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Image Watermarking in Frequency Domain using Hu's Invariant Moments and Firefly Algorithm

Sachin Sharma
Professor, Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, AP, India
Email: rj14.sachin@gmail.com

Shikha Choudhary
Associate Professor, Department of Computer Engineering, Rajasthan College of Engineering for Women, Jaipur, Rajasthan, India
Email: shikha.chaudhary18@gmail.com

Vijay Kumar Sharma
Assistant Professor, School of Computing and Information Technology, Manipal University Jaipur, Rajasthan, India
Email: vijaymayankmudgal2008@gmail.com

Ankur Goyal
Associate Professor, Department of Computer Engineering, AIT, Chandigarh University, Mohali, Punjab, India
Email: e11106.ankur@cumail.in

Meena Malik
Assistant Professor, Department of Computer Engineering, Sagar Institute of Science and Technology, Bhopal, Madhya Pradesh, India
Email: meenamlk@gmail.com

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Abstract: Preventing the digital content from being copied, manipulated and illegal ownership claims is one of the biggest challenges that appeared with the widespread usage of computing facilities. Watermarking is one way to tag a digital document with a watermark, perceptible or imperceptible, so as to later prove the ownership or authenticity of the document, in case the need arises. Robust and Fragile watermarking is used in case of proving ownership and authenticity, respectively. This paper proposes a watermarking approach based on Discrete Wavelet Transform (DWT), Hessenberg Decomposition (HD) and Singular Value Decomposition (SVD) approach, augmented with Firefly Algorithm (FA). To make the approach blind, the proposed technique uses Hu's invariant moments which are invariant against rotation, scaling and translation (RST) attack over the image. In the resulting watermarked image, the watermark is imperceptible, which make it suitable for a large class of watermarking applications. In the proposed approach, a given colour image is subjected to 2 Level DWT for decomposing into sub-bands, namely LL, LH, HL and HH bands. These coefficients of HH band are fed as input for HD. The output is operated for SVD for obtain U, S and V matrices. The Hu's invariant moments are scaled and mapped to binary string using logarithm scaling. The binary matrix, corresponding to binary watermark, is XoRed with the invariant moments, in a repeated manner, to obtain a new binary matrix, of the same dimension as count of 2X2 partitions of S. The watermark is embedded by changing the orthogonal V matrices. The magnitude of the change is computed with Firefly algorithm considering the robustness and imperceptibility as the trade-off parameters. The firefly algorithm is one of the nature inspired optimization algorithm. The proposed watermarking approach is capable of withstanding JPEG compression attack, filtering attacks and noise. PSNR and SSIM are used as the quality metric for accessing the watermarked image quality. It turns out that the proposed watermarking technique gives a considerable improvement over robustness and imperceptibility as compared to the benchmark approaches. The performance of the proposed approach as compared to the benchmark approach, increases in linear manner with the dimension of the image under consideration, reaching from 1 percent to 4 percent for image dimensions ranging from 400X400 to 1200X1200 pixels.

Index Terms: Discrete Wavelet Transform, Singular Value Decomposition, Heisenberg Decomposition, Firefly Algorithm, Hu's Invariant Moments

1. Introduction

Watermarking refers to a process of hiding a digital content inside a digital media with intent of, proving the ownership or authenticity of the digital media. The robust watermarking is usually used for copyright protection whereas the fragile watermarking is used for authenticity of the content [1]. In the current era of digital revolution wherein thousands of illegal copies of the digital content can be made and can be distributed all over the internet, almost instantaneously, the application of digital watermarking is immense and critical [2].

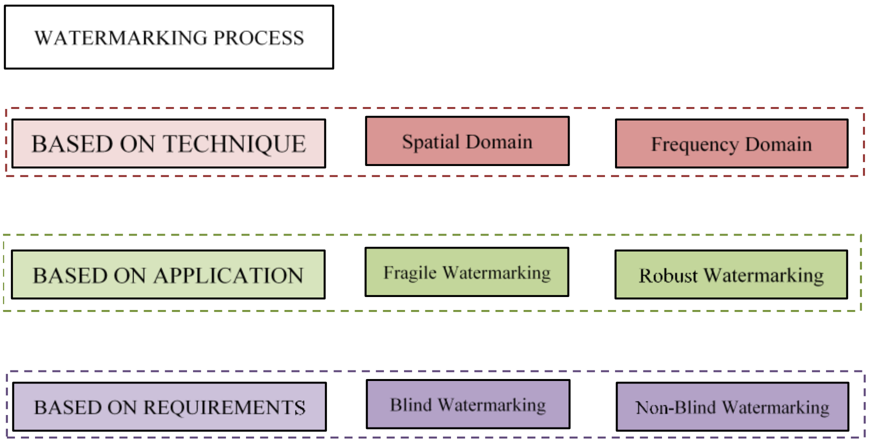


Fig. 1. Classification of Watermarking techniques based on Techniques, Applications and the requirements.

The application of watermarking the digital content is immense and these are becoming increasingly important in modern context. This is due to rapid proliferation of internet through which a single digital file can be replicated and transferred to a number of recipients, irrespective of the authorization and/or access permissions. As explained in previous section, there are diverse requirements applicable as per the context of the watermarking approach. Fig. 1 gives the classification of the watermarking techniques depending upon the context of application, techniques used, and the requirements of the watermarking system.

