Block-based Discrete Wavelet Transform Singular Value Decomposition image watermarking scheme using Human Visual System characteristics and Firefly Algorithm

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CANDIDATE'S DECLARATION

I, Avinash Singh, 2K16/SPD/05, of M.Tech, hereby declare that the project Dissertation Titled "Block-based Discrete Wavelet Transform Singular Value Decomposition image watermarking scheme using Human Visual System characteristics and Firefly Algorithm" which is submitted by me to the Department of Electronics and Communication, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "Block-based Discrete Wavelet Transform Singular Value Decomposition image watermarking scheme using Human Visual System characteristics and Firefly Algorithm" which is submitted by Avinash Singh, Roll No 2K16/SPD/05, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi

Date:

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……………………
AVINASH SINGH

ABSTRACT

Digital image watermarking has gained a great interest in last decade among researchers. Having such a great community which provide a continuously growing list of proposed algorithms, it is rapidly finding solutions to its problems. However, still we are far away from being successful. Therefore, more and more people are entering the field to make the watermarking idea useful and reliable for digital world. Of these various watermarking algorithms, some outperform others in terms of basic watermarking requirements like robustness, invisibility, processing cost, etc.

In this thesis, we study a new hybrid block-based image watermarking scheme which when combined with firefly algorithm provides us better results. Following illustrative points are made to describe the thesis in a nutshell which will later on be discussed in detail.

- Firstly we divide our watermark in 32x32 blocks. This needs to be done because we need top 1024 blocks of our host image with lowest human value system characteristics i.e lowest entropy values and lowest edge entropy values.

- Our host image is divided into 8x8 blocks. Total 64 rows and 64 columns are there of 8x8 blocks. In total 64x64x8 blocks of host image i.e the size of host image is 512x512.

- Now we generate a random threshold. This threshold is used in embedding and extraction algorithm. Using Human Value System characterstics, i.e choosing best 1024 lowest entropy blocks, we perform embedding and extraction on host image.

- This embedding and extraction is done using Discrete Wavelet Transform and Singular Value Decomposition algorithm, which is explained in later chapters.

- Now using this embedded image we find PSNR value and using the extracted watermark image we find correlation values.

- Firefly Algorithm is performed using these PSNR and Correlation values i.e a fitness function is found for each threshold we generated previously. This fitness value defines the best value of threshold which we require for best embedding and extraction procedure. This algorithm is explained later on in detail.

- We find best value of threshold using this Firefly Algorithm. Also we get the best extracted watermark image using this algorithm.

- In a nutshell, this project has combined four major algorithms to generate best results possible. These adopted criteria significantly contributed to establishing a scheme with high robustness against attacks without affecting the visual quality of the image.

To describe it briefly the project consists of following four subsections-

1. Discrete Wavelet Transformation (DWT)
2. Singular Value Decomposition (SVD)
3. Firefly Algorithm (FA)
4. Human Value System Characterstics (HVS)

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LIST OF SYMBOLS, ABBREVIATIONS

1.1 - Output of high pass filter

1.2 - Output of low pass filter

1.3 - IDWT expression

1.4 - SVD matrices representation

1.5 - Entropy

1.6 - Probability lies between 0 and 1

1.7 - Total sum of probability is 1

1.8 - Edge entropy

1.9 - Uncertainty of pixel value

1.10 - Distance between firefly i and firefly j

1.11- Distance between firefly i and firefly j in 2-D

1.12- Attractiveness of a firefly

1.13- Movement of firefly equation

1.14- Random walk parameter

1.15- Random movement expression

1.16- Random walk parameter

2.1- Equation for finding SVD

2.2- Equation for finding SVD of watermark

2.3- Equation for change in S values (embedding)

2.4- Inverse SVD

CHAPTER 1 INTRODUCTION

Recent years have seen a rapid growth in the availability of digital multimedia content. Today, digital media documents can be distributed via the World Wide Web to a tremendous number of people without much effort and money. Additionally, unlike traditional analog copying, with which the quality of the duplicated content is degraded, digital tools can easily produce large amount of perfect copies of digital documents in a short period. This ease of digital multimedia distribution over the Internet, together with the possibility of unlimited duplication of this data, threatens the intellectual property (IP) rights more than ever. Thus, content owners are eagerly seeking technologies that promise to protect their rights.

Cryptography is probably the most common method for protecting digital content since it has a well-established theoretical basis and developed very successfully as a science. The content is encrypted before delivery and a key is provided to the legitimate owner (who has paid for it). However, the seller is unable to discover how the product is handled after it is decrypted by the buyer. Encryption protects the content during the transmission only. When transmitted to the receiver, data must be decrypted in order to be valuable. Once decrypted, the data is no longer protected and it becomes vulnerable. The buyer may turn out to be a pirate distributing illegal copies of the decrypted (unprotected) content. Therefore, encryption must be complemented with a technology that can continue to protect the valuable data even after it is decrypted. This is the point where watermarking comes in. Digital watermarking technology is receiving increasing attention since it presents a possible solution for prohibiting copyright infringement of the multimedia data in open, highly uncontrolled environments where cryptography cannot be applied successfully. A digital watermark is a distinguishing piece of information that is adhered to the data (generally called cover or host data) that it is intended to protect.

Watermarking embeds (generally hides) a signal directly into the data and the signal becomes an integral part of the data, travelling with the data to its destination. This way, the valuable data is protected as long as the watermark is present (and detectable) in it. At any given moment, the hidden signal can be extracted to get the copyright-related information. Thus, the goal of a watermark must be to always remain present in the host data. However, in practice the requirement is somewhat weaker than that: Depending on the application, a watermark is required to survive all the possible manipulations the host data may undergo as long as they do not degrade *too much* the quality of the document. The main difference between watermarking and encryption is that encryption disguises the data and protects it by making it unreadable without the correct decryption key, while watermarking aims to provide protection in its original viewable audible form.

Watermarking, like cryptography, needs secret keys to identify legal owners. The key is used to embed the watermark, and at the same time to extract or detect it. Only with a correct key can the embedded signal be revealed. While a single bit of information indicating that a given document is watermarked or not is sufficient sometimes, most applications demand extra information to be hidden in the original data. This information may consist of ownership identifiers, transaction dates, logos, serial numbers, etc., that play a key role when illegal providers are being tracked.

Watermarking can be used mainly for owner identification (copyright protection), to identify the content owner; fingerprinting, to identify the buyer of the content; for broadcast monitoring to determine royalty payments; and authentication, to determine whether the data has been altered in any manner from its original form. While digital watermarking for copyright protection is a relatively new idea, the idea of data hiding dates back to the ancient Greeks and has progressively evolved over the ages. The inspiration of current watermarking technology can be traced to paper watermarks which were used some 700 years ago for the purpose of dating and authent -icating paper. In the area of image watermarking, some commercial watermarking products already emerged on the market. Digimarc Corporation's *Picture Marc* is available as a tool in Adobe Photoshop image processing program. The detector can find watermarks in the images if they were embedded into the image by the Digimarc product.

In this thesis, our aim is to build new watermarking scheme which combines various watermarking algorithms. Initially in my previous project I have worked upon firefly algorithm to get best results i.e a good value of PSNR and a correlation factor close to 1. In this thesis I have combined a Hybrid block-based image watermarking scheme in my previous project. The blocks are selected based on several HVS characteristics, and the embedding process is achieved by modifying the orthogonal matrix U. These adopted criteria significantly contributed to establishing a scheme with high robustness against attacks without affecting the visual quality of the image. The following are the highlights and features of the proposed scheme:

(i) The proposed scheme is a block-based scheme, in which the watermark affects specific regions of the image. Such schemes have several features, such as the following:

- Segmenting the host image into small blocks satisfies the un-detectability and imperceptibility requirements.

