colour Image Watermarking based on Wavelet and QR Decomposition

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***Abstract*—In this work, a new image watermarking algorithm on colour images is proposed. The proposed algorithm divides a cover image into three colour bands of red, green and blue. Then the following tasks are done on all three channels separately. First, Each colour band is divided into patches of small sizes then the entropy of each patch is calculated. At this step a threshold is found based on the average entropy of all patches and following is applied to all patches which have entropy lower than the threshold. A wavelet representation of each patch are given by applying a discrete wavelet transform. Then Singular value decomposition, orthogonal-triangular decomposition, and a chirp z-transform are used to embed a watermark on the cover image. Several signal processing attacks are applied on watermarked images in order to robustness of the algorithm. The Proposed algorithm is compared with one conventional and two state-of-the-art algorithms. Experimental results show superiority of the proposed algorithm compare with other algorithm in the area of image watermarking.**

Keywords*—*digital Image Watermarking, DWT, CZT, Entropy, SVD, QR.

I. Introduction

Due to the rapid growth of the role of social networks and communications in everyday lives, taking and sharing images frequently has become a widespread practice, where a remarkable division of modern movable phones and computers, as well as digital cameras, handle high resolution imaging. However, transferring the foregoing images from a device to another one may be seriously exposed to the risks of security, manipulation and copyright attacks, unless it has been carefully taken care of by embedding the data into the media contents through watermarking [1], [2], [3], [4], [5].

Watermarking provides a vital platform aiming at protecting multimedia materials from a variety of undesired operations and illegal interferences, such as distribution and manipulation, meaning that for a reliable performance, they need to generate seamless watermarks which could handle large volumes of data robustly and securely. The foregoing properties of watermarking schemes will be discussed in more details in what follows.

One of the most important characteristics of a watermarking algorithm is the robustness of the resulting multimedia information against possible attacks made through image processing techniques. Moreover, the watermark needs to be imperceptible, i.e. it should distort the data available in the original image. Furthermore, the data capacity is one of the main criteria in assessing the performance of a watermarking procedure, which stands for the largest amount of data that can be passed through the algorithm while preserving the visual appearance of the cover image. Last but not least, security of a watermarking technique is of paramount importance, as it denotes the resistance of the process against unauthorized detection, embedding or removal.

The studies reported on watermarking schemes in the literature heretofore [6], [7], [8], [9], [10] have categorized them into three major classes, namely, non-blind, semi-blind and blind. The underlying notion of the foregoing perception lies in the fact that in non-blind watermarking, both the original image and the watermark are required for embedding and extraction, whereas in semi-blind watermarking only the watermark image is needed, and in the blind variant, neither of them is necessary. Alternatively, watermarking algorithms can be classified based on the domain within which they operate, i.e. either the spatial domain or frequency, where the latter modify the parameter values according to the frequency-domain representation of the cover image [11]. On the other hand, watermarking in the spatial domain revises the pixel values, and consequently, demands a comparatively lower computational complexity and cost, but suffers from the deficiency that relatively less amounts of information could be embedded into the cover image, which may result in a lack of robustness against signal processing operations [12], [13], [14].

The rest of this paper is organized as follows, The proposed system is explained in Section II. Section III presents and discusses the experimental results. Finally, a conclusion of work is presented in Section IV.

II. Proposed Approach

In this work, we focus on embedding a watermark into an colour image and extracting it after applying several different attacks. This way, we consider all possible attacks and propose a non-blind colour image watermarking scheme. The embedding and extraction of a watermark image is done by a combination of characteristics of QR decomposition, Chirp Z-Transform (CZT), Discrete Wavelet Transform (DWT), and Singular Value Decomposition (SVD). a detail description of these steps of the proposed method are described in following.

