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Firefly Algorithm for Optimization of Scaling Factors During Embedding of Manifold Medical Information: An Application in Ophthalmology Imaging

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Augmented influence of globalization in the medical domain is quite noticeable and is very much evident from the modern medical approaches. Exchanging medical information using communication technologies to provide health care services for mutual availability of therapeutic case studies amongst various diagnostic centers or hospitals is a very common practice. In this present work, a novel approach is proposed to design a robust biomedical content authentication system by embedding multiple logo of the hospital or multiple electronic patient record (EPR) within the retinal image by means of combined discrete wavelet transformation—discrete cosine transformation—singular value decomposition (DWT-DCT-SVD) based approach of watermarking teamed with firefly algorithm (FA). One of the modern nature-inspired meta-heuristic algorithms required for optimization is firefly algorithm. This algorithm is used to find the best possible scaling factors for embedding. It is evident from the results that the proposed method can prove to be an accurate authentication system for information exchange along with high level of robustness, imperceptibility, and payload.

Keywords: Discrete Wavelet Transformation (DWT), Discrete Cosine Transformation (DCT), Watermarking, Electronic Patient Record (EPR), Firefly Algorithm (FA), Singular Value Decomposition (SVD).

1. INTRODUCTION

Rapid growth of digitization and globalization has influenced the medical field immensely. Globally, all doctors and medical practitioners are now accustomed with exchange of medical data via wireless media. This sharing of medical information is for mutual availability of therapeutic case studies. Various hospitals and diagnostic centers across the globe exchange medical information among themselves to improve diagnostic results. With the rise in use of internet, multimedia security and digital rights management are becoming important issues. Watermarking is a method to protect the intellectual property rights. It involves embedding of some information as watermark within an original multimedia object and claims the original object after extraction of the watermark.

In other words, it can be said that watermark[1–4] is actually an ownership data which is embedded within an object, and later, after extraction, proves the rights on the object. Various watermarking techniques provide a scope for authentication of hospital logo or hiding patient information (Electronic Patient Record). Electronic Patient Record (EPR) is a concept which is an organized compilation of information pertaining to health issues of patients, stored and transmitted electronically. EPR is a documentation of health related information, such as: Medical history, Medication, Allergic susceptibilities, Laboratory test reports, Immunization history and present status, Radiology images, Demographics, Vital signs, Personal data like age, weight, billing information etc.

This data is stored in digital format. EPR can be exchanged across various health care centres or hospitals worldwide by way of network-connected, enterprise-wide information systems and

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other information networks. Sharing information over the network can be harmful or unsafe; therefore, the concept of data hiding in EPR justifies its role in safeguarding the data.

In literature, a number of studies are present based on biomedical content authentication using watermarking technique. A method for optimization of watermarking performances by using error correcting codes and repetition was proposed[5] by Zinger et al. in 2001. Their paper reported various ways of applying error correction codes, repetition and some combinations of two different capacities of a fixed image for different error rates of the watermarking channels. This method helps in obtaining optimal selection for a given length of signature. In 2002, Sebe et al. presented[6] a new approach in authentication of images and multilevel access to precision-critical watermarked images by applying invertible spread-spectrum watermarking technique. Invertible spread-spectrum watermarking technique is introduced in this work, which can be implemented for image authentication in any lossless format (i.e., to establish their reliability). In 2003, Malvar et al. developed[7] an original modulation technique for robust watermarking by enhancing the spread spectrum. In 2004, Xuan et al. suggested[8] a new wavelet spread spectrum based reversible data hiding technique. Optimization in image watermarking by employing genetic algorithms was proposed[9] by Kumsawat et al. in December 2005. Spread spectrum image-watermarking algorithm using Discrete Multiwavelet Transform was discussed in this paper. Planitz et al. (2006) presented[10] a paper on block-based medical image watermarking technique using a perceptual similarity metric for content verification, improving data security, and numerical image reliability. In 2006 itself, Xu et al. proposed[11] a CDMA spread spectrum based (using orthogonal gold sequences) digital image watermarking algorithm where multiple watermarks are convolutionally encoded and block interleaved. The CDMA encoded wavelets are embedded in the wavelet sub-bands. In 2007, Ping et al. proposed[12] a method for watermarking of medical images by having two dissimilar domain schemes. The two domain schemes are: (1) circular watermarking and (2) RSA encryption and decryption with feature-based watermarking. In 2010, implementation of digital image watermarking based on particle swarm optimization (PSO) was reported[13] by Tao et al. In 2011, Kumar et al. proposed[14] a method of DWT based high capacity spread-spectrum watermarking technique for applications in telemedicine. In the same year, Ramly et al. presented[15] a paper on medical image watermarking using SVM-SS. In digital image watermarking, ooptimization of fidelity by implementing a new genetic algorithm was introduced[16] by Venkatesan et al. in the year 2012.