- The ability to handle each block separately allows multiple secret keys to be used for the selected blocks and improves security.
- The watermark capacity will vary between blocks according to their properties, improving the robustness and imperceptibility.
- Block-based schemes are widely used in numerous applications, such as region of interest (ROI) functions in medical images. To secure medical images through watermarking, ROI blocks are preserved, and the watermark is embedded in the remaining portion of the image; this portion is called the region of non-interest.

(ii) The scheme employs HVS characteristics (entropy and edge entropy) to determine in which parts (blocks) of the image will produce un-noticeable distortion and achieve maximum robustness during embedding.

(iii) DWT is applied to each selected block individually. The advantages of using DWT (wavelet transform) instead of DCT, which was adopted in Lai, are as follows:

- DWT has multi-resolution properties, leading to a hierarchical analysis of the signal and the ability to perform an analysis similar to HVS . Wavelet transformations more accurately model aspects of HVS compared to DCT.
- DWT requires less computational time compared to DCT because it does not suffer from blocking artefacts.
- The basic function of the DCT is $f(x) = \exp(i\omega x)$. Therefore, the DCT has perfect localisation in frequency only. Wavelets offer a trade-off between time/space and frequency/scale. Therefore, incorporating DWT in a watermarking scheme produces a watermark with a spatially global and spatially local support. Therefore, watermarking techniques based on wavelets are more robust against attacks than those based on DCT.

(iv) An SVD is performed on the transformed coefficients of the LL sub-band of each block. The embedding process is performed by examining the second and third entries of the first column of the U matrix instead of examining the third and fourth entries [as previously proposed by Lai. Embedding in SVD vectors (U matrix)] will improve the robustness, invisibility and security.

Below, in detail, is described the basic skeleton of all the four algorithms used in this thesis that are-

- Discrete Wavelet Transform
- Singular Value Decomposition
- Firefly Algorithm
- Human Value System

1.1 DISCRETE WAVELET TRANSFORM

DWT is widely used in many signal processing applications. The wavelet energy is concentrated in time and is more suitable for the transient analysis of time varying signals. In nature, most signals are time varying. Therefore, wavelet transforms are suitable for many applications. As with any wavelet transform, a DWT is used to describe an image as small waves (called wavelets) of varying frequencies and limited durations.

A DWT is a mathematical tool that provides multiple-resolution analysis of an image. This tool decomposes the image into two components: high frequency and low frequency. The decomposition process is achieved by passing the signal through a series of high-pass filters to analyse the high frequencies and passing the signal through a series of low-pass filters to analyse the low frequencies. Moreover, signals are analysed at different resolutions by using filters with different cut-off frequencies. By definition x[n] is the original signal that extends across the frequency range of 0 to p rad/s. First, x[n] passes through a half-band high-pass filter (g[n]) and a low-pass filter (h[n]). Due to Nyquist's rule, half of the samples can be eliminated after the filtering process. Accordingly, the signal now has a maximum frequency of π/2 radians instead of π radians.

Therefore, the signal can be sub-sampled by 2. This process represents a one-level DWT decomposition, mathematically, this process can be expressed as follows

$$y_{\text{high}}[k] = \sum_{n} x[k]g[2k - n] \tag{1.1}$$

and

$$y_{\text{low}}[k] = \sum_{n} x[k]h[2k - n] \tag{1.2}$$

where y_{high} and y_{low} are the outputs of the high-pass and low-pass filters after sub-sampling by 2, respectively. They indicate DWT coefficients, and the process is a DWT forward process that can be repeated for further decomposition. IDWT is the inverse DWT, which uses the DWT coefficients to reconstruct the original image.

The IDWT can be expressed as follows

$$y[n] = \sum_{n} (y_{\text{high}}[k]g[-n+2k] + y_{\text{low}}[k]h[-n+2k]) \qquad (1.3)$$

In two-dimensional applications, the DWT decomposes an image or frames of a video into sub-bands (LL, HL, LH and HH). LL is the low frequency and denotes the approximation of an image, whereas HL, LH and HH are the high frequencies and denote the image details. Each sub-band has half the size of the original image.

For higher decomposition levels, the sub-band size decreases by half until they reach the required decomposition level. Embedding the watermark in the high frequency sub-bands of an image provides more imperceptibility because they include the edge components, which are less sensitive to change. However, embedding the watermark in the low frequency provides greater robustness. Once the top 1024 blocks are chosen, in which embedding has to be done, we perform this transform in LL subband. H in this subband mean high frequency and L in this subband means low frequency. Low frequency means the component in the image which are easily detectable by human eye. High frequency means the component in the host image which are not easily detectable by human eye. In past there had been so much work done on HH, HL, LH subbands. Changes in these high frequency subbands does not affect the visibility so much so that it is visible. Hence insertion of the watermark into the LL sub-band does not alter the original image information and it retains its appearance to an optimum level since it does not contain the fine information of the image.

Here in my thesis I have used LL subband. The LL frequency sub-band is selected, which covers low frequencies. It is robust against different filtering noises and geometric noises.

Below is an image of how this Discrete Wavelet Transform works to divide the image each time in one fourth the host image size. Each sub-band has (1/4)th of the size of original image. In the technique proposed, one of the sub-band is selected by applying DWT to the original image.

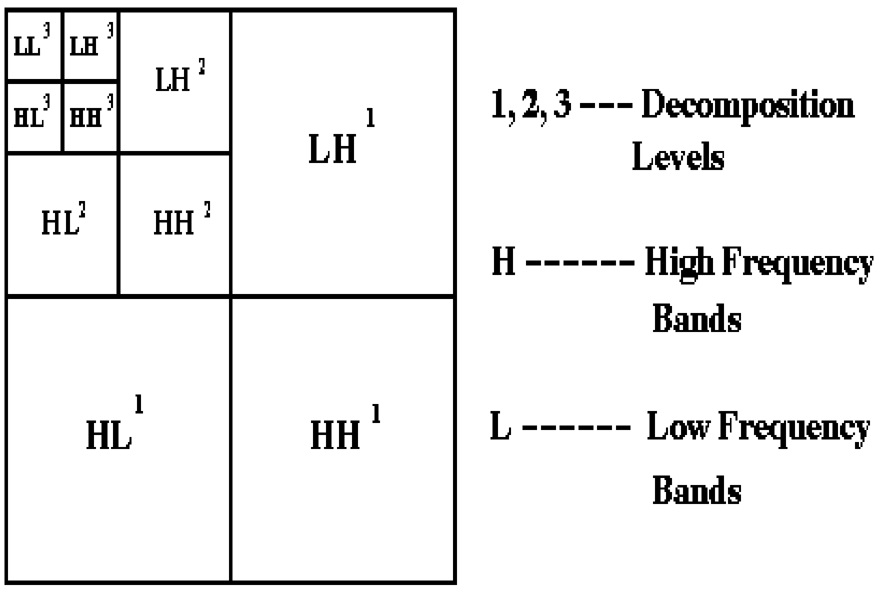


Fig 1

1.2 SINGULAR VALUE DECOMPOSITION

SVD is a numerical technique that is widely used because of its properties, such as good stability (e.g. applying an SVD to an image does not noticeably affect the appearance when a small interfering signal is added to the image). SVD is widely applicable in a lot of signal and image applications, such as noise reduction, image hiding, image compression and image watermarking. In image processing applications, image A is a matrix of n × n entries. Applying an SVD to A helps to extract the information of the image feature. An SVD decomposes the matrix into U, S and V matrices, where U and V describe the geometric properties of the image and S describes the luminance. These matrices can be defined as follows

