An Optimized Dual Watermarking Scheme for Color Images

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Abstract— **Multiple watermarking techniques for images is receiving more attention in recent years for its wide variety of applications in different fields such as piracy of digital data, and copyrights protection. Current approaches rely on adding many watermarks in different bands or channels by means of scaling factor, and embedding locations that are mainly defined by experts. This brought many challenges in achieving equilibrium between security, robustness, and quality. Aiming to fill the gap of the stationary scaling factor and embedding locations, the work proposed in this paper adapts genetic algorithm to find the optimality of these issues that will enhance both of watermarking capacity and imperceptibility in color images. To increase security, the suggested system encodes the watermarks using 2-D Walsh transform. Furthermore, Singular value decomposition as a dimension reduction tool is utilized to factorize Wavelet coefficients to determine the most salient embedding locations. Trials results demonstrate that the proposed technique is more robust against common image manipulation attacks in terms of peak signal to noise ratio and normal correlation coefficient**.

***Keywords*— Dual image watermarking, Genetic algorithm, intelligent embedding system, Copyright protection.**

I. INTRODUCTION

The astonishing progression of Internet, peer-to-peer file sharing, and signal processing knowledge have made it easier to replicate, manipulate, and distribute multimedia data much than ever before. This unavoidably increases the demand for protection of copyrighted data, where digital image watermarking is a promising technology for such a goal [1-3]. Early image watermarking methods were based on single watermark embedding, as there are great limitations when single watermark embedding algorithms are tried into practical applications, like when multiple users share the copyright, it needs to support multiple users to embed their watermarks synchronously [4] [5]. This highlights the needs for multiple watermarks embedding as a method to provide extra security to an image by embedding two or more secret messages into the cover image [6].

Unfortunately, there are still some problems that facing dual watermarking approaches and mainly depend on several different factors [7-10]: (1) adding multiple watermarks (noises) affect the perceptibility (quality) of the cover image. (2) The embedding of each watermark should be at a different location that must be known exactly at the extraction phase; i.e. the system requires extra data to save these locations and therefore needs extra payload. The attention here is to deal with the tradeoff between watermark capacity, extra payload, computational cost, and imperceptibility.

The existing multiple watermarking algorithms can be divided into three classes, namely: re-watermarking, composite watermarking, and segmented watermarking [8] [11-14]. In re-watermarking, the watermarks are simply embedded one after the other. The advantage is that it is not essential that embedders should know each other or know the number of embedded watermarks in advance. Composite watermarking builds a single combined watermark from a group of watermarks and then embed it into the cover image in the common way. This approach has the need for a trusted party which does the composition and embedding of the single watermarks and all watermarks have to be present at once. Regarding segmented watermarking, it divides the cover image into several partitions and allocates each partition for a different watermark. Here, the number of divisions limits the number of watermark signals to be embedded. Besides, when the size of each watermarks increases the number of blocks decreases. It must be confirmed that the embedded watermark is not easily lost and imperceptibility is also preserved.

Recently, integrating genetic algorithm (GA) into a watermarking scheme to improve its performance and effectiveness has received a great deal of attention among researchers working in this field. Motivated by above challenges and in order to cope with them, the work in this paper aims to introduce an intelligent dual watermarking scheme for color images based on a multi-purpose evolutionary algorithm to optimize both of additive embedding's scaling factor and embedding locations with the purpose of enhancing embedding strength to achieve robustness against different types of attacks and imperceptibility. Herein, the embedding is within the different color channels to increase the capacity and achieve multi-purpose watermarking such as copyright protection and content integrity. The incoming sections of the paper are as follows: Section 2 labels some of the modern related works. The detailed description of proposed system has been made in Section 3. In Section 4, the results and discussions on the dataset are given. Finally conclusion and some of possible future works are annotated in Section 5.

