma2 \geq ... \geq \sigma_r$. Further, we rearrange this decomposition as

$$A = \sum_{r=1}^{r} \sigma U t V' t$$

Use of SVD in digital image processing has some advantages. First, the size of the matrices from SVD transformation is not fixed. It can be a square or a rectangle. Secondly, singular values in a digital image are less affected if general image processing is performed because bigger singular values not only preserve most energy of an image but also resist against attacks. Generally, the matrix S has many small singular values. Finally, singular values possess intrinsic algebraic image properties. It is important to note that each singular value specifies the luminance of an image layer while the corresponding pair of singular vectors specifies the geometry of the image layer.

Singular value decomposition is a linear algebra technique used to solve many mathematical problems. The theoretical background of SVD technique in image processing applications to be noticed is:

a) The SVs (Singular Values) of an image has very good stability, which means that when a small value is added to an image, this does not affect the quality with great variation.

b) SVD is able to efficiently represent the intrinsic algebraic properties of an image, where singular values correspond to the brightness of the image and singular vectors reflect geometry characteristics of the image.

c) An image matrix has many small singular values compared with the first singular value. Even ignoring these small singular values in the reconstruction of the image does not affect the quality of the reconstructed image.

Any image can be considered as a square matrix without loss of generality. So SVD technique can be applied to any kind of images. If it is a gray scale image the matrix values are considered as intensity values and it could be modified directly or changes could be done after transforming images into frequency domain. The SVD belongs to orthogonal transform which decompose the given matrix into three matrices of same size.To decompose the matrix using SVD technique it need not be a square matrix. Let us denote the image as matrix A.

The SVD decomposition of matrix A is given using (1)

$$A = USV^T \qquad (1)$$

U and V are unitary matrices such that $UU^T = I$, $VV^T = I$, where I is an Identity matrix.

$$U=[u_1, u_2, u_3 \dots u_n] \ \& \ V=[v_1, v_2, v_3 \dots v_m] \qquad (2)$$

U matrix is called left singular values and V matrix is called right singular values. The decomposition of matrix A is obtained using (2).

$$SVD (A) = USV^T = U \begin{bmatrix} D & 0 \\ 0 & 0 \end{bmatrix} V^T$$

S=[D 0;0 0] such that all the elements in main diagonal are in decreasing order like $\sigma1 \geq \sigma2 \geq \sigma3 \geq ... \sigma n \geq 0$, where S is the diagonal matrix having in its main diagonal all positive singular values of A. Number of nonzero values equals the rank of the matrix. These positive singular values can be used to embed watermark. The order of singular matrix is same as A, and hence the resultant matrix is also square. Hence images of equal size can be taken as cover object.

5. Arnold Transform

Arnold transform is commonly known as cat face transform. Arnold transformation defined by Eq. 2 is a one-to-one transformation. From the view of sampling theory, digital images can be viewed as a matrix of 2D discrete points derived from sampling according to a certain interval and a certain method:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \left[\begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} mod1 \right] \qquad (2)$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \left[\begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} modN \right] (x, y) \epsilon 0, 1 \dots, N-1 \qquad (3)$$

Equation 3 is used to transform each and every pixel coordinates of the images. Where (x, y) is the location coordinates of the original image pixels and (x', y') is the location coordinates of image pixels that after transform When all the coordinates are transformed, the image we obtain is scrambled images. In addition, when one digital image is transformed by Arnold transformation, the transforming process can be achieved continually. At a certain step of iteration, if the image we achieve reaches our anticipated target, we have achieved the scrambled image we need. The decryption of image relies on the transformation periods. The periods change in correspondence to the size of images. The iteration periods is 96 for a 128×128 image; 48 for a 64×64 image. Here the number that images are scrambled is used as an encryption key and modulated by binary pseudo random sequence, which further strengthens the security of watermark. Due to its pseudo random and the pseudo random of binary sequence, attackers can hardly detect the watermark without first knowing the pseudo random sequence.