$$\boldsymbol{A} = \boldsymbol{U} \times \boldsymbol{S} \times \boldsymbol{V}^{\mathrm{T}}$$

$$\boldsymbol{A} = \begin{bmatrix} u_{1,1}, \ \ldots, u_{1,n} \\ u_{2,1}, \ \ldots, u_{2,n} \\ \cdot \\ \cdot \\ u_{n,1}, \ \ldots, u_{n,n} \end{bmatrix} \begin{bmatrix} \sigma_{1,1}, 0, \ \ldots, 0 \\ 0, \sigma_{2,2}, \ \ldots, 0 \\ \cdot \\ \cdot \\ 0, 0, \ \ldots, \sigma_{n,n} \end{bmatrix} \begin{bmatrix} v_{1,1}, \ \ldots, v_{1,n} \\ v_{2,1}, \ \ldots, v_{2,n} \\ \cdot \\ \cdot \\ v_{n,1}, \ \ldots, v_{n,n} \end{bmatrix}^{\mathrm{T}} \tag{1.4}$$

U and V are n × n orthogonal matrices; $U^TU = I$, $V^TV = I$ and $S = diag(\sigma_{1,1}, \sigma_{2,2},\ldots, \sigma_{n,n})$ that includes non-negative singular values arranged in a descending order. These matrices can be rectangular or square. Many hybrid digital image watermarking schemes use SVD with other transforms watermark. A lot of them explore the singular values, S; to embed the watermark.

The LL subband we chose above in host image undergoes SVD transform. After this SVD transform the subband is divided into three matrices i.e U, S, V.

1.3 HUMAN VALUE SYSTEM CHARACTERSTICS

Incorporating HVS models into watermarking schemes assists in achieving the robustness and imperceptibility requirements. By utilising the characteristics of HVS to select the most suitable components to embed the watermark, no significant distortions are produced. The HVS characteristics of entropy and edge entropy have been employed to select the significant embedding regions, because they carry important information about the image. The entropy (average information) is used to measure the spatial correlation of neighboring pixels. The following mathematical formula is used to calculate the entropy as defined by Shannon for a set of n-elements

$$E_{\text{entropy}} = -\sum_{i=1}^{n} p_i \log(p_i) \qquad (1.5)$$

pi represents the occurrence probability of an event i with

$$0 \leq p \leq 1 \qquad (1.6)$$

and

$$\sum_{i=1}^{n} p_i = 1. \qquad (1.7)$$

This process does not capture the real pictorial information of the image/sub-image; rather, it only measures the entropy. The value depends only on the probability distribution of the intensity of the pixel and does not consider the co-occurrence of the pixel values. Accordingly, the edge entropy together with the entropy of each image block is considered to identify the suitable regions in the image for embedding the watermark. A minimum number of edge points of the host image should be modified during watermark embedding.

This process can be defined as follows-

$$E_{\text{edge entropy}} = \sum_{i=1}^{n} p_i \exp^{u_i} = \sum_{i=1}^{n} p_i \exp^{1-p_i} \qquad (1.8)$$

where $u_i = 1 - p_i$ (1.9)

indicates the ignorance or uncertainty of the pixel value. Many watermarking techniques that employ HVS are available.

1.4 FIREFLY ALGORITHM

The Firefly Algorithm(FA) was first developed by Yang (2008) at Cambridge University. This is a new swarm intelligence optimization technique and is inspired by flashing light of fireflies. Two basic functions of the flash light are to attract mating partners and to attract potential prey.

FA is based on the assumption that solution of an optimization problem can be perceived as fireflies whose ‘‘brightness’’ is proportional to the value of its objective function within a given problem space.

In the FA, there are three idealized rules:

(1) All fireflies are unisexual, so that one firefly will be attracted to other fireflies regardless of their sex.

(2) Attractiveness is proportional to their brightness, thus for any two flashing fireflies, the less brighter one will move towards the brighter one and,

(3) If there are no fireflies brighter than a particular firefly, it will move randomly.

In formulating the FA there are two important issues: – the variation of light intensity and formulation of the attractiveness. The attractiveness of a firefly is determined by its brightness which is proportional to the encoded objective function. For maximization, the brightness of a firefly at a particular location x is proportional to the objective function. However, the attractiveness b is relative, it will vary with the distance ri,j between the firefly i and firefly j. It also varies with the degree of light absorption by the medium (air). Yang (2008) used a Cartesian distance ri,j where i and j are two individual fireflies at location xi and xj respectively as given by Equation-

$$r_{i,j} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{c} (x_{i,k} - x_{j,k})^2} \quad (1.10)$$

where $x_{i,k}$ is the kth component of the spatial coordinate x_i of ith firefly.

For a 2-D case, $r_{i,j}$ is given by Equation

$$r_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (1.11)$$

The attractiveness b of a firefly is determined by using Equation.

$$\beta \leftarrow \beta_0 e^{-\gamma r_{ij}} \quad (1.12)$$

where β_0 is the attractiveness at $r_{i,j} = 0$ and c is the light absorption coefficient of the medium.

The movement of a firefly i is attracted to another more attractive (brighter) firefly j and is given by Equation.

$$x_i \leftarrow x_i + \beta_0 e^{-\gamma r_{i,j}}(x_j - x_i) + \alpha u_i \quad (1.13)$$

where the random walk parameter u_i is evaluated by Equation.

$$u_i = \left(\text{rand } 1 - \frac{1}{2}\right) \quad (1.14)$$

If there are no fireflies brighter than a particular firefly i with maximum objective value then i will move randomly according to the Equation.

$$x_{i^{max}} \leftarrow x_{i^{max}} + \alpha\, u_{i^{max}} \quad (1.15)$$

In this case the random walk parameter uimax is evaluated by Equation-

$$u_i^{max} = \left(\text{rand}2 - \frac{1}{2}\right) \tag{1.16}$$

where rand1 = U(0, 1) and rand2 = U(0,1) are random numbers obtained from uniform distribution. The brightness of the firefly is affected or determined by the objective function f(x).

Below we have an algorithm to explain Firefly algorithm for maximum optimization:

Define objective function f(x), x = $[x1, x2, . . . , xd]^T$
Generate initial population of fireflies x_p(p = 1,2,. . . ,n)
Define α, β_o maximum generation number (ML) and c

Output: The best solution x_i^{max} with the largest objective
function value

Begin

while (t < ML)

for p = 1: n all n fireflies
for q = 1: n all n fireflies
if $f(x_p) < f(x_q)$, Move firefly p towards q; end if
Attractiveness varies with distance r via exp [cr]
Evaluate new solutions and update objective function

end for q
end for p

Rank the fireflies and find the current global best x_p^{max}

end while
End

CHAPTER 2 PROPOSED WATERMARKING SCHEME

A robust hybrid digital image watermarking scheme based on DWT, SVD, Firefly Algorithm and HVS characteristics is presented in this work. The watermark embedding and extracting procedures, depicted in figures below, are presented in the subsequent subsections. Before listing the watermarking steps, we highlight two important points.