II. LITERATURE REVIEW

Most of the recent studies have not indicated a clear distinction between multipurpose and multiple watermark (or cocktail watermarking) algorithms [3] [7]. In order to solve the dual watermarking problems described above, the authors in [4] has suggested applying de-interlacing process on the transformation sub-bands of host image according to its even and odd row pixel value. In recent years, swarm-based evolutionary algorithms have been received much attention from researchers [7] [15]. The multiple objectives are the perceptual quality, security, and robustness. Yet, this method lacks immunity to geometric attack and has very complex computational processes. Concurrently, in 2012, Liao [3] had examined other aspects of visual cryptography, wavelet transformation domain, and YC_bC_r color model required to assure the re-watermarking concept in which all owners will has dual watermark authentication embedded in a protected color image, and the number of ownership can be increased without re-computing. To solve the problem of revealing different image color space, the authors in [11] produced a novel hybrid digital watermarking technique based on the exploitation of both RGB and YC_bC_r color spaces using spatial domain techniques.

In recent times, frequency domain transformations have become a cutting edge in the field of multiple images watermarking [12] [13]. For instance, the authors in [13] inserted multiple binary watermarks into middle and high wavelet frequencies. Usually when embedding both watermarks into a single image, one could achieve extremely high robustness properties with respect to a large amount of image processing operations. The authors in [16] suggested a new multiple watermarking approach in vector data rather than raster data. Although image dual watermarking has been studied for few decades, there is still room to make it more efficient and practical in real applications. According to the aforementioned review, it can be found that past studies were primarily devoted to: (1) devising different type of watermarking either multi-objective or multi-purpose that employs the image information (color spaces, regional statistics, and image salient features), (2) Not addressing the issues associated with the choosing of appropriate scaling factor for embedding (manually adjusted), and (3) Embedding locations are usually identified randomly or according to criteria that do not consider image characteristics into account. However, to the best of our knowledge, little attention has been paid to advising new optimal selection algorithm to determine both scaling factor and embedding locations and improving its efficiency in multi-watermarking algorithm as well.

III. PROPOSED METHODOLOGY

This paper proposes a new method that combines both of the first and third watermarking categories (Re-watermarking and segmented) that does not rely on supervised training for determining pixel embedding locations. Besides, it takes the human visual system into consideration by embedding in specific color channels. The main diagram of the suggested hybrid dual watermarking categories is depicted in Fig. 1 (embedding process), and Fig. 2 (extraction process). The following subsections describe in details the steps of the system.

