A New Robust Color Digital Image Watermarking Algorithm in DCT Domain Using Genetic Algorithm and Coefficients Exchange Approach

Mohammad Moosazadeh
Department of Information Technology Engineering
University of Mehrastan
Astaneh Ashrafiyeh, Gilan, Iran
moosazadeh7@gmail.com

Azam Andalib
Department of Computer Engineering
Rasht Branch - Islamic Azad University
Rasht, Gilan, Iran
azam.andalib@gmail.com

***Abstract*— The Internet influence is increasing in daily life as a developing technology. On the other hand, as the capacity of images, sounds and digital videos develops, the undesirable destructive and illegal copyright techniques increase. Watermarking embeds copyright information in a given media, so that it is not recognizable for human visual system. In this paper, a digital image watermarking algorithm in YCbCr color space and DCT domain is proposed that uses coefficients exchange for embedding watermark bits and Genetic algorithm to select the target Y component coefficients of the host image. One of the differences between this method and other methods of coefficients exchange is using Arnold transform to scramble the Y component of the host image in order to spread the distortions of watermarking and increase robustness against cutting attacks. Another difference is using Genetic algorithm for selecting two suitable coefficients to embed watermark bits. The third difference is in defining confidence interval variable and increasing the two coefficients distance equal to the size of this variable, hence watermarking transparency and robustness would be balanced. The evaluation results suggest that the coefficients exchange approach is improved.**

Keywords—Watermarking, Frequency domain, Coefficients Exchange, DCT, YCbCr

I. Introduction

Extraordinary growth of Internet, peer-to-peer file sharing and signal processing technologies has made the reproduction, manipulation and distribution of multimedia data much easier than ever before. This unavoidably increases the demand for protection of copyrighted data. Digital watermarking is a promising technology for copyright protection [1]. Watermarking techniques can compliment encryption by embedding a secret imperceptible signal into the host signal in such a way that the embedded signal always remains present [2]. Digital watermarking contains embedding and extraction watermark modules. The main types of watermarks that can be embedded into media are Gaussian pseudo-random sequence and binary images [3]. Copyright protection, content authentication, manipulation detection, etc. are the basic reasons for watermark embedding. Digital watermarking algorithms are generally divided into two domains: spatial domain methods that directly add digital watermarks into image pixel values by a special algorithm, and frequency domain methods that by changing the values of image transform coefficients, embed digital watermarks into them. Frequency domain techniques have more capacity for embedding watermark bits. Choosing the best location for embedding watermark and embedding procedure are main challenges for researchers in this domain [4].

One method of watermark embedding is employing coefficients exchange approach. In [5], an algorithm of digital watermark embedding in the middle frequency adaptively, based on the DCT domain is presented. According to the energy of the block size after transforming, the algorithm can select the middle frequency coefficient adaptively to do embedding operation. Thus, Compared to traditional DCT domain fixed-point algorithm [6], it results a better balance between resistance and transparency. In this method the coefficients of each sub-block are sorted after DCT transforming, then it finds two coefficients with average energy and records their locations. After that, in order to embed a watermark bit in each block, two selected coefficient in that block are compared, if the watermark bit is '0', the first coefficient should be larger than the other, and if the watermark bit is '1', the second coefficient should be larger than the other; otherwise this two coefficient would be exchanged in order to properly establish these rules. In [7] an approach is proposed in which sub-blocks that have a complex texture according to human visual system (HVS), would be selected to embed watermarks. For this purpose, variance, which is an effective parameter for reflecting the complexity of the image texture, is employed. The image sub-block with small variance contains simple texture, while the ones with large variance contain more complex texture. Then selected sub-blocks are converted to the frequency domain by DCT transformation. Next, the watermark image is scrambled by Arnold transformation and each pixel of watermark image is embedded separately in a sub-block by adjusting the amount of correlation coefficient of selected medium frequency. The watermarking image scrambling time is used as watermarking key. In [8], the author proposes a semi-fragile image watermarking algorithm based on DCT transformation to authenticate image content. At first in this method the main