First, the scheme is a block-based scheme embedding the watermark in specified regions (blocks); therefore, the image is decomposed into (8 × 8) non-overlapping blocks. HVS characteristics are employed to select the desired blocks by calculating the entropy and edge entropy using equation as given in chapter 3, for each block. These two obtained values of each block are summed, and the resulting magnitude values are sorted in ascending order. It is desirable to modify the minimum number of edge points of the host image during the watermark embedding. Therefore, the blocks with the lowest magnitude values (called low informative blocks) are selected as the best regions to insert the watermark. The number of selected blocks is 1024, equal to the watermark size (32 × 32).

The second point is that the embedding process is achieved by extracting the algebraic properties of the image from the first column of the U vector, and the watermark bits are embedded by changing the relationship between the $U_{2,1}$ and $U_{3,1}$. Empirically, selecting $U_{2,1}$ and $U_{3,1}$ in the first column of U to embed a watermark bit achieves better results than Lai scheme, who employed $U_{3,1}$ and $U_{4,1}$ to embed the watermark.

The changing process in each block is based on examination of the binary watermark bit at the location of the block (as explained in the following algorithm).

Before going on the actual procedure which has been used in this thesis I would explain the basic skeleton of DWT-SVD which is a sub part of this process. Discrete Wavelet Transform and Singular Value Decomposition is a complete watermarking algorithm which is explained below. Later on we add Firefly algorithm and Human Value System characteristics in this procedure and improve our watermarking scheme.

We consider the host image I of size N x N and the watermark W of size m x m. The embedding scheme is given below:

<u>Step 1.</u> Apply 3 level DWT using HAAR filter on the host image I to obtain LL3 sub-band of size m x m

Step 2. Apply SVD on LL3 sub-band coefficients of the host image obtained in step1 by using Equation given below hence obtain S

$$[U,S,V]= SVD(LL3) \quad (2.1)$$

Step 3. Apply SVD on the watermark (W) using Equation given below and identify the singular values (S_w)

$$[U_w,S_w,V_w]= SVD(W) \quad (2.2)$$

Step 4. Embed S_w into S values using the formula given by Equation-

$$S`=S+\delta*S_w \quad (2.3)$$

Where δ is the single scaling factor which controls the tradeoff between imperceptibility and robustness of the proposed watermarking scheme.

Step 5. Compute the modified LL3 sub-band coefficients 427 using Equation given below:

$$LL3`= U*S`*V^T \quad (2.4)$$

Step 6. Apply inverse 3-level IDWT to obtain the signed image I`.

The embedded watermarks are recovered from signed images. The extraction is carried out by applying DWT–SVD combination again to signed images. The extracted watermark is denoted by W`. The watermark extraction algorithm is given below:

Step 7. Apply 3 level DWT using HAAR filter on the host image I and signed image I` to obtain LL3 and LL3` sub band coefficients of size m x m respectively for the two images.

Step 8. Apply SVD on the LL3 and LL30 sub-band coefficients using Equations given below to obtain the singular values S and S` respectively

$$[U, S,V] = SVD(LL3)$$

$$[U`,S,V`]= SVD(LL3`)$$

Step 9. Compute the singular values of the watermark using the formula given by Equation-

$$S_w=(S`-S)/\delta \quad (2.5)$$

Step 10. Recover the extracted watermark image using the formula given by Equation-

$$W`=U_W*S`_w*V^T_W \quad (2.6)$$

2.1 FIREFLY ALGORITHM PROCEDURE

HVS based watermarking scheme which makes use of threshold(T) by using a recently developed optimization tool known as FA. This FA based DWT–SVD watermarking scheme makes use of the embedding and extraction algorithm. Below is illustrated Firefly Algorithm which will be used later on -

<u>Step1</u>. Initialize n fireflies randomly, where each firefly is a row
vector of size m x m (equal to the size of watermark).

<u>Step2</u>. For each firefly i of the firefly population do as follows:

i. Run HVS algorithm that is, full embedding and extraction using HVS characteristics scheme explained later on.

ii. Extract the watermarks form the watermarked images using the algorithm given in subsequent chapters.

iii. Compute the PSNR between the original image I and signed image I\` and NC(W, W\`) values for attacked images.

iv. Calculate the objective value of firefly (x) using objective function given by Equation given below

$$\text{objective} = \text{PSNR} + \phi * [NC(W, W') + \sum_{i=1}^{T} NC(W, W_i')] \qquad (2.7)$$

where NC(W,W\`) is the normalized cross-correlation between the original watermark and extracted watermark from signed image, NC($W$,$W_i$\`) is the normalized cross-correlation between the original watermark and extracted watermarks.

<u>Step3</u>. Move these n fireflies according to the procedure given in chapter 1.4

<u>Step4</u>. Repeat Step2 and Step3 until the maximum number of generations (ML) is reached.

The PSNR is much larger as compared to the associated NC values therefore a weighting factor ϕ is used to balance out the influences caused by the two parameters.

2.2 HUMAN VALUE SYSTEM CHARACTERSTICS PROCEDURE

2.2.1 HVS Embedding procedure

- Divide the host image into (8 × 8) non-overlapping blocks.
- Sum the entropy and edge entropy for each block. Arrange the blocks in ascending order and select the first 1024 blocks that have the lowest values as the appropriate blocks in our proposed scheme for watermark embedding.
- Apply a DWT to the selected blocks; four sub-bands LL, LH, HL and HH are obtained for each block.
- Apply an SVD on the LL sub-band of each block.
- Examine the $U_{2,1}$ and $U_{3,1}$ entries of matrix U to embed the watermark by updating the relationship. Algorithm 1 states the steps to achieve this updating process.
- Perform an inverse SVD.
- Perform an inverse DWT to obtain the watermarked image. A threshold value is used to control the trade-off between the imperceptibility and the robustness.