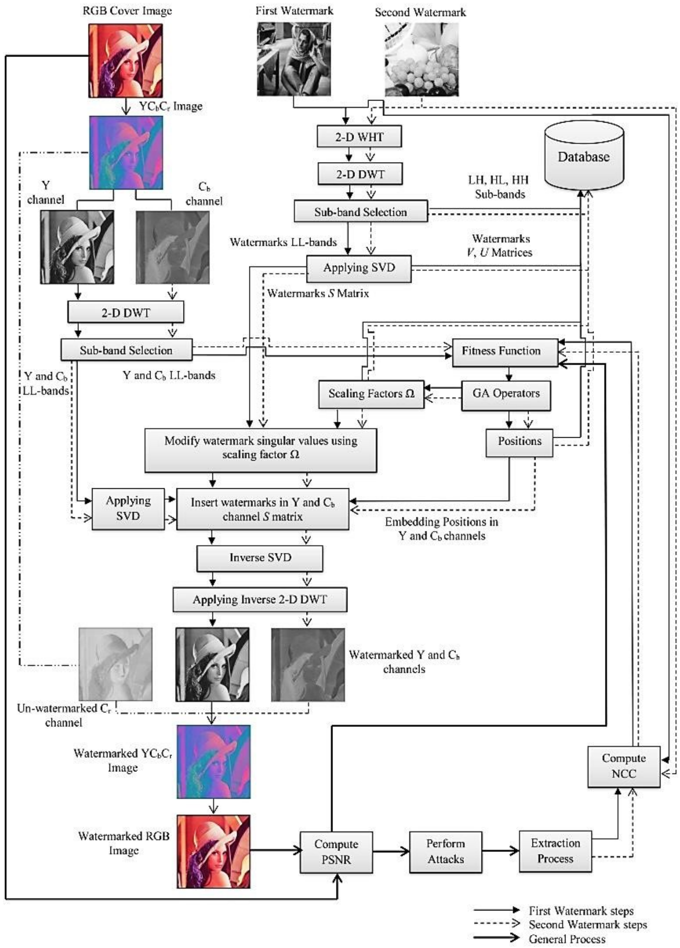


Fig.1. Embedding Process in Y and C_b Channels.

Watermark Embedding and Extraction Stage

Watermark embedding function considers where and how to embed the watermarks satisfying various requirements of the cover images. Irrespective of the embedding region, domain and type, however, an embedding function can take the dual watermark, w_1, w_2 and the original image data, I as input to output the watermarked image data, $\bar{I}$. The following steps are performed to embed two gray scale images as watermarks inside a color RGB cover image.

A. Converting into YC_bC_r Color Space

The cover image is converted to YC_bC_r color space as it is better to model the human color perception [10] [11]. Herein, the embedding is performed in Y, and C_b as the luminance channel 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; whereas the chrominance channel, C_b channel has more ability to defeat various types of attacks compared to chrominance space C_r [1] [17].

B. Securing Watermarks using Walsh Hadmard Transform (WHT)

The suggested system encrypts the watermarks to increase the security; so that it is difficult to handle the watermarks even after being extracted by the attackers. Herein, the WHT is employed because it contains only ±1, and no multiplications are required in the computation [18] [19].

C. Salient Features Extraction using Discrete Wavelet Transform (DWT)

DWT is more frequently used in digital image watermarking due to its excellent spatial localization and multi-resolution techniques [20][21]. The excellent spatial localization property is very convenient to recognize the area in the cover image in which the watermarks are embedded efficiently. In general, most of the image energy is found at the LL sub-band and therefore the embedding of the watermarks in other sub-bands may degrade the quality of image [21-23]. DWT is applied on both the cover image in addition to the dual encrypted watermarks for the selected channels only.

D. Dimension Reduction using Singular Value Decompostion (SVD)

SVD is a matrix decomposition method to obtain a smaller set of values which has maximum signal content from the derived wavelet coefficients [17]. These singular values represent the most energy of the signal. Because of translation, scaling properties of SVD it can be used as a tool to develop watermarking schemes [2] [22]. The system applies SVD to the LL band for image watermarks in which for a given two matrices WT_{LL,w_1}, WT_{LL,w_2} of size $n \times n$. The rationale of using SVD is that when a small perturbation is added to an image, the large variation of its singular values of S matrix does not occur, furthermore, it represents intrinsic algebraic image properties [22] [24].

E. Determining Optimal Embedding Positions and Scaling Factor

In general, determining the scaling factor for additive watermarking to control the strength of watermarks embedding is an important parameter to satisfy the perceptibility even when dual watermarks are embedded. Furthermore, finding the paramount locations for the watermarks embedding to achieve optimal robustness against various types of attacks represents an essential requirement for watermarking schemes [1] [2]. The strength of embedding watermark and embedding locations are determined by utilizing GA method to balance the robustness and perceptual transparency requirements [24-27]. Given the initial watermarked image, the next step is to optimize the embedding locations by utilizing GA besides the optimal scaling factor given a specific objective function. In this case, an instance of a GA-based dual watermarking optimization problem can be described in a formal way as a four- tuple (P, Q, ζ, f) defined as:

- P is the solution space (initial population – a combination of 2^n indexed blocks) where n represent the number of bits needed to represent the block index. Each bit is signified as a gene and every block is represented as a chromosome [27].
- Q is the feasibility predicate (different operators- selection, crossover, and mutation). The crossover is the process of exchanging the parent's genes to produce one or two offspring that carry inherent genes from both parents to increase the diversity of the mutated individuals [28]. Herein, a single point crossover is employed because of its simplicity. The purpose of mutation is to prevent falling into a locally optimal solution of the solved problem [29]; a uniform mutation is employed for its simple implementation. The selection operator retains the best fitting chromosome of one generation and selects the fixed numbers of parent chromosomes. Tournament selection is probably the most popular selection method in genetic algorithm due to its efficiency and simple implementation [30].
- ζ is the set of feasible solutions (new generation populations). With these new generations, the fittest chromosome will represent the best block of the cover's LL band that gives the optimal embedding location according to its index. This individual (block) will specify the optimal scaling factor explicitly according to the block's singular values [27] [28].
- f is the objective function (fitness function). The individual that has higher fitness will win to be added to the predicate operators' mate [2]. Herein, the fitness function is computed based on $PSNR$ value that shows the extent of distortion introduced to the original cover image due to dual watermark insertion (transparency indicator) and NCC that specifies the degree of similarity between original watermarks and extracted watermarks of each block in the population for each generation (robustness indicator) [26].

$$f_{Bi} = (PSNR + \mu \times NCC)^2 + \frac{1}{1-(PSNR + \mu \times NCC)} \qquad (1)$$

Bi is the block with index i, and μ is a weight used to make a balance between transparency and robustness impact. The fitness parameters $PSNR$ and NCC are calculated under different type of attacks such as Gaussian noise, cropping, and geometric attacks.

During the embedding process, some values will be stored in the database to be used later in the extraction process where the suggested system falls under the semi-blindness category. These values include $S_{I,Cb,Bi}$ and $S_{I,Y,Bi}$ of the original cover image, the embedding locations of both watermarks $\perp_1$, and $\perp_2$, the scaling factors used in the embedding process for both watermarks $\Omega_{I,Y,Bi}$, and $\Omega_{I,Cb,Bi}$, U, V matrices, LH, HL, HH sub-bands as additional data that are needed to fully extract the watermarks. As these matrices are sparse (most of items are zeros) in natural, they do not need a large storage space. Herein, extraction process is done in a reverse way to the embedding process [1] [2] [11] [18] [21-25] [31].

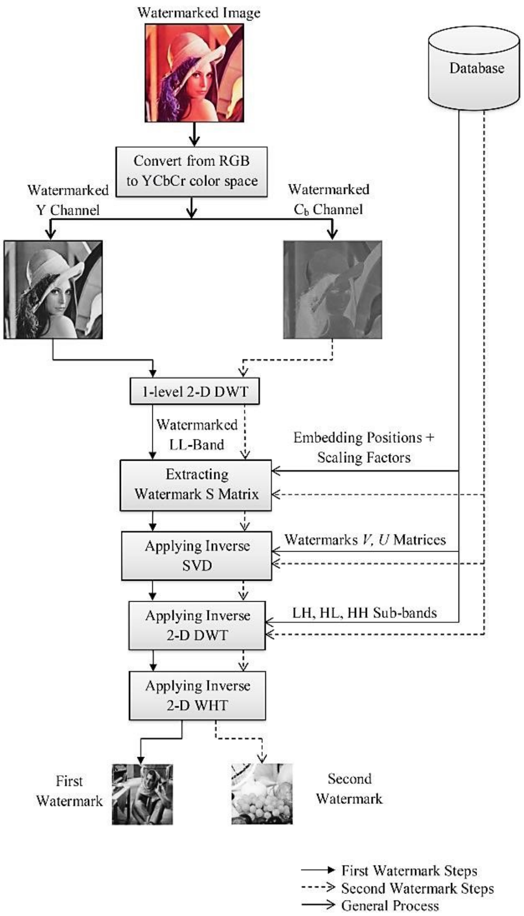


Fig.2. Extraction Process.

