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A new approach for colored watermarking image into gray scale image using wavelet fusion

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Abstract With the quick growth of technologies and great spread of the Internet, many challenges face data hiding. Nevertheless, significant data may be protected by burring it in an image as a watermark. This paper shows an efficient data hiding watermarking approach for color image by using singular value decomposition (SVD), multi-level discrete wavelet transform (DWT) and wavelet fusion. The main idea in this work is to separate the color image into its basic components (three channels); red, green, and blue. Then, fuse every channel with an image which is gray scale and integrate the three fused images into one gray scale fused image. Finally, the fused image is burred into a cover gray scale image to produce the watermarked image by using DWT and SVD. The proposed approach evaluation is done by using several images and different hacking on the transmitted image. The experimental results show that the marked images which are generated by the proposed approach are tolerant to versatile attacks such as Gaussian, blur, wrap, and cropping. Above all, the extracted watermark images are recognized even when the watermarked images suffered from attacks.

Keywords Image watermarking · Wavelet fusion · SVD · DWT · Data hiding

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1 Introduction

In recent years, digital image watermarking is used widely to solve ownership issues and verify the authenticity issue of text, image, audio or video. Researchers have proposed a lot of effective techniques aiming to secure information, and copyright protection authentication (Wang et al. 2012). One can define watermarking as process of hiding data, which can be logo, signature, image, sound, label or text, into multimedia object (text, image, audio or video). The embedded object will be later extracted by the other side to achieve the intended purpose such as securing information, authentication of an object and checking ownership (AL-Mansoori and Kunhu 2012).

Watermarking techniques could be categorized into two essential groups that are in spatial domain or in frequency domain. In spatial domain, watermark is embedded directly into pixels of original image by changing pixel values themselves. Least significant bits (LSB) is the simplest technique of all spatial domain techniques, LSB is based on modifying the least significant bits of the original image by watermarking (Ali et al. 2014). Generally, most spatial domain techniques are easy to implement. Unfortunately, spatial domain techniques are not robust to attacks (Ali et al. 2014).

In frequency domain, embedding process is done by transforming representation of spatial domain into frequency domain then modifying its frequency coefficients to embed the watermark. There are a lot of transform domain watermarking methods such as Discrete Fourier Transforms (DFT) (Lu et al. 2010), Discrete Cosine Transforms (DCT) (Phadikar et al. 2011), SVD (Mohammad et al. 2008), and DWT (Ouhsain and Hamza 2009). Frequency domain techniques are better than most of spatial domain techniques in terms of resisting attacks, but require higher computational cost (Ali et al. 2014).

This paper presents an efficient digital image watermarking technique for color image hiding. The proposed approach embeds a color image into a gray scale image by using DWT, SVD and wavelet fusion. Image wavelet fusion is known as the process of combining two or more images to improve the quality and reduce redundancy (James and Dasarathy 2014). The main idea is to split the color image into three basic components (red, green, blue), then fuse every channel with a gray scale image, and integrate the three fused images to construct watermark image by using fusion. Finally, a stego-image is constructed by embedding the watermark into a gray scale cover image by using DWT and SVD. The stego-image then sent via Internet. The transmitted image will appear to attacker as a completely gray scale image.

The rest of this paper is organized as the following arrangement, Sect. 2 briefly discusses the problem of data hiding while Sect. 3 shows the previous related work to solve the problem. Section 4 presents the principles of watermarking and some details for the DWT, SVD and Wavelet Fusion algorithms. Section 5 presents the proposed approach embedding and extracting process. Section 6 introduces the image quality measures and presents the experimental results. Finally, the paper conclusions are shown in Sect. 7.

2 Problem statement

Today, many secret data are being transmitted on the Internet. However, most of secret important messages may get high risks while being transmitted over many public communication channels. The problem now is how to achieve safe secret communication of critical messages.

Some researchers show that a private message can be easily encrypted into some cipher text using a cryptographic technique like data encryption standard (DES) before sending out through the communication channel, to appear meaningless and hence guarantee safe secret communication. Nevertheless, the appearance of secret information as cipher texts readily attract the hackers' attention. Under such circumstances, if the message is attacked and decrypted by unwanted parity, the data will no longer be secured. In addition, even though chances for the hackers to perform decryption of ciphertexts is weak because of the cryptographic system strong security, at least the upset hackers can destroy the ciphertexts easily and spoil the transmission process.

To easily fix this problem, various kinds of plaintexts like images, audios, videos, etc., are used as a cover to hide the existence of the secret message from the attacker. Although there are multitude plaintext media, images are known to be the most commonly used as they are widely ubiquitous and readily found on the Internet. Also, the higher distortion tolerance degree that images have over other diverse kinds of plaintexts provides them with a very large hiding capacity.

3 Related work

Abdallah et al. (2007a) proposed a robust simple image watermarking technique which embed a watermark in transform domain using the fast Hadamard transform (FHT), DWT and SVD. The applied technique makes improvements in the data embedding system efficiently. As it improves the watermark imperceptibility and resist against several attacks. Abdallah et al. (2007b) proposed a tensor video watermarking scheme which is based on SVD technique. The main idea is to embed a watermark image into the stable coefficients of video frames. That can be applied by modifying singular values (SVs) of high order tensors which belongs to intra-frames video. The proposed method performance shows good robustness and surviving against various attacks such as frame averaging, frame dropping and geometric attacks.

