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Image Enhancement in Digital Image Watermarking Using Hybrid Image Transformation Techniques

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Abstract: *Digital image watermarking is hiding information in any form (text, image, audio and video) in original image without degrading its perceptual quality, which is based on the Discrete 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 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: *Watermarking, DWT (Discrete Wavelet Transform), SVD (Singular Value Decomposition), DCT (Discrete Cosine Transform), PSNR (Peak Signal to Noise Ratio).*

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 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. 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 property.

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 SV T, where U and V are orthogonal matrices, and *S* = diag*(*λi*)* is a diagonal matrix of singular values λi , 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

$$A = USV^T = \sum_{i=1}^{r} \lambda i \; ui \; viT$$

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.

III. Proposed Algorithm Using DWT, DCT And SVD Techniques

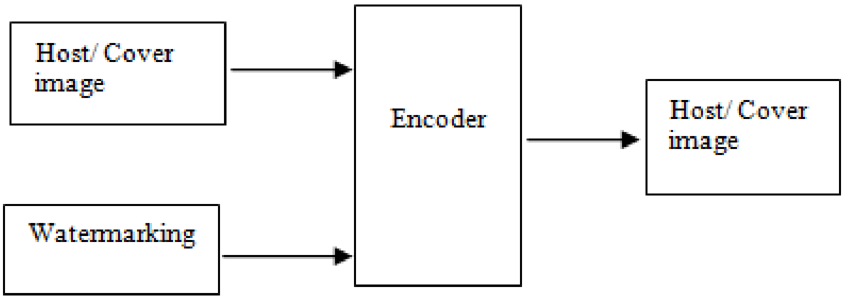


Fig 1: Watermark Embedding

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., LL3,LH3,HL3, and HH3) Apply SVD to each sub band i.e.

$$Ai=U_iS_iV_i^T \quad \text{where } A_i= HL3$$

Apply SVD to the watermarked i.e.

$$W= U_wS_wV_w^T \text{ , where } W= \text{Watermark}$$

Modify the singular value of the Ai by embedding singular of W such that

$$S_{iw}= S_i*\alpha \text{ x } S_w$$

Where Siw is modified singular matrix of Ai 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 Aw by applying inverse DWT using one modified and other non modified DWT coefficients.
In this step obtain the watermark image Aw by multiplying the matrices.

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.

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

$$A_{iw}=U_{iw} *S_{iw}*V^T_{iw}$$

Compute $S^*w = (S_{iw} - S_i)/ \propto$, 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.,

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

Now Compute extracted watermark

$$W^*= U_w \text{ x } S\_ S^*_w \text{ x } V^T_w$$

Then processing A^*_w with Arnold transform and get the extracted of watermark image.

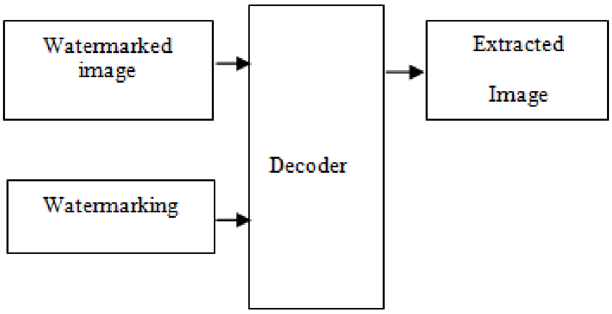


Fig 2: Watermark Extraction

IV. Result Analysis

To demonstrate this experiment were carried out to verify the validity of the proposed watermarking scheme. The gray-level image with size 256 × 256 is used as the cover image and the gray-level image of size 128 × 128 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;

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

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:

$$\text{MSE} = \frac{1}{MN}\sum_{j=1}^{N}(xij \ - \ yij)2$$

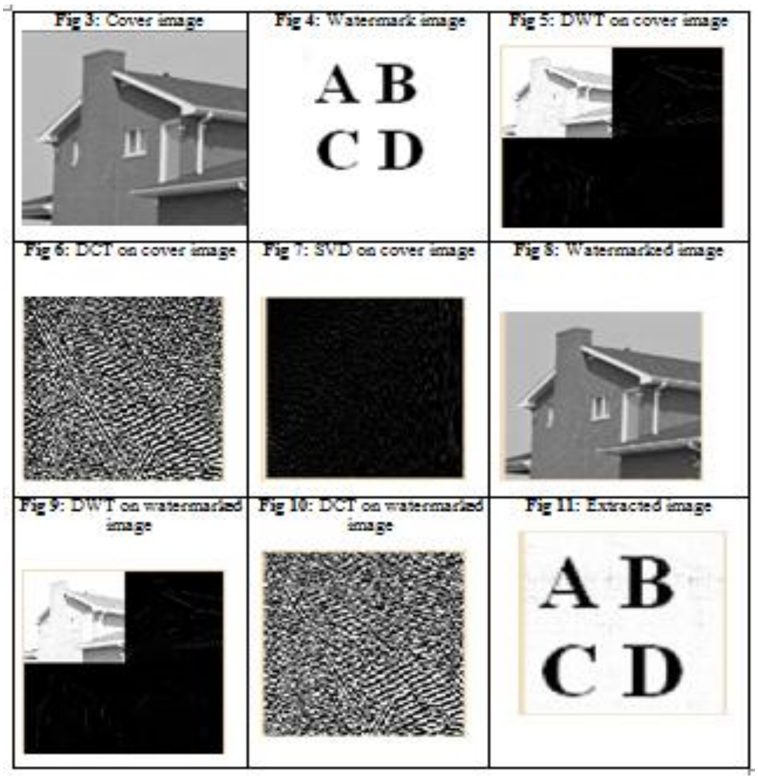
One problem with mean-squared error is that it depends strongly on the image intensity scaling. A mean-squared error of 100.0 for an 8-bit image (with pixel values in the range 0-255) looks dreadful; but a MSE of 100.0 for a 10-bit image (pixel values in [0, 1023]) is barely noticeable. Peak Signal-to-Noise Ratio (PSNR) avoids this problem by scaling the MSE according to the image range.

Typical values for the PSNR in lossy image and video compression are between 30 and 50 dB, provided the bit depth is 8 bits, where higher is better. For 16-bit data typical values for the PSNR are between 60 and 80 dB. Acceptable values for wireless transmission quality loss are considered to be about 20 dB to 25 dB. In the absence of noise, the two images are identical, and thus the MSE is zero. In this case the PSNR is infinite.

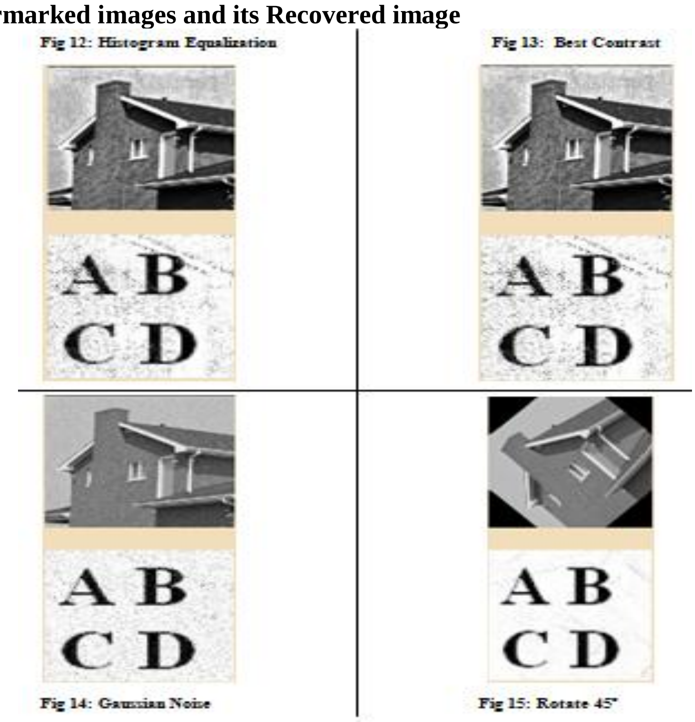
Motivation for Use as an Image Quality Metric

The mean squared error (MSE) for our practical purposes allows us to compare the “true” pixel values of our original image to our degraded image. The MSE represents the average of the squares of the "errors" between our actual image and our noisy image. The error is the amount by which the values of the original image differ from the degraded image. The proposal is that the higher the PSNR, the better degraded image has been reconstructed to match the original image and the better the reconstructive algorithm.

2.1 Effect of DWT DCT and SVD



2.2 Attacks on Watermarked images and its Recovered image



4.3 Experiment Results for various attacks

Attacks	PSNR	Normalization Coefficient(NC)	Correlation Coefficient(CR)
Normal	45.7764	0.9870	0.9952
Histogram Equalization	45.7364	0.9335	0.8946
Best Contrast	45.7364	0.9335	0.8946
Gaussian Noise	45.7364	0.9846	0.9534
Rotate_45^{o}	45.7364	0.9838	0.9926
Speckle Noise	45.7364	0.9738	0.9861
JPEG Compression	45.7364	0.9870	0.9952

V. Result

1. The SVD-DWT-DCT based watermarking was found to be a very robust method when it is faced the attacks for e.g. Histogram Equalization, 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.

VI. Conclusion

In this paper we have presented various aspects for digital watermarking like overview, framework, techniques, applications, challenges and limitations. Apart from it a brief and comparative analysis of watermarking techniques is presented with their advantages and disadvantages which can help the new researchers in related areas. We also tried to classify the digital watermarking in all the known aspects like robustness, host signal, perceptivity, purpose, watermark type, domain, detection process and use of keys. In this paper we tried to give the complete information about the digital watermarking which will help the new researchers to get the maximum knowledge in this domain.

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