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image is transformed from RGB to YIQ and its Y components are divided into 8×8 blocks. Then DCT transformation is employed on each block and coefficients are scanned in a zigzag way. Then the first 12 coefficients of low frequency of each block are chosen as the main features of the image, and with the contribution of a specific equation are doubled. Next, in order to develop a 12 bit watermarking signal, that shows each block's content, the chosen low frequency coefficients are converted to XOR by a 12 bit user key, and therefore are embedded into the middle frequency coefficient of another block (which is chosen in a semi-random way). Thereafter, these steps are executed to all other blocks and finally the image is converted back to its original format, RGB. After all of these steps, the content features of the image are remembered by the image and it is capable to authenticate its content. In this algorithm, watermark detecting is based on the correlation calculation between the low frequency coefficients and the corresponding middle frequency coefficients. In [9], a robust digital image watermarking is presented by converting DCT in order to protect private massages, in which embedding process is based on exchanging the two selected coefficients. In this algorithm, at first two coefficients are selected for watermark embedding which are neighbor to each other. In the next step, three variables(x and y) are considered which are used to modify the coefficients values. After that, in order to embed a watermark bit in each block, two coefficients are compared in that block, if the watermark bit is '0'; the first coefficient should be larger than the other. If the watermark bit is '1', the second coefficient should be larger than the other; otherwise these two coefficients would be exchanged to properly establish these rules. This paper, in addition to the distribution of watermark throughout the image, attempted to provide a suitable method for selecting appropriate values for embedding and also one that increases the robustness of these coefficients against changes caused by attacks.

The remaining part of this paper is organized as follow. In section II, Digital Watermarking Evaluation Metrics is explained. Discrete Cosine Transform, Arnold Transform, YCbCr Color Space and Genetic Algorithm are described in section III, IV, V, VI respectively. In section VII the Proposed Watermarking Method is described. Performance Evaluation of The Proposed Method is presented in Section VIII and Performance Comparison with other Similar Algorithms is given in section IX. Finally, the Conclusion of this paper is drawn in Section X.

II. Digital Watermarking Evaluation Metrics

The main requirements of digital watermarking methods are transparency, robustness and capacity [4]. Cox et al. define transparency or imperceptibility as "perceptual similarity between the original and the watermarked versions of the cover work" [10]. According to Eq. 1, peak signal to noise ratio (PSNR) is used as a measure for determining the degree of degradation of watermarked image quality compared to the host image.

$$PSNR=10\log_{10}(L\times L/MSE) \quad (1)$$

$$MSE=1/XY\left[\sum_{i=1}^{X}\sum_{j=1}^{Y}[C(i,j)-e(i,j)]^2\right]$$

In which L is the peak signal value in the host image that equals to 255 in 8-bit images. In general, when PSNR> 30, it is difficult for the human eye to distinguish between host image and watermarked image [11].

Cox et al. define robustness as "ability to detect the watermark after common signal processing operations" [10]. According to Eq. 2, the normalized correlation (NC) has been used for quantitative evaluation of the similarity between original and extracted watermark:

$$NC = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} W(i,j)\times W^{F}(i,j)}{\sum_{i=1}^{N}\sum_{j=1}^{N}[W(i,j)]^2} \quad (2)$$

In which W (i, j) and F (i, j) are original and extracted watermark respectively. In general, similarity of the original and extracted watermark is achieved with NC> 0.85 [12].

III. Discrete Cosine Transform

In Discrete Cosine Transform or DCT, an image is transferred from spatial domain to frequency domain and it is broken into three different frequency bands, including high, middle and low frequency bands. DCT watermarking field is classified in two categories include global DCT watermarking and block based DCT watermarking [13].

