A SVD and Modified Firefly Optimization Based Robust Digital Image Watermarking Technique

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Abstract—Digital Watermarking is a technology, to facilitate the authentication, copyright protection and Security of digital media. The objective of developing a robust watermarking technique is to incorporate the maximum possible robustness without compromising with the transparency. Singular Value Decomposition (SVD) using Firefly Algorithm provides this objective of an optimal robust watermarking technique. Multiple scaling factors are used to embed the watermark image into the host by multiplying these scaling factors with the Singular Values (SV) of the host image. Firefly Algorithm is used to optimize the modified host image to achieve the highest possible robustness and transparency. This approach can significantly increase the quality of watermarked image and provide more robustness to the embedded watermark against various attacks such as noise, geometric attacks, filtering attacks etc.

Keywords—FA, MSF’s, MFA Singular Values, Robustness, PSNR.

I. INTRODUCTION

The development and growth of the internet has created new challenges to protect digital data from piracy [35]. Digital watermarking technique provides a superior and robust solution for ownership problem. It becomes much important to maintain the copyright of the digital data which is a form of intellectual properties. Digital watermarking technique embeds copyright information or watermark in to original host image. The embedded information should be imperceptible. These watermarks are difficult to remove by altering or damaging the original host image. The digital image watermarking is a process of embedding watermark in to audio signal to show authenticity and ownership proof. The watermark is permanently embedded in to the digital image and embedding should not degrade the quality of digital image.

The term digital watermarking [1], first came into existence in 1993 when Tirkel presented watermarking techniques to hide the watermark data in the image. Due to the rapid growth in computer and communication industry, cost effective and popular digital recording and storage devices made it possible to copy, and have unauthorized access of the original digital multimedia contents. Digital watermarking has evolved as a solution to these problems of copyright protection, authorization, illegal modifications and distributes the data in an effortless ways without having legal permission of the author. Digital watermarking provides a way to imperceptibly embed digital signal or information into the digital multimedia content. The watermarking is done by embedding a watermark signal into the host data for the purpose of copyright protection, access control, Broadcast monitoring etc. A watermark can be a signal, a tag or a label. The embedding process should be in such a way that the watermark image can be extracted from the watermarked image any perceptible loss of quality of the host image. Watermarking techniques can be classified according to domain, visibility and permanency.

According to domain, watermarking is classified as spatial domain and transform domain [2]. In spatial domain, watermark is embedded directly into the pixel value of the original image. In transform domain, the watermark is embedded by modulating the coefficients in a transform such as discrete cosine transforms (DCT), discrete Fourier transform (DFT), discrete wavelet transform (DWT). The transform domain provides more robust and secure watermarking which has attracted many researchers to work in this domain. The main advantage of working in the transform domain is the fact that when the image is inverse transformed the watermark is distributed irregularly over the host image which makes the attacker difficult to modify and copy the host image.

The singular value decomposition (SVD) [3] is a kind of transform domain technique. SVD divides a N x N matrix into three matrices:

\[ A = U S V^T \]

where S is an N x N diagonal matrix, U and V^T are N x N orthogonal matrices, whose column vectors are \( u_i \)'s and \( v_i \)'s, respectively. The important property of the singular values is that any modifications done on these values do not show any change in the respective matrix. Based on this property, the singular values are modified with the singular values of the watermark image. An N x N image can have N singular values that reveal various tolerances to modifications [4].

