Adaptive Digital Image Watermarking for Color Images using Wavelet

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Abstract. Internet and social media have become an inseparable part of the human life which has led to extensive sharing of all kinds of digital information including but not limited to photos and videos. The risk of plagiarism and counterfeiting follows with the technology of information sharing. Digital watermarking deals in encrypting useful information within various forms of media for copyright protection and authentication. In this paper, an algorithm is used to embed a colored watermark image within colored cover image in a robust fashion. In the proposed technique Principal Component Analysis (PCA) is applied to get compressed watermark image. By using Bhattacharya Distance and Kurtosis, the embedding and scaling factors are computed to create an adaptive digital watermarking mechanism. The embedding and extraction algorithms are developed by considering image segmentation in RGB space. Performance of the proposed method was tested using PSNR and NCC parameters on multiple cover and watermark images and also by considering common image processing attacks like salt and pepper, cropping, rotation.

Keywords: Digital image watermarking**,** Principal Component Analysis, Discrete Wavelet Transform, Kurtosis, Bhattacharya distance.

1 Introduction

In recent times due to data sharing and continuous exchange of digital information over the internet, ensuring authentication of digital content ownership is a major concern. Digital image watermarking is the method of embedding a watermark image into a cover or host image without distorting its visual form. It also maintains the authenticity and integrity of the cover image. One of the key criteria of a watermarked image is to be robust against multiple attacks. Imperceptibility means the visual quality of the original image is not affected by watermark embedding. A robust watermark is the one that remains detectable even after common image processing operations as well as the one which is intended to merely to remove the watermark [1]. Every watermarking algorithm should possess these properties to make it consistent and effective for its purpose. The technique is reliable only if it satisfies properties of robustness, imperceptibility and embedding capacity. These techniques are classified as spatial domain and transform domain [2]. Frequency domain techniques are considered better as it increase imperceptibility. Discrete Cosine Transform (DCT) is a lossy compression technique in frequency domain where data is lost when the original image is reconstructed from compressed image as described by Arvind Kumar [3]. Watermark embedding & extraction algorithm using DWT coefficients, distance measurement and encryption using Arnold transform is demonstrated [4]. Prasanth Vaidya S. [5] suggested an adaptive digital watermarking scheme in the wavelet domain, where scaling and embedding factors are calculated using Bhattacharya distance and kurtosis. Authors presented watermarking through texturization, statistical parameters (mean, standard deviation, skew, kurtosis and variance) and Bhattacharya distance [6]. Kamal N. Kaur proposed algorithm for image watermarking using visual cryptography that generates two shares with DWT-SVD [7]. As the watermark image is embedded in the cover image, it tends to affect the visual quality of the cover image. Hence, dimensionality reduction is required so that only the significant components required to generate an image (in this case, watermark image) are selected, and all other insignificant components are removed. This process is known as Principal Component Analysis. In this process, only significant components are embedded in the cover image to form the embedded watermarked image by maintaining its visual quality [8 - 10]. Author [11] reviews the significant work addressing the need for a formal generic watermarking model. The paper presents a formal generic model for digital image watermarking and key-based watermarking and various attacks. Lei Chen [12] used redundant discrete wavelet transformation and SVD based watermarking scheme for copyright protection of videos. The proposed method was tested for variety of attacks like adding noise, rotation and compression. Most of the watermarking algorithms developed earlier have a static embedding factor. In this paper, a digital watermarking algorithm with an adaptive embedding factor is proposed. Due to this any image can be used as a cover image and any image can be used as a watermark image. Adaptive embedding factor makes the system more flexible, robust and imperceptible against attacks. The proposed algorithm also uses RGB color splitting in order to adapt watermarking of color images.

In this paper, section 2 provides complete information about algorithms proposed for watermark embedding and extraction process. Section 3 present results obtained and observations. Section 4 concludes the paper.