6. Watermark Embedding Algorithm

The flow diagram of embedding process is shown in Fig. 1. The steps in the process of embedding are follows:
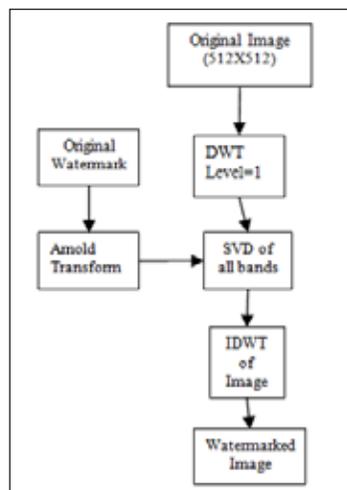
1. Take the original image and resize it to 512x512image. Make one-level wavelet decomposition of the original image and all frequency band as the embedded domain.

2. The wavelet coefficient of all bands are singular value de-

composed by block size of 4.

3. Take the Arnold transform of the watermark and resize it to 64X64 bit binary image.
4. After the Arnold transformation, apply Arnold transformed watermark into SVD calculated original image.
5. Perform the embedding of the watermark in the original image the obtained image will be watermarked image.
6. Take inverse DWT of watermarked image to transform image back into domain.

7. Watermark Extraction Algorithm

Watermark extraction is reverse process of watermark embedding, the steps for extraction of watermark Without attacks is given below:

1. Receive watermarked image considering without attack.
2. Take one level DWT of watermarked image and calculate value of bands.
3. Apply SVD on each band and calculate singular values across all bands.
4. Perform Arnold transform on singular value decomposed image.
5. The obtained image is Watermark image.
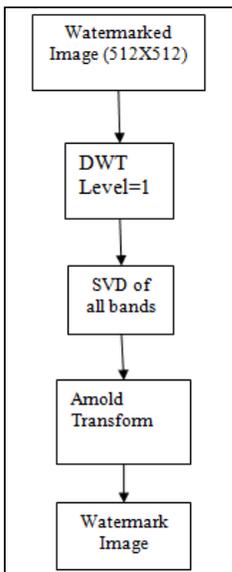
Figure (2): watermark Extraction

6. Parameters used

For simulation and result analysis of this method two parameters are calculated:

1. PSNR: the Peak signal to noise ratio shows degree of noise present in image and where E is mean square Error is given by

$$PSNR = 10\lg(\frac{255^2}{E})$$

$$E = \frac{1}{M \times N} \sum_{i=1}^{N} \sum_{j=1}^{M} [(f(i,j) - f'(i,j)]^2$$

2. NCC: the normalize correlation coefficient shows degree of similarity between two images and is given by:

$$NC = \frac{\sum_{i=0}^{N} \sum_{j=0}^{M} W(i,j) \times W^*(i,j)}{\sum_{i=0}^{N} \sum_{j=0}^{M} [W(i,j)]^2}$$

Where W (i,j) = original watermark image.

W*(i,j)= Extracted watermark image.

N and M =width and height of watermark image.

7. Results

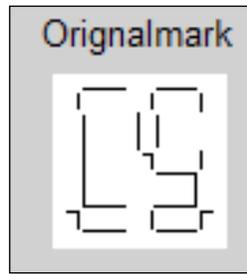Figure (3) shows Original watermark of 32X32 size and figure (4) shows Arnold transformed watermark of 32X32 size.
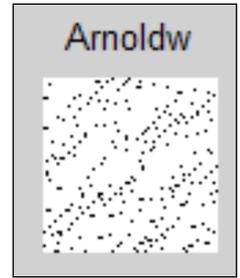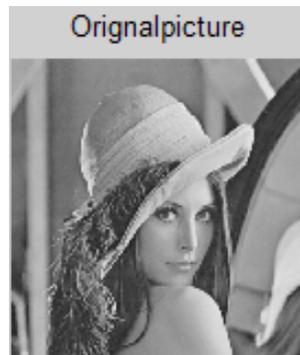

| Figure (3) | figure (4) |

The original image of size 512X512 is used with watermarked image obtained of 512X512 size. Figure (5) & figure (6) figure (7) shows original and watermarked images & Extracted watermark with PSNR 74 dB & NCC is 0.99.

Figure (5): original image

Figure (6): Watermarked image

Figure (7): Extracted Watermark

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