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HYBRID WATERMARKING SCHEME BASED ON FAST WALSH-HADAMARD TRANSFORM AND SINGULAR VALUE DECOMPOSITION USING PARITY FUNCTION

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ABSTRACT

Digital image watermarking is a useful solution to the problem of information security, copyright and network security. This paper shows a new scheme for robust and high rate embedding of watermarks into digital images using Fast Walsh Hadamard Transform (FWHT) and singular value decomposition (SVD). The proposed technique consists of five steps. The main features of the proposed method are its simplicity, Elasticity in data embedding capacity. The experimental results executed using MATLAB software and it showed good performance, imperceptibility for the watermark and security for the embedding data in comparison with some of the recently existing techniques. It showed also robustness against the most common attacks such as salt and pepper noise insertion attack, JPEG compression, cropping, rotation, resizing, average filtering, Gaussian filtering, motion-blur filter and histogram equalization.

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INTRODUCTION

Our society is now digital: in digital world people share their ideas, feelings, and their data in a completely natural and friendly way. This sharing depends on using internet tools like the blogs, the RSS feeds, the forums, or the sharing servers located on the cloud. The counterpart of this freedom is that for many people, the notion of copyrights associated to digital contents has become more and more vague. The watermarking technologies were born at this time in order to provide solutions in this context. Digital watermarking is "the process of hiding digital information in a carrier signal; the hidden information should, but does not need to contain a relation to the carrier signal" [12]. There are many watermarking techniques in terms of their characteristics, application areas, and purposes and they have different insertion and extraction methods. Figure 1 shows different classifications of digital watermarking Techniques. In spatial domain, the watermark is embedded directly by modifying the intensity values of pixels [3]. In frequency domain, the watermark is embedded in the spectral coefficient of the image.

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The transform techniques like Fourier transform (FT), discrete Fourier transform (DFT), fast Fourier transform (FFT), discrete Hadamard transform (DHT), Walsh–Hadamard transform (WHT), discrete cosine transform (DCT) [13]. These transform techniques convert the signal informationto a magnitude and phase component of each frequency. The transformation of signal is converted to the power spectrum, which is the magnitude of each frequency component squared. In hybrid techniques, more than one transformation or domain transformation may be used in the watermarking scheme. In this paper a new Hybrid Fast Walsh Hadamard Transform (FWHT) - Singular Value Decomposition (SVD) watermarking method was proposed using two major constraints the first was the Entropy value of each 4*4 block for selecting the watermarked blocks and the second was applying the odd parity technique for watermark embedding.

Related Work: Different methods were published for using the Hadamard transform in digital watermarking. In [8], the multi resolution Walsh Hadamard transform using singular value decomposition (SVD) was proposed to improve both imperceptibility and robustness. In [10], the watermarks were hidden into Hadamard transform coefficients, which are controlled by pseudo-radon permutation as a security key, while extraction process was blind without needing for the host image. In [5] proposed a simple and robust image watermarking methodology for embedding a watermarked in the transform domain. The key idea is to encode the SVs of the watermarked image after applying the FHT to small blocks computed from the four DWT subbands. The proposed method in [17] used the complex Hadamard transform, where the watermark was embedded in the imaginary part of the transform coefficients. Aris Marjuni, Rajasvaran Logeswaran, and M. F. Ahmad Fauzi proposed a watermarking scheme in which fast Walsh Hadamard transformation (FWHT) is applied on the original watermark before it is embedded on the DC coefficients of the host image [2]. Falkowski and Lim [7] used multiresolution Hadamard transform for embedding watermark. Gilani *et al.* [9] discussed multiresolution watermarking using Haar transform and Hadamard transform techniques.

