A DIGITAL COLOR IMAGE WATERMARKING SYSTEM USING BLIND SOURCE SEPARATION

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ABSTRACT

An attempt is made to implement a digital color image-adaptive watermarking scheme in spatial domain and hybrid domain i.e host image in wavelet domain and watermark in spatial domain. Blind Source Separation (BSS) is used to extract the watermark The novelty of the presented scheme lies in determining the mixing matrix for BSS model using BFGS (Broyden–Fletcher–Goldfarb–Shanno) optimization technique. This method is based on the smooth and textured portions of the image. Texture analysis is carried based on energy content of the image (using GLCM) which makes the method image adaptive to embed color watermark. The performance evaluation is carried for hybrid domain of various color spaces like YIQ, HSI and YCbCr and the feasibility of optimization algorithm for finding mixing matrix is also checked for these color spaces. Three ICA (Independent Component Analysis)/BSS algorithms are used in extraction procedure ,through which the watermark can be retrieved efficiently . An effort is taken to find out the best suited color space to embed the watermark which satisfies the condition of imperceptibility and robustness against various attacks.

INDEX TERMS *— ICA,GLCM,BSS,BFGS*

1. INTRODUCTION

One of the more interesting applications is in field of image data security/authentication where digital watermarking is proposed. Watermarking is a promising technique to help protect data security and intellectual property rights.[1-3]

There are numerous techniques for embedding a digital image watermark like additive spread spectrum ,multiplicative spread spectrum DC-QIM etc.

The separation of mixed images is a very exciting area of research, especially when no a priori information is available about the mixed images. In such a case, blind signal separation (BSS) technique is needed to recover independent sources given only sensor observations, which are assumed to be unknown linear mixtures of unknown independent images. [4,5]. The watermarked image is viewed as linear mixture of sources i.e. original image and watermarks. Independent Component Analysis (ICA) is probably the most powerful and widely used method for performing BSS [6-9].

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2. SYSTEM DESCRIPTION

The basic principle of digital image watermarking technique is based on BSS model to embed the watermark in the host image. Watermark embedding is carried out in spatial domain and hybrid domain. These embedding techniques are explained in following sections w. r. t. blue channel of RGB space covertext image.

2.1. Embedding in Hybrid Domain

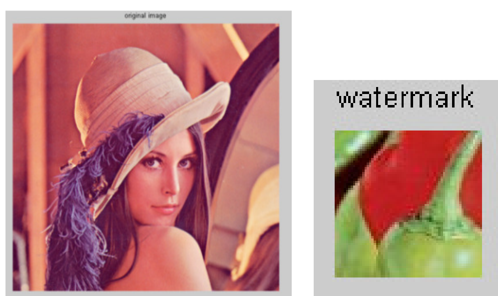
Step-1 Take the host and watermark color images, respectively of size (MxM) and (NxN) with M>>N. Select their blue channels.

Step-2 Select textured region block based on energy of the sub-image . Take one level DWT and use LL1 for further processing in single level of DWT . Similarly LL2 and LL3 a in case of two level DWT and three level DWT. Spatial domain watermark is used for embedding.

Step-3 Obtain the mixing matrix using Quasi-Newton (BFGS) algorithm [14] in order to keep spatial domain watermark hidden in textured sub-image to form the watermarked mixtures. The inverse wavelet transform of watermarked mixtures is taken.

Step-4 One of the compound sub-images (watermarked sub-image) is encrusted into the corresponding blocks of the earlier chosen region of high energy in the original image. The other secret watermarked mixture in blue channels must be kept for a prospective use in the watermark extraction process.

Above steps are explained with Figure 1 trough Figure 5 during embedding process.



(a) (b)

Figure 1: Original Image (a) Watermark (b).

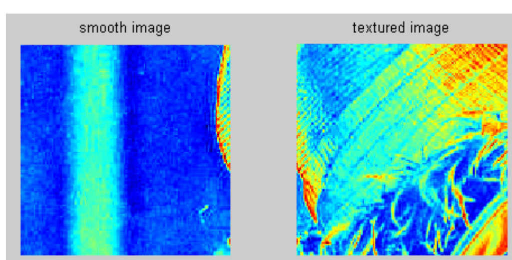


Figure 2: Smooth and Textured Portions of Original Image

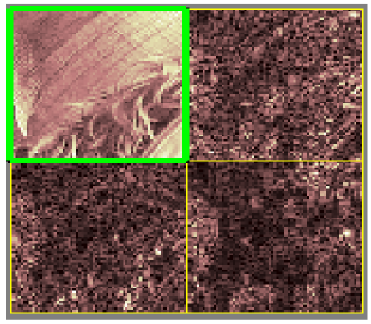


Figure 3: DWT of Textured Sub-image in Level1

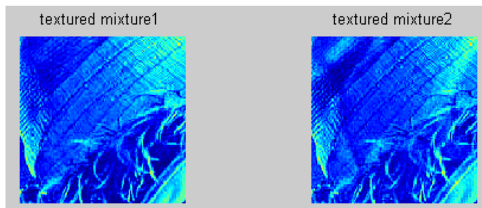
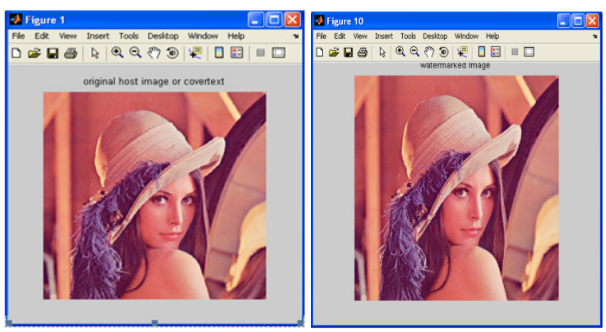