2. Watermark Embedding & Extraction Procedure

The proposed algorithm mainly focuses on color images by implementing DWT-PCA with Bhattacharyya distance and Kurtosis, to create robust and adaptive Digital watermarking. Kurtosis and Bhattacharyya distance are combined for the calculation of scaling and embedding factors. These two factors have an impact on the shape of the probability distribution. The similarity between the input images determines the strength of the watermark image, which is embedded in the cover image; as a result, the perceptibility of the cover image is retained to the maximum. Using Kurtosis and Bhattacharyya distance, we are able to determine correct values for the scaling and embedding factors, thus making the task simple rather than random guessing, which may not result in better output. Further, in the embedding process, the colored cover image and watermark image are divided into RGB, that is, red, blue and green channels/components. Here each component is treated as a separate monochromatic cover image and watermark image respectively. Further DWT is applied to the red (R) component of the cover image. The red component of watermark image is embedded into the approximation sub-band, i.e. the LL sub-band of the red component of the cover image and then combined with the remaining sub-bands to form the final red component of the image embedded with watermark. Here the LL sub-band is chosen for embedding as it contains the maximum information of the image. Similarly, the above procedure is repeated for blue (B) and green (G) components of the cover image in which blue and green components of watermark image are embedded respectively. Now all three obtained RGB components are merged to form the embedded image. During the extraction process, the embedded image is separated into RGB components. Then the LL sub-band for the red component of extracted watermark image is obtained and further modified by adding the scaling and embedding factors. Similarly, the procedure is repeated for the remaining two components, which are green and blue. Finally, the obtained RGB components are merged to form the extracted watermark image. PCA is a technique that is used for various application like dimension reduction, feature extraction and visualization. Use of PCA in digital watermarking compresses the watermark image to get principle components which reduce the number of pixels to be embedded. As a result, only the principal components of the watermark image get embedded into the cover image, which further helps to recover the watermark image more precisely. Figure 1 shows the watermark embedding process and figure 2 shows the watermark extraction process.

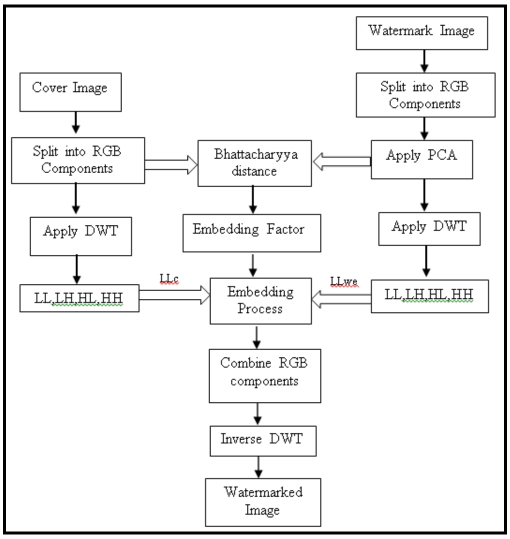


Fig. 1. Watermark Embedding Process

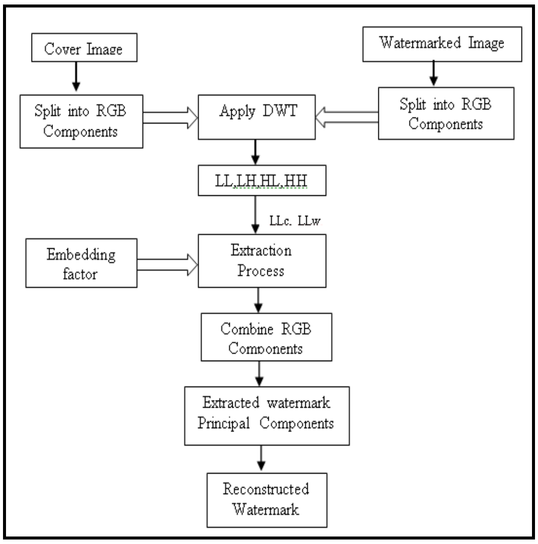


Fig. 2. Watermark Extraction Process

2.1 *Watermark Embedding Algorithm*

Input: Colored cover image (I), Colored watermark image (W)
Output: Watermark Embedded Image (W')

1. Cover and watermark images are divided into their respective red, green and blue (RGB) components.
2. Perform PCA on the R component of watermark image and compress the image to r.

3. Calculate the scaling and embedding factors (α, β) using Bhattacharyya distance and Kurtosis.
4. Apply 2-level DWT using Haar wavelet on the cover image R component.
5. Extract LL band.
6. Insert the watermark using the following equation:

   $$\mathbf{LL' = LL + (\beta/\alpha) \times r} \quad \ldots\ldots(1)$$

   where, α = Bhattacharyya Distance and β = Kurtosis
7. Combine the modified LL sub frequency band (LL') with other LH, HL and HH bands of the cover image R component.
8. Apply inverse DWT to get R component of watermark embedded image.
9. Repeat Steps 1 to 8 for G and B Components.
10. Combine the obtained RGB components to form watermark embedded image.

2.2 *Watermark Extraction Algorithm*

Input: Cover image (I) and watermark embedded image (I').
Output: Extracted Watermark Image (wm).

1. Divide watermark embedded image, cover image and watermark image into RGB components.
2. Apply 2-level DWT using Haar wavelet on the R component of watermark embedded image and R component of cover image.
3. Extract low frequency bands of both images.
4. Obtain scaling and embedding factors (α, β) calculated during the embedding process.
5. Extract R Component of watermark image using following equation:

   $$\mathbf{LLwm = (LL' - LL) \times \alpha / \beta} \quad \ldots\ldots(2)$$

6. Reconstruct the R component of extracted watermark image by applying inverse DWT.
7. Repeat steps 1 to 6 for G and B Components.
8. Combine these RGB components to form extracted watermark image.