A. Embedding Watermark into Cover Image

The Watermark embedding step is explained in the following. At the first step, three colour channels of Red (R), green(G) and blue(B) are extracted from the cover coloured image. Then patches size of $\alpha \times \beta$ are extracted from each colour channel of size of $m \times n$, where α and β divide m and n respectively. We can consider $N = \frac{n}{\beta}$ and $M = \frac{m}{\alpha}$. Then each patch can be described as in equation 1.

$$B_{mn} : n \in \{1 \ldots N\}, m \in \{1 \ldots M\} \tag{1}$$

For each patch, an entropy value (E) is calculated then a threshold value T is considered based on an average of all entropy values E of all patches. where T is founded by the following equation

$$T = \sum_{m=1}^{M} \sum_{n=1}^{N} \frac{E(B_{mn})}{m \times n} \tag{2}$$

After finding the threshold, a two-level discrete wavelet transform (DWT) is applied on patches with a value of E less than T, in order to decompose them into four subbands of one Low frequency (ll) and three high frequency in vertical (LH) , horizontal and diagonal direction as given in equation (3).

$$\begin{aligned} &LL_{mn}LH_{mn}HL_{mn}HH_{mn} = DWT(B_{mn}), \\ &\forall B_{mn} \in \{B_{mn} : E(B_{mn} < T\} \end{aligned} \tag{3}$$

In the next step a CZT of LL_{mn} is calculated for all decomposed patchs as given in equation (4).

$$C_{mn} = CZT(LL_{mn}) \tag{4}$$

A QR decomposition algorithm is applied in this step to matrix C_{mn} from equation (4) to calculate diagonal matrix in the following equation.

$$\begin{aligned} [Q_{mn}R_{mn}] &= QR(C_{mn}) \\ D1_m &= diag(R_{mn}) \\ D_{mn} &= Zeros(R_{mn}) \\ D_{mm} &= D1_m \end{aligned} \tag{5}$$

a SVD algorithm is applied to diagonal matrix D_{mn} in order to further decompose it as shown in equation (6).

$$[U_{mn}S_{mn}V_{mn}] = SVD(D_{mn}) \tag{6}$$

On the other hand, the SVD algorithm is applied to a watermark image W in order to decompose it to three matrices of U_1, S_1 and V_1. modified upper-triangular matrix R_{mn} and Unitary matrix Q_{mn} are combined as shown in following equation.

$$C_{2_{mn}} = Q_{mn} \times R_{mn} \tag{7}$$

An inverse CZT of $C_{2_{mn}}$ is used to get watermarked LL subband as illustrated in equation (8).

$$LL_{2_{mn}} = ICZT(C_{2_{mn}}) \tag{8}$$

Then an inverse DWT is used to get watermarked image patch. Instead of using LL_{mn}, a modified $LL_{2_{mn}}$ is used as shown in equation (9).

$$I_{mn} = IDWT(LL_{2_{mn}}LH_{mn}HL_{mn}HH_{mn}) \tag{9}$$

Finally, modified version of patches with low entropy, high entropy patches and all three colour channels are combined in order to generate watermarked colour image.

B. Extraction of Watermark

The extraction of Watermark is explained in the following. The first steps of watermark extraction are the same as the watermark embedding section. The steps from eqn 1 to equation 6 are used for watermark extraction as well. Singular values of cover image patches and the singular values of watermarked image patch are subtracted from each other then the singular values of the extracted watermark image is found bu a divination of the subtraction result and scaling factor γ, as shown in following equation

$$S_{1'_{mn}} = (S'_{mn} - S_{mn})/\gamma \tag{10}$$

Then u_1 and V_1 are combined from watermark image with the singular values founded in above egn. in order to extract watermark for each patch as shown in equation (11).

$$W_{1_{mn}} = U_1 \times S'_{mn} \times V_1^T \tag{11}$$

III. EXPERIMENTAL RESULTS

Several experiments has been conducted for this algorithm. Several well-known benchmark images used as a cover image which has been watermarked with several different types of watermark images. cover images what were used in experiments are colour images which are taken from *set14* dataset [15] like Zebra, Barbara and comic and images from an uncompressed colour image database [16]. Fig. 1 shows three images which are used as a cover image for this work. Watermark images have a size of 128×128 where all of them are in grayscale. Fig. 2 shows three watermark images of Cameraman, Baboon and Barbara which are used for experimental results.