In this paper, a robust blind watermarking technique, based on Discrete Wavelet Transform, Singular Value Decomposition [3], Hessenberg Decomposition [4] and Firefly algorithm [5] is presented. The blind watermarking technique generally utilizes image invariant features [6] for embedding of a watermark. By the term "invariant-features", we usually refer to those parameters of the image which remain unchanged after the embedding of watermark. The Hu's invariant moments are used as the invariant features which remains invariant under rotational, scaling and translational (RST) distortions [7,8].

Fig. 2 shows a generic scenario in which the watermarked image is subjected to attacks, thereby making it difficult to detect/ extract the watermark by the detection system.

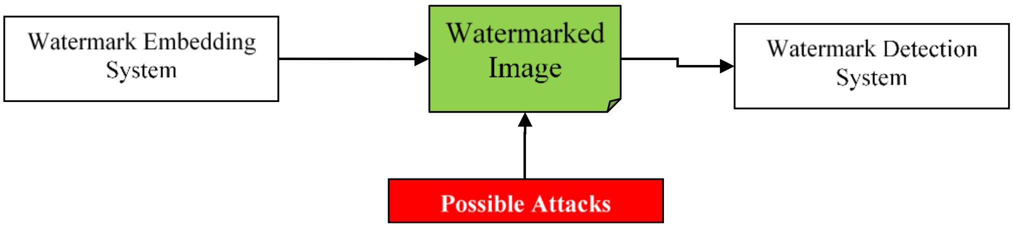


Fig. 2. Watermarking System under attack.

A. Motivation

There exists a number of techniques for watermarking of Images, which belongs to one or more of the representative class of categories, including perceptible or imperceptible techniques, blind or non-blind techniques, spatial or temporal domain watermarking, robust or fragile watermarking etc. Each of these can be further classified into subcategories, like robustness can be categorized as (1) Robust against JPEG Compression (2) Robust against Rotation, Scaling and Translation (RST) transformation etc. A large class of watermarking applications require those which ate robust, imperceptible (invisible), RST invariant, transform domain and most importantly, blind. The proposed technique is one such technique which met all these requirements. Thus, it is applicable for a wide class of applications ranging from natural images from camera, medical imaging, microscopic images and scientific applications.

B. Problem Statement

Since digital watermarking is a considerably old discipline, a number of techniques has been proposed by several researchers over significant time span. However, not much research has been contributed towards development of blind watermarking techniques [9], which are robust, imperceptible, transform domain based and allows for the embedding of custom watermarks [10].

For most of the applications in which blind watermarking is used, the copyright protector is interested only in the detection of the watermark, and not interested in extraction of watermark. Thus, the watermarking scheme answers the question -YES or NO, in context of the presence of watermark, but there is no provision of extraction of the watermark, as the watermark is actually in the form of some features extracted from the media and embedded again into the same in one way or the other. This is because embedding custom watermarks in digital media in a blind manner requires feature extraction from the image itself. This particular set of watermarking class has a large number of applications in most of the applications related to digital watermarking. The proposed watermarking scheme focuses on digital watermarking of color images in a manner that allows for embedding custom watermarks in digital images in robust, imperceptible and blind manner.

The major contribution of this paper is as follows:

1. Application of Hu's Invariant Moments and Heisenberg Transform to improve the Image Watermarking Process for implementing a robust watermarking technique.
2. Using 2X2 partitions of orthogonal matrices for binary watermark embedding, preserving the orthogonal characteristics.
3. Using Firefly Algorithm to compute the optimum value of Cost Function framed as weighted sum of PSNR and SSIM

This paper is organized as follows. Section 1 presents an overview of the subject matter and gives the problem statement and the approach for the research. Section 2 provides the motivation and literature review to the subject. It also makes a background for the concepts and techniques presented in subsequent sections. Section 3 and Section 4 presents the proposed model for embedding and extraction of watermark using DWT, HD and Firefly Optimization, including the simulation results and the plots for various performance matrices. Section 5 concludes the paper and provides an insight for future prospective of the work.

2. Literature Review

Watermarking techniques are extensively used for Intellectual Property Rights protections in diversified applications across all verticals of digital content distribution. It provides security, authorization and most importantly, copyright protection to the digital media. A critical review of the recent advancements in the field of digital watermarking which relates to frequency domain, robust and blind watermarking techniques is given in table 2.1.

Table 1. A review of Digital Image Watermarking Techniques in Frequency Domain

Paper	Authors	Year	Details
An Optimized Image Watermarking Method Based on HD and SVD in DWT Domain [11]	Junxiu Liu, Jiadong Huang, Yuling Luo, Lvchen Cao	2019	In this paper, the authors proposed a scheme of embedding of image watermark inside a color image using HD and SVD in DWT Domain. The said technique is resistant against jpeg compression. However, the proposed approach is not a blind technique.
A Robust Image Watermarking Scheme Based on SVD in the Spatial Domain [12]	Heng Zhang, Chengyou Wang and Xiao Zhou	2017	The paper proposed a technique in embedding inside the coefficients of S matrix of SVD Transform. Moreover, the embedding is done in spatial domain as no frequency domain transform is applied over the image matrix. The proposed approach is non-blind, which requires the original (non-watermarked) image at the receiver.
A robust information hiding algorithm based on lossless encryption and NSCT-HD-SVD [13]	O P Singh and A. K. Singh	2021	The paper proposes a robust information hiding algorithm based on lossless encryption, non-subsampled contourlet transform (NSCT), Hessen-berg decomposition (HD) and singular value decomposition (SVD). The scheme proposed in the paper suggest the embedding of textual data in the image using pseudo magic cubes. The PSNR and NC is used as quality matrices for the comparison of the results.

