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Advanced Technique of Digital Watermarking based on SVD-DWT-DCT and Arnold Transform

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Abstract-With the growing popularity of internet and digital media, we propose a method of non-blind transform domain watermarking which is based on the Direction Cosine Transform (DCT), Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) by using Arnold Transform method. DCT based watermarking techniques offers compression while DWT based compression offers scalability. Thus all these desirable properties can be utilized to create a new robust watermarking technique. The DCT coefficients of the DWT coefficients are used to embed the watermarking information. So we go for SVD based digital watermarking which is a method of authentication data embedding in image characteristics with expectation to show resiliency against different type of unintentional or deliberate attacks. Here discrete wavelet transform plays the important role of an efficient tool due to its multi-resolution capability. Along with this wavelet transform we mix up another very strong mathematical tool called the singular value decomposition (SVD). Though till date both of them have individually been used as a tool for watermarking of digital media, very few works have utilized their skills in tandem, especially in this area. Our work here by focuses on using Direction Cosine Transform (DCT), Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) by using Arnold Transform method which provide a hybrid technique developed for protection of the intellectual property with better robustness against the popular malicious attacks. This we have seen practically by attacking the watermarked image against simulated attacks and recovering the logo from it.

Keywords: Singular Value Decomposition, Discrete Wavelet transform, Direction Cosine Transform, Arnold Transform

I. Introduction

Because of the huge rapid growth of the Internet, the traditional business has been expanded to deal in on the Internet nowadays. It is quite convenient for businessmen and consumers to sell or buy some commodities in this way. However, dealing in on the Internet also brings about some problems on information security, such as corruption, stealing, and assuming another's name to exchange. These problems usually can be solved by encryption. Besides, on the Internet, the transmission of digital multimedia, such as image, audio, and video can also settle the problem of protecting rightful ownership. Digital watermarking techniques are used to solve this problem. The digital watermark of rightful owner is hidden into the protected multimedia to avoid others' detection. Because the little distortional multimedia data is acceptable, most digital watermarking techniques exploited this property of multimedia data to hide watermark.

Generally, digital watermarking techniques must conform to some following requirements.

(1) Invisibility: the difference between watermarked and original multimedia must not be noticed by naked eyes, namely, the quality of watermarked multimedia must be good.

(2) Security: everyone except rightful one cannot detect watermark which is hidden in multimedia. Furthermore, watermarking algorithm must be public, namely, the security of the watermarking system should not build on attackers who do not know how the system works.

(3) Efficiency: in order to be implemented efficiently, the watermarking algorithm must have good executing efficiency, and it does not need original multimedia to extract watermark.

(4) Robustness: after the embedded multimedia is processed by digital signal processing (such as filtering, compressing, cropping, sharpening, blurring, etc.), the watermark still can be extracted when the quality of the multimedia is acceptable.

Digital watermarking schemes are usually classified into two categories: one is in spatial domain. It directly changes digital data to hide watermark. The advantage of this kind is low computational complexity. But, it is weak to be against digital signal processing. Another is in frequency domain. It must first transform digital data to be in frequency domain with transformation (such as Fast Fourier Transformation or Discrete Cosine Transformation or Discrete Wavelet Transformation, etc.). Then, it changes the coefficients which are obtained by transformation to hide watermarks. Finally, it inversely transforms these changed coefficients to be in spatial domain. Compared with the first one, it needs more computation, but it can provide better robustness. The purpose of this paper is to propose a new SVD-based watermarking scheme. Our proposed method is block-based, and it does not need original image or storing additional matrices to extract the watermarks, that is, our proposed method can directly extract the watermarks from the watermarked images. Furthermore, it also maintains high robustness and good embedding quality.

II. Literature Review

A digital watermarking technique was not very popular in past decades but after some time some authors wrote many research papers in this field like X. G. Xia et al (1997) gave a multiresolution watermark for digital images again in 1998 Hsu and J. Wu extend the work of X. G. Xia as Multi-resolution watermarking for digital images. M. Barni et al proposed a method of a DCT-domain system for robust image watermarking. Further in 1999 F. Gonzalez et al wrote a tutorial on Digital watermarking and F. Hartung et al also gave Multimedia watermarking Techniques. J. Eggers et al (2000) presented a Robustness of a Blind Image watermarking scheme. In 2001 many authors contribute their research paper in the field of digital watermarking C.S. LU et al gave us Multipurpose watermarking for image authentication and protection, also Kunder D. worked on thesis Multi-resolution Digital watermarking algorithm and implications for multimedia signals and H. Daren et al proposed A DWT-Based Image watermarking algorithm.