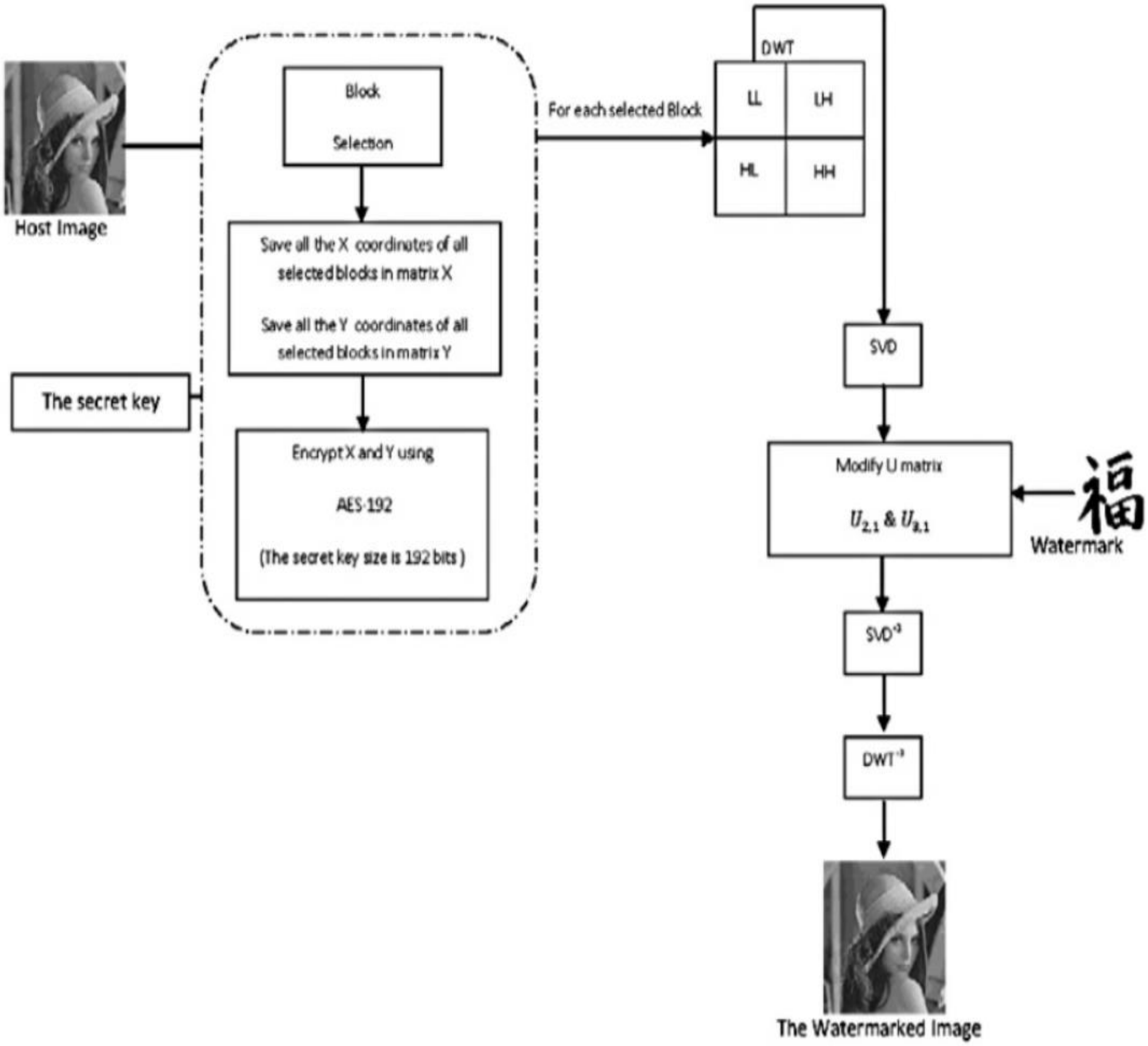

Host Image
Block
Selection
Save all the X coordinates of all selected blocks in matrix X
Save all the Y coordinates of all selected blocks in matrix Y
The secret key
Encrypt X and Y using
AES-192
(The secret key size is 192 bits)
For each selected Block
DWT
LL
LH
HL
HH
SVD
Modify U matrix
Watermark
The Watermarked Image

Fig 2

Input: Binary watermark logo and the host image (divided as (8×8) blocks)

Output: Watermarked image

Initialization;

Define threshold T ;

foreach *U matrix in the selected block* **do**

  Compute $\mu = (| U_{2,1} | + | U_{3,1} |)/2$;

  Check the binary watermark bit;

  while *Any of these conditions incorrect;*

  - $U_{2,1} \geq U_{3,1} and \mid (U_{2,1} - U_{3,1}) \mid > T;$

    when the binary watermark bit =1

  - $U_{2,1} < U_{3,1} and \mid (U_{2,1} - U_{3,1}) \mid > T;$

    when the binary watermark bit =0

  do

    Check the binary watermark bit;

    if *the binary watermark bit =1* **then**

      Modify $U_{2,1}$ and $U_{3,1}$ as follows;

      $U_{2,1} = \mu + T/2;$

      $U_{3,1} = \mu - T/2;$

    else

      Modify $U_{2,1}$ and $U_{3,1}$ as follows;

      $U_{2,1} = \mu - T/2;$

      $U_{3,1} = \mu + T/2;$

    end

  end

end

Fig 3

2.2.2 HVS Extraction procedure

- Decompose the watermarked image into non-overlapping blocks of 8 × 8 pixels.
- Apply a DWT to the all target blocks.
- Apply an SVD to the LL sub-band of each of these blocks.
- Extract the watermark bits by examining $U_{2,1}$ and $U_{3,1}$ of matrix U. If $U_{2,1}$ is larger than $U_{3,1}$, then the watermark bit = 1, otherwise the watermark bit = 0.

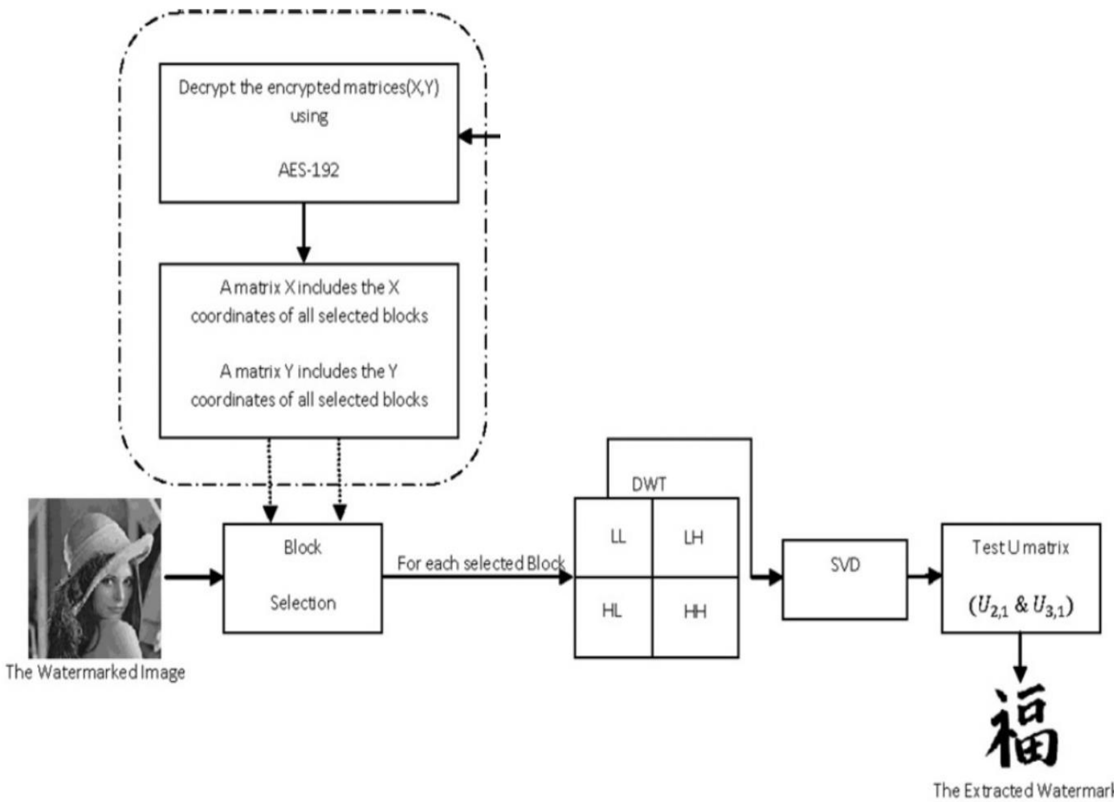


Fig 4

2.3 PROPOSED PROCEDURE

This following scheme has been performed with three host images and two watermark images.

- Divide the host image into (8 × 8) non-overlapping blocks. These 8x8 non-overlapping blocks have 64 rows and 64 columns that is, a total of 512x512 is the size of host image.

- Divide the watermark into 32x32 size. This is done so as to include 1024 watermarking bits which will be later on compared with each host image 8x8 block.

- Perform Firefly Algorithm as explained in chapter 2.1 and obtain 10 different values of threshold.

- Now we perform HVS scheme as explained in chapter 2.2

- According to these 10 different values of thresholds we obtain respective values of PSNR, correlation factor and fitness value.

- Find the minimum value of fitness value and its respective position.