This paper proposes an original support vector machine cum spread spectrum (SVM-SS) watermarking model for watermarking medical images. In this work, the medical images are classified into three key stages, namely,

(1) Region of Interest (ROI)
(2) Region of Non-Interest (RONI); and
(3) Embedding patients' data and other relevant information in the image.

Finally, it is followed by extraction of information from the watermark images. In 2012 Seema et al. presented[17] a paper on secure watermarking technique in medical images by means of no-reference quality metrics. In 2013 Kaur et al. published[18] a work on medical image watermarking technique for embedding binary EPR followed by its quality assessment using no-reference metrics. In this work, DWT and DCT are jointly used for the embedding process. In 2013, Dey et al. proposed a method of hospital logo watermarking into ECG signal.[19] In this work, cuckoo search (CS) is used to optimize the scaling factors of watermark embedding. The main limitations of all these techniques stated above, are payload and robustness, which can be further improved. Apart from these, in most of the cases, the watermark image is binary image. To our knowledge, no work has yet been reported which can hide any watermark irrespective of binary or gray in an optimized way. Information required for detection of diseases is conveyed through medical images. Therefore, any kind of misrepresentation can result in flawed diagnosis. However, for authenticity and security of data, a small amount of distortion can be ignored. Hence, achieving a watermarking technique with an insignificant amount of distortion in bio-medical information is an exigent task.

In this current work, a well-established joint DWT-DCT-SVD[20, 21] based watermarking techniques is used to embed multiple watermarks within a gray retinal image. Depending upon the texture information and the image size, the watermarking embedding factors vary from one cover image to another. To optimize the level of robustness and perceptibility of the watermarking technique, selection of an optimum set of embedding factors is very essential. The watermarked image of the individual is then transmitted through a communication channel. The optimal scaling factors are sent through some secret communication channel. Then, in the recipients end, the gray hospital logo and EPRs are extracted from the watermarked image. The size of the watermark is not required to be sent to the recipient's end explicitly as the watermark size is the same as the watermarked image.

The current paper comprises of the following sections: Section 2 provides a brief introduction to watermarking and authentication, and the brief introduction of firefly algorithm (FA).[22–24] Section 3 presents a detailed account of the proposed method. Section 4 encompasses the main results and discussions. Finally, Section 5 brings out the conclusion of our proposed work.

2. DWT-DCT-SVD BASED WATERMARKING AND FIREFLY ALGORITHM

In this study, a combination of DWT, DCT and SVD along with a well known meta-heuristic algorithm of recent times, namely, firefly algorithm (FA) has been applied to embed multiple medical data within a biomedical image in an optimized way.