In 2002 Barni M. et al introduced a multichannel watermarking of color images. Also P. Tay et al proposed an Image watermarking using wavelets. R. Mehul (2003) presented Discrete wavelet transform based multiple watermarking scheme. A. Reddy (2005) et al proposed a new wavelet based logo-marking scheme. As well as P. Kumswat et al presented A new approach for optimization in image watermarking by using genetic algorithm and P. S. Huang et al proposed Robust spatial watermarking technique for colour images via direct saturation adjustment-vision, iamge and signal processing. In 2006 L. Ghouti et al proposed a digital image watermarking using balanced multi-wavelets. Chin-Chen C. et al (2007) presented a digital watermarking scheme based on singular value decomposition. In 2009 V. Santhi et al worked on DWT-SVD combined full band robust watermarking for color images in YUV color space. In 2011 Baisa L. Gunjal et al presented a comparative performance analysis of DWT-SVD based color image watermarking technique in YUV, RGB and YIQ color spaces. Also Mehdi Khalili presented A novel effective, secure and robust CDMA digital image watermarking in YUV color space using DWT2. C.L.H. Funng et al presented a review study on image digital watermarking and Chin- Chin L. et al proposed a digital watermarking scheme based on singular value decomposition and tiny genetic algorithm. As well as Divya S. presented a digital watermarking algorithm based on SVD and Arnold Transform. In 2012 D. Samiappan et al presented a Robust digital image watermarking for color images and Yogesh kumar et al proposed a Semi-blind color image watermarking on high frequency band using DWT-SVD.

III.Basics of Transforms Used For Watermarking

Discrete Cosine Transforms (DCT)

DCT is used to linearly transform image to frequency domain. The energy of the image is concentrated in only a few low frequency components of DCT depending on the correlation in the data.

Discrete Wavelet Transform (DWT)

DWT uses filters with different cutoff frequencies to analyze an image at different resolutions. The image is passed through a number of high-pass filters, also known as wavelet functions, to analyze the high frequencies and it is passed through a number of low-pass filters, also known as scaling functions, to analyze the low frequencies. After filtering, half of the samples can be eliminated according to the Nyquist criteria. This constitutes one level of decomposition. Thus, decomposition halves the time resolution (half the number of samples) and doubles the frequency resolution (half the span in the frequency band). The above procedure, also known as the sub-band coding, is repeated for further decomposition in order to make a multiresolution analysis.

Singular Value Decomposition (SVD)

Singular value decomposition (SVD) is a numerical technique used to diagonalize matrices in numerical analysis. It is an algorithm developed for a variety of applications. The main properties of SVD from the viewpoint of image processing applications are:

(1) The singular values (SVs) of an image have very good stability, i.e., when a small perturbation is added to an image, its SVs do not change significantly;

(2) SVs represent intrinsic algebraic image properties.

Singular Values of the image gives very good stability. When a small value is added, it does not result too much variation. Hence Singular Value decomposition in linear algebra is used to solve many mathematical problems. In SVD-based watermarking, several approaches are possible. A common approach is to apply SVD to the high frequency band of the Original image, and modify the singular values to embed the watermark data. An important property of SVD based watermarking is that the largest of the modified singular values change very little for most types of attacks.

There are three main properties of SVD from the viewpoint of image processing applications:

• The singular values of an image have very good stability, that is, when a same perturbation is added to an image, its Singular values do not change significantly.

• Each singular value specifies the luminance of an image layer while the corresponding pair of singular vectors specifies the geometry of the image.
• Singular values represent intrinsic algebraic image properties.