3. Simulation Results

Watermark embedding and extraction algorithm was implemented on different images which is presented below. The entire processing was done using MATLAB software and executed on Intel i5 processor with 4 GB RAM and 1.19 GHz processing speed.

Case - I

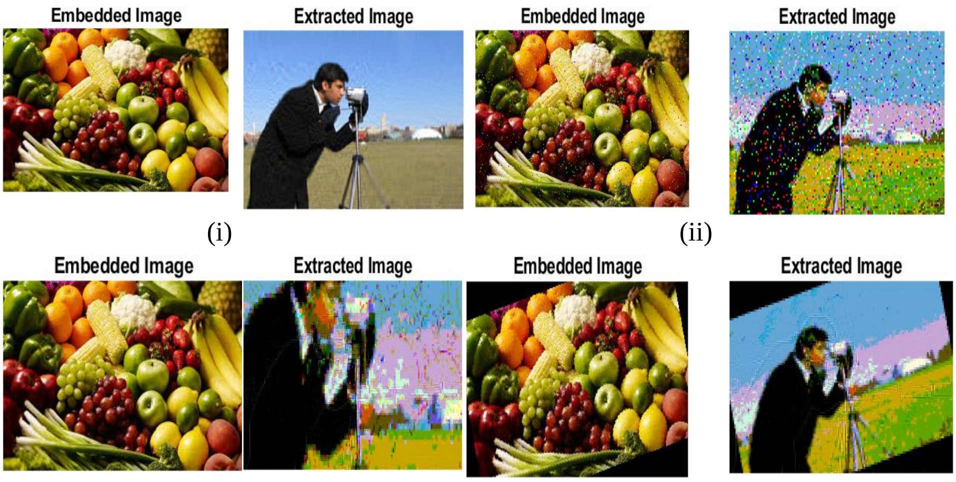
Figure 3 (a) shows the original cover images and figure 3(b) shows the watermark image of Cameraman. (Images from internet and from C:\Program Files\MATLAB\R2020a\toolbox\images\imdemos).

(a) **(b)**

(a) Cover Images (Fruits, Lena, flamingos and strawberries) (b)Watermark Image (Cameraman)

Fig. 3 Cover and watermark images (Case-I)

Three general attacks such as salt and pepper attack, geometric attack through rotation and cropping attack are considered. Figure 4 shows the three types of attacks on watermark embedded image used for extraction algorithm.



(iii) (iv)

(a) Embedded and Extracted Images – (i) no attack (ii) salt and paper attack (iii) cropping attack (iv) rotation attack

Fig. 4 Results (Cameraman) (Case-I)

The two important metrics were determined to evaluate the results of the proposed method which are :

A. **PSNR** (Peak Signal to Noise Ratio): It is a quality metric used to measure distortion in the image after the embedding process.

$$\mathbf{MSE} = \frac{1}{m \times n} \left(\sum_{x=1}^{m} \sum_{y=1}^{n} |I(x,y) - O(x,y)|^2 \right) \quad \text{………..…..(3)}$$

$$\mathbf{PSNR} = 10 * \log_{10} \left(\frac{255^2}{mse} \right) \quad \text{…… ………………….…...........(4)}$$

where I(x,y) and O(x,y) are the input carrier and watermarked output image respectively. m x n are the dimensions of carrier image.

Table 1. show PSNR(dB) values and table 2 show the watermarking parameters NCC evaluated between original watermark image and extracted watermark image at various attacks and without attacks.

Table 1. PSNR Ratio (Peak Signal to Noise Ratio) (in dB) **(Case-I)**

Mode used	Images used			
	Fruits	**Lena**	**Flamingos**	**Strawberries**
DWT+PCA	45.797	40.245	45.795	44.851
DWT	41.148	40.143	42.169	40.176

B. NCC (Normalized Correlation coefficient): It is used to find correlation coefficient between watermark and extracted watermark with and without attack.

$$\mathrm{NCC} = \frac{\sum_{x=1}^{m}\sum_{y=1}^{n} w(x,y) * we(x,y)}{\sum_{x=1}^{m}\sum_{y=1}^{n} |w(x,y)|^{2}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

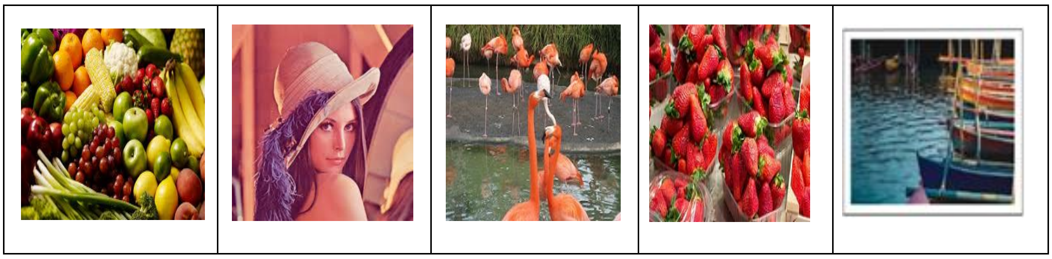
where w(x,y) is the input watermark and we(x,y) is the extracted watermark image.