Background

Image Entropy: Image entropy is a quantity, which is used to describe the `business' of an image, i.e. the amount of information, which must be coded for by a compression algorithm. Low entropy images, such as those containing a lot of black sky, have very little contrast and large runs of pixels with the same values. An image that is perfectly flat will have an entropy of zero. Consequently, they can be compressed to a relatively small size. On the other hand, high entropy images such as an image of heavily cratered areas on the moon have a great deal of contrast from one pixel to the next and consequently cannot be compressed as much as low entropy images. The human visual system (HVS) extracts perceptual information from a group of pixels not from a single pixel. Entropy is a measure of unpredictability of information content and is a good measure for spatial correlation of neighboring pixels. Shannon [3] formula shows the Entropy equation.

$$Entropy = -\sum_i P_i \, log_2 P_i Eq \dots\dots\dots\dots\dots\dots (1)$$

Where pi is the probability of occurrence of the event i, $0 \leq P_i \leq 1$ and $\sum_{i=1}^{n} P_i = 1$

This entropy depended on the relative occurrence of the symbols, irrespective of their position of occurrence. Pal and Pal defined average edge information as an exponential form of entropy formula that can capture 2D spatial correlation of images better than Shannon's entropy. Entropy defined in [15] as

$$E = \sum_{i=1}^{n} P_i \;\; exp^{u_i} = \sum_{i=1}^{n} P_i \, exp^{1-P_i} \qquad Eq(2)$$

Where $u_i = (1 - p_i)$ is uncertainty of the pixel value.

In the present work, the average grey information Eq. (1) and average edge information Eq. (2) were used to find robust and resilience blocks of images for data hiding. These two quantities for each block were computed and added. Following this, was the sorting of the values in ascending order, as a linear chain. This chain was divided into 3 parts: low, medium and high-informative blocks. The medium-informative blocks were selected for embedding process to satisfy both imperceptibility and robustness requirements.

Fast Walsh–Hadamard Transform (FWHT): The advantage of Hadamard transforms in signal processing is its simpler implementation, low computation cost and high resiliency on low quality compression. Let [X] represents the original image and [Y] the transformed image, the 2D-Hadamard transform is given by:

$$[Y] = H_w[X] \qquad Eq(3)$$

H_w is the Walsh ordered matrix extracted as in [1]. Hence, the Hadamard transform matrix has the following property:

Hn = H_n^* = HT = H−1.

Where H_n represents an N×N Hadamard matrix, $N=2^n$, n=1,2,3…, with element values either +1 or –1. The advantages of Hadamard transform are that the elements of the transform matrix H_n are simple: they are binary, real numbers and the rows or columns of H_n are orthogonal.

Since Hn has N orthogonal rows HnHn = N (I) (I is identity array) and $HnHn = NHnH_n^{-1}$, thus $H^{-1} = Hn/N$. The inverse 2D-fast Hadamard transform (IFHT) is given as

$$[X] = H_w[Y] \qquad Eq \qquad (4)$$

A two-dimensional FHT of the segmented 4×4 blocks is performed by applying a one-dimensional FHT on the rows sequentially for each block and reconstruct the blocks to be ready for embedding stage according to the selected criteria proposed in this paper. For N=2, the Hadamard matrix, H1, is called a core matrix, which is defined as:

$$H_1 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

The Hadamard matrix of the order n is generated in terms of Hadamard matrix of order n-1 using Kronecker product,□, as

$$H_n = H_{n-1} \otimes H_1 \qquad Eq \quad \dots\dots\dots\dots\dots\dots..(5)$$

$$H_n = \begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & -H_{n-1} \end{bmatrix} \quad Eq \;\dots\dots\dots\dots\dots\dots\dots.(6)$$

Since in our algorithm, the processing is carried out based on the 4×4 sub-blocks of the whole image, the second order Hadamard transform matrix H2 is used for N=4. By applying Eq (5) or Eq (6), H2 becomes as n Eq (7):

$$H_2 = H_1 \otimes H_1 = \frac{1}{2}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \qquad Eq\ (7)$$

The forward and inverse WHT can be defined as a linear combination of a set of square waves of different sequences. Those formulas are given in Eq (8 - 11), respectively.