IV. EXPERIMENTAL RESULTS

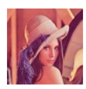
Experiments were conducted on a benchmark color image dataset [32]. The database is divided into volumes based on the basic character of the pictures. Images in each volume are of various sizes such as 512×512 pixels, or 1024×1024 pixels. All images are 8 bits/pixel for black and white images, 24 bits/pixel for color images. Table 1 shows GA parameters that were taken for optimizing the suggested scheme.

The first set of experiments was performed to show how the quality of the suggested system in terms of imperceptibility depends on GA parameters for Lena cover image with different sizes. Table 2 shows that the smaller the cover image's size, the better PSNR result is acquired. One possible explanation for this result is that smaller size is associated with smaller search space; so that GA can acquire optimal solution [5]. It is also clear from the table that the increase in population size has a limited effect on number of optimal solution when number of generations is constant. Regarding the effect of the number of generations on the convergence to the optimal solution, the more the number of generations, the more diversity of the population. In general, populations often stabilize after a time, in the sense that the best programs all have a common ancestor and their behavior is very similar (or identical) both to each other and to that of high fitness programs from the previous generations. Convergence can be avoided with a variety of diversity-generating techniques [33] [34].

Table 1: Genetic Algorithm Parameters.

Encoding Style	Binary Coding
Generation Number (GN)	Ranging from (5-50)
Population Size (PS)	Ranging from (5-50)
Crossover Rate	0.7
Type of Crossover	Single Point Crossover
Mutation Rate	0.3
Type of Mutation	Uniform Mutation
Selection Type	Tournament Selection

Table 2: Effect of Crossover and Mutation Rate of GA on Watermarking Imperceptibility.

Image	**Size 1024×1024**		**PSNR**	**Size 512×512**		**PSNR**
	GN	***PS***		***GN***	***PS***	
	5	5	51.6957	5	5	51.9152
		20	51.7650		20	51.9400
		50	51.7425		50	51.9233
	10	5	51.6349	10	5	51.9109
		20	51.7650		20	51.9400
		50	51.7425		50	51.9233
	20	5	51.6349	20	5	51.9218
		20	51.7650		20	51.9400
		50	51.7425		50	51.9233
	50	5	51.8039	50	5	51.9360
		20	51.7650		20	51.9429
		50	51.7425		50	51.9233

The second set of experiments were conducted to show how the PSNR values of the suggested system depend on the embedding in different color channels in order to determine the most suitable color channels for the embedding process. It can be inferred from Table 3 that higher PSNR values are achieved in both of Y and C_b color channels. One explanation of this result is that most of the visible information is in the Y channel (carry the intensity value of the pixel) and human eyes tolerate both lower spatial resolution and more aggressive quantization in the C_b and C_r channels that contains color information of the pixel. The component C_b is strong in places of occurrence of bluish colors [8] [11]. Pixels have lower intensity in C_b channel are shown as dark regions in the image. C_r channel is the brightest area in the image similar to Y channel [35]. As stated in [36], the non-uniform color spaces such as YC_bC_r color space indeed provide a large amount of perceptual redundancy for embedding high-strength watermarking signals which can survive various attacks.

Table 3: Effect of Embedding Process in the Different Color Channels in Term of PSNR.

Host Image	Y Channel	C_b Channel	C_r Channel
Pepper	52.007	51.795	51.509
Lena	51.277	51.844	51.135
Mandrill	51.657	51.778	51.352
Airplane	52.105	52.330	52.068
Tulip	51.930	51.895	51.878

The third set of experiments was performed to compare the robustness, and imperceptibility performance of the suggested dual hybrid watermarking system (successive and segmented) that employs GA to find the optimal parameters with Mohananthini method [9] that implements DWT – SVD based dual watermarking technique for successive and segmented watermarking approaches separately. As shown in Table 4, the proposed dual watermark system achieves 37.1 % improvement in terms of PSNR (cover image quality) compared to the other system which outperforms with a very small ratio in terms of NCC (watermark quality) from the suggested system. One possible explanation for this improvement is that the merge of the two watermarking techniques yields a solution to the issue of watermarks interference with each other. Furthermore, the suggested system is based on embedding the watermarks in the most suitable locations with optimal scaling factors, whereas the other system determines the optimal scaling factor only.