Hemdan et al. (2013a) proposed a hybrid image watermarking technique that is based on fusing two gray scale images using wavelet fusion. Their experimental results demonstrate that wavelet fusion is really an efficient algorithm. Hemdan et al. (2013b) proposed a robust efficient hybrid watermarking technique which is based on wavelet fusing to two gray scale images using three-level DWT and wavelet fusion. Their proposed algorithm increases the embedded information capacity without affecting the original image perceptual scene, and is robust against severe attacks like Gaussian noise, filtering and cropping attacks.

Agarwal et al. (2014) proposed an optimized watermarking embedding and extracting technique which is based on DWT and SVD. The LL3 sub-band SVs coefficients of the cover image are modified by using of watermark SVs. Experimental results declare that the proposed technique guarantee high PSNR values, good visual quality after attack and high robustness against some image processing operations.

Mohananthini and Yamuna (2015) proposed a scheme which is based on fusing the two watermarks into single watermark then embed it into the cover original image using the discrete wavelet transforms. The experimental results declare that this proposed algorithm give the watermarked image good visual quality and is survival to a lot of image attacks like: Gaussian noise, salt and pepper noise, speckle noise, cropping, median filtering, and rotation.

Narula et al. (2015) proposed two watermarking approaches DWT and DWT–SVD which are applied to ensure image content security and watermark robustness. After that they applied both watermarking approaches and compared values of peak signal to noise ratio (PSNR). Experimental results show that the hybrid DWT–SVD is much better than DWT approach alone. It is shown that after applying the two watermarking approaches, the quality of the watermarked image degrades significantly when using DWT approach watermark embedding in comparison to DWT–SVD.

Naidu et al. (2016) proposed a DWT–SVD watermarking method that aims to embedding a single watermark image that can be exactly as large as the cover image. It is proved that modifying the cover image SVs of DWT domain provides highly robustness against several common attacks. Another beneficial point of DWT–SVD algorithm is high PSNR and high correlation coefficient of the watermarked image compared to the results of using only DWT.

4 Preliminaries

4.1 Principles of image watermarking

Generally, image-watermarking scheme has two main phases; embedding process, and extraction process, as shown in Fig. 1. In embedding process, the insertion of watermark into original image is done using an algorithm that produces watermarked image. This watermarked image is then transmitted to the other side via communication channel. It may pass safely or be exposed to an attack. In extraction process, the other side receives the watermarked image and uses that chosen algorithm to separate the watermark and original images. Without attack, the extracted watermark is often the same as the watermark before sending. However, with attack, without a robust algorithm, the extracted watermark will be ruined.

The image watermarking algorithm should fulfill the following requirements which must integrate with each other in addition to trade-offs in order to produce a powerful watermarking algorithm (Singh 2011):

(1) *Robustness* the watermark shouldn't be affected or removed by an unauthorized party. Therefore, it should be very resilient against common signal processing manipulations like cropping, filtering, or compression.
(2) *Imperceptibility* the watermark shouldn't degrade the quality of the original image and it shouldn't be observed by human naked eye.
(3) *Capacity* maximum number of bits which can be buried in the original image.
(4) *Security* watermark should be only detected by the authorized party.

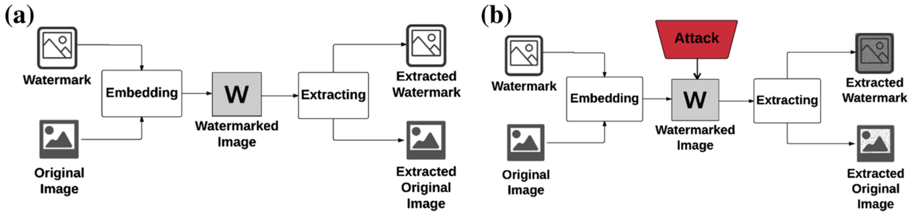


Fig. 1 General framework of digital image watermarking. **a** Without attack, **b** with attack

4.2 Discrete wavelet transform

Discrete wavelet transform (DWT) is widely used in the field of signal processing. It can be used in removal of noise in audio as well as compression of image, audio and video. One dimensional DWT or one level DWT decomposes the image into 4 bands denoted by lower resolution image approximation (LL), horizontal (HL), vertical (LH) and diagonal (HH) as shown in Fig. 2a (Hemdan et al. 2013a; Mohamed 2010). Multi-level DWT is done by applying previous decomposition again on a band. The image can be decomposed onto N level wavelet transformation, as shown in Fig. 2b (Bhatnagar and Raman 2009).

4.3 Singular value decomposition

Singular value decomposition (SVD) is a mathematical technique that is based on linear algebra theorem which shows that the rectangular matrix 'A' can be decomposed into three matrices (Hemdan et al. 2013b): U (Orthogonal matrix), S (Diagonal matrix) and V (Transpose of an orthogonal matrix). The theorem can be presented usually as:

$$A = USV^T. \tag{1}$$

4.4 Wavelet fusion

4.4.1 Definition

Image fusion is defined as the process that can combine two or more images into a single image which is called Fused Image. This is shown in Fig. 3. The fused image keeps most

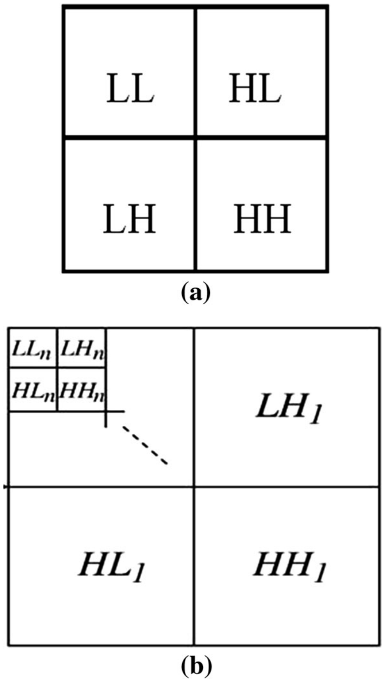


Fig. 2 Discrete wavelet transform (DWT). **a** One level DWT, **b** Multi level DWT

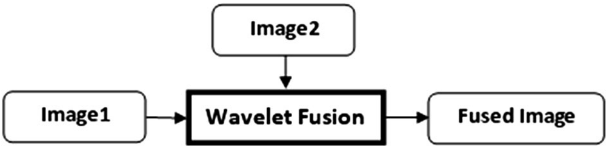


Fig. 3 Fusion of two images

important features of the original cover image. Image fusion is a vital technique used in many applications such as computer vision, microscopic imaging, robotics and remote sensing (Hemdan et al. 2013b).