DWT: A multi-resolution decomposition process in respect to signal expansion is described by the discrete wavelet transform. Decomposition takes place into a set of wavelet basis functions. Excellent space frequency localization is the characteristic feature of discrete wavelet transformation (DWT).[25, 26] Filter banks, which are composed of filters to separate a signal into a number of frequency bands, are used by DWT to build up multiresolution time-frequency plane. In each dimension, DWT application on 2D images corresponds to 2D filter image processing. There are 4 non-overlapping multi-resolution sub-bands, namely,

(i) LL_1 (approximation coefficients),
(ii) LH_1 (vertical details),

(iii) HL_1 (horizontal details) and
(iv) HH_1 (diagonal details).

Filters segment the loaded image into these sub-bands. The aim of this segmentation is to achieve a final level "N." In order to attain the next coarser scale of wavelet coefficients, sub-band (LL_1) is again processed. The process is continued until the final level "N" is achieved. Here $3N+1$ sub-bands comprising of the multi-resolution sub-bands, LL_X and LH_X, HL_X and HH_X are obtained. Here, "X" ranges from 1 until "N." Conventionally, the LL_X sub-bands stores the maximum portion of the image energy. Haar wavelet is the simplest and easiest orthogonal wavelet transform. Haar wavelet is not differentiable as it is discontinuous and this feature proves to be beneficial for analysis of signals with sudden transitions. The following equation illustrates the basis of Haar wavelet:

$$\psi_{Haar}(t) = \begin{cases} 1 & for\ 0 < t < 0.5 \\ -1 & for\ 0.5 < t < -1 \\ 0 & otherwise \end{cases} \quad (1)$$

Its scaling function $\phi(t)$ can be described as

$$\phi(t) = \begin{cases} 1 & 0 \leq t < 1, \\ 0 & otherwise \end{cases} \quad (2)$$

DCT: A method in which a signal is converted into fundamental frequency components is termed as discrete cosine transform (DCT).[27] The cosine functions are mainly used for image compression. An application, pioneered by Chen and Pratt in 1984, summed up these functions which oscillate between different frequencies to represent a sequence of finitely numerous data points.

There are several similarities and disparities between DCT and discrete fourier transform (DFT).

Similarities:

• The frequency domain coefficients generated by DCT and DFT operations are similar while operating on a block of pixels. Both 2N-point DFT and N point DCT has the same frequency resolution as they are closely related. In a complex frequency plane, N frequencies of a 2N point DFT corresponds to N points on the upper half of the unit circle.

Disparities:

• Complexity of DFT, in magnitude and phase, is more than DCT which is purely real.
• In case of image data, DCT is more efficient in concentrating energy into lower order coefficients than DFT.
• Unlike DCT, the magnitude of the coefficients in DFT is spatially invariant (phase of the input being insignificant) in a periodic input. One-dimensional signals such as speech waveforms are processed by using one-dimensional DCT and a 2D version of DCT is employed to analyze 2D signals such as images. The 2D DCT is separable in the two dimensions as it can be determined by applying 1D transforms independently to the rows and columns.

The following equation defines two-dimensional discrete cosine transform and its inverse transformation of an $N \times N$ digital image $f\ (x, y)$.

$$C(u, v) = \alpha(u)\alpha(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x, y)\cos\left[\frac{\pi(2x+1)u}{2N}\right] \times \cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad (3)$$

$$f(x, y) = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} \alpha(u)\alpha(v)c(u, v)\cos\left[\frac{\pi(2x+1)u}{2N}\right] \times \cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad (4)$$

Here, $C\ (u, v)$ is known as DCT coefficient, which is the result of discrete transform.

where, $u, v = 0, 1, 2, \ldots N-1$ and $x, y = 0, 1, 2, \ldots N-1$

$\alpha(u)$ is defined as follows:

$$\alpha(u) = \sqrt{(1/N)} \quad u = 0; \quad \text{and} \quad (5)$$

$$\alpha(u) = \sqrt{(2/N)} \quad u = 1, 2 \ldots N-1 \quad (6)$$

SVD: Singular value decomposition (SVD) has been developed primarily to find a solution for the least square problems and also for a number of operations. SVD also encompasses image processing applications such as image hiding, image compression, noise reduction, image water marking etc.[28] The feature of SVD which states that there is no significant change in the singular values of the image even after addition of small interference to it has subsequently increased the utility of SVD in different image processing schemes.