As there is no idea of the sensitivity of the image to various scaling factors. Therefore, an optimization algorithm [5] is needed to obtain optimum scaling factors [6] that can give highest possible robustness and transparency. For this purpose, firefly algorithm [7] is used, which is a metaheuristic algorithm for optimization problems. The algorithm is based upon the flashing behavior of fireflies. Randomly generated solutions are treated as fireflies. It has two basic components- brightness and attractiveness. Attractiveness is directly proportional to the brightness but decreases with distance. Brightness is computed on the basis of an objective function. Thus the basic rule is that the brighter firefly will attract the more fireflies and if no such brighter firefly is present then the firefly will move in random
direction [8]. This random movement may decrease the brightness depending on direction. As a consequence the overall performance of the algorithm is decreased in that particular iteration. Now if we change this property of random movement by moving in a particular direction in which its brightness increases then it will not degrades the performance in that iteration. If such direction does not exist then the firefly will remain at its current position. Hence the modified singular values (SV) by the watermark values will be more robust and secure. Also it will enhance the overall watermarking scheme and decreases the trade-off between robustness and transparency and less vulnerable to various attacks. The paper is organized in the following manner: Section II elaborates the description of Singular Value Decomposition (SVD); Section III is for Modified Firefly algorithm. The proposed model is being given in Section IV. Section V gives the conclusion of the paper and the proposed model.

II. SINGULAR VALUE DECOMPOSITION (SVD)

Singular value decomposition (SVD) comes under the category of transform domain technique of digital image watermarking, which is akin theory of diagonalizing of symmetric matrix in linear algebra. SVD decomposes a matrix into three sub-parts: U, S and V. U and V are the orthogonal matrices while S is the diagonal matrix. These diagonal elements are called the singular values of the corresponding matrix. This decomposition can be illustrated as:

\[ A = U S V^T \]  

Where \( A \) is a matrix of dimension \( m \times n \). \( U \) is made up of the eigen vectors of \( A A^T \) and is called left singular vector. \( V \) is formed by the orthogonal vectors of \( A^T A \) and is called right singular vector. \( S \) contains the square roots of either \( U \) or \( V \) in descending order in its diagonal being a diagonal matrix. Let the rank of the matrix \( A \) be \( r \) (\( r \leq n \)), then the diagonal elements of \( S \) will follow the following relation:

\[ \alpha_1 \geq \alpha_2 \geq \cdots \geq \alpha_r > \alpha_{r+1} = \alpha_{r+2} = \cdots = \alpha_n = 0 \]  

Now can be derived as:

\[ A = \sum_{i=1}^{r} \alpha_i u_i v_i^T \]  

Where \( \alpha_i \) is the diagonal element of matrix \( S \) at \( i^{th} \) position.

The singular values gives the luminance of the image at each \( i^{th} \) position, whereas singular vectors gives the geometrical property. The most important property of SVD is that if any changes are applied to the singular values then will be no significant changes seen on the given matrix. Using this property the watermark image is modified by applying change in its singular values and embedded into the singular values of the host image without getting any distortions and any perpetual change.

A. Properties of SVD:

1. Singular values preserve the energy as well as prevent the image from attacks.
2. The matrix in SVD can be variable. It need not be always scalar.
3. The singular values \( \alpha_i \) are unique in the matrix \( S \).
4. The rank of the matrix is given by the the non-zero elements in the diagonal matrix, \( S \).

III. MODIFIED FIREFLY ALGORITHM

Firefly algorithm [7] is a metaheuristic algorithm for optimization problems. The algorithm is based upon the flashing behaviour of fireflies. Randomly generated solutions are treated as fireflies. It has two basic components- brightness and attractiveness. Attractiveness is directly proportional to the brightness but decreases with distance. Brightness is computed on the basis of an objective function. Thus the basic rule is that the brighter firefly will attract the more fireflies and if no such brighter firefly is present then the firefly will move in random direction [8].

In firefly algorithm, the brightest firefly is a firefly with current global best solution and it will move in random direction if no brighter firefly is found. This random movement may decrease the brightness depending on direction. As a consequence the overall performance of the algorithm is decreased in that particular iteration.

It is proved in elementary physics that intensity of light is inversely proportional to the square of the distance from the source to the object. Therefore we can formulate the light intensity, \( I \) in terms of distance, \( r \) as follows:

\[ I(r) = I_0 e^{-\lambda r} \]  

Where \( \lambda \) is the light absorption coefficient and \( I_0 \) is the light intensity at the source point.