From the perspective of image processing, an image can be viewed as a matrix with nonnegative scalar entries. The SVD of an image A with size m × m is given by $A = U S V^T$, where U and V are orthogonal matrices, and $S = diag(\lambda_i)$ is a diagonal matrix of singular values λ_i , i = 1, . . . ,m, arranged in decreasing order. The columns of U are the left singular vectors, whereas the columns of V are the right singular vectors of the image A. This process is known as the Singular Value Decomposition (SVD) of *A*, and can be written as

$$A = USV^T = \sum_{i=1}^{r} \lambda_i u_i v_i^T$$

Where r is the rank of A, u_i and v_i are the left and right singular vectors, respectively. It is important to note that each SV specifies the luminance of the image, whereas the respective pair of singular vectors specifies the intrinsic geometry properties of images. It was discovered that slight variations of SVs do not affect the visual perception of the cover image, which motivates the watermarking embedding through slight modifications of SVs in the segmented images.

Arnold Transform

To confirm the security and improve the robustness of the proposed watermarking scheme, the watermark should be pre-processed before embedded into the original image. Due to the periodicity process of the Arnold transform, the image can be easily recovered after the permutation concept. So, the Arnold transform is applied to the original image watermark.

Let us consider the size of original image is N*N, (i, j) T and its coordinate of the watermark image's pixel.(i',j')T and these coordinate are gained after transform. Arnold transform can be expressed as

$$Let \begin{bmatrix} i' \\ j' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} i \\ j \end{bmatrix} \pmod N$$

Where $i,j \in \{0,1,\dots,N-1\}$ and

$$W = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} i \\ j \end{bmatrix} \text{ is input, } \begin{bmatrix} i' \\ j' \end{bmatrix} \text{ is output.}$$

IV.Proposed Algorithm Using DWT, DCT, SVD and Arnold Transform Techniques

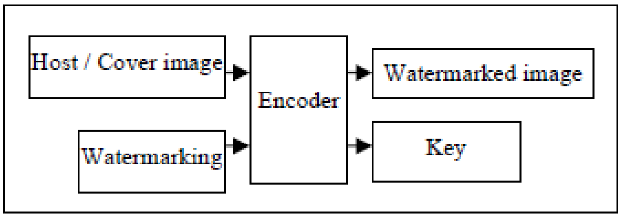

Fig 1: Watermark Embedding

A. Embedded Watermark

- Firstly the SVD is employed in a cover image A to obtain U, V, and S three matrices.
- Use three level Haar DWT to decompose the image A in to four sub bands(i.e., LL_3,LH_3,HL_3, and HH_3)
- Apply SVD to each sub band i.e,

  $A_i = U_i S_i V^T_i$ where $A_{i} = HL_3$
- Apply SVD to the watermarked i.e

  $W = U_w S_w V^T_w$, where W= Watermark
- Then apply the Arnold transform on watermark image(W) and change the watermark image to the Arnold scrambling.
- Modify the singular value of the A_i by embedding singular of W such that

  $\hat{S}_{iw} = S_i * \alpha \times S_w$

  Where

  S_{iw} is modified singular matrix of A_i and

  α denotes the scaling factor, is used to control the strength of watermark signal
- Then apply SVD to this modified singular matrix S_{iw} i.e

  $S_{iw} = U\_S_{iw} S\_S_{iw} V\_S_{iw}^T$
- Obtain modified DWT coefficients. i.e.,

  $A_{iw} = U_i \times S\_S_{iw} \times V_i^T$
- Obtain the watermarked image A_w by applying inverse DWT using one modified and other non modified DWT coefficients.
- In this step obtain the watermark image A_w by multiplying the matrices. After that Arnold Transform convert U_i and V_i into one-dimensional

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sequence respectively to compose the embedding watermark W. $\hat{S}_i$ is kept as the secret key.

$A_{wi} = U_i * S_i * V^T_i$

B. Watermark Extraction:

The extraction algorithm process is the inverse of the embedding process. It is assumed that the watermark as well as the see value is available at the receiver end to the authorized users.

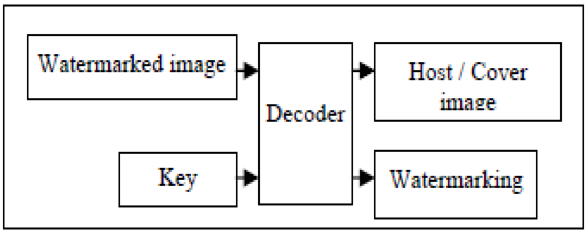


Fig 2: Watermark Extraction

- Apply DCT to the reordered cover image matrix.
- Apply three level haar DWT to decompose the watermarked image A_w in to four sub bands(i.e., LL_3, LH_3, HL_3, and HH_3)
- Apply SVD process to each sub band in watermark image