IV. Arnold Transform Map

There are many common ways to scramble watermarked images such as Arnold transformation, Magic Transformation, Hilbert Curve, Conway Game, Broad Gray Code Transformation and Orthogonal Latin Square Transformation [14]. The Arnold Transform Map or ATM is defined as Eq. 3:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix}\left(\bmod N\right) \quad (3)$$

In which (x, y) are the location coordinates of the original image pixels, and (x', y') are the location coordinates of transformed image pixels, and N is the size of the image [15]. Arnold transforming as a reversible transformation has a specific feature whereby, after certain times of this transforming, image returns to its original state. The watermarking image scrambling time is used as watermarking key.

V. YCbCr Color Space

Further existing watermarking schemes are for gray images and a relatively small number of works are done on color image watermarking that are mainly implemented on RGB, YUV, YIQ color spaces [16-18]. The algorithms implemented in RGB usually embed the watermark in the blue channel, but embedding in the blue channel is not robust against JPEG compression [19]; so the question remains as which color space is ideal for watermarking. Selection of appropriate color space and choice of suitable channel for watermark embedding is investigated in [20, 21]. For robust watermarking, a change in one color component from the original image at the time of wartermark embedding should have minimal impact on other color components. YCbCr color space is chosen because its color components have minimum correlations [22].

In YCbCr color space, the luminance component (Y) represents the intensity of the image. It is the ideal space for data hiding whenever tolerance against JPEG compression and noise addition are the most important concerns. The chrominance components (Cb and Cr) specify the blueness and redness of the image, respectively. Cr channel is the best choice when the proposed algorithm should resist against scaling and rotation attacks while Cb channel is a better option for resistance against cropping [23].

VI. Genetic Algorithm

Logical principles of Genetic algorithm were built by Holland for the first time [24]. These algorithms, in comparison with natural behavior, are guided, and include an initial population and each individual of this population represents a possible solution. GA repeatedly changes its solution population and selects individuals from current population as parents and uses them for the production of the next generation children; hence new generation is produced which includes a good proportion of properties belonging to elite members of previous generations. With successive generations of populations, GA evolves towards a good solution. At each step of creating the next generation from the current population, GA uses three main principles: (1) Selection: selecting individuals or the participating parents in the next generation population. (2) Crossover: combining two parents to create the next generation children (3) Mutation: making changes into parents to make children. The steps of the algorithm are as follows:

The algorithm starts with an initial population

Running the following steps to create the next generation:

1. Scoring current population's members by calculating the value of their fitness
2. Ordering the individuals based on fitness scores
3. Transforming some individuals of the current population, with high fitness, to the next population as qualified individuals.
4. Selecting a number of members as parents
5. Producing children from parents
6. Replacing the current population with the children to create the next generation
7. The algorithm will stop when the stop criteria is satisfied

VII. Proposed Methode

A. Watermark Embedding Algorithm

The proposed model for watermark embedding is shown in Fig. 1 and the steps are as follows:

1. Scrambling watermark image by Arnold transform (5 times)
2. Converting the host image from RGB to YCbCr color space and separating the three components Y, CB and CR.
3. Selecting the Y component for watermark embedding, and scrambling it by Arnold transform (one time), in order to spread watermark image across host image and become robust against cutting attack
4. Transferring scrambled Y component to frequency domain by DCT and executing 8×8 blocking
5. Running the zigzag scan on every block and separating coefficients into low, mid and high bands
6. Selecting the suitable DCT coefficients from middle band for watermark embedding using GA
7. Determining confidence interval variable D in order to create distance between selected DCT coefficients and enhance the watermarking robustness
8. Performing embedding operations for each block and the corresponding watermark bit
   - If the watermark bit is 0 and the first coefficient is larger than second coefficient, exchange the chosen frequency coefficients
   - If the watermark bit is 1 and the second coefficient is larger than first coefficient, exchange the chosen frequency coefficients
   - If the difference between two coefficients is less than D, Increase the larger coefficient up to value of D
9. Running inverse zigzag scan on every block and recombining blocks of DCT coefficients, then returning Y component to spatial domain by inverse DCT
10. Performing initial order between embedded Y component pixels by inverse Arnold transform
11. Recombining obtained Y component with original CB and CR components, then returning host image from YCbCr to RGB color space and finally obtaining the watermarked image