Figure 4: Watermarked Mixture Sub-images after IDWT



(a) (b)

Figure 5: Original Host Image (a) Watermarked Image (b)

2.2. Extraction Procedure

Step-1 Extract the marked block from the tampered watermarked image by using the first part of the key which is the position key.
Step- 2 Obtain the blue channels of the extracted blocks.
Step -3 The key watermarked mixture and extracted watermarked mixture are used as the inputs for BSS/ICA algorithms .
Step-4 BSS/ICA algorithms namely Eigen Value Decomposition ,SOBI and JADE are used to recover both host sub-image and watermark.

3. METHODOLOGY AND ANALYSIS

3.1. BSS Model

Suppose that there exist N mutually independent source signals S1, S2, ……….. SN and M observed mixtures X1, X2, ……….. Xm of the source signals (usually M ≥ N). Assuming that these mixtures are linear, instantaneous and noiseless, the model of BSS can be represented as

$$X = A.s \qquad (1)$$

were S = [S1, S2, ……….. SN]T and X = [X1, X2, ……….. Xm]T represents source signals vector and observed vector respectively, and A is M X N scalar mixing matrix of full rank which is composed of the mixing coefficients.

We use (1) as the mixture model, and a random 2 X 2

$$\text{Matrix } A = \begin{pmatrix} a_1 & b_1 \\ a_2 & b_2 \end{pmatrix}$$

Where ‘ A’ should be a full rank matrix, and the elements of it, which corresponds to the embedding watermark, should be smaller than other elements relating to the host signal to achieve the robustness and inperceptibility.

$$X = A.\,s = \begin{bmatrix} a_1 s_1 + b_1 w \\ a_2 s_2 + b_2 w \end{bmatrix} = \begin{bmatrix} sw_1 \\ sw_2 \end{bmatrix}$$

Where sw1 and sw2 are two observed signals with length L. sw1 is as the watermarked signal, and sw2 is kept as the secret key k2.

3.2. Algorithm for Generating Mixing Matrix

Likelihood function (Likelihood Vs Iterations) is used for the estimation of Mixing Matrix generation which is shown below in Figure 6.

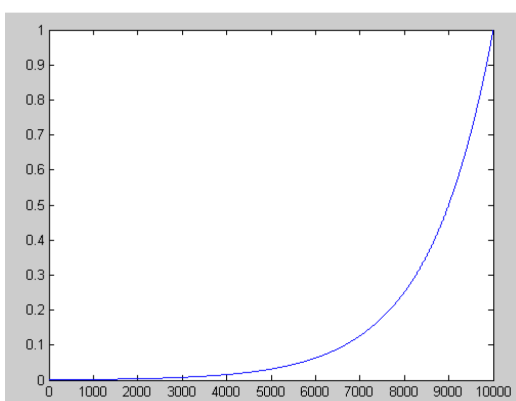


Figure 6: Likelihood surface

i) Number of iterations are selected in terms of sample points. In proposed method 1000 sample points are considered.

ii) At each time sample the energy difference (gradient) is calculated between latent mixture model and original image. Two energy gradient vectors are formed corresponding to two mixtures .

iii) Mixing Matrix is $\begin{pmatrix} 1 & t(i,j) \\ 1 & -t(i,j) \end{pmatrix}$

Where i and j are the sample points on likelihood surface at which the gradient is minimum.

iv) Thus the time varying mixing matrix is used to form watermarked mixtures adaptively.

3.3. Performance Parameters

A series of attacks are tested to verify the robustness of three algorithms include Gaussian low pass fiter,median filter, adding salt and pepper noise ,adding Gaussian noise ,JPEG compression etc. The performance analysis parameter viz. Mean Square Error (MSE), PSNR (Peak signal to Noise Ratio) and NC (Normalized Cross-Correlation) are used to estimate the quality of extracted watermark.

The equations used are given in Part-I are repeated below-

$$MSE = \frac{1}{MN}\sum_{m,n}[W - W']^2 \tag{2}$$

$$PSNR = 10\log_{10}\left[\frac{255^2}{MSE}\right] \tag{3}$$

$$NC = \frac{\sum_{m=1}\sum_{n=1} W * W'}{\sqrt{\sum_{m=1}\sum_{n=1} W^2} \times \sqrt{\sum_{m=1}\sum_{n=1} W'^2}} \tag{4}$$

Where W is original watermark image and W’ is recovered watermark image.