  $\hat{A}_{iw} = U_{iw} * S_{iw} * V^T_{iw}$

- Compute $S^*_w = \frac{(Siw - Si)}{\propto}$, where S^*_w singular matrix of extracted watermark (possibly distorted).
- Now construct the coefficient of the sub-band by using SVD to S^*w i.e.,

$$A^*_w = U\_ S^*_w S\_ S^*_w V\_ S^*_w{}^T$$

- Now Compute extracted watermark $W^* = U_w$ x $S\_ S^*_w$ x V^T_w
- Then processing A^*_w with Arnold transform and get the extracted of watermark image.

V.Results Analysis

To demonstrate this experiment were carried out to verify the validity of the proposed watermarking scheme. The gray-level image of Lena with size 256 × 256 is used as the cover image and the gray-level image of size 64 × 64 is used as the watermark image.

The peak signal-to noise ratio (PSNR) was used as a measure of the quality of a watermark image. To evaluate the robustness of the proposed approach, the watermarked image was tested against five kinds of attacks:

1) Geometrical Attack: cropping (CR) and rotation (RO).

2) Noising Attack: Gaussian noise (GN).

3) De-noising Attack: average filtering (AF).

4) Format-Compression Attack: JPEG compression.

5) Image-Processing Attack: histogram equalization (HE), gamma correction (GC), and Blurring Attack (BL).

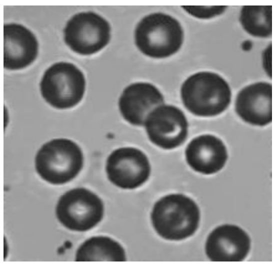
To compute the PSNR between the original image and extracted image.

$$PSNR = 10 \log \left(\frac{(M*N)^2}{MSE}\right)$$

Where mean-squared error (MSE) between the original watermark and the estimated watermark provides a convenient way to measure how well a watermark resists estimation. Its formula is:

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (x_{ij} - y_{ij})^2$$

Fig.3 Original Image **Fig.4** Watermark Image



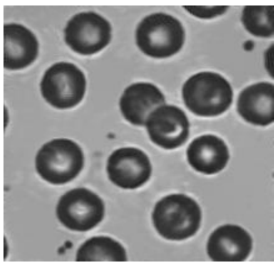


Fig. 5 Watermark Original image **Fig.6**Recovered watermark image

Table -1 PSNR Experiment Result

Images	Original Image (PSNR)	Watermarked Image (PSNR)
Original image	**86.1412**	**90.1520**
Watermarked Image	**137.1630**	**141.1630**
Original watermark	**81.3698**	**86.3778**
Recovered Watermark image	**375.8948**	**380.8860**

Table 1 show the peak signal to noise ratio of performance of our proposed method of watermarked image and original image with various watermark image, where our watermarked images peak signal to noise ratio has a better performance than others.

Fig.7 (a) Cropped (b) Guassian Blur (c) JPEG Compression (d) Motion Blur

Table-2 Experiments Results for various attacks

Attack Experiment	NC
Cropped	**0.4820**
Guassian noise	**0.4931**
De-noising	**0.5317**
Contrast	**0.6388**
Brightness	**0.7598**

VI. Results

1. The SVD-DWT-DCT AND Arnold based watermarking was found to be a very robust method when it is faced the attacks for e.g. cropping, Gaussian noise, contrast and brightness attacks.
2. In most of the DCT-based watermarking schemes, the lowest frequency coefficients are not modified as it is argued that watermark transparency would be lost. In this approach, we did not experience any problem in modifying the coefficients.
3. One advantage of SVD-based watermarking is that there is no need to embed all the singular values of a visual watermark. Depending on the magnitudes of the largest singular values, it would be sufficient to embed only a small set.

VII.Conclusion

In this paper, a Digital Watermarking Algorithm based on DWT-DCT-Singular Value Decomposition and Arnold Transform is proposed. The DCT-SVD based method is very time consuming while the process of SVD-DWT-DCT and Arnold Transform method is found to be very fast and this new method was found to satisfy all the requisites of an ideal watermarking scheme such as imperceptibility, robustness and good capacity. This method can be used for authentication and data hiding purposes.

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