An Adaptive Image Watermarking Method Combining SVD and Wang-Landau Sampling in DWT Domain [14]	Baowei Wang and Peng Zhao	2020	This paper proposes an adaptive image watermarking method combining singular value decomposition (SVD) and the Wang–Landau (WL) sampling method. In this method, the third-level approximate sub-band obtained by applying the three-level wavelet transform is decomposed by SVD to obtain the principal component, which is firstly selected as the embedded position. Then, the information is finally embedded into the host image by the scaling factor.
Optimised blind image watermarking method based on firefly algorithm in DWT-QR transform domain [15]	Yong Guo, Bing-Zhao Li, Navdeep Goel	2017	The paper employs FA in figuring out the optimized value of watermark embedding strength factor that leads to a balance between the requirements of robustness and imperceptibility.

All the five approaches, proposed by authors [11-15] are the state-of-the-art techniques for image watermarking. However, [11,12] are non-blind which, gives additional overhead of keeping original, non-watermarked image file at the time of watermark extraction / detection. Moreover, [12] uses spatial domain for embedding watermark bits, a process which is not regarded as optimal for evenly embedding. Authors in [13] propose a technique to embed textual watermark in the cover image, which has comparatively less applications as compared to an image watermark. Technique used in [14] suffers from low embedding capacity. Moreover, the watermark embedding is non-resistant to attacks like rotation, scaling and translation. None of the DWT-SVD, RST invariant watermarking techniques, including those in [11,12,13,14] use any nature inspired technique to achieve optimization over some cost function. A cost function is usually designed using weighted sum of parameters like embedding capacity, PSNR/MSE, SSIM etc. The authors in [15] proposed classical watermarking augmented with Firefly Algorithm. However, the prosed technique is fragile as it is not resistant to either RST attack or JPEG compression. All these issues and challenges, in one form or the other in the existing techniques motivated for the development of watermarking technique which is robust, blind and imperceptible.

3. Proposed Watermarking Scheme

A. Watermark Embedding Process

The proposed watermarking scheme is explained stepwise as given below:

1. Input the Image to be watermarked. Let the image dimensions be NXN.
2. Perform 2 level DWT Transformation over the image to convert it into LL, LH, HL and HH bands. After this transform, each of the band has a total of N/2 X N/2 coefficients.
3. Apply Heisenberg Decomposition (HD) over HH to obtain P and H matrices. The operation is shown as:

$$[P, H] = HD(HH)$$

   HH is considered for watermark embedding as it contains most of the information of the original image. Thus, consideration of HH will provide a much more robust watermarking scheme as compared to any other sub-band. The reversibility of the operations can be verified using the following reverse operation.

$$HH = P * H * P^T$$

   Each of the H and P matrices are of dimensions N/2 * N/2.
4. The H matrix has the characteristic property that the lower diagonal elements are all zero, whereas the upper diagonal elements consists of both zero and non-zero values.
5. The P matrix is partitioned into non-overlapping regions of dimensions 2X2. Let the individual partitions be $P_1, P_2, P_3 \dots\dots.. P_n$, considering row-major order. Apply SVD Transform over each of these matrices to obtain the corresponding U_i, S_i and V_i matrices.

$$[U_i, S_i, V_i] = SVD(P_i)$$

6. The total count of such matrices is (N/4)* (N/4). Each such matrix is used to embed a watermarking bit. Thus the proposed algorithm gives an embedding capacity of 1/16 for a given image size.
7. Obtain the Hu's RST invariant moments of the Image. These are 7 numerical values which remains unchanged irrespective of rotation, scaling and translation of the image.

$$[m_1 , m_2, m_3 , m_4 , m_5 , m_6, m_7] = Inv\_Moments(I)$$

8. Map the seven values over a logarithmic scale from 0 to10 to obtain 7 normalized values in the range from 0 to 10. These values do not change irrespective of any RST operation performed over the image. Rounding-off of these values to the nearest integer is performed. A mapping of even and odd numbers to 1 and 0 is done to obtain a binary string (S), which is used for watermark embedding and detection using bitwise XoR operator

$$[m_1 , m_2, m_3 , m_4 , m_5 , m_6, m_7] \rightarrow [B_1 , B_2, B_3 , B_4 , B_5 , B_6, B_7], where\ for\ all\ i, B_i\ belongs\ to\ \{\mathbf{0}, \mathbf{10}\}$$

9. Consider a Binary image watermark of dimension 1/4th of that of the cover image. Being binary, the values of the individual pixels can be zero or one. Reshape the binary watermark to row vector.
10. The S string is repeatedly XORed with the watermark string to produce another binary string T. This T string is used for the purpose of watermark embedding for the simple property of XoR operator which is as shown:

A XoR B = C, implies A XoR C = B and B XoR C = A

11. The T string is again reshaped to the same dimension as that of the watermark image. Let this matrix be Y.
12. The binary matrix Y, so obtained is embedding into the U and V matrices of the partitions P1, P2,… Pi of the P matrix, considering the orthogonally property. Although either of the U or V matrices can be considered for watermarking embedding, the particular choice of either U or V depends upon the imperceptibility of the watermark.

$$[V_i\ ] \rightarrow [V_i'\ ]\ ; Embedding\ bit\ 0\ or\ 1$$

The embedding rule of a watermark bit into an orthogonal matrix is explained in the subsequent section.
13. Each of the converted V_i are subjected to inverse SVD transform to obtain the corresponding Pi'.
14. All the Pi are arranged to form a P matrix.
15. The P matrix is combined with H matrix, using inverse HD, to form the HH band.
16. The inverse DWT is performed to obtain the watermarked image from the LL, LH, HL and the modified HH block.
17. The weighting parameter α used in the embedding scheme used to embed binary bit into 2X2 size binary matrix is computed using Firefly Algorithm, to manage tradeoff between robustness and imperceptibility, using PSNR as the quality metric.