Suppose M is the matrix representing the input image. M is an $N \times N$ matrix whose rank r is less than or equals to N i.e., $r <= N$. SVD is applied on the input image matrix M to decompose it in UPV^T. U is an $N \times N$ orthogonal matrix which can be represented as

$$\begin{bmatrix} u_{1,1} & \cdots & u_{1,N} \\ \vdots & \ddots & \vdots \\ u_{N,1} & \cdots & u_{N,N} \end{bmatrix}$$

V is also an $N \times N$ orthogonal matrix which can be represented as

$$\begin{bmatrix} v_{1,1} & \cdots & v_{1,N} \\ \vdots & \ddots & \vdots \\ v_{N,1} & \cdots & v_{N,N} \end{bmatrix}^T$$

P is a diagonal matrix with diagonal entries

$$P = \begin{bmatrix} \sigma_1 & 0 & \ldots & 0 \\ 0 & \sigma_2 & \ldots & 0 \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & \ldots & \sigma_N \end{bmatrix}$$

where, $\sigma_1 \geq \sigma_2 \geq \sigma_3 \geq \ldots \geq \sigma_r \geq \sigma_{r+1} \geq \ldots \geq \sigma_N = 0$. So, SVD of the square matrix M can b represented as

$$M = UPV' = \begin{bmatrix} u_{1,1} & \ldots & u_{1,N} \\ \vdots & \ddots & \vdots \\ u_{N,1} & \ldots & u_{N,N} \end{bmatrix} \times \begin{bmatrix} \sigma_1 & 0 & \cdots & 0 \\ 0 & \sigma_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & \cdots & \sigma_N \end{bmatrix} \times \begin{bmatrix} v_{1,1} & \cdots & v_{1,N} \\ \vdots & \ddots & \vdots \\ v_{N,1} & \cdots & v_{N,N} \end{bmatrix} = \sum_{i=0}^{r} P_i U_i V_i^T \quad (7)$$

Begin
Objective function $f(y), y = (y_1, \ldots, y_d)^T$
Generate initial population of fireflies $y_i (i = 1, 2, \ldots, m)$
Light intensity l_i *at* y_i *is determined by* $f(y_i)$
Define light absorption coefficient K
While $t < MaxGeneration(G)$
  For $i = 1{:}m$ *all m fireflies*
    For $j = 1{:}m$ *all m fireflies*
    If $(I_i < I_j)$, *Move firefly i towards j;*
    End if
    Attractiveness varies with with distance r_{ij} *via* $\exp[-K * r_{ij}]$
    Evaluate new solutions and update light intensity
    End for j
  End for i
Rank the fireflies and find current best.
End while
Postprocess on the best-so-far results and visualization
End

Fig. 1. Firefly meta-heuristic algorithm (Pseudo-code).

DWT-DCT based watermarking techniques offer both scalability and compression. The utility of DCT in our current study is to capture the low frequency information of watermarking image. DCT helps to increase robustness and concealment. DWT-SVD and DCT-SVD based approach is much more efficient than traditional watermarking techniques as SVD has the ability to withstand attacks unlike conventional techniques.

In this work, three different gray watermarks having the same size as the original image are embedded into different DWT subbands (HH, HL, LH). This process is followed by DCT and SVD of the cover image using three embedding factors. The level of robustness of the watermarking technique can be improved by optimizing the embedding factors used for singular value modification for best results. Thus, an optimum set of embedding factors are selected for singular value modification by using firefly algorithm. Because of the variation in size and resolution of the cover image, the optimal value of the embedding factor should vary from one cover image to another. The robustness and security of the proposed algorithm may get affected by the strength of the watermark.