Image fusion's common form of transform is the wavelet transform fusion (Hill et al. 2002). First, two images are transformed into wavelet transforms. Then, the transformed images are combined in transform domain by using a defined fusion rule. At last images transformed back to spatial domain to give the resultant fused image. Mathematically wavelet transform fusion can be defined by considering wavelet transforms W of two registered input images $I_1(x, y)$ and $I_2(x, y)$ together with fusion rule ∅. After that, inverse wavelet transform ω^{-1} is computed, and fused image $I(x, y)$ is reconstructed. This process is shown in Fig. 4 and expressed by Eq. (2) (Hill et al. 2002).

$$I(x, y) = \omega^{-1}(\emptyset(\omega(I_1(x, y))), \omega(I_2(x, y))) \tag{2}$$

4.4.2 Why to choose wavelet fusion?

The proposed approach applies multi-level wavelet decomposition for both the cover and watermark image. When images apply wavelet decomposition, their components are separated directly into bands which have approximately equal bandwidth. This idea is like retina of human eye when it splits any image into its components. So, it is expected to use discrete wavelet transform as it makes the independent processing of resulting components much like human eye. For that reason, using of wavelet decompositions for fusion of images is very popular. Fusion is known as the process of combining information (Kundur and Hatzinakos 1997).

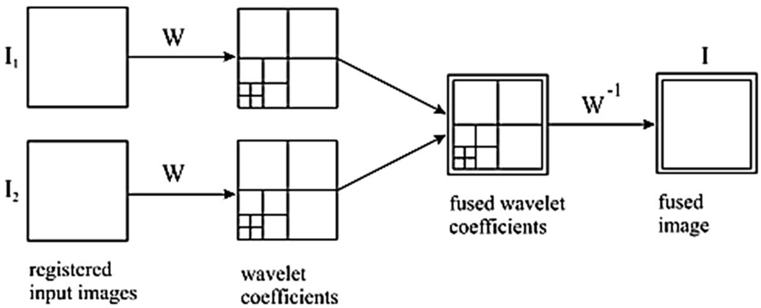


Fig. 4 Fusion of wavelet transforms of two images

5 Proposed approach

In this section, color image watermarking approach is proposed. It is based on SVD, DWT and wavelet fusion techniques. The major goal of this proposal is to embed a colored watermark image into a gray scale image without perceptual degradation of colored watermark image taking into account robustness against common attacks. The proposed watermarking approach consists of two main phases; embedding phase and extraction phase.

5.1 Embedding process

Figure 5 illustrates the embedding process of the proposed algorithm. It works as follows:

1. Analyze/split colored watermark image into three channels; red, green, and blue.
2. Fuse every channel of colored image into the same gray scale image separately using wavelet fusion. This produces ‘Fused Image1’ for red channel, ‘Fused Image2’ for green channel and ‘Fused Image3’ for blue channel.
3. Fuse ‘Fused Image1’ and ‘Fused Image2’ using wavelet fusion to produce ‘Fused mixed1’.