B. Embedding Process in 2X2 Vi matrices (Step 12)

As Vi is an orthogonal matrix, its determinant would be ±1. Thus

$$|Vi| = \pm 1$$

An orthogonal matrix is of dimensions 2X2, is always of the form

$$Vi = \begin{bmatrix} a & -b \\ b & a \end{bmatrix}$$

where the diagonal elements are of the same sign and the off-diagonal elements are of different sign. In this case, the value of the determinant comes out to be:

$$a^2 + b^2 = 1$$

It is clear that the absolute value of the elements of the U matrix, a and b satisfy the relationship that the sum of square of both a and b is 1. Thus, we can find angle in the range

$$[0, \frac{\pi}{2}]$$

where

$$\mathrm{Sin}\theta = \frac{a}{\sqrt{a^2 + b^2}}$$

and

$$\text{Cos}\theta = \frac{b}{\sqrt{a^2 + b^2}}$$

Considering the embedding in V matrix, let α and β be two variable such that

$$U' = \begin{bmatrix} -(a-\alpha) & -(b-\beta) \\ (b-\beta) & (a-\alpha) \end{bmatrix}$$

To keep the orthogonally property unchanged, it is required that

$$|U'| = -(a-\alpha)^2 - (b-\beta)^2 = -1$$
$$(a-\alpha)^2 + (b-\beta)^2 = 1$$
$$a^2 + \alpha^2 - 2a\alpha + b^2 + \beta^2 - 2b\beta = 1$$
$$\alpha^2 + \beta^2 - 2(b\beta + a\alpha) = 0$$
$$\alpha^2 - 2a\alpha - (2b\beta - \beta^2) = 0$$
$$\alpha = \frac{2a \pm \sqrt{4a^2 + 4(2b\beta - \beta^2)}}{2}$$

Thus, for a given value of β, the value of α can be computed as shown above. The pair of these variables is chosen with Firefly Technique, so as to obtain the desired balance between imperceptibility and robustness.

We propose the following embedding policy for embedding of the XORed bits into the V matrices.

1. Obtain a, b, c and d values of the 2X2 V matrix.
2. Considering only the magnitude of these values, obtain the angle (in first quadrant) of the unit circle, as shown in fig. 3.
3. Obtain the Floor / Ceiling of the angle values as shown below:
   Upper = ceil(angle); %% Matlab Function ceil for next higher integer
   Lower = floor(angle); %% Matlab Function floot for just lower integer
   Difference_1 = difference (Upper, angle);
   Difference_2 = difference(angle-Lower);
4. Setting Up Bin Ranges for embedding policy for 0 and 1:
   a. For 1; [1,2,3……90]
   b. For 0; [0.5, 1.5, 2.5,…..89.5]

   In general, the bin ranges can be set for a particular choice of the value of parameter β, such that, for the embedding of bits 0 and 1, we can have,
   c. For 1; [1,2,3……90]
   d. For 0; [β, 1+ β, 2+ β,……89+ β] where 0< β<1

   The particular choice of the parameter β is obtained from the Firefly Optimization Technique considering the PSNR metric as the optimization parameter.
5. The values of the angle corresponding to bit 0 and 1 can be set to either Upper or Lower, depending upon the smaller of the values from [Difference_1, Difference_2], or can be set to (Upper + Lower)/2 or any choice of bins between lower and upper range for embedding 0 and 1 correspondingly.

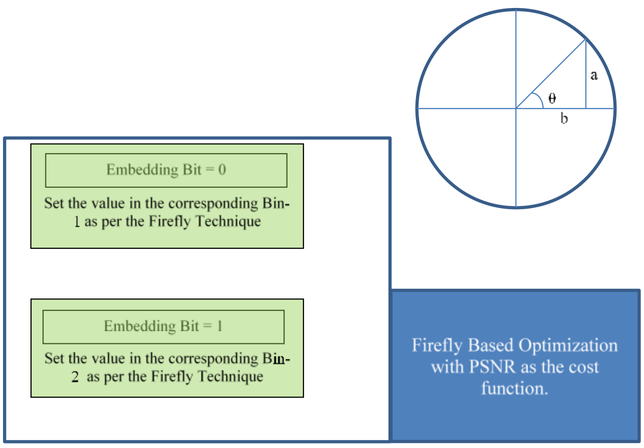


Fig. 3 Embedding Process Using Firefly Optimization Technique

C. Watermarking Extraction Process

The extraction process of the watermark is straightforward. It takes into input, the watermarked image and gives as the output, the watermark which was embedded in the process.