$$Y_w(k) = \sum_{n=0}^{N-1} X(n)\, w_N(k,n) \qquad Eq\ (8)$$

$$= \sum_{n=0}^{N-1} X(n) \prod_{i=0}^{M-1} (-1)^{n_i k_{M-1-i}}, \qquad k = 0,1,\dots,N-1 \quad Eq\ (9)$$

$$X(n) = \frac{1}{N}\sum_{k=0}^{N-1} Y_w(k) w_N(k,n) \qquad Eq(10)$$

$$= \frac{1}{N}\sum_{k=0}^{N-1} Y_w(k) \prod_{i=0}^{M-1} (-1)^{n_i k_{M-1-i}}, \qquad n = 0,1,\dots,N-1 \; Eq\,(11)$$

Where $N=2^n$, $M=\log_2 N$, and n_i is the i-th bit in the binary representation of n.

Singular Value Decomposition (SVD): The SVD is a linear algebra technique used for diagonalizable matrices and it transfer of convert most of the signal energy into very few singular values. Any MxN matrix A can be written as the product of an MxN column-orthogonal matrix U, an NxN diagonal matrix W with positive or zero elements (the singular values), and the transpose of an N x N orthogonal matrix V.

$$\begin{pmatrix} \\ A \\ \\ \end{pmatrix} = \begin{pmatrix} \\ U \\ \\ \end{pmatrix} \cdot \begin{pmatrix} w_0 & & & \\ & w_1 & & \\ & & \cdots & \\ & & \cdots & \\ & & & w_{N-1} \end{pmatrix} \cdot \begin{pmatrix} V^T \end{pmatrix} \qquad Eq\,(12)$$

We return to the case of a square N x N matrix A. U, V, and W are also square matrices of the same size. Their inverses are also trivial to compute: U and V are orthogonal, so their inverses are equal to their transposes; W is diagonal, so its inverse is the diagonal matrix whose elements are the reciprocals of the elements w_j . The inverse of A is

$$A^{-1} = V\,.\left[diag\left(1/w_j\right)\right].\,U^T Eq\,(13)$$

SVD is an optimal matrix decomposition technique in a least square sense that it packs the maximum signal energy into as few coefficients as possible. It has the ability to adapt to the variations in local statistics of an image [4]. In this paper, U and V will be saved as a key for extraction process and the SVD weights W will be embedded in the cover image.

Properties of SVD: Generally a real matrix A has many SVs, some of which are very small, and the number of SVs which are non-zero equals the rank of matrix A. SVD has many good mathematical characteristics. Using SVD in digital image processing has some advantages:

(1) The size of the matrices from SVD transformation is not fixed and can be a square or a rectangle.
(2) The SVs (Singular Values) of an image have very good stability, i.e. when a small perturbation is added to an image, its SVs do not vary rapidly;
(3) SVs represent algebraic image properties which are intrinsic and not visual

Proposed method: The medium-informative blocks of size 4*4 total number of useful blocks for an N*N image will be (N*N)/(16*3). For N=512 the number of selected blocks will be (512*512)/(16*3) ≈5461 pixels. In this paper using only LSB of each pixel was supposed so, the total number of bits can be used will be ≈ 5461 bits ≈682 pixel. This mean that I can cover up to 26 *26 image but in fact I need only 64*8 =512 bits to represent the SVs of 64*64 image watermark.

Embedding side algorithm

- Read the original cover image, which is chosen of size 512x512, and watermark image is chosen of size 64x64.
- The cover image is converted into its gray scale components.
- Split cover image to 4*4 blocks.
- Calculate Entropy for each block.
- Arrange the values of Entropy ascending.
- Choose blocks with Medium-informative Entropy.
- The positions of the selected blocks will be saved as a secret key (key1) used in the extraction process.
- Apply Fast Walsh Hadamard Transform on each selected block and get the Hadamard coefficients.
- Read the Watermark Image.
- Apply SVD on the watermark image and change the singular values to bits string. U and V were the left and right singular vectors of W respectively will be saved to be used as a secret key (key2).
- Distribute the bits of the watermark over the transformed cover blocks based on odd parity bit technique for embedding Table 1 illustrates the Procedure used for watermark embedding depending on the odd Parity bit Technique.
- An inverse Hadamard Walsh Transformation applied for blocks.
- Merge blocks together to get the watermarked image.
- Convert gray scale image to colored image. Figure 2 explains the watermarking steps