- Now, for different instants of time we perform the above steps for 10 different times and accordingly compare the fitness value with minimum fitness value and update the minimum fitness value.

- Finally we get the best value of threshold for which embedding and extraction of watermark is efficient. Also we get corresponding value of correlation factor and PSNR value.

CHAPTER 3 RESULTS AND DISCUSSIONS

Several experiments are conducted to evaluate the validity and the performance of the proposed scheme. 512 × 512 grey-level image (pepper) is used as host image. 32 × 32 binary image that are used as watermark logo in the experiment. In this paper, the performance of the proposed scheme and the other schemes are compared and investigated in terms of imperceptibility and robustness. Many criteria are suggested to estimate the imperceptibility and robustness. The most widely used criteria are the PSNR and the normalised cross-correlation (NC). The PSNR is used to estimate the imperceptibility. Imperceptibility is a term used to evaluate the similarity between the host image and the watermarked image and can be defined as follows :

$$\mathrm{PSNR} = 10\log_{10}\left[\frac{\max(x(i,j))^2}{\mathrm{MSE}}\right] \tag{3.1}$$

where i, j are the coordinates of each pixel of the host image x and the mean-square error (MSE) between the host image x and the watermarked image y is defined as follows :

$$\mathrm{MSE} = \frac{1}{m*n}\sum_{i=1}^{m}\sum_{j=1}^{n}[x(i,j) - y(i,j)]^2 \tag{3.2}$$

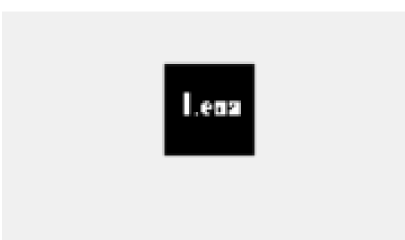
When good imperceptibility is achieved, the watermarked image appears nearly identical to the host image; in other words, we can say that the host image is not affected by the embedding process.

Correlation is the mathematical quantity which tells how robust the watermarking procedure is. The extracted watermark is compared with the original watermark. Value closed to 1 is expected for a robust procedure

$$NC(W, W') = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} [W(i,j) \cdot W'(i,j)]}{\sum_{i=1}^{m} \sum_{j=1}^{n} [W(i,j)]^2} \qquad (3.3)$$

In this project I have done a detail analysis for imperceptibilty and correlation value. Firstly the results were analysed for a procedure which did not included firefly algorithm. Two host images were analysed with two different watermark images. The results were found for three different values of threshold used in HVS algorithm. Below are the results for procedure which did not included firefly algorithm and included DWT-SVD along with HVS.

Host Image 1



Watermark 1

For this combination of host image and watermark we performed embedding and extraction, for three values of threshold, which gave us following results -

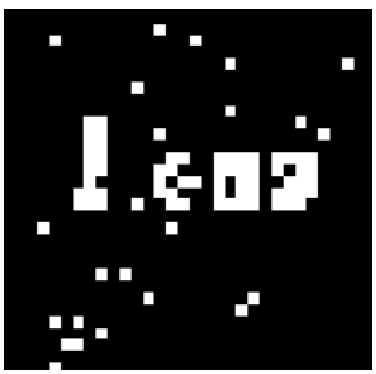
Threshold 1– 0.005 PSNR—58.61 NC- 0.80434
 Embedded image
 Extracted image

Table 3.1

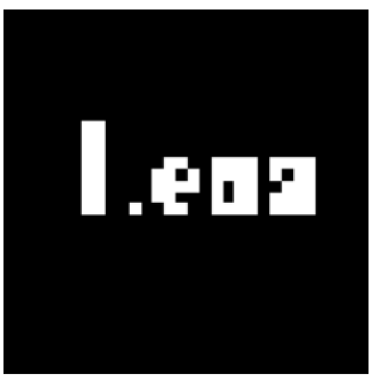
Threshold 2– 0.05 PSNR— 40.4615 NC- 1
 Embedded image
 Extracted image

Table 3.2

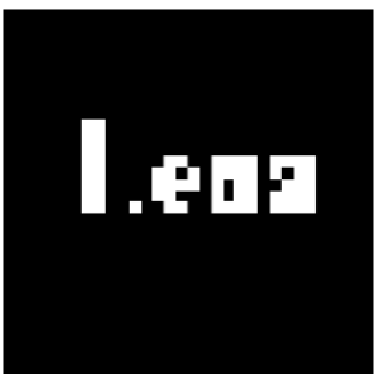
Threshold 3– 0.1 PSNR— 34.4694 NC- 1
 Embedded image
 Extracted image

Table 3.3

Host Image 1

Watermark 2

For this combination of host image and watermark we performed embedding and extraction, for three values of threshold, which gave us following results -

Threshold 1– 0.005 PSNR—58.5482 NC- 0.86334
 Embedded image
 Extracted image

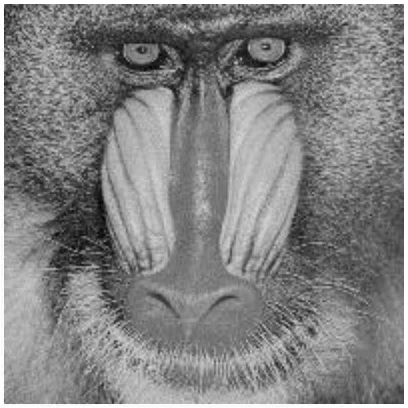
Table 3.4

Threshold 2– 0.05 PSNR—40.4685 NC- 1
 Embedded image
 Extracted image

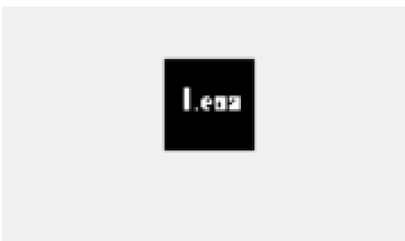
Table 3.5

Threshold 3– 0.1 PSNR—34.4804 NC- 1
 Embedded image
 Extracted image

Table 3.6



Host image 2



Watermark 1

For this combination of host image and watermark we performed embedding and extraction, for three values of threshold, which gave us following results -

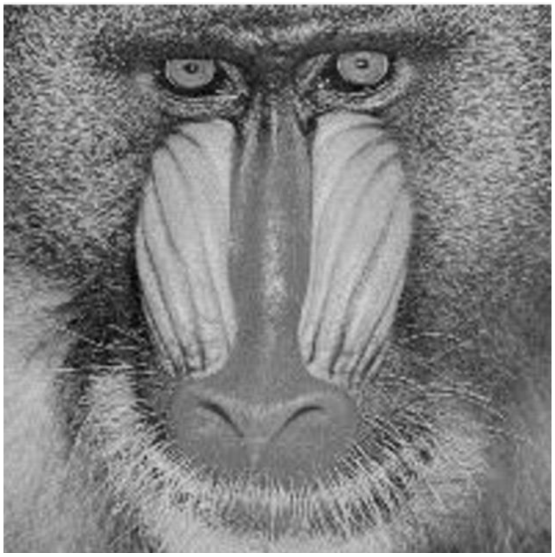
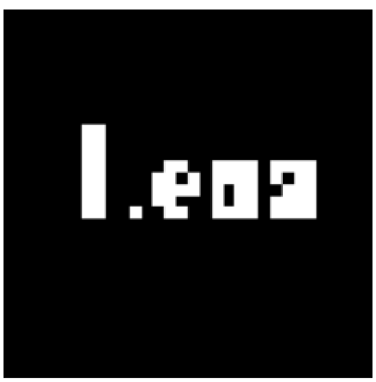
Threshold 1– 0.005 PSNR—51.46 NC- 1
 Embedded image
 Extracted image