1. Apply 2-Level DWT transform over the watermarked image to obtain LL, LH, HL and HH bands.
2. Apply HD over the HH band to obtain P and H matrices as shown:

$$[P, H] = HD(HH)$$

3. Partition H matrix into bocks of size 2X2 and apply SVD to each of the block to obtain U, S and V matrices.

$$[U, S, V] = SVD(H)$$

4. Obtain the string of 0's and 1's from the angle measurement of individual orthogonal matrix V.
5. Obtain the Hu's Invariant Moments of the cover image. Quantize it to obtain string S of length 7. Using identical mapping as performed in the embedding process; obtain the string of values of 0's and 1.
6. XoR the strings obtained in (4) and (5) to obtain the desired string of 0's and 1's.
7. Reshape the string vector to square matrix of obtain the binary watermark image.

The proposed watermarking scheme embeds a binary image watermark into the host image. The embedding process is implemented by segmenting the image into non-overlapping blocks and embedding a binary bit into each of the blocks. Thus, if the given color cover image has a dimension of NXN, an embedding capacity of NXN/(4X4) can be achieved, where k is the size of the image segment. In the proposed watermarking scheme, blue color plane is considered for watermark embedding as the human eye has least perceptiveness for Blue color as compared to Red and Green Color. This results into robust watermarking scheme considering the perceptual characteristics of the human visual system.

To implement a blind watermarking scheme, provisions are needed to be inculcated at the receiver end that the watermark can be extracted/ detected without the need of original unmarked file at the receiver. In fact, the receiver is not supposed to be provided with any kind of key or cue to facilitate the detection and/or extraction of the watermark. Such a scheme is difficult to implement using custom watermarks, except in the simplest of the schemes like LSB encoding. Blind watermarking can be implemented using custom watermarks or watermarks generated from the feature vectors of the image, considering only those features only that remain unchanged before and after the watermarking process. In the proposed scheme, custom watermark are used and the same is extracted at the receiver. It is important to note that almost all the blind watermarking schemes that are proposed in most of the literature makes use of the (invariant) features of the original image in one form or other. In the proposed work, the watermarking is performed on the Blue color plane using features that are generated from Red and Green Planes.

Table 2 shown above explains the steps involved in the proposed watermarking scheme in an illustrative way. The operation indicated in green color block holds the major details of the watermarking scheme and can be altered to implement a robust or fragile watermarking scheme. The embedding process is accomplished by embedding of bits obtained as a result of XoR operation, into orthogonal V matrices of the SVD transform, using α and β parameters obtained from Firefly Algorithm

Table 3. Parameter Specification

S. No.	Object	Specification
1	Original Image : Dimension	N X N X 3
2	Original Image /Blue Plane Segment Dimension	NXN
3	HH Band of Segment, after DWT transform	(N/2)X(N/2)
4	Heisenberg Decomposition matrices, wherein P matrix is considered for watermarking	(N/2)X(N/2)
5	Hu's Invariant Transformation : 7 values- Invariant to RST Transformation: Computed for Red / Green Plane	7 values : Mapped to Binary values
6	SVD Decomposition U, S and V matrices of HH	2X2 Each: Total Count: (N/4) *(N/4)
7	Binary Watermark (Dimension N/4 X N/4); Transformed to linear vector considering row major pattern.	Total Count: (N/4) *(N/4)
8	Binary String to be embedded is obtained from XoR operation of (6) with repeated values of Hu's Invariant Moments (4)	Maximum Length: (N/4) *(N/4)

D. Firefly Optimization

Firefly Algorithm is a nature inspired algorithm proposed by Yang [16]. It is inspired by the flashing behavior of Fireflies. The algorithm makes the following assumptions:

1. All Fireflies are unisexual, means a firefly can be attracted to any other firefly.
2. Attractiveness between two fireflies is a mutual property. It decreases as the distances increases, and increases with the brightness of the Fireflies.
3. The brightness of the Firefly depends upon the objective function.

The attractiveness between the fireflies at a distance $r_{i,j}$ can be defined as:

$$\beta = \beta_0 e^{-\gamma r^2{}_{i,j}}$$

Where ϒ is the light absorption coefficient of the medium.

The movement of the fireflies can be considered as a random walk. The fireflies move towards/away from each other depending upon the attraction and the existing distance, given by the following equation:

$$x^{t+1}{}_i = x^t{}_i + \beta\left(x^t{}_j - x^t{}_i\right) + a€$$

where, the second term represents the attraction, the third term is disturbance term which set for avoiding trapping into local optimum. The parameter α is the controlling factor for step size and ε is a vector drawn from a Gaussian or other distribution.

E. Firefly Algorithm Mapping to PSNR

The Objective Function (OF) in the case of digital watermark embedding can be constructed as a weighted sum of the parameters representing the PSNR values and those which represents robustness. In case of changing the value of the elements of orthogonal matrix, it is the magnitude of change that represents the robustness.

$$OF = a_0.\mathrm{MSE} + a_1(\alpha, \beta)$$

The parameters a_0 and a_1 are the weighting factors for MSE and the parameters α and β. One way of the visualization of these two parameters is the closed interval $(0,0.7071)$, represents the range from 0 to 1/√2, which represents the two quantities the sum of squares of which is 1.

Steps of Implementation of FA:

1. Calculate the minimum and maximum difference between the pair of values of set of all 2X2 orthogonal matrices.
2. The values of both the parameters α and β always lies in this range, additionally, both these values are dependent upon each other through the equation explained in 3.1. Obtain a number of such pairs, let these pairs be termed as the initial population of fireflies.
3. Given a particular choice of α, a specific value of MSE is obtained and correspondingly, the value of OF can be computed.
4. Obtain a different value of α corresponding to the random walk of the firefly, in accordance with the attraction function as shown:

$$\alpha^{t+1}{}_i = \alpha^t{}_i + \beta\left(\alpha^t{}_j - \alpha^t{}_i\right) + a€$$

where

$$\beta(i,j) = \beta_0 e^{-\gamma r^2{}_{i,j}}$$

Obtain the new values of α and β based upon the closest and best match random walk of OF, for optimized values of MSE.