Table 2. NCC (between Extracted Watermark and Watermark) **(Case-I)**

Mode used	Types of attacks	Images used			
		Fruits	**Lena**	**Flamingos**	**Strawberries**
DWT+PCA	No Attack	0.999	0.999	0.999	0.999
	Salt and Pepper	0.363	0.243	0.360	0.326
	Cropping	0.709	0.714	0.747	0.694
	Rotation	0.314	0.506	0.598	0.558
DWT	No Attack	0.999	0.999	0.999	0.999
	Salt and Pepper	0.306	0.234	0.324	0.345
	Cropping	0.701	0.703	0.697	0.674
	Rotation	0.225	0.491	0.406	0.508

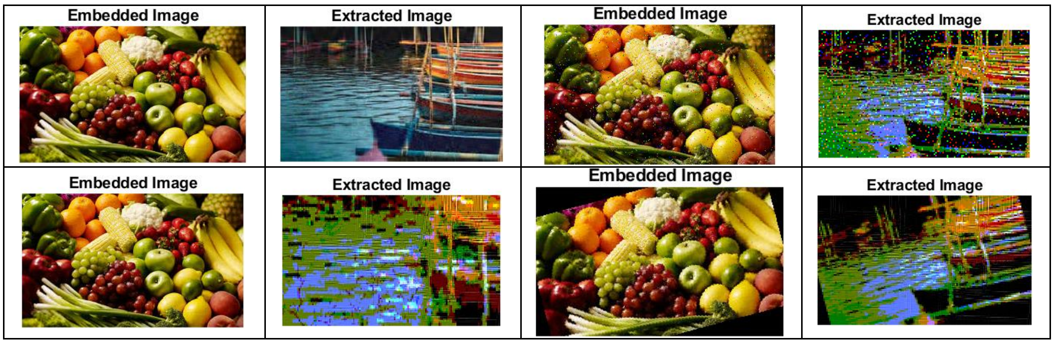
Case - II

Figure 5 shows the original cover images and watermark image (Boat image). Figure 6 shows the three types of attacks on watermark embedded image used for extraction algorithms.



(a) Cover Images (Fruits, Lena, Flamingos and Strawberries)   (b) Watermark Image (Boat)

Fig.5 Cover and watermark images (Case-II)



Embedded and Extracted Images
(i) no attack, (ii) salt and paper attack, (iii) cropping attack, (iv) rotation attack
Fig. 6. Results-Color (Boat) (Case-II)

Table 3 show PSNR ratio and table 4 show the watermarking parameters NCC evaluated between original watermark image and extracted watermark image at various attacks and without attacks.

Table 3. PSNR Ratio (Peak Signal to Noise Ratio) (in dB) **(Case-II)**

Mode used	**Images used**			
	Fruits	**Lena**	**Flamingos**	**Strawberries**
DWT+PCA	50.329	45.746	42.855	48.309
DWT	48.078	44.034	40.105	48.135

Table 4. NCC (between Extracted Watermark and Watermark) **(Case-II)**

Mode used	**Types of attacks**	**Images used**			
		Fruits	**Lena**	**Flamingos**	**Strawberries**
DWT+PCA	No Attack	0.999	0.999	0.999	0.999
	Salt and Pepper	0.211	0.306	0.289	0.260
	Cropping	0. 318	0.598	0.498	0.500
	Rotation	0.314	0.506	0.598	0.558
DWT	No Attack	0.999	0.999	0.999	0.999
	Salt and Pepper	0.183	0.413	0.295	0.268
	Cropping	0.544	0.599	0.530	0.496
	Rotation	0.550	0.478	0.526	0.521

4. Conclusion

In this paper, a digital image watermarking through PCA and DWT on image segments in RGB space is presented. Statistical parameter like kurtosis and Bhattacharya distance are used to create an adaptive digital watermarking mechanism for coloured images. Performance of the technique was tested on multiple carrier images like Fruits, Lena, Flamingos, Strawberries and watermark images like

Cameraman and Boat, under common image processing attacks, which yield better results. The PSNR and NCC values of both test cases are sufficiently high to imply that the algorithm ensures robustness and imperceptibility. In the future work blind digital watermarking method can be used where host image is not required to extract the watermark.

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