Table 1. Procedure for watermark embedding Using Odd Parity bit Technique

Number of ones in cover block pixel	Bit from watermark	LSB in cover block pixel
Odd	0	*1*
Even	1	*0*

Extracting side algorithm

- Read the watermarked colored Image.
- Convert the watermarked colored Image to grayscale image.
- Split gray watermarked image to 4*4 blocks
- Use the secret key1 to retrieve the positions of watermarked blocks.
- Apply Fast Hadamard Transform on the specified blocks.
- Extract the bits of the singular values using the inverse technique of odd parity bit) (the original cover without watermark must be existed for extraction). Apply the following on the watermarked blocks.
- If LSB in the pixel of watermarked blocks =1 and Number of ones in cover pixel is odd then the watermark bit was 0.
- If LSB in the pixel of watermarked blocks =0 and Number of ones in cover pixel is even then the watermark bit was 1.
- Reconstruct the extracted bits to get the Singular Values (SVs)
- Merge SVs, U and V matrices (key2) to get SVD blocks.
- Apply inverse SVD on the reconstructed blocks to get the watermark image.

- Figure 3 explains the water extraction steps.

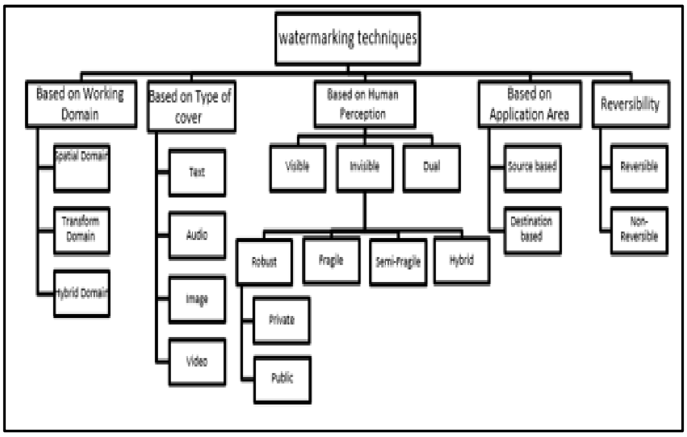

Figure 1: digital watermarking classification

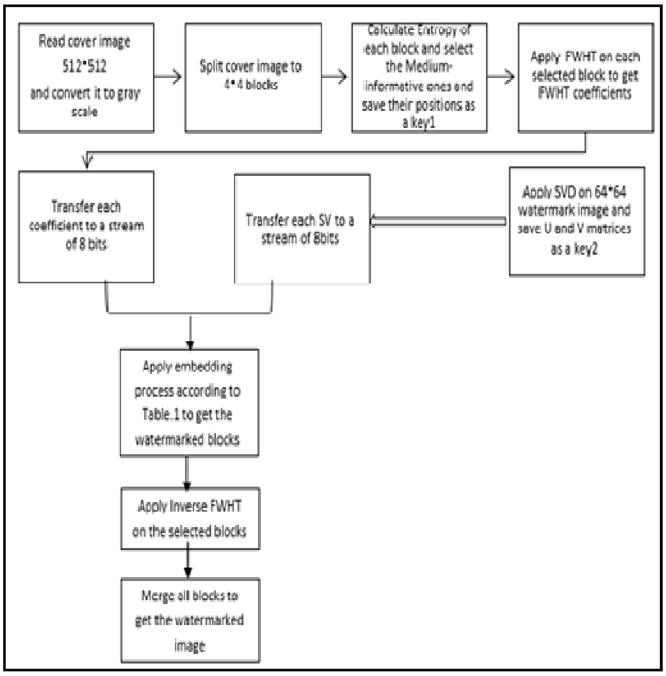

Figure 2. Block diagram for the proposed watermarking technique

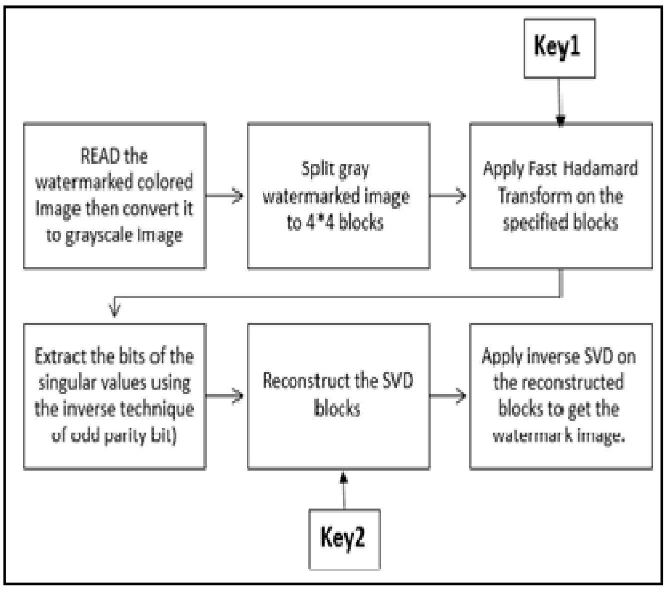

Figure 3. Block diagram represents watermark extraction steps

EXPERIMENTAL RESULTS

Different images of size 512*512 used as cover for the experimental results and two different watermarks each of size 64*64 used separately. The proposed algorithm is tested on different colored images differ in entropy values. Evaluation metrics (Mean Square Error (MSE)-Peak Signal Noise Ratio (PSNR). Normalized Cross Correlation (NCC)- Bit Error Rate(BER)). MSE can be calculated according to the following equation.

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(X_{ij} - Y_{ij})^2 \qquad Eq\ (14)$$