4. Results

Consider an Original Image (I), of dimension 400X400. Fig. 4 shows the original images along-with the separation of the image in Red, Green and Blue color planes each having the values in the range from 0-255.

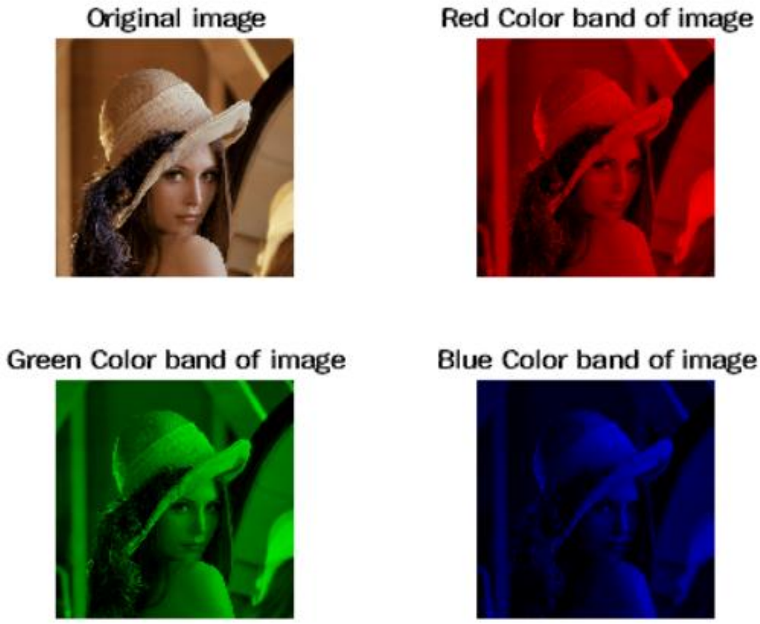


Fig.4. Original Image and Color Bands

As state already, blue color plane is chosen for watermark embedding as it is the one which is least perceptible for human eye. Consider this plane, the next step is the transformation of the Blue Color Band Grayscale image into HH, HL, LH and LL bands as shown in Fig 5.

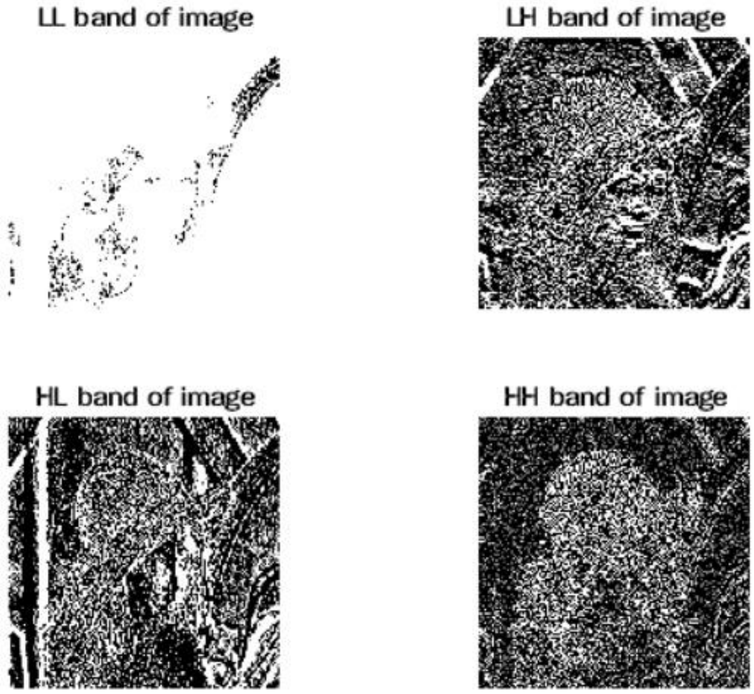


Fig. 5 DWT Bands of the Blue Color Plane of Original Image

The HH band is considered for watermark embedding. The HH band is usually considered for implementing robust watermarking, whereas the LL band is considered to implement Fragile watermarking. The Heisenberg Transform is performed over the HH band to obtain H and P matrices of dimension 200X200. The absolute, logarithmic scale and rounded values of the Hu's invariant moments are obtained as follows:

Table 4. Invariant moment key Generation

Moment	M1	M2	M3	M4	M5	M6	M7
Normalized Value	6	17	23	13	42	30	35
Binary Translation	110	10001	10111	1101	101010	11110	101101
Third LSB for ExOR Key	1	0	1	1	0	1	1

A. Comparative Analysis of Proposed Work

It is evident through perceptiveness that the proposed techniques perform well over the color images. The Quality Metric of the watermarking process are always analyzed with Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Structural Similarity Index (SSIM) and Normalized Cross Correlation (NC).

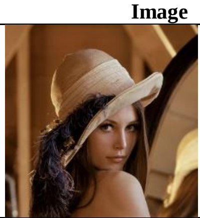
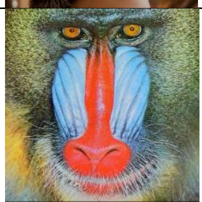
The MSE is defined as the mean value of the sum of square of the differences between the watermarked image and the original image, hence termed as Mean Square Error. The PSNR and the MSE are related with each other in the following way.

$$\text{PSNR} = 10\, log_{10} \frac{Max\ Value * Max\ Value}{MSE}$$

The image used as watermark to be embedded in the cover image is shown in Fig. 6. The MSE and PSNR values of the sample images are shown in table 4.3.