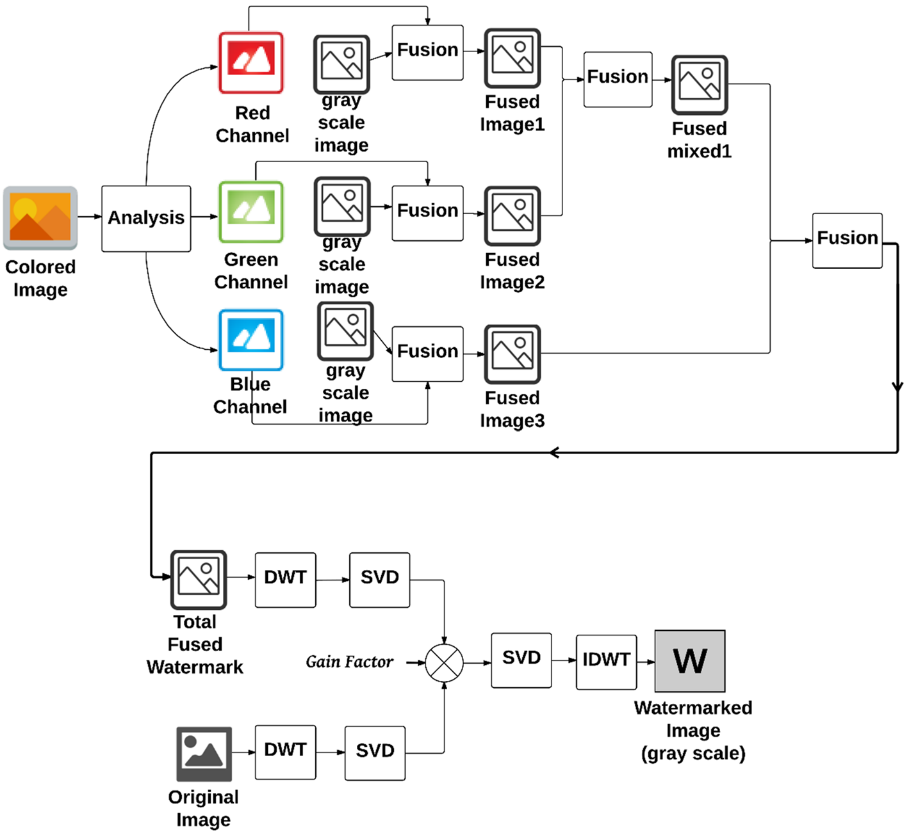


Fig. 5 Embedding process of the proposed approach

4. Fuse 'Fused mixed1' and 'Fused Image3' using wavelet fusion to produce 'Total Fused Watermark' that will be embedded onto an original gray scale image.
5. Apply one-level DWT to 'Original Image' as well as 'Total Fused Watermark'.
6. Apply SVD to A matrix of the resultant 'Total Fused Watermark'

$$A = U_1 S_1 V_1^T \tag{3}$$

7. Apply SVD to resultant 'Original Image' matrix B according to equation:

$$B = USV^T \tag{4}$$

8. Add SVs of Matrix B 'Original Image' to SVs of Matrix A 'Total Fused Watermark' according to equation

$$D = S + k * S_1 \tag{5}$$

   where, k is a gain factor that controls the watermark strength.
9. Apply SVD to the new altered D matrix resultant from step 8 as:

$$S_w = U_w D V_w^T \tag{6}$$

10. Obtain resultant image A_w By using altered matrix:

$$A_w = US_w V^T \tag{7}$$

11. Apply one-level inverse DWT (IDWT) to resultant image A_w To produce the 'Watermarked Image', which is gray scale image.

5.2 Extraction process

Figure 6 illustrates the extraction process of the proposed algorithm. It works as follows:

1. Apply one-level DWT to 'Extracted Watermarked Image' to produce 'Extracted Resultant Image'.
2. Apply SVD to 'Extracted Resultant Image' A_w^* matrix according to equation:

$$A_w^* = U^* S_w^* V^{*T} \tag{8}$$

3. Compute matrix D^* according to equation:

$$D^* = U_w S_w^* V_w^T \tag{9}$$

4. Obtain 'Extracted Total Fused Watermark' $W*$ according to the equation.

$$W^* = \frac{D^* - S}{k} \tag{10}$$

5. Apply IDWT (inverse DWT) to construct the 'Extracted Total Fused Watermark'
6. Apply Anti-fusion on the resultant 'Extracted Total Fused Watermark' to produce 'Extracted Fused mixed1' and 'Extracted Fused Image3'.
7. Apply Anti-fusion to 'Extracted Fused mixed1' to produce 'Extracted Fused Image1' and 'Extracted Fused Image2'.
8. Apply Anti-fusion to 'Extracted Fused Image1', 'Extracted Fused Image2' and 'Extracted Fused Image3' to produce the extracted channels (red, green, blue) respectively.
9. Combine the three extracted channels to obtain 'Extracted Colored Image'.

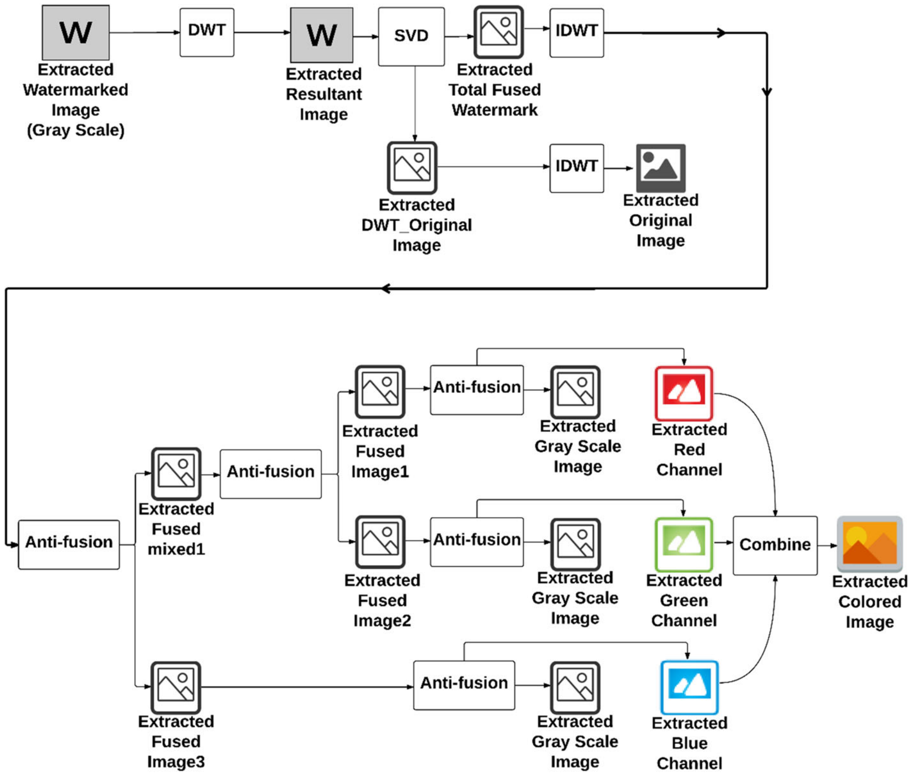


Fig. 6 Extraction process of the proposed approach

Note that * is a mark of probable corruption resultant from attacks.

6 Experimental results and discussion

The proposed algorithm is coded in MATLAB ® R2015a environment and implemented on a PC which has 8 GB RAM and core i5 processor.