Our aim is to introduce firefly algorithm (FA), which shows enhanced performance in solving the complex optimization task of selecting proper scaling factors for singular value modification. In this work, the strength is measured using a set of three embedding factors used for singular value modification, namely, K_1, K_2 and K_3. The manual selection of these factors to achieve optimality is a complicated and challenging task. This demands an automated selection strategy of embedding factors in an optimized way. In this work, selection of optimal embedding factors for singular value modification will be performed using firefly algorithm (FA). FA is a nature-stimulated meta-heuristic search algorithm inspired by the behavior of fireflies.

Meta-heuristics and Firefly Algorithm (FA): Meta-heuristics never guarantees that the global optimality will always be achieved. Although in practice global optimality can be found in many cases. Meta-heuristics is a powerful tool in achieving global optimal solution to problems. They command all modern algorithms because of the fact that they follow and draw their inspiration from natural and biological systems which have evolved through natural selection over millions of years. Most of the meta-heuristic algorithms use various stochastic components. The most important attributes of meta-heuristic algorithms are best-fit selection and environmental adaptability. Considering the behaviour of the algorithm, intensification and diversification are its two major components.

Intensification has a tendency to explore local regions for selecting best solutions or candidates around the region of the existing best solutions. On the contrary, diversification tends to explore the search space in a better way by generating solutions with greater variety. In conventional gradient-based methods, gradient of the function to be optimized has important information for rapid finding and optimization of the solutions for a specific problem. Though, in case of dealing with highly non-linear, non-differentiable, non-smooth, non-convex problems which are contrary to the necessary conditions in relevance to these methods, the gradient-based method faces complexities on convergence and frequently gets entrapped in local optima.

The firefly optimization algorithm can remarkably improve the technique of the global search and local optimization ability.

FA (non-gradient based) is a simple objective function based evolutionary technique that can produce an effective result in time of dealing with highly non-linear dynamic optimization problems having quite a few limitations. These can be done by evading bad numerical behavior because of gradient evaluations. Like all other well-tested meta-heuristic algorithms for optimization, FA can also find an optimal solution to a problem by iteratively making an effort to enhance a candidate solution considering a specified measure of solution quality. A nature stimulated meta-heuristic algorithm was developed by Yang in 2007,[29] namely Firely Algorithm (FA), which is, based

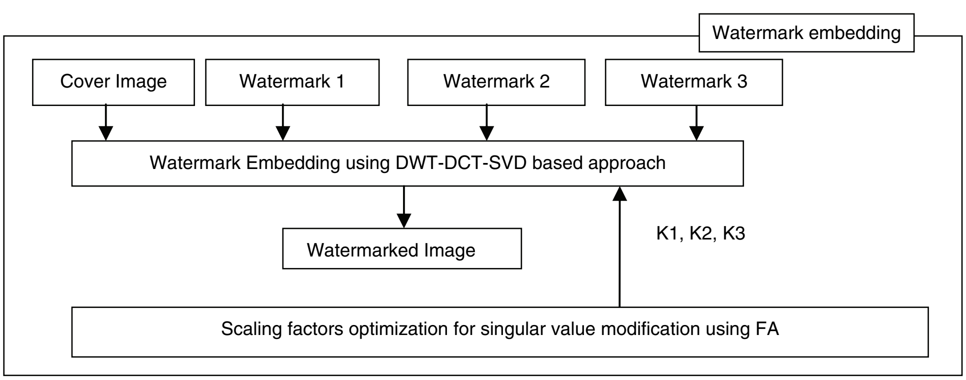

Fig. 2. Proposed method of watermark embedding.