Table 3.7

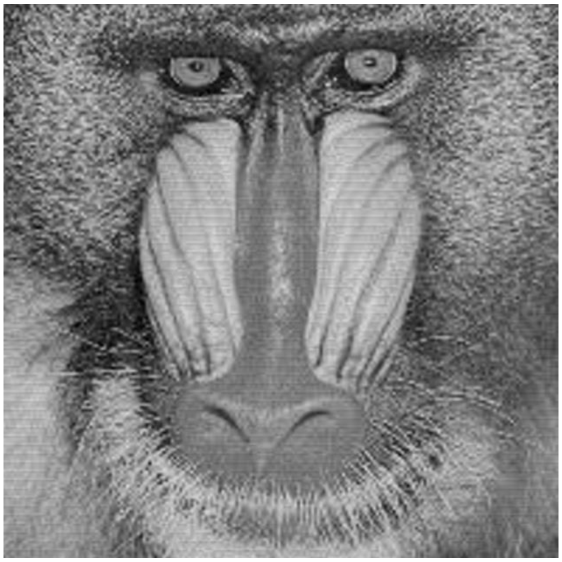
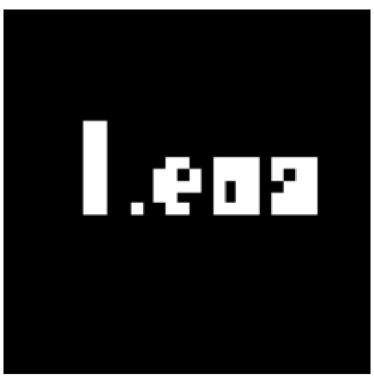
Threshold 2– 0.05 PSNR—39.452 NC- 1
 Embedded image
 Extracted image

Table 3.8

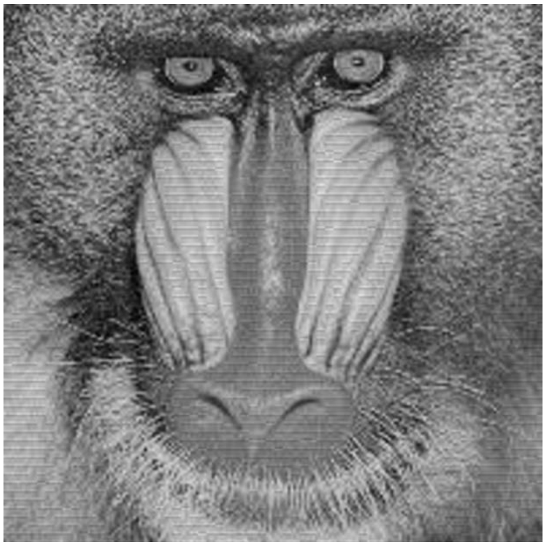
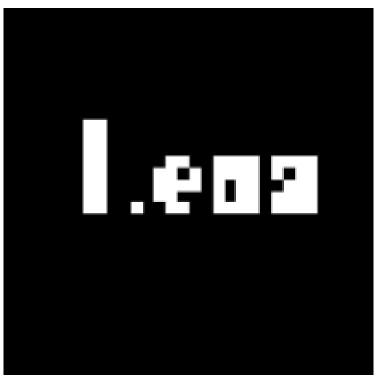
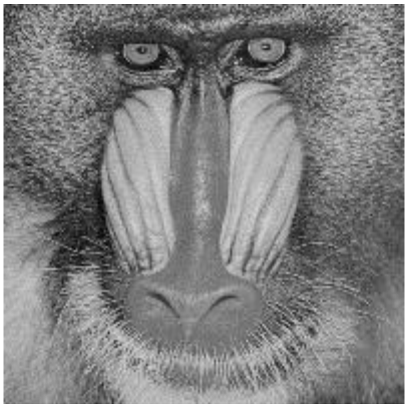
Threshold 3– 0.1 PSNR—33.6981 NC- 1
 Embedded image
 Extracted image

Table 3.9



Host image 2

Watermark 2

For this combination of host image and watermark we performed embedding and extraction, for three values of threshold, which gave us following results -

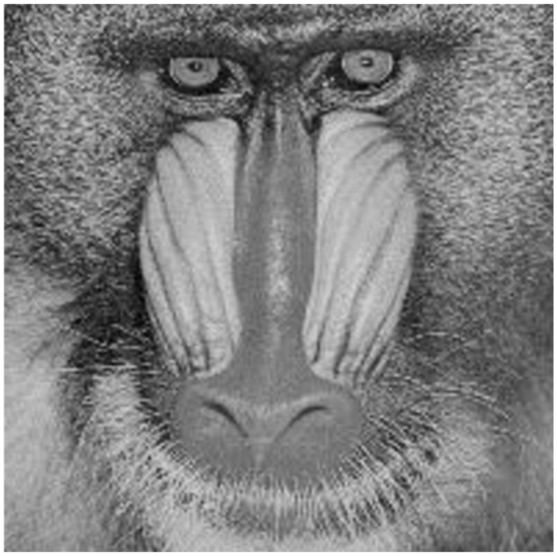
Threshold 1– 0.005 PSNR—51.416 NC- 0.99598
 Embedded image
 Extracted image

Table 3.10

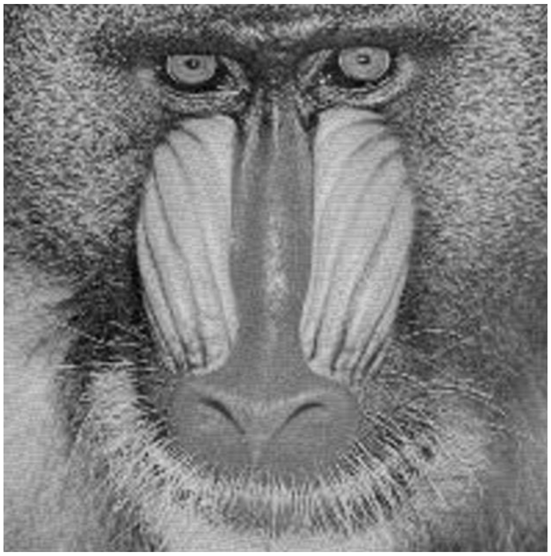
Threshold 2– 0.05 PSNR— 33.6931 NC- 1
 Embedded image
 Extracted image

Table 3.11

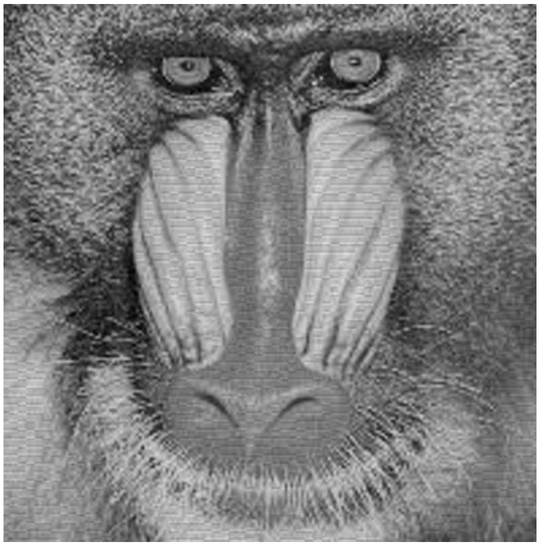
Threshold 3– 0.1 PSNR—33.6931 NC- 1
 Embedded image
 Extracted image

Table 3.12

Above results as stated were based on the algorithm HVS without firefly algorithm.