6.1 Quality metrics

In this paper, PSNR, Correlation (Cr) and mean square error (MSE) are chosen as quality measure factors (Avcibas et al. 2002, 2003)

6.1.1 Peak signal to noise ratio

Watermarked image quality can be measured by using peak signal to noise ratio (PSNR). In the ideal case, the PSNR should be infinite (AL-Mansoori and Kunhu 2012). In fact, this can't be accomplished with watermarked image. So, the larger PSNR the better. The PSNR is defined as:

$$PSNR = 10log_{10}\left(\frac{max * max}{MSE}\right) \quad (11)$$

where max = 255 for grey scale image.

6.1.2 Mean square error

Mean square error (MSE) is a standard quality measurement. In ideal case, the MSE must be zero(Mohamed and El Mohandes 2012; Planitz and Maeder 2005). In fact, this is can't be reached with watermarked image. So, the smaller the value of MSE, the better the quality is. MSE is defined as:

$$MSE = \sum_{i=1}^{m}\sum_{j=1}^{n}\frac{ORG(i,j) - WM(i,j)}{m \times n} \quad (12)$$

where, 'ORG' is original image, 'WM' is watermarked image and m & n are the original image width and height respectively.

6.1.3 Correlation coefficient

Correlation coefficient (Cr) is used in measuring closeness between original image and watermarked image. In ideal case, Cr should equal 1(Avcibas et al. 2003; Hemdan et al. 2013b). In real, this can't be achieved so the value of Cr near one. The Cr is defined as:

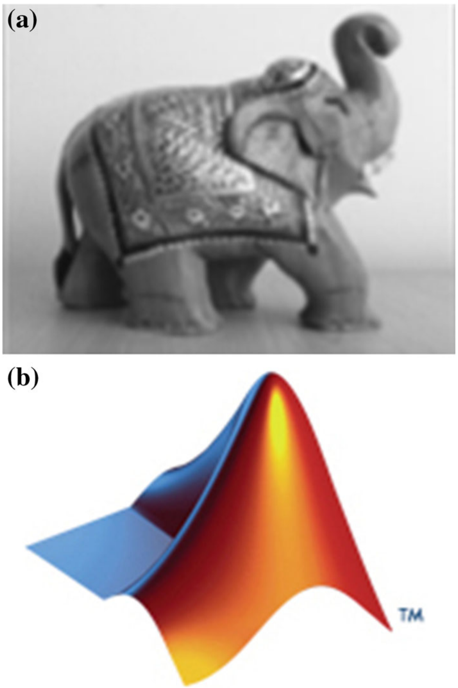


Fig. 7 Cover and watermark images of first test. **a** Cover image (elephant.jpg), **b** Watermark color image (bg_global_logo.jpg)

$$C_r = \frac{\sum_m \sum_n (Xi - X')(Yi - Y')}{\sqrt{\left(\sum_m \sum_n (Xi - X')^2\right)\left(\sum_m \sum_n (Yi - Y')^2\right)}} \tag{13}$$

where, X′ is original image average value and Y′ is watermarked image average value.

Note that, PSNR, MSE and Cr are calculated for gray scale image. For color image, the calculation of each parameter may be done by taking the average value of corresponding parameter of the colored image three channels because each channel is considered as a gray scale image.

Table 1 Results for first quarter (Ll) at various gain factor

Gain factor	PSNR for color image with and without attack					
	Without attack	Gaussian	Blur	Wrap	Cropping	
					50%	75%
0.1	Infinity	1.4542	3.2478	2.0634	1.4226	1.4257
0.2	Infinity	1.4558	4.9228	2.1633	1.4368	1.4366
0.3	Infinity	1.4567	6.2397	2.2543	1.4453	1.4438
0.4	Infinity	1.4567	7.2606	2.3379	1.4506	1.4485
0.5	Infinity	1.4567	8.0715	2.4155	1.4541	1.4512
0.6	Infinity	1.4567	8.7348	2.4930	1.4567	1.4531
0.7	Infinity	1.4567	9.2940	2.5624	1.4589	1.4544
0.8	Infinity	1.4567	9.7694	2.6235	1.4609	1.4553
0.9	Infinity	1.4567	10.1810	2.6773	1.4627	1.4560
1	Infinity	1.4567	10.5417	2.7257	1.4645	1.4566

Table 2 Results for second quarter (LH) at various gain factor

Gain factor	PSNR for color image with and without attack					
	Without attack	Gaussian	Blur	Wrap	Cropping	
					50%	75%
0.1	Infinity	9.1258	9.5913	12.9723	10.5532	9.3787
0.2	Infinity	10.6126	11.2315	16.1264	13.3271	10.9091
0.3	Infinity	11.5879	12.3607	18.1082	15.2771	11.9490
0.4	Infinity	12.3536	13.2529	19.4998	16.7817	12.7849
0.5	Infinity	12.9964	13.9889	20.5637	17.9796	13.4952
0.6	Infinity	13.5516	14.6134	21.4048	18.9578	14.1109
0.7	Infinity	14.0372	15.1487	22.0901	19.7794	14.6500
0.8	Infinity	14.4685	15.6153	22.6579	20.4788	15.1296
0.9	Infinity	14.8539	16.0233	23.1372	21.0797	15.5584
1	Infinity	15.2016	16.3829	23.5486	21.6031	15.9421