Fig. 6. Image used as Watermark (100X100) Binary Image.

Table 5. PSNR and MSE values of the sample images

S. No.	Image	Quality Index [Proposed]	Quality Index [10]
1		MSE = 0.1142	MSE = 0.1144
		PSNR = 57.58dB	PSNR = 57.5465
		SSIM = 0.9924	SSIM = 0.9910
2		MSE = 0. 4096	MSE = 0.4099
		PSNR = 52.0415 dB	PSNR = 52.0040
		SSIM= 0.9981	SSIM = 0.9980
3		MSE = 0. 4616	MSE = 0.4620
		PSNR = 51.5217dB	PSNR = 51.4844
		SSIM = 0.9294	SSIM = 0.9291
4		MSE = 0. 2110	MSE = 0.2203
		PSNR = 54.9229 dB	PSNR = 54.7007
		SSIM = 0.9877	SSIM = 0.9854

The graphical illustration for MSE and PSNR between the proposed and the base approach is shown in subsequent graphs.

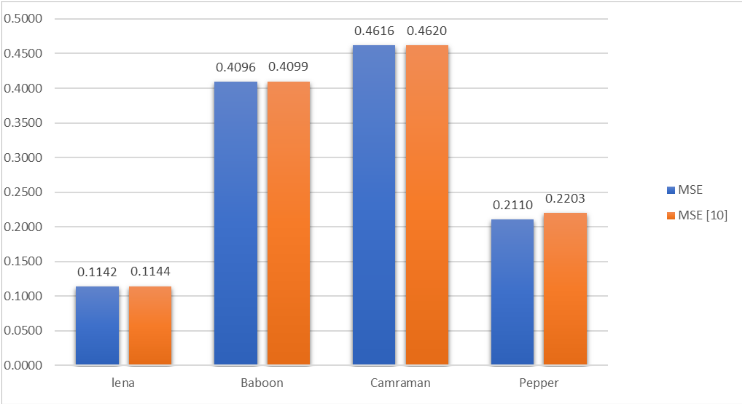


Fig. 7. Comparison of MSE Values of Proposed Approach and [10] over the same 400X400 Benchmark Images with 100X100 binary watermark image.

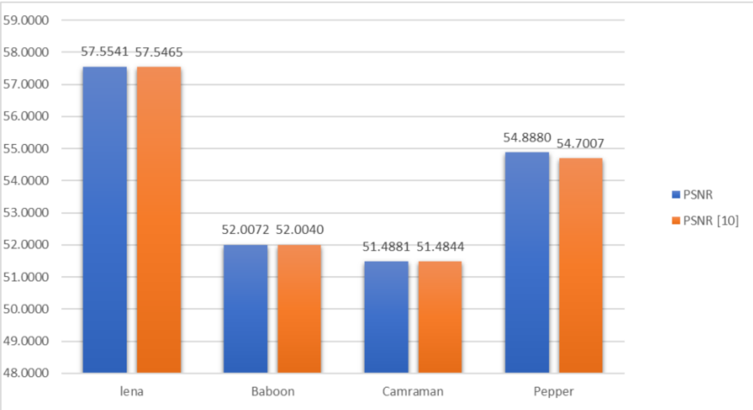


Fig. 8. Comparison of PSNR Values of Proposed Approach and [10]

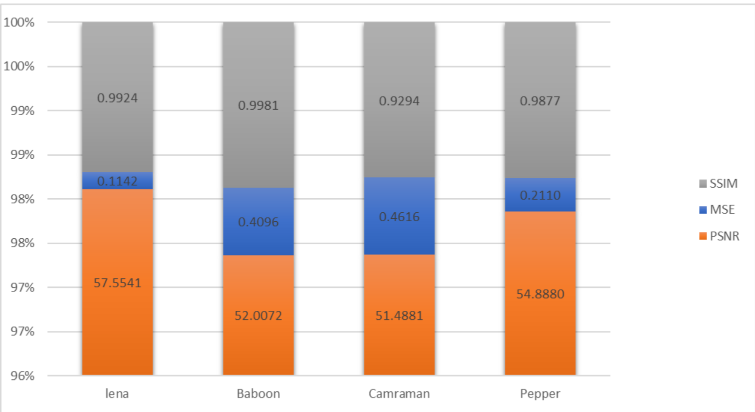


Fig. 9. Comparison of the MSE, SSIM and PSNR values (100% Stacked)

The SSIM metric is an image quality metric that assesses the visual impact of three characteristics of an image: luminance, contrast and structure. The SSIM map is show in Fig.10-13.

Fig. 10. Lena: Global SSIM value = 0.99237

Fig. 11. Baboon: Global SSIM value = 9981

Fig. 12. Cameraman: Global SSIM value =0.9294

Fig. 13 Pepper: Global SSIM value =0. 9877

Generally, the small values of local SSIM appear as dark pixels in the local SSIM map. Regions with small local SSIM value correspond to areas where the blurred image noticeably differs from the reference image. Large values of local SSIM value appear as bright pixels. Regions with large local SSIM correspond to uniform regions of the reference image, where blurring has less of an impact on the image.

