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Robust Image Watermarking based on Discrete Wavelet Transform, Discrete Cosine Transform & Singular Value Decomposition

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Abstract

With the rapid growth of network multimedia systems and other numerical technologies, images, audio, text and video can be more easily produced, processed as well as stored by digital devices in recent years. To conceal data in transmitting message for copyright protection the secret is very important. Various Digital Watermarking Techniques are developed to protect the secret data. This paper presents a digital watermarking technique which is based on DWT, DCT and SVD. DWT has excellent spatial localization, frequency spread and multi-resolution characteristics. DCT & SVD based watermarking techniques offer compression. These desirable properties are used in this combined watermarking technique. Compared with DWT-DCT, DCT SVD, DWT-SVD based watermarking techniques; experimental results show that this algorithm is robust to various attacks such as JPEG compression, cropping, rotation, and noise.
Keywords- Singular Value Decomposition (SVD), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Peak Signal to Noise Ratio (PSNR), Correlation Coefficient, JPEG Compression, Gaussian Blurring.

1. Introduction

The Internet is an excellent sales and distribution channel for digital assets, but copyright compliance and content management can be a challenge. These days, digital images can be used everywhere – with or without consent. Images that are leaked or misused can hurt marketing efforts, brand image and, ultimately, sales. The possible implications of this situation include the unauthorized distribution of such material with the purpose of making illegal profit or otherwise damaging the legal owner. Inevitably the business world and the authorities have expressed great concern over this issue, and as a result, the scientific community has become extremely active trying to provide techniques for copyright protection of digital material. One way to address this problem is Image Watermarking. It is the process of inserting hidden information in an image by introducing modifications of minimum perceptual disturbance. Robustness, perceptual transparency, capacity and blind watermarking are four essential factors to determine quality of watermarking scheme [1]. Image watermarking techniques can be divided into two groups in accordance with processing domain of host image. One is to modify the intensity value of the luminance in the spatial domain [2] and the other is to change the image coefficient in a frequency domain [3][4]. In recently, a transform called Singular Value Decomposition (SVD) was explored for watermarking [5][6]. Frequency domain techniques are used commonly because of their robustness to various types of attacks like JPEG compression, cropping, rotation, noise, blur etc. SVD-based watermarking algorithms are also very robust against these attacks. DWT has excellent spatial localization and multi-resolution characteristics, which are similar to the theoretical models of the human visual system. DCT and SVD based watermarking techniques offer compression. Further Performance improvements in DWT-based digital image watermarking algorithms, DCT-based watermarking algorithms and SVD-based watermarking algorithms could be obtained by combining DWT, DCT and SVD. The idea of combining these transforms is based on the fact that combined transforms could compensate for the drawbacks of each other, resulting in effective watermarking.

In Singular Value Decomposition, singular values correspond to the luminance of the image (i.e, image brightness) and the corresponding singular vector specifies the intrinsic geometry properties of the image [2]. Many singular values have small values compared to the first singular value. If these small singular values are ignored in the reconstruction of the image, the quality of the reconstructed image will degrade only slightly. Slight variations of the singular values do not affect the visual perception of the image, i.e., singular values do have a good stability. Based on these properties of SVD, diagonal matrix containing singular values is mainly used to embed watermark. The DCT has special property that most of the visually significant information of the image is concentrated in low frequency coefficient of the DCT. In the literature various hybrid techniques are proposed by the researchers such as DCT-SVD [7], DWT-SVD [8] and DWT-DCT [10]. In our proposed method, watermark is embedded into the singular values of the low frequency band of the DCT block of selected DWT sub-band. We compare our proposed method with DWT-SVD, DCT-SVD based techniques.

The rest of paper is organized as follows. Section II describes the proposed algorithm for watermarking. The simulation and results are evaluated in Section III. Finally, the conclusion is given in Section IV.

2. Proposed Watermarking Algorithm

The proposed algorithm uses DWT, DCT and SVD. So before discussing the proposed algorithm we will discuss these transforms in brief as follows:

2.1. Singular Value Decomposition

From the viewpoint of linear algebra, the discrete image is non-negative real matrix. The SVD of a matrix is a kind of orthogonal transforms used for matrix diagonalization. Let I be an image, and its size be $M \times N$. The SVD of I can be described as follows:

$$I = USV^T \quad (1)$$

Where U and V are two $M \times N$ and $N \times N$ unitary orthogonal matrices, and S is an $N \times N$ diagonal matrix. The elements of S are nonnegative values on diagonal representing singular values of I. The diagonal elements of matrix S = diag (s1, s2,…….., sn) satisfy the order: $s1 \geq s2 \geq \ldots \geq sn$. It is important to note that

- The nonnegative components of S represent the luminance value of the image.
- Changing them slightly does not affect the image quality and they also don't change much after attacks, watermarking algorithms make use of these two properties.