Table 3 Results for third quarter (HL) at various gain factor

Gain factor	PSNR for color image with and without attack					
	Without attack	Gaussian	Blur	Wrap	Cropping	
					50%	75%
0.1	Infinity	8.5364	8.9077	10.0377	10.2521	8.8249
0.2	Infinity	9.9702	10.5697	14.0109	12.9812	10.4974
0.3	Infinity	10.9137	11.6657	16.7379	14.8200	11.6014
0.4	Infinity	11.6277	12.5129	18.6322	16.2243	12.4671
0.5	Infinity	12.2221	13.2082	19.8897	17.3567	13.1892
0.6	Infinity	12.7348	13.7861	20.7061	18.2985	13.8028
0.7	Infinity	13.1855	14.2722	21.2267	19.0907	14.3289
0.8	Infinity	13.5812	14.6910	21.5535	19.7707	14.7925
0.9	Infinity	13.9283	15.0580	21.7579	20.3588	15.2013
1	Infinity	14.2375	15.3818	21.8843	20.8715	15.5693

Table 4 Results for fourth quarter (HH) at various gain factor

Gain factor	PSNR for color image with and without attack					
	Without attack	Gaussian	Blur	Wrap	Cropping	
					50%	75%
0.1	Infinity	10.8045	10.9804	16.3009	13.9870	11.0712
0.2	Infinity	12.8442	13.0756	20.7089	17.9863	13.2913
0.3	Infinity	14.2620	14.5265	22.9977	20.6015	14.8646
0.4	Infinity	15.3797	15.6633	24.3728	22.4773	16.1067
0.5	Infinity	16.2974	16.5911	25.2710	23.9092	17.1066
0.6	Infinity	17.0589	17.3560	25.8913	25.0487	17.9447
0.7	Infinity	17.7109	18.0129	26.3400	25.9833	18.6667
0.8	Infinity	18.2812	18.5845	26.6760	26.7676	19.2952
0.9	Infinity	18.7825	19.0845	26.9376	27.4397	19.8467
1	Infinity	19.2273	19.5288	27.1443	28.0183	20.3318

Table 5 Results for best Case (sub-band HH with gain factor = 1)

	MSE	PSNR	Cr
Without attack	0	Infinity	1
Gaussian	41.1456	19.2275	0.9219
Blur	40.2732	19.5288	0.9265
Wrap	22.1651	27.1443	0.9859
Cropping 50%	28.6422	28.0183	0.9886
Cropping 75%	39.6652	20.3318	0.9374

Table 6 Test images

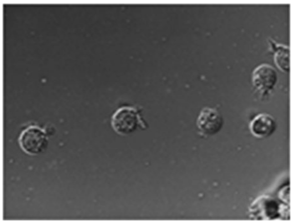
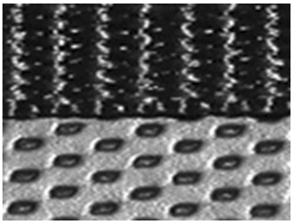
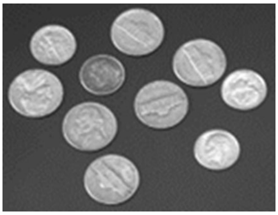
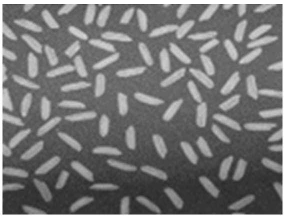
Case	Gray scale image with its name in MATLAB	Color watermark image with its name in MATLAB
A	 AT3_1m4_01.tif	 board.tif
B	 cameraman.tif	 autumn.tif
C	 bag.png	 coloredChips.png
D	 coins.png	 concordaerial.png
E	 rice.png	 fabric.png

Table 7 Results for best case (sub-band HH with gain factor = 1) for images in Table 6

Cases	With no attack			Gaussian			Blur			Wrap			Cropping					
	MSE	PSNR	Cr	MSE	PSNR	Cr	MSE	PSNR	Cr	MSE	PSNR	Cr	50%			75%		
													MSE	PSNR	Cr	MSE	PSNR	Cr
A	0	Infinity	1	79.9026	15.4822	0.7310	79.1438	15.6294	0.7379	63.4243	19.2873	0.8706	58.8958	22.2817	0.9323	72.4404	18.6295	0.8524
B	0	Infinity	1	63.7023	17.7546	0.9106	62.2523	18.0513	0.9158	36.3661	23.3144	0.9726	46.7114	23.9768	0.9762	59.9034	19.8296	0.9413
C	0	Infinity	1	71.6360	19.6657	0.8927	68.2189	20.4544	0.9086	18.9489	31.9096	0.9927	39.7178	27.5323	0.9802	60.2280	23.2231	0.9488
D	0	Infinity	1	77.8928	18.5934	0.6822	75.8797	19.0404	0.7029	39.4189	27.0392	0.9340	38.5687	27.9962	0.9468	65.9987	21.9608	0.8186
E	0	Infinity	1	92.1187	16.4462	0.7098	90.6826	16.8125	0.7262	69.9691	21.4120	0.8798	60.9132	24.3807	0.9353	81.7715	20.0511	0.8458

6.2 Experimental results

In this section, several experiments are carried out to evaluate performance of the proposed watermarking approach. Here, the proposed approach is tested on variety of reference test images (different original and watermark images) and different attacks.