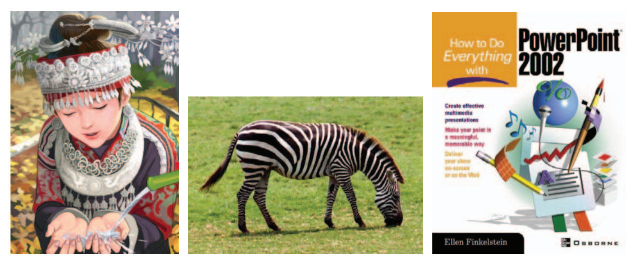

Fig. 1. Three different style images which are used as the cover images

In order to evaluate the proposed algorithm, the Peak Signal to Noise (PSNR) metric is used. PSNR algorithm measures image quality in decibels. According to the literature, an image with PSNT of more than 35 dB is considered to have high quality [17]. PSNR results of the proposed method is compared with one conventional and two state-of-the-art algorithms of LSB [18], Lai & Tsai method [11], and the algorithm which is proposed by Agoyi et al. [10]. Results of this comparison are shown Table I.

Several signal processing attacks are selected in order to apply on the cover image which is watermarked with a watermark image. These test check the robustness of the proposed algorithm over several attacks. The correlation coefficient (CC) metric is used to evaluate Extracted watermark image. CC value shows similarity between original watermark image and extracted watermark from a cover image. The proposed

Fig. 2. Three gray scale images which are used as the Watermark images

TABLE I. PSNR COMPARISON OF THE PROPOSED ALGORITHM WITH LSB AND TWO MORE ALGORITHMS AT [11] AND [10]

	Watermark image	Comic	Zebra	PPT3
LSB	Baboon	41.44	41.45	42.69
	Cameraman	41.44	41.45	42.69
	Barbara	41.44	41.45	42.69
Algorithm at [11]	Baboon	26.77	27.53	28.82
	Cameraman	25.19	27.05	28.22
	Barbara	26.66	26.89	28.09
Algorithm at [10]	Baboon	41.44	40.95	42.45
	Cameraman	39.83	39.46	40.93
	Barbara	40.76	40.26	41.81
Proposed method	Baboon	88.56	88.25	86.99
	Cameraman	87.40	87.81	85.75
	Barbara	87.78	88.45	86.89

algorithm in this work is compared with two state-of-the-art algorithms presented at [11] and [10]), and LSB algorithm which is considered as a conventional algorithm. Fig. 3 shows a visual of the cover image after applying some attacks on it. It can be concluded from experimental results that the proposed algorithm works excellent when sharpening, contrast enhancement, equalized histogram, blurring and scaling attacks are used to apply on cover image. Table II confirmed that the proposed algorithm has incomparably better CC results with all attacks except filliping and jpeg attacks which show slightly worse CC results compare with two algorithms of [11] and [10]. Table II illustrates a comparison between one conventional and two state-of-the-art algorithms when Zebra image is used as a cover image and Baboon as a watermark image.

IV. CONCLUSION

In this work, a novel watermarking algorithm is proposed for coloured images. The algorithm embeds a watermark into singular values of all three colour channel of cover image. At the First step, the a cover image is branched into three colour channels of R, G, and B, and then each channel is divided into patches. Then a proper patch which has a low entropy is found in order to watermark embedding. then these patches are decomposed into frequency channels by using DWT and further decomposed using CZT. Then orthogonal-triangular decomposition and Singular value decomposition are used to embed a watermark on the cover image. Experimental results confirm the superiority of the proposed method compare to