Table 4: Result of Comparison between the Dual Watermarking Systems without Attacks.

Images (512×512)	N. Mohananthini [9]				Proposed System	
	Successive Watermarking		*Segmented Watermarking*		*Hybrid Watermarking (Successive and Segmented)*	
	PSNR	***NCC_1 NCC_2***	***PSNR***	***NCC_1 NCC_2***	***PSNR***	***NCC_1 NCC_2***
Lena	37.96	1	39.93	1	51.94	0.99
Mandrill	38.04	1	40.04	1	51.97	0.99
Pepper	38.03	1	40.03	1	52.16	0.99
Airplane	37.26	1	39.66	1	52.08	0.99
Apple	37.99	1	39.99	1	51.66	0.99
Boat	37.65	1	39.64	1	51.15	0.99

The fourth set of experiments was implemented to validate the robustness of the suggested system against different types of attacks. Table 5 summarizes the results in terms of PSNR for the watermarked image for both the suggested system and the comparative one. It is evident that the robustness of performance of the proposed system is superior to the existing method for the Lena image. The results clarified that the rotation attack has achieved the least PSNR value as it changes the pixels' locations and consequently loss the synchronization between the original watermarks locations and the stored locations in the database. Whereas, the JPEG compression attack has achieved the highest PSNR value as this type of attack is usually applied to the high-frequency components, on the contrary the proposed system embeds the dual watermarks in the low-frequency components so this attack has no significant impact on the quality [9] [14]. In common, simple attacks like noises attempt to damage the embedded watermark by manipulations of the whole watermarked data without an attempt to identify and isolate the watermark. The difference in the NCC values for the two extracted watermarks for the same cover image is due to the nature of the characteristics of the image. These values are small in the case of rotation attack (NCC equals 0.4117 for the first watermark and 0.6323 for the second watermark).

Table 5: PSNR Values for Different Attacks on Multiple Watermarking Techniques for Lena Cover Image.

Attacks	N. Mohananthini [9]		Proposed System
	Successive watermarking	*Segmented watermarking*	*Hybrid watermarking (successive and segmented)*
	PSNR	***PSNR***	***PSNR***
Salt and Pepper noise	21.3882	21.3710	21.5771
Gaussian Noise	21.2456	21.2425	21.2801
Cropping	18.7839	18.8023	19.1883
Rotation	9.8067	8.5919	9.8419
JPEG Compression	37.4234	37.7035	37.8427
Sharpening	25.3802	23.9824	34.9838

Table 6: Average Time Consumed for the Whole System Performance in Seconds.

Time in Seconds	N. Mohananthini [9]		Proposed System
	Successive Watermarking	*Segmented Watermarking*	*Hybrid Watermarking*
	2.792121	7.503938	3.333379

V. CONCLUSION

A new multi-objective genetic fitness function for optimal embedding strength and locations selection to achieve conflicting goals of imperceptibility and robustness in semi-blind image dual watermarking in wavelet domain is developed. In this work, GA-based watermarking algorithm, the imperceptibility parameter (PSNR) and the robustness parameter (NCC) are used to design the objective function. In this case, a multi-objective problem is reduced to the simple and computationally efficient single object problem using the weighted sum approach. Experiments using different types of color images show that the GA-optimized embedding locations depend on the cover image characteristics. An interesting result of this study is the insight into the trade-off between imperceptibility and robustness. To set a plan for future works, the GA can be replaced with another appropriate optimization method to fine-tuning watermarking parameters. Finally, link the proposed system to the modern applications of e-business such as the blockchain.

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