B. Watermark Extraction Algorithm

Watermark extraction steps are shown as follows in Fig. 2:

1. Converting the watermarked image from RGB to YCbCr
2. Separating the Y component for watermark extracting and scrambling it by Arnold transform (one time).
3. Transferring scrambled Y component to frequency domain by DCT and executing 8×8 blocking

4. Running the zigzag scan on every block
5. Performing extracting operations (for each block)
   - If the first coefficient is larger than second coefficient, the watermark bit is 1
   - If the second coefficient is larger than the first coefficient, the watermark bit is 0
6. Combining the extracted bits together and finally obtaining the extracted watermark image

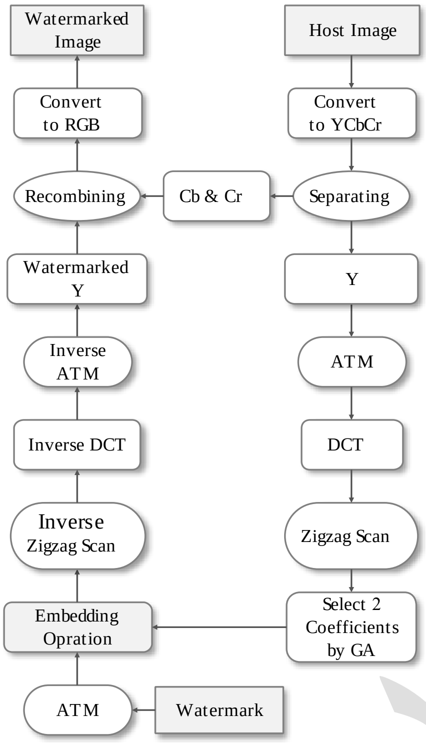


Fig. 1. Watermark embedding model

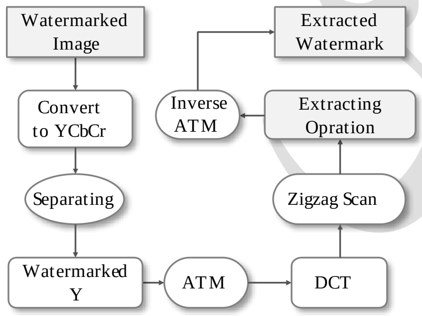


Fig. 2. Watermark extraction model

VIII. PERFORMANCE EVALUATION OF THE PROPOSED METHOD

To evaluate the proposed method, the Pepper and Baboon images with size of 512×512 pixels are used as host image and an image with size 32×32 pixel is used as watermark image. In GA, Initial Population=200, Crossover rate= 0.95, Mutation rate=0.05, Stopping Criteria (max iteration) =10, and also Fitness Function is given as Eq. 4:

$$FC=PSNR+\lambda.NC_{(JPEG\%60\_Attack)} \quad (4)$$

Where the PSNR means watermarking transparency, $NC_{(JPEG\%\ 60\_Attack)}$ means robustness against JPEG attack with quality factor Q=60 and λ is weighting parameter to create balance between transparency and robustness impact in Fitness Function, which is considered 50 .The result of GA for Peppers image is to choose 13th and 26th coefficients and for Baboon image is to choose 26th and 25th coefficients in zigzag scan as intended coefficients for watermark embedding. Finally by using the confidence interval parameter D=37, PSNR value obtained equals to 39 that according to condition PSNR>30, has a good proportionality for the human visual system. When there is no attack, the robustness (NC) equals to one, which is ideal. In this regard, NC value and extracted watermark against various attacks are shown in Table I. and Table II.