2.2. Discrete Cosine Transform

The DCT is similar to the discrete Fourier transform: it transforms a signal or image from the spatial domain to the frequency domain. It has been widely used because of its energy compaction property. DCT is faster than DFT because its transform kernel is real cosine function while it is complex exponential in DFT. The DCT has special property that most of the visually significant information of the image is concentrated in low frequency coefficient of the DCT.

2.3. Discrete Wavelet Transform

DWT has excellent spatial localization and multi-resolution characteristics, which are similar to the theoretical models of the human visual system. The original image is decomposed into four sub-band images by DWT: three high frequency parts (HL, LH and HH, named detail sub images) and one low frequency part (LL, named approximate sub-image). The detail sub-images contain the fringe information while the approximate sub-image is the convergence of strength of original image. Relative to the detail sub-images, approximate sub image is much more stable, since the majority of image energy concentrates here. Therefore, watermark is embedded into approximate sub-image to gain a better robustness.

2.4. Proposed Algorithm

2.4.1. Watermarking Embedding Process: The Embedding process is as follows

1) DWT is applied to host image **I** of size 512 x 512 to decompose it into four sub-bands **LL, HL , LH** and **HH** each of size 256x256.

2) Choose **LL** sub-band and then divide it into 2*2 square blocks and then apply DCT to each block.
3) Collect the DC value of each DCT coefficient matrix **C** and combine it to get a new matrix **DC** of size 128*128.
4) Then apply SVD to **DC**, **DC** = $U1*S1*V1^T$ to obtain **U1, S1 and V1**.
5) Take Watermark image **W** of size 128*128. Then modify S1 with W as **Sm = S1 + a*W**.
6) Now apply SVD to modified singular values i.e. Sm = $U2*S2*V2^T$ to obtain **U2, S2 and V2**.
7) Now calculate the modified DC matrix **DCM =** $U1 * S2 * V1^T$ which contain the watermark information.
8) Change each DC value of each DCT coefficient matrix **C** in above step to **DCM**, obtain the new coefficient matrix **CM.**
9) Apply inverse DCT to each **CM** to produce the watermarked low frequency band **LLM**.
10) Apply inverse DWT to **LLM, HL, LH** and **HH** to get the watermarked image **IW**.

2.4.2. Watermarking Extraction Process: The Extraction process is as follows

1) Apply DWT to **IW**, obtain **LLW, HL, LH** and **HH**.
2) Choose **LLW** sub-band and then divide it into 2*2 square blocks and then apply DCT to each block.
3) Collect the DC value of each DCT coefficient matrix **CW** and combine it to get a new matrix **DCW** of size 128*128.
4) Then apply SVD to **DCW**, **DCW** = $UW*SW*VW^T$ to obtain **UW, SW and VW**
5) Combine **SW** with **U2, V2** to obtain **E=** $\mathbf{U2*SW*V2^T}$**.**
6) Now obtain the watermark as **EW = (E-S1)/a**

3. Simulation & Results

We test the proposed scheme on gray scale image of size 512 × 512 and watermark of size 128 x 128. The proposed scheme was tested under various attacks: Gaussian blur, Gaussian noise, Salt Pepper noise, JPEG compression, Rotation with cropping. We have taken two performance evaluation metrics: PSNR which is used to measure Imperceptibility & Normalized Coefficient which is used to measure Robustness.

Imperceptibility: Imperceptibility means that the perceived quality of the host image should not be distorted by the presence of the watermark. As a measure of the quality of a watermarked image, the peak signal to noise ratio is typically used. The PSNR has been utilized to calculate similarity between the original image and the watermarked image. The PSNR is defined as

$$\text{PSNR} = 10*\log_{10}((255)^2/\text{MSE}) \quad (2)$$

$$\text{MSE} = \sum_{i=1}^{M-1}\sum_{j=1}^{N-1}(I(i,j) - IW(i,j))^2 \quad (3)$$

where I is original image, IW is watermarked image, MSE is mean square error.