6.2.1 First case

The first test is carried out by using "elephant.jpg" image as the original/cover image and "bg_global_logo.jpg" image as color watermark image, as shown in Fig. 7. The purpose is to determine the best quarter (LL, LH, HL or HH) to embed the watermark and to find the proper gain factor. Indeed, to test robustness of the proposed watermarking approach several kinds of common attacks have been used. Four types of attacks have been applied on watermarked image including: Gaussian noise, blurring filtering, wrap and cropping (50 and 75%).Both watermarked image and its attacked version are taken in account to calculate robustness of watermarking. Tables 1, 2, 3, and 4 show PSNR for color image with and without attack for the sub-bands LL, LH, HL and HH respectively, at various gain factor from 0.1 to 1. These results show that, with no attack PSNR equals infinity. This means that extracted image after attack is identical to the watermark image before attack. Also, it is obvious from the results that PSNR increases as gain factor increases. From these results, embedding a color watermark image into a gray scale image in HH sub-band

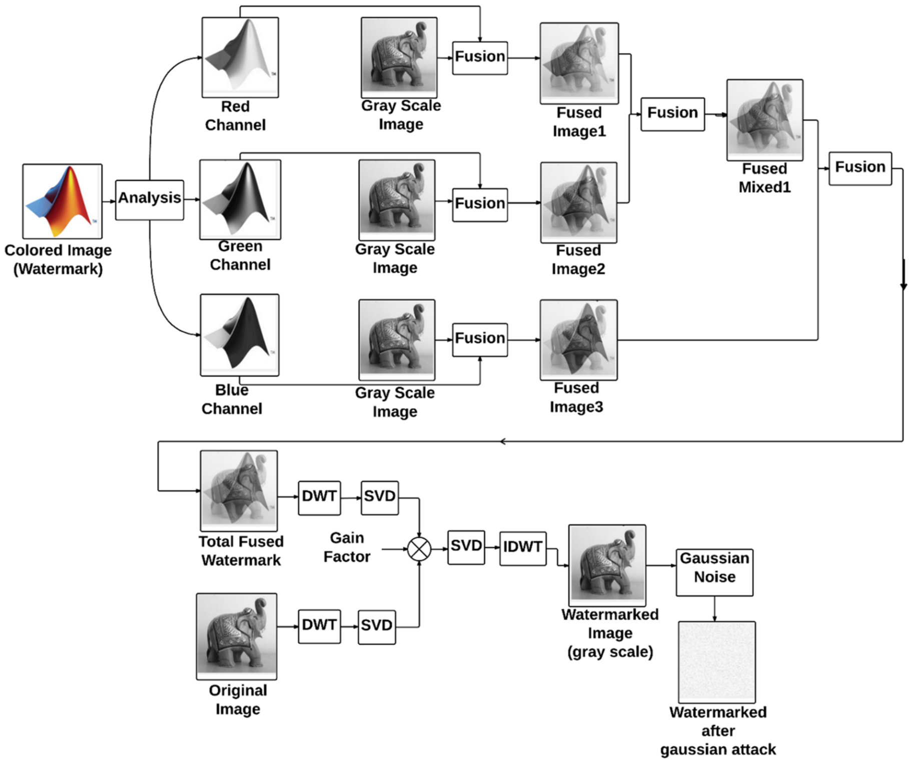


Fig. 8 Proposed embedding algorithm for images in Fig. 7

achieves best results compared to results from other bands. This deduction proves that, the best quarter for embedding a color watermark image into a gray scale image is the fourth quarter (HH) with gain factor equal to 1. Table 5 shows MSE, PSNR, and Cr at best case, sub-band HH with gain factor 1.