TABLE I. PROPOSED METHOD ROBUSTNESS AGAINST VARIOUS ATTACKS

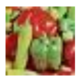
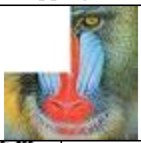
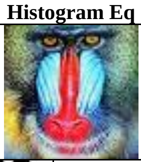
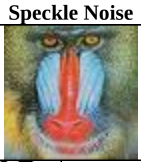
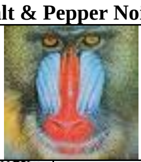
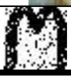
Cropping %25	Average Filter	Lowpass Filter
		
NC=0.751	NC=0.878	NC=1
Sharpening	**Histogram Eq**	**Gaussian Noise**
		
NC=1	NC=998	NC=0.920
Speckle Noise	**Salt & Pepper Noise**	**Poisson Noise**
		
NC=0.858	NC=0.848	NC=1
Scaling 256×256	**JPEG %10**	**JPEG %20**
		
NC=0.907	NC=0.307	NC=0.753
JPEG %30	**JPEG %60**	**JPEG %90**
		
NC=0.920	NC=0.974	NC=1

TABLE II. PROPOSED METHOD ROBUSTNESS AGAINST VARIOUS ATTACKS

Cropping %25	Average Filter	Lowpass Filter
		
 NC= 0.7450	 NC= 0.7347	 NC= 0.9863
Sharpening	**Histogram Eq**	**Gaussian Noise**
		
 NC=1	 NC=1	 NC= 0.8292
Speckle Noise	**Salt & Pepper Noise**	**Poisson Noise**
		
 NC= 0.8032	 NC= 0.7560	 NC= 0.9961
Scaling 256×256	**JPEG %10**	**JPEG %20**
		
 NC= 0.7604	 NC= 0.2069	 NC= 0.5191
JPEG %30	**JPEG %60**	**JPEG %90**
		
 NC= 0.6768	 NC= 0.8562	 NC=1

IX. PERFORMANCE COMPARISON WITH OTHER SIMILAR ALGORITHMS

In this section, by applying various attacks on the Lena image, a fair comparison is presented between the proposed method and other algorithms that use coefficients exchange approach that is shown in Table III. Results suggested that watermarking robustness is improved.

X. CONCLUSION

In recent years, with the development of the Internet technologies, there are a great deal of digital media contents transmitting on the Internet every day. To protect the copyright of the digital contents, digital watermarking have become more and more important. In this paper, a new color digital image watermarking algorithm in YCbCr color space and DCT domain is proposed that uses coefficients exchange for watermark embedding in Y component of the host image. In the proposed method, in order to increase the robustness, Y component of the host image and also watermark image is scrambled by Arnold transform. Then, two coefficients from DCT middle band are selected by Genetic algorithm to embed watermark in order to reduce the JPEG attack adverse impact on watermarking transparency. After that, to make a balance between watermarking transparency and robustness, confidence interval variable D is determined and if the difference between two coefficients is less than D, the higher coefficient is increased to the size of D value.

TABLE III. COMPARISON WITH COEFFICIENTS EXCHANGE ALGORITHMS

		Proposed method	[7]	[8]	[9]
PSNR (dB)		39	38.27	35.39	37.43
No Attack		1	0.9769	0.9347	
Cropping %25		0.7503	0.7017		0.8571
Average Filter		0.8248			
Low pass Filter		0.9961			0.8798
Sharpening		1			0.8782
Histogram Eq		1		0.7321	
Gaussian Noise		0.8379	0.7647		0.8538
Speckle Noise		0.8275			
Salt & Pepper noise		0.7346	0.7647		
Poisson Noise		1	0.8529		
Scaling 256×256		0.8660			
JPEG	**Q=10**	0.2846			0.1432
	Q=20	0.6566			0.2692
	Q=30	0.8843			0.3969
	Q=60	0.9882			0.6118
	Q=90	1		0.7495	0.8825

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