Above parameters are also used to find the retrieval performance with attack compared to the performance without attack for watermark image. In that case W is treated as recovered watermark without attack.

4. RESULTS

The Digital Watermarking Method tested for various color spaces viz RGB,YIQ ,YCbCr and HSI in hybrid domain (DWT for Host and Spatial for Watermark) is compared for mentioned color spaces.

Figure 7 and Figure 8 shows the sample RGB results for correlation coefficient and PSNR respectively.

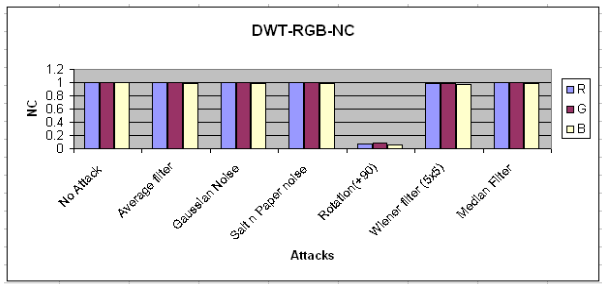


Figure 7: RGB color space correlation coefficient comparison

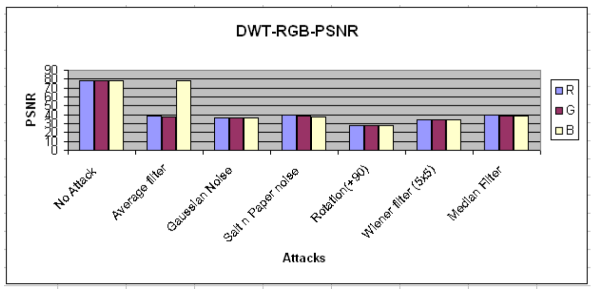


Figure 8: RGB color space correlation coefficient comparison

It is observed that during the recovery of watermark in hybrid domain using three algorithms for BSS/ICA ,viz. EVD,SOBI JADE , the watermark is recovered in 4 color channels all the time .These color channels are Blue in RGB,Y inYIQ,Y in YCbCr and S from HIS. Figure 9 and 10 shows the comparison for above mentioned color spaces in hybrid domain for correlation coefficient (NC) and PSNR for recovered watermark respectively.

Figure 11 describes NC Comparison for Extracted Watermark in Y Channel for spatial and hybrid domain.

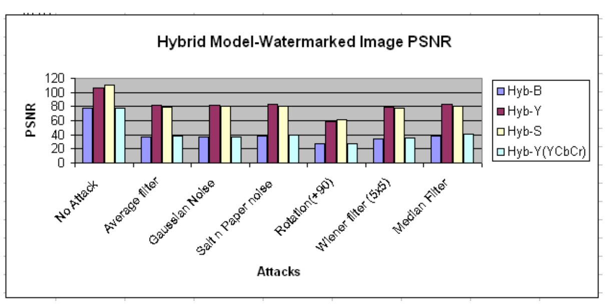


Figure 9: Hybrid Model PSNR Comparison for 4 color Spaces

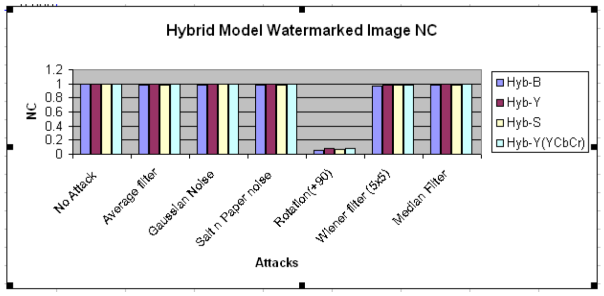


Figure 10 : Hybrid Model NC Comparison for 4 color Spaces

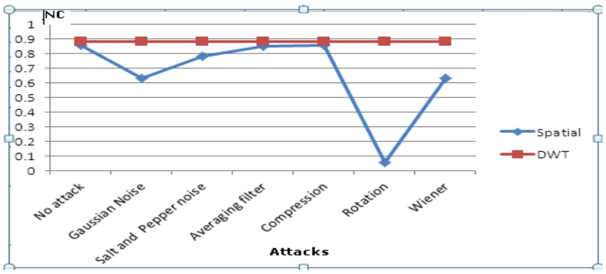


Figure 11:NC Comparison for Extracted Watermark in Y Channel

5. CONCLUSIONS

An image adaptive watermarking system is presented which satisfies imperceptibility and robustness conditions of watermarking. The novelty of the presented scheme lies in determining the mixing matrix for BSS model using BFGS optimization technique. This method is based on the smooth and textured portions of the image. Texture analysis is carried based on energy content of the image (using GLCM) which makes the method image adaptive to embed color watermark. The performance evaluation is carried for spatial domain and hybrid domain of various color spaces like YIQ, HSI and YCbCr. The feasibility of optimization algorithm for finding mixing matrix is also checked for these color spaces. Y-Channel of YIQ space has produced motivating results in hybrid domain.

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