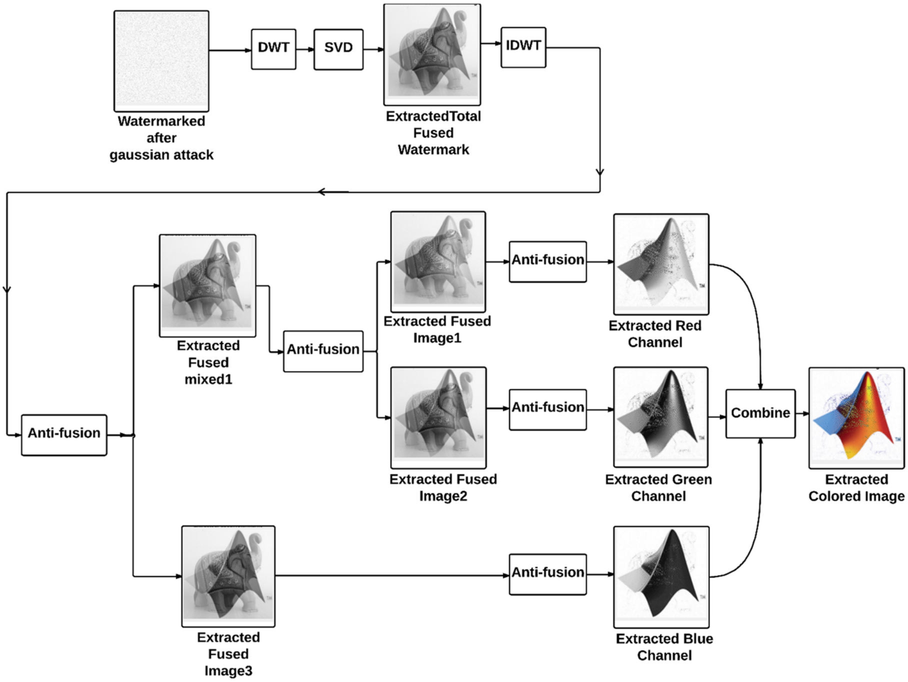


Fig. 9 Proposed extraction algorithm for images in Fig. 7

Fig. 10 Extracted color image

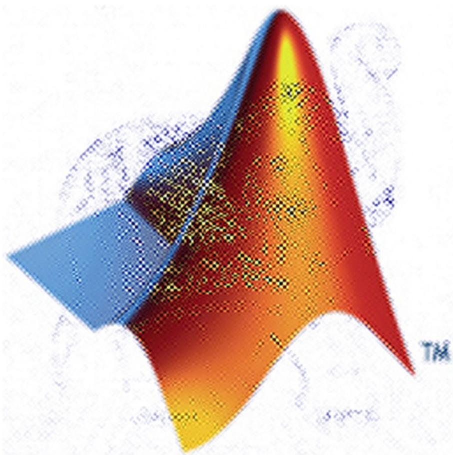
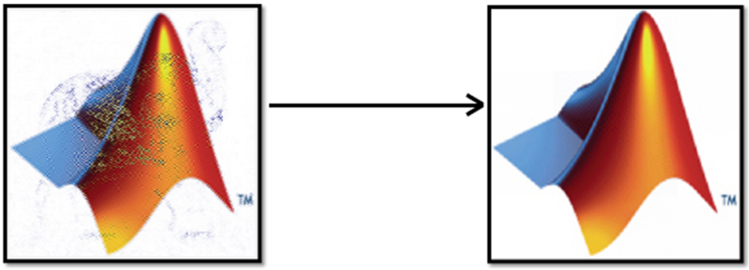


Table 8 Results of multilevel DWT for HH and gain factor = 1

Level	PSNR for color image with and without attack					
	Without attack	Gaussian	Blur	Wrap	Cropping	
					50%	75%
1	Infinity	19.2275	19.5288	27.1443	28.0183	20.3318
2	Infinity	21.8606	22.0355	28.9460	30.7397	23.1762
3	Infinity	28.4985	28.6600	34.0963	37.5943	30.0615
4	Infinity	33.0333	33.1359	37.8827	41.7287	34.1651
5	Infinity	39.8040	40.0347	43.6855	47.5301	41.5112
6	Infinity	43.9664	43.9664	45.9154	50.4765	45.2023



1 level DWT 6 level DWT

Fig. 11 Quality improvement of extracted image

6.2.2 *Other cases*

Evaluation of proposed watermarking approach is done with several color watermark images and gray images which play the role of host/cover image. Test images are selected from MATLAB image database. Table 6 shows test images used with their names in MATLAB. In addition, four types of attacks have been applied to the watermarked image including: Gaussian noise, blurring filtering, wrap and cropping. Table 7 shows experimental results for different images considering sub-band HH with gain factor =1. It shows MSE, PSNR, and Cr with and without attack.

6.2.3 *Limitations of one level DWT*

Although proposed watermark approach is robust against attacks, the quality of the extracted image after attack is low. Figure 8, shows the various stages of embedding process in HH sub-band while Fig. 9, shows the various stages of extraction process. Figure 10, shows extracted color image after Gaussian noise attack. It is clear from Fig. 10, that the extracted image quality is low. The extracted image reveals some details of original image (elephant image). This problem appears also with all other types of test cases in Table 7

Table 9 PSNR Comparison between 1st level and 6th level for images of Table 6 considering sub-band HH with gain factor = 1

Cases	With no attack		Gaussian		Blur		Wrap		Cropping			
	6th level	1st level	6th level	1st level	6th level	1st level	6th level	1st level	50%		75%	
									6th level	1st level	6th level	1st level
Case under study	Infinity	Infinity	43.9664	19.2275	43.9664	19.5288	45.9154	27.1443	50.4765	28.0183	45.2023	20.3318
A	Infinity	Infinity	43.9519	15.4822	44.1758	15.6294	47.1950	19.2873	48.9340	22.2817	46.5739	18.6295
B	Infinity	Infinity	45.0733	17.7546	45.0733	18.0513	53.8104	23.3144	55.4008	23.9768	46.7152	19.8296
C	Infinity	Infinity	44.6848	19.6657	45.0603	20.4544	50.5543	31.9096	53.1916	27.5323	48.7371	23.2231
D	Infinity	Infinity	45.8833	18.5934	45.8833	19.0404	50.6361	27.0392	52.5023	27.9962	48.4068	21.9608
E	Infinity	Infinity	45.1421	16.4462	45.4467	16.8125	48.7711	21.4120	51.5102	24.3807	46.9051	20.0511

6.2.4 Suggested solution

To solve the low-quality problem of the extracted image, the proposed approach is modified by using multi-level DWT instead of using one level DWT. The problem now is to determine which level of the DWT is the best for embedding process. Table 8 shows PSNR of color image for first 6 levels of multilevel DWT considering the fourth quarter (HH) and gain factor =1. This test is done on test images shown in Fig. 7, where, “elephant.jpg” image is used as the original/cover image and “bg_global_logo.jpg” image is used as a colored watermark image. From Table 8, level 6 DWT achieves best PSNR value.

Figure 11, shows quality improvement of extracted image. It shows the extracted image when using level 6 of multilevel DWT and extracted image when using level 1 DWT.

Table 9 shows a comparative study between the PSNR of color image when applying 1 level DWT and applying 6 level DWT on test images of Table 6. The results indicate that applying 6th level DWT is better than applying 1st level DWT.

7 Conclusion

In this paper, a new efficient color image watermarking approach for data hiding by using SVD, multi- DWT and wavelet fusion is developed, discussed, and tested. The suitable quarter of DWT and suitable gain factor are first selected. Then, many tests are done using the best HH quarter with gain factor 1 with and without attack. Another improvement has been achieved in the proposed watermarking approach by applying 6th level DWT to overcome the problem of revealing some details of original image in the extracted image. The simulation results demonstrate that watermarked images generated by proposed watermarking approach are tolerant to versatile attacks such as Gaussian, blur, wrap, and cropping. The experimental results prove that using multi-level DWT improves colored watermark image quality after extraction. In addition, experimental results show that using the 6th level DWT is more robust against severe attacks.

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