Finally, the relationship of the value of the parameters α and β, and the value of MSE derived through the Firefly iterations are depicted in Fig. 14.

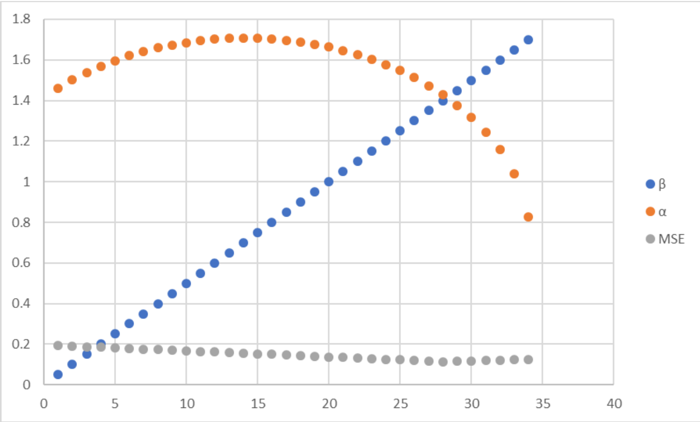


Fig. 14 MSE as a function of parameters α and β. The horizontal axis shows the iterations of FA for minimum MSE.

It is evident that the proposed technique outperforms that of the approach proposed by benchmark approaches Also, the proposed technique embeds the watermark in the HH band thereby implementing a robust watermarking scheme resistant to several kind of attacks. Section 5 concludes the paper and gives the scope for future work.

5. Conclusion and Future Scope

A robust watermarking scheme is presented using the combination of techniques which are predominant in the watermarking processes of digital images. In the proposed scheme, based on human perceptiveness, the blue color plane is used for watermark embedding. As the proposed scheme is blind, a feature vector needs to be generated from the original image. In this paper, Hu's Invariant Moments are used to embed custom watermark in the given sample image. The parameters α and β are used to modulate the strength of embedding of watermark. These are the parameters which are considered in the cost function which is then optimized using Firefly Algorithm. Fig 14 shows that the minimum value of PSNR is achieved which the value of both these parameters is equal. The proposed technique outperforms those of the benchmark techniques by a factor of 1% to 4%, which is significant in scenario where image quality / imperceptibility is critical concern.

The proposed approach can be extended by embedding after image segmentation wherein the logical segments of the image can be identified for watermark embedding. There exist several techniques for segmentation of the images, however, still a broad research area for AI enthusiasts. The utility of the proposed technique can be increased several folds by augmenting it with suitable segmentation technique.

The watermark is embedded bit by bit into the HH matrix of the non-overlapping segments of the image. The proposed scheme outperforms as proposed in the base research work. However, a main reason for obtaining better PSNR level is the low embedding capacity, as compared to the other techniques like LSB and DFT. The comparison of the results proves the effectiveness of the proposed technique as compared with the base approach.

As the future scope of this work, a DWT-SVD based watermarking approach is to be formulated which is resistant to attacks like jpg compression and print and scan attacks. Moreover, the watermarking techniques needs to be semi fragile as per the need of time, so that it can provide tempering protection and at the same time, used for embedding the watermark so robustly that no attacker can destroy or remove the watermark. Another aspect of the future work is to improve the embedding capacity of the scheme. Moreover, the current technique embeds the watermark in U matrix of the SVD decomposition. As a future aspect, of this work, the watermark is embedded in the matrices much more evenly so as to provide better perceptual quality of the watermarked image.

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Authors' Profiles

Dr. Sachin Sharma received Ph.D. in Computer Science and Engineering from Gyan Vihar University, Jaipur, India in 2018; He received his M. Tech. degree in Computer Science and Engineering in 2010 from Rajasthan Technical University, Kota, Rajasthan. His research interest includes Image Processing, Data Science and Machine Learning. He is Professor in the Department of Computer Science and Engineering at Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, AP, India.

Shikha Choudhary is Research Scholar at RIET, Rajasthan, She received her M. Tech degree in Computer Science and Engineering from Banasthali Vidhyapeeth, Niwai, Rajasthan, in 2006, and B.E. degree in Computer Engineering from Mody College of Engineering, Sikar, Rajasthan in 2002. Her professional activities have been focused in Image Processing, Cloud Computing, and Theory of Computation.

Dr. Vijay Kumar Sharma received Ph.D. degree from Manipal University Jaipur, in 2019, M.Tech. degree in Computer Engineering from Rajasthan Techncial University, Kota, Rajasthan in 2012. He is currently Assistant Professor at Manipal University Jaipur. His professional activities have been focused in Image Processing, Microprocessor and Interfaces and Computer Graphics.

Dr. Ankur Goyal is working as Associate Professor at Chandigarh University, Mohali, Punjab. His professional activities have been focused in Blockchain Technologies, Data Science and Image Processing.

Dr. Meena Malik is Assistant Professor in the Department of Computer Science and Engineering of Sagar Institute of Science and Technology, Gandhi Nagar, Bhopal, Madhya Pradesh, India. She has completed PhD (CSE) from Maharshi Dayanand university, Rohtak, M. Tech(CSE) from Banasthali University, Rajasthan and B.Tech (CSE) from Kurukshetra University. She has qualifed GATE 2012 and have 6 years of teaching experience. She has more than 15 research publications in international journals and conferences. She has collaborated actively in various FDPs seminars and national/international conferences organized by different academics institutions. Her research interests lie in the area of Wireless Sensor Networks and Machine Learning .

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