Where X_{ij} are the image pixel values of original cover image and Y_{ij} are the image pixel values of watermarked image and m and n are the dimensions of the original and the watermarked image. MSE values for the proposed method is less than the available MSE values for the other existing methods, this means better performance for the proposed method as described in Table 2. PSNR is a good metric for watermarking imperceptibility and can be calculated according to the following equation.

$$PSNR = 10log_{10}\left(\frac{MAX^2}{MSE}\right)\ dB \qquad Eq\ (15)\quad [11]$$

Where MAX is the maximum fluctuation in the input image data type. For used images in this paper MAX=2b-1 where b is the bit depth of the original image. In this work MAX=255. PSNR of 100% indicates completely imperceptible watermark. In the proposed method, the PSNR is high in comparison with the available existing methods as described in Table 2 & Table 3. NCC is a good measure for watermarking robustness because it measures the watermark's flexibility to corruption when extracted from the watermarked, even after the watermarked image has been distorted or damaged. This value can be obtained by calculating the correlation between the original watermark and the recovered watermark. This value can be calculated according to the following equation [14].

$$NCC = \sum_{i=1}^{r}\sum_{j=1}^{c}(OW_{ij} * RW_{ij}) / \sum_{i=1}^{r}\sum_{j=1}^{c}OW_{ij}^2 \qquad Eq\ (17)$$

Where $OW_{ij}$are the Original Watermark pixels values and RWij are the image Recovered Watermark pixels values and r and c are the dimensions of the watermark image. When NCC is near to 1 this means better performance the proposed method is very close to 1 for most common attacks as described in Table 2 & 4. BER is the number of bit errors(N_{ERR}) divided by the total number of transferred bits (N_{bits})during a studied time interval. N_{ERR} can be calculated by comparing the original watermark with the recovered one and N_{bits}in this work will be 64*64*8 =32768 bits.

$$BER = \frac{N_{ERR}}{N_{bits}} \qquad Eq\ (18)$$

For the proposed method this ratio is close to zero this means better performance as described in Table 2 & 5.In the proposed method, Figure 4 shows that for no attacks, the watermark was imperceptible.