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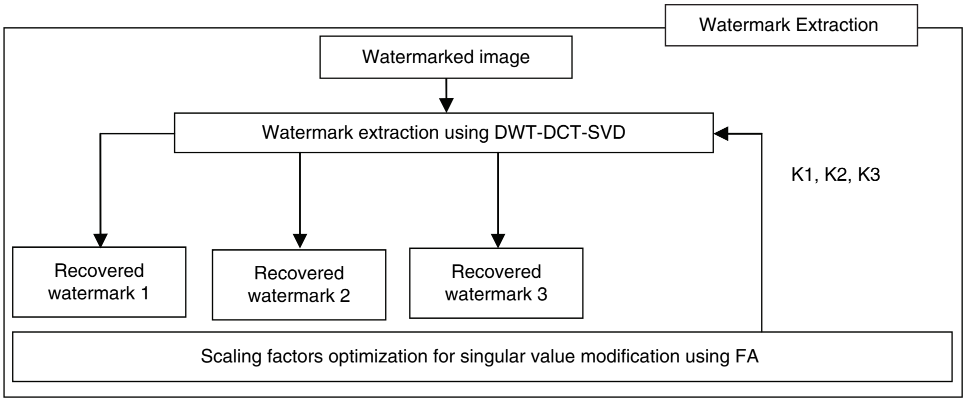

Fig. 3. Proposed method of watermark extraction.

on the flashing patterns and behavior of fireflies.[30–32] This modern meta-heuristic algorithm uses three idealized rules as stated below:

- Fireflies are unisexual. They move towards more appealing and brighter fireflies irrespective of their sex.
- Attractiveness is proportional to brightness. Brightness is inversely proportional to the distance amongst fireflies. For any two flashing fireflies, the less bright moves towards the brighter one. A firefly moves randomly, if there are no brighter firefly than the particular one.
- The landscape of the objective function determines the brightness of a firefly. In most of the problem domain the value of the objective function is proportional to brightness.

The two most important issues in the firefly algorithm are:
(1) Light intensity variation; and
(2) Formulation of attractiveness.

The firefly's attractiveness is proportional to the light intensity seen by adjacent fireflies. A monotonically decreasing function namely attractiveness function $\beta(r)$ with the distance r (r is the