For the sake of simplicity this can be written as:

\[ I(r) = \frac{I_0}{1 + kr^2} \]  

Likewise, attractiveness can also be derived:

\[ A(r) = \frac{A_0}{1 + kr^2} \]  

Where \( A_0 \) is the attractiveness at \( r = 0 \).

Steps of implementation of firefly are as follows:

1. Generate a solution set randomly.
2. Find the intensity for each of the generated firefly.
3. The movement of the firefly will be done in the direction of brighter firefly and if no such direction is found then the firefly will move in random direction.
4. Now, solution is updated.
5. End the process if termination condition holds true; else go back to step 2.
The main drawback of the FA is that if there is no such direction in which the brightness increases, it moves the firefly randomly, and this random movement may sometimes cause degradation in the performance of FA because brightness may reduce in some random direction. Now if we change this property of random movement by moving in a particular direction in which its brightness increases then it will not degrade the performance in that iteration. If such direction does not exist then the firefly will remain at its current position. This is the Modified Firefly algorithm.

The movement of the firefly will be according to the following relation:

\[ d = d + \alpha \mu \]  

Where, \( d \) is the location of the firefly, \( \mu \) is the chosen direction in which movement is to be done and \( \alpha \) is the step length selected randomly.

Attractiveness of a firefly can be calculated as:

\[ A_0 = \frac{I_0'}{I_0} \]  

Where \( A_0 \) is the attractiveness of a firefly say, \( i \) at \( r = 0 \), \( I_0' \) is the intensity of firefly \( i \) and \( I_0 \) is the intensity of firefly \( j \).

IV. PROPOSED WATERMARKING MODEL

Let the host image be \( H \) and watermark image be \( W \) of size \( N \times N \), then the following are the steps of the algorithm by which this model works:

Step 1: \( n \) no. of fireflies are generated randomly using MFA.

Where \( n = [\rho_1, \rho_2, \rho_3, \ldots, \rho_n] \)

Step 2: for each generated firefly, \( \rho \), perform the following operations:

1. Apply embedding process discussed in the previous section on the host image and watermark image.
2. Induce \( r \) number of attacks on the watermarked image \( (H_w) \); hence attacked images \( (H_w') \) are generated.
3. Extract the watermark from the host image and attacked images using extraction algorithm described above.
4. Compute the PSNR values of the host image \( (H) \), watermarked image \( (H_w) \) and attacked images \( (H_w') \).
5. Compute the objective function \( (O) \) of the firefly\( (\rho) \) using the objective function below:

\[ O = \text{PSNR}(H,H_w) + \text{PSNR}(W,H_w') + \sum_{i=1}^{r} \text{PSNR}(W,H_w') \]  

Where \( \text{PSNR}(W,H_w') \) is the peak signal to noise ratio between watermark image and the watermark extracted from the attacked image.

Step 3: Now take the maximum value of the objective function to choose the multiple scaling factor which in turn optimizes the trade-off between the imperceptibility and robustness of the watermarking procedure.

V. IMPLEMENTATION RESULTS

The implementation is carried out on the MATLAB platform with 6 host images as shown in the fig 1. Fig. 2 represents the recovered watermark image infinity.
Robust watermarking scheme can provide better authentication and security of the digital images. In this rapid growing era of technology there are many tools available which can easily modify or extract the watermark from an image, hence it is a necessary thing to have more robust watermarking scheme which can witheld these attacks and forgeries.

This is a new optimal method of robust image watermarking based on SVD using Modified Firefly Algorithm. Modified Firefly Algorithm is used to employ optimize function that was defined by two conflicting requirements of watermarking i.e. visibility and robustness. The watermark image is embedded into the host image by modifying the singular values of the image. To achieve maximum robustness without losing transparency, modifications are to be done using multiple scaling factors obtained by Modified Firefly Algorithm.

REFERENCES