Figure 4. Watermarked image and recovered watermark without attacks: (a) Pepper, (b) Nature, (c) Lena, (d) House, (e) – (l) recovered watermarks

Figure 5. Effect of different attacks on the extracted watermark. (a1-i1) the watermarked Pepper images, (1-18) the extracted watermarks respectively and separately, (a2-i2) the watermarked Nature images, (1-18) the extracted watermarks respectively and separately

Figure 6. Effect of different attacks on the extracted watermark. (a3-i3) the watermarked Lena images, (1-18) the extracted watermarks respectively and separately, (a4-i4) the watermarked House images, (1-18) the extracted watermarks respectively and separately

Table 2. PSNR, BER, NCC for the proposed method

Type of attack		PSNR(db)	BER	NCC
GN (variance=0.2)	Pepper	43.83	0.193	0.8612
	Nature	44.12	0.198	0.8991
	Lena	43.76	0.200	0.8586
	House	43.80	0.201	0.8575
AWGN (variance=0.3)	Pepper	43.23	0.247	0.8500
	Nature	43.98	0.233	0.8732
	Lena	43.20	0.254	0.8351
	House	43.52	0.249	0.8333
salt and pepper(noise density0.05)	Pepper	45.23	0.063	0.9992
	Nature	45.94	0.048	0.9998
	Lena	45.14	0.094	0.9998
	House	45.32	0.091	0.9994
salt and pepper(noise density0.25)	Pepper	44.04	0.192	0.9982
	Nature	44.21	0.210	0.9993
	Lena	43.96	0.237	0.9988
	House	43.87	0.251	0.9984
salt and pepper(noise density 0.5)	Pepper	43.12	0.211	0.9913
	Nature	43.74	0.254	0.9981
	Lena	43.57	0.266	0.9975
	House	43.44	0.275	0.9977
Scaling factor (1.5) [628*628]	Pepper	18.581	0.005	0.9971
	Nature	18.662	0.003	1.0000
	Lena	18.343	0.008	0.9931
	House	18.302	0.006	0.9947
Scaling factor (0.5) [256*512]	Pepper	16.321	0.4714	0.8847
	Nature	16.461	0.4693	0.8912

	Lena	16.110	0.4821	0.8541
	House	16.209	0.4664	0.8469
JPEG compression (Quality factor 30%)	Pepper	40.02	0.3060	0.9999
	Nature	40.50	0.3090	0.9998
	Lena	40.30	0.3250	0.9965
	House	40.38	0.3110	0.9998
JPEG compression (Quality factor 50%)	Pepper	43.21	0.0165	0.9982
	Nature	43.53	0.0122	1.0000
	Lena	43.30	0.0521	0.9975
	House	43.41	0.0465	0.9998
Cropping (Percent of cropping 20%)	Pepper	22.53	0.0136	0.8775
	Nature	22.86	0.0091	0.8964
	Lena	22.23	0.0215	0.8565
	House	22.33	0.0196	0.8632
cropping (Percent of cropping 50%)	Pepper	20.31	0.1802	0.7978
	Nature	20.82	0.1436	0.8264
	Lena	20.10	0.1964	0.7965
	Pepper	20.32	0.2075	0.8032
Rotation (angle of rotation 100)	Pepper	22.46	0.0263	0.8321
	Nature	22.67	0.0201	0.8654
	Lena	22.31	0.0261	0.8123
	House	22.09	0.0207	0.8575
Rotation (angle of rotation 450)	Pepper	21.34	0.0729	0.9034
	Nature	21.69	0.0513	0.9462
	Lena	21.75	0.0680	0.9234
	House	21.66	0.0592	0.9333
average filtering 3x3	Pepper	44.32	0.0453	0.9832
	Nature	44.52	0.0420	0.9910
	Lena	44.12	0.0498	0.9814
	House	44.24	0.0470	0.9896
motion-blurring filtering □ = 45^0	Pepper	20.45	0.0513	0.7621
	Nature	20.87	0.0429	0.8319
	Lena	20.10	0.0658	0.8112
	House	20.22	0.0615	0.8004
Histogram equalization (HE).	Pepper	44.82	0.0468	0.9321
	Nature	45.21	0.0421	0.9845
	Lena	44.63	0.0445	0.9561
	House	44.78	0.0407	0.9672