TABLE II. CC VALUE OF ZEBRA IMAGE, WHERE BABOON IMAGE IS USE AS A WATERMARK

Attack	LSB	Algorithm at [11]	Algorithm at [10]	Proposed algorithm
correction of gamma	0.6875	0.9755	0.9847	0.9621
Flipping	0.6607	1	1	0.9999
Crop	0.7375	0.8306	0.3004	0.8591
JPEG	0.5057	0.9823	0.9318	0.786
Blurr	0.6604	0.1609	0.6839	0.9989
Enhancement of Contrast	0.7869	0.9857	0.9765	0.9965
Salt & pepper noise	0.6412	0.9033	0.6511	0.9393
Equalized Histogram	0.8632	0.6021	0.7037	1
Gaussian noise	0.6208	0.6675	0.5778	0.9244
Sharpening	0.9067	0.5394	0.8090	0.9996
Scaling	0.6458	0.2420	0.6791	0.8322
White Gaussian noise	0.5076	0.4955	0.5911	0.8845

other state-of-the-art digital image watermarking algorithms.

ACKNOWLEDGMENT

This work is supported Estonian Research Council Grant (PUT638), the European Network on Integrating Vision and Language (iV&L Net) ICT COST Action IC1307 and the Estonian Centre of Excellence in IT (EXCITE) funded by the European Regional Development Fund.

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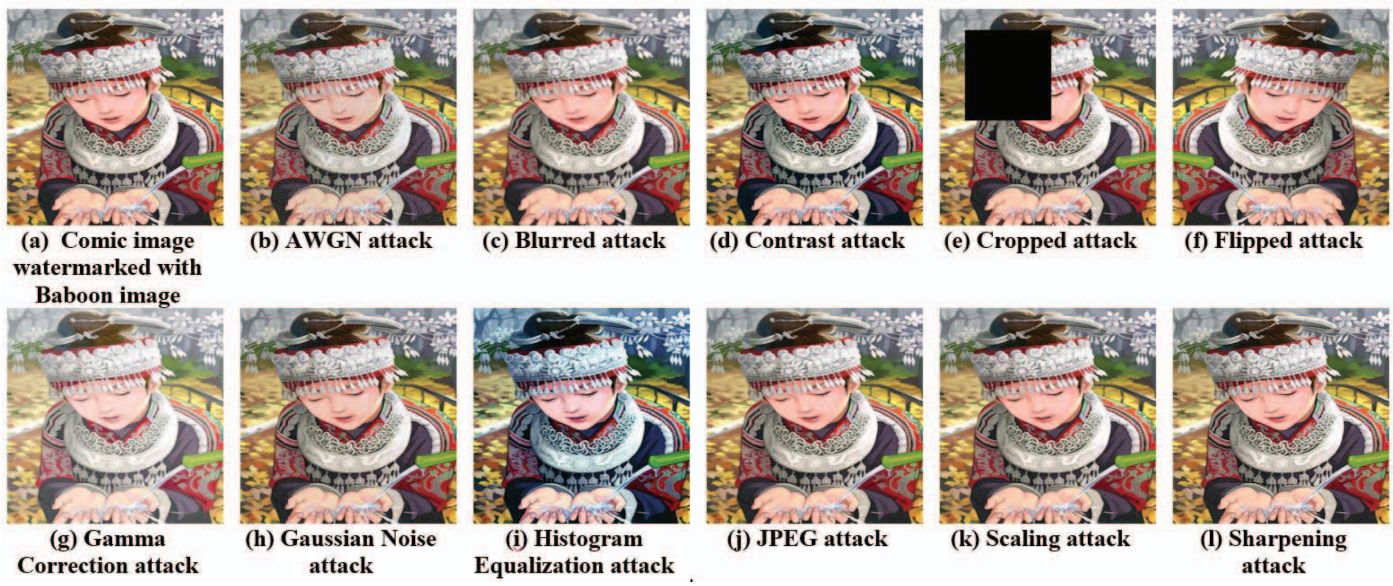

Fig. 3. (a) is a cover image image, (b-l) are watermarked images when different attacks have been applied.

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