Robustness: Robustness is a measure of the immunity of the watermark against attempt to remove it by different types of attacks. We measure the similarity between the original watermark and the extracted watermark from the attacked image using the Normalized Correlation (NC) factor. The NC is defined as

$$NC = \frac{\sum_{i=1}^{i=M-1}\sum_{j=1}^{j=N-1} W(i,j) * EW(i,j)}{\sum_{i=1}^{i=M-1}\sum_{j=1}^{j=N-1} (W(i.j))^2 * (EW(i.j))^2} \qquad (4)$$

where W is original watermark image, EW is extracted watermark image.

Figure 1 shows the original lena image, figure 2 shows the watermark image, figure 3 shows the watermarked image using DCT-SVD, figure 4 shows the watermarked image using DWT-SVD, figure 5 shows the watermarked image using DWT-DCT-SVD.


Figure1


Figure 2


Figure 3


Figure 4


Figure 5

Table 1 shows the PSNR between the original lena image and watermarked lena image calculated using DWT-DCT-SVD, DWT-DCT, DWT-SVD, DCT-SVD techniques.

Table 2 shows the NC between the original watermark image and extracted watermark image calculated using DWT-DCT-SVD, DWT-DCT, DWT-SVD, DCT-SVD techniques under various attacks.

Table 1: PSNR Comaprision

Techniques	PSNR (dB)
DWT-DCT-SVD	101.9195
DWT-SVD	71.1892
DCT-SVD	64.6035

Table 2: NC comparision under various attacks

Attack	DWT-DCT-SVD	DWT-SVD	DCT-SVD
JPEG Compression	0.9965	0.8874	0.7777
Gaussian Noise	0.9408	0.7974	0.8281
Gaussian Blur	0.9899	0.7549	0.8151
Salt Pepper Noise	0.9546	0.7877	0.8358

Rotation with Cropping	0.9879	0.9461	0.8321

4. Conclusion

The DWT-DCT-SVD technique has a good performance on imperceptibility and robustness as compared to DWT-SVD, DCT-SVD based techniques. Furthermore, the algorithm is robust to various attacks such as JPEG compression, Gaussian Noise, Gaussian Blur, Salt & Pepper Noise and Rotation with cropping. The PSNR value is very high in DWT-DCT-SVD as compared to DWT-SVD, DCT-SVD based techniques. The NC value is also higher in DWT-DCT-SVD under various attacks as compared to DWT-SVD, DCT-SVD based techniques under various attacks.

References

[1] M. S. Hsieh, "Perceptual Copyright Protection using multiresolution Wavelet Based Watermarking and Fuzzy Logic," *International Journal of Artificial Intelligence & Applications*, Vol.1, No.3, July 2010.

[2] N.Nikolaidis and I.Pitas, "Robust image watermarking in the spatial domain," *Signal Processing,* Vol.1, No.66, pp.385-403, 1998.

[3] C. T. Hsu and J. L. Wu, "Multiresolution Watermarking for Digital Images," *IEEE Transaction on Circuits and System II*, Vol. 45, No. 8, pp. 1097-1101, August 1998.

[4] W. C. Chu, "DCT-Based ImageWatermarking Using Subsampling," *IEEE Transaction on Multimedia*, Vol. 5, No. 1, March 2003.

[5] R. Sun, H. Sun, "A SVD and quantization based semi-fragile watermarking technique for image authentication," *International Conference on Signal Processing*, Vol.2, pp 1952–1955, 2002.

[6] R. Liu and T. Tan, "A SVD-Based watermarking scheme for protecting rightful ownership," *IEEE Transaction on Multimedia*, Vol. 4,No.1, pp 121-128, March 2002.

[7] Z. M. Lu, H. Y. Zheng et. al., "A Digital Watermarking Scheme Based on DCT and SVD," *Third International Conference on Intelligent Information Hiding and Multimedia Signal Processing*, Vol.1, pp 241 – 244, November 2007.

[8] S. K. Bhagyashri, M.Y. Joshi, "Robust image watermarking based on singular value decomposition and discrete wavelet transform," *Third IEEE International Conference on Computer Science and Information Technology*, Vol. 5, pp 337 – 341, July 2010.

[9] K. Deb, M. S. A. Seraj et. al., "Combined DWT-DCT based digital image watermarking technique for copyright protection," *Seventh International Conference on Electrical & Computer Engineering*, Vol.1, pp 458 – 461, December 2012.