Table 3. PSNR comparison between [1] and the proposed method

Cover image	Type of attack	Proposed method	Method [1]
Lena	Salt & pepper (noise density 0.5)	43.57	43.0127
	JPEG compression (Quality factor 30%)	40.30	38.0279
	JPEG compression (Quality factor 50%)	43.30	41.3880
	Cropping 20%	22.23	20.4952
	Rotation 450	21.75	20.7103
	Shrinking (scaling factor 0.5)	16.11	13.6175
Pepper	Salt & pepper (noise density 0.5)	43.12	42.1067
	JPEG compression (Quality factor 30%)	40.02	36.8767
	JPEG compression (Quality factor 30%)	42.21	40.2561
	Cropping 20%	22.53	20.7003
	Rotation 450	21.34	20.6328
	Shrinking (scaling factor 0.5)	16.32	13.9568

Table 4. NCC comparison between [1] and the proposed method

Cover image	Type of attack	Proposed method	Method [1]
Lena	Salt & pepper (noise density 0.5)	0.9975	0.9971
	JPEG compression (Quality factor 30%)	0.9965	0.9936
	JPEG compression (Quality factor 50%)	0.9975	0.9936
	Cropping 20%	0.8565	0.8101
	Rotation 450	0.9234	0.8915
	Shrinking (scaling factor 0.5)	0.8541	0.8489
Pepper	Salt & pepper (noise density 0.5)	0.9913	0.9906
	JPEG compression (Quality factor 30%)	0.9999	0.9616
	JPEG compression (Quality factor 30%)	0.9982	0.9741
	Cropping 20%	0.8775	0.8033
	Rotation 450	0.9234	0.8825
	Shrinking (scaling factor 0.5)	0.8847	0.8611

Table 5. BER comparison between [1] and the proposed method

Cover image	Type of attack	Proposed method	Method[1]
lena	Salt & pepper (noise density 0.05)	0.094	0.116
	JPEG compression (Quality factor 30%)	0.3250	0.401
	JPEG compression (Quality factor 50%)	0.0521	0.113
	Rotation 100	0.0261	0.036
	dilation(scaling factor 1.5)	0.00	0.00

The imperceptibility of the watermark and robustness against some common attacks: Noising attacks like Add White Gaussian Noise(AWGN), salt and pepper and scaling, format-compression attacks like JPEG compression, geometrical attacks like cropping and rotation, filtering attacks like average filtering, motion-blur filtering and image-processing attacks like histogram equalization (HE). In the proposed method, Figure 5 and Figure 6 display effect of different attacks on the extracted watermark from different watermarked mages. As shown from the Table 2 when the imperceptibility is increased the robustness will decrease. The proposed method compared with the method [1] and the method [6] and the result of comparison illustrated in Table 3 & 4.

Conclusion and future work

In this paper, a hybrid Watermarking Scheme based on Fast Walsh-Hadamard Transform (FWHT) and Singular Value Decomposition (SVD) is introduced using the Parity function and this technique implemented using Matlab software. The proposed method was simple and the use of fast Hadamard transformation reduced the computation cost. The result showed robust against different types of attacks for different types of images and the watermark was imperceptibility in no attacks case. The proposed technique is not tested for video watermarking and this can be considered as an extension for this research.

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