Now, we perform this HVS algorithm which included firefly algorithm as well. Since we performed firefly algorithm here in this case for 10 iterations, I have stated the results for each iteration below.

Host Image 1

Watermark 1

For this combination of host image and watermark we performed embedding and extraction, for 10 iterations of firefly algorithm, which gave us following results –

Iteration 1	objective value-1.0234	best threshold value-0.0385
Iteration 2	objective value-1.0223	best threshold value-0.0297
Iteration 3	objective value-1.0208	best threshold value-0.0206
Iteration 4	objective value-1.0207	best threshold value-0.0199
Iteration 5	objective value-1.0205	best threshold value-0.0189
Iteration 6	objective value-1.0205	best threshold value-0.0189
Iteration 7	objective value-1.0205	best threshold value-0.0189
Iteration 8	objective value-1.0205	best threshold value-0.0189
Iteration 9	objective value-1.0205	best threshold value-0.0189
Iteration 10	objective value-1.0205	best threshold value-0.0189
Final best threshold- 0.018935		
PSNR- 48.6828		
NC- 1		

Table 3.13

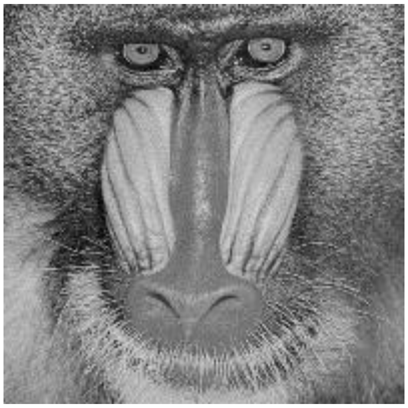
Host Image 1

Watermark 2

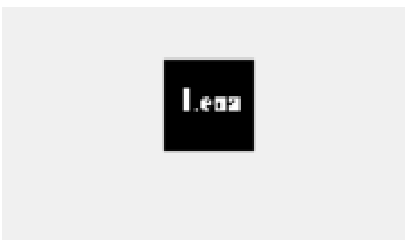
For this combination of host image and watermark we performed embedding and extraction, for 10 iterations of firefly algorithm, which gave us following results –

Iteration 1	objective value-1.0253	best threshold value-0.0555
Iteration 2	objective value-1.0241	best threshold value-0.0443
Iteration 3	objective value-1.0235	best threshold value-0.0393
Iteration 4	objective value-1.0212	best threshold value-0.0232
Iteration 5	objective value-1.0202	best threshold value-0.0176
Iteration 6	objective value-1.0202	best threshold value-0.0175
Iteration 7	objective value-1.0202	best threshold value-0.0174
Iteration 8	objective value-1.0202	best threshold value-0.0174
Iteration 9	objective value-1.0202	best threshold value-0.0174
Iteration 10	objective value-1.0202	best threshold value-0.0174
Final best threshold- 0.0017354		
PSNR- 49.5755		
NC- 1		

Table 3.14



Host image 2

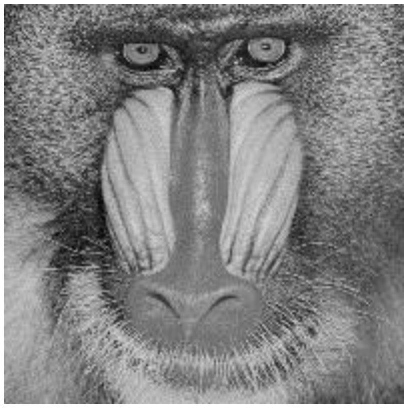


Watermark 1

For this combination of host image and watermark we performed embedding and extraction, for 10 iterations of firefly algorithm, which gave us following results –

Iteration 1	objective value-1.0201	best threshold value-0.0097
Iteration 2	objective value-1.0196	best threshold value-0.0061
Iteration 3	objective value-1.0195	best threshold value-0.0057
Iteration 4	objective value-1.0195	best threshold value-0.0057
Iteration 5	objective value-1.0195	best threshold value-0.0057
Iteration 6	objective value-1.0195	best threshold value-0.0057
Iteration 7	objective value-1.0195	best threshold value-0.0057
Iteration 8	objective value-1.0195	best threshold value-0.0057
Iteration 9	objective value-1.0195	best threshold value-0.0057
Iteration 10	objective value-1.0195	best threshold value-0.0057
Final best threshold- 0.0057288		
PSNR- 51.2656		
NC- 1		

Table 3.15



Host image 2

Watermark 2

For this combination of host image and watermark we performed embedding and extraction, for 10 iterations of firefly algorithm, which gave us following results –

Iteration 1	objective value-1.0194	best threshold value-0.0053
Iteration 2	objective value-1.0194	best threshold value-0.0053
Iteration 3	objective value-1.0194	best threshold value-0.0053
Iteration 4	objective value-1.0194	best threshold value-0.0053
Iteration 5	objective value-1.0194	best threshold value-0.0053
Iteration 6	objective value-1.0194	best threshold value-0.0051
Iteration 7	objective value-1.0194	best threshold value-0.0051
Iteration 8	objective value-1.0194	best threshold value-0.0051
Iteration 9	objective value-1.0194	best threshold value-0.0051
Iteration 10	objective value-1.0194	best threshold value-0.0051
Final best threshold- 0.0051249		
PSNR- 51.6118		
NC- 1		

Table 3.16

CHAPTER 4 CONCLUSION

In this thesis, a DWT–SVD block-based image watermarking scheme is presented. Several characteristics were employed to achieve high-level grades for the watermarking requirements and maintain the trade-off between them. Initially, blocking was used to divide the image into blocks. Then, only a portion of these blocks were selected to include the watermark; this selection ensured that the embedding process would affect specific regions of the image. The HVS characteristics of entropy and edge entropy were used to select the low informative blocks as the best embedding regions. The scheme employed the properties of a DWT and SVD. These methods aimed to provide high robustness by selecting the most robust regions with an emphasis on maintaining non-noticeable distortions, in other words, to maintain imperceptibility.

The proposed scheme outperformed all similar previous schemes and achieved the highest imperceptibility. In terms of robustness, good resiliency was observed against all types of image processing attacks and several types of geometrical attacks. Unlike most SVD-based watermarking schemes that embed the watermark into the singular values S, in this proposed scheme, the watermark was embedded by examining elements in U. This process avoided the false positive problem and provided a reliable SVD-based scheme.

From part 1 of the project that is, HVS algorithm without firefly iterations, we observe that on increasing the threshold, that we use in HVS algorithm, PSNR value decreases. This decrease in PSNR value indicates that the, the watermarked image appears more dissimilar to the host image. Host image gets affected after watermark embedding. Also on increasing the value of threshold Correlation value increases. This increase in numerical correlation (NC) value indicates that extracted watermark is more similar to the original watermark image.

This tradeoff between PSNR and NC values makes this procedure or we can say the first part of our project a little less reliable and we needed a new and a more robust algorithm to tackle this tradeoff. This made me add firefly algorithm in this procedure. Now this firefly algorithm iterates the above algorithm for n no. of times (here 10). Each time it gets a best value of threshold for which tradeoff between PSNR and NC is minimum. Now for each iteration we compare the results with the previous best and update our values. Observing the above results showed us that this algorithm outperforms the previous procedure. Including firefly algorithm in previous proposed algorithm made our results more robust and gave us satisfactory results.

CHAPTER 5 REFERENCES

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