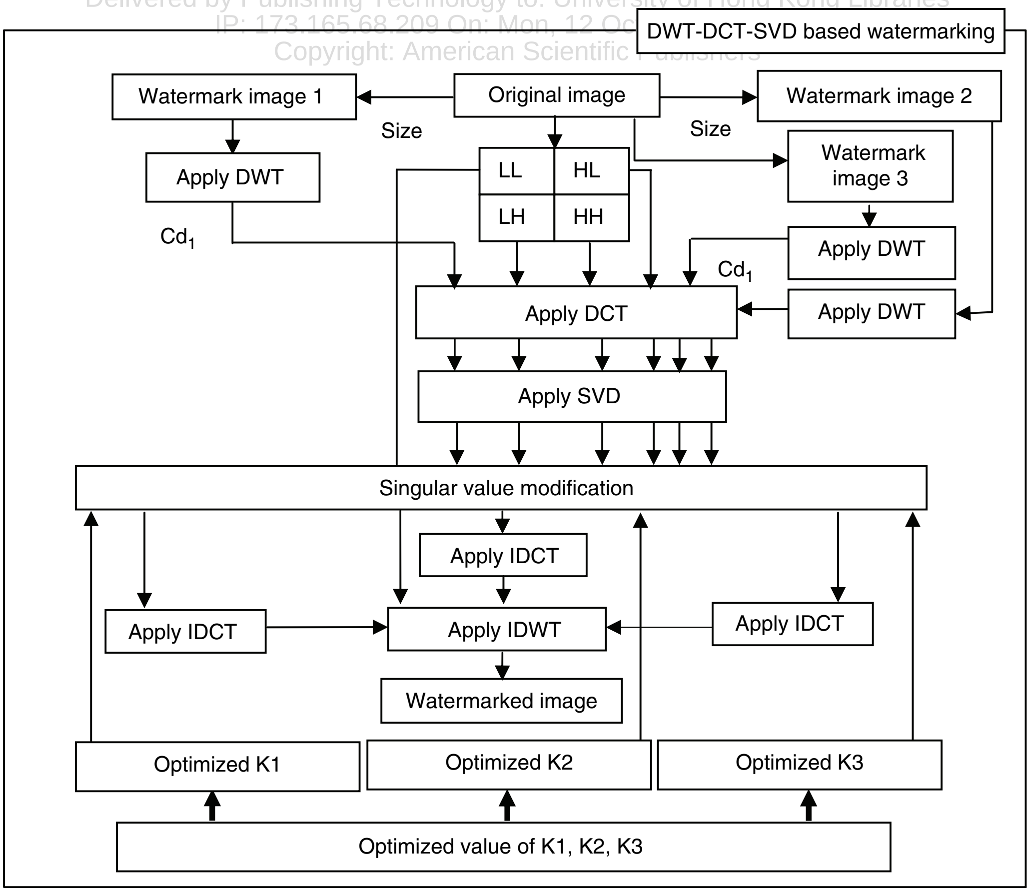

Fig. 4. Proposed method of watermarking embedding in detail.

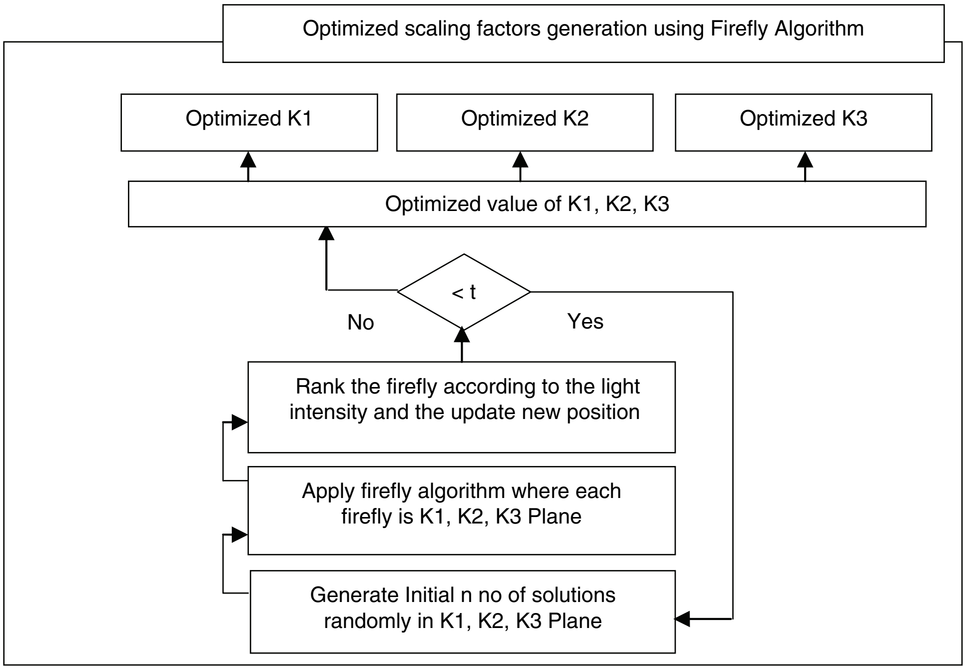

Fig. 5. Optimized scaling factor generation for watermarking embedding.

distance between two adjacent fireflies) can be represented as the following generalized form:

$$\beta(r) = \beta_0 e^{-Kr^n}, \quad (n \geq 1) \tag{8}$$

Where, β_0 denotes maximum attractiveness at $r = 0$. K is a fixed light absorption coefficient. It controls the decrease in light intensity. Though $K \in [0, \infty)$ but still in practice the value of K is determined by the characteristic length of the system to be optimized which normally ranges[33] within 0.1 to 10.

Characteristic distance Γ is the distance over which the attractiveness changes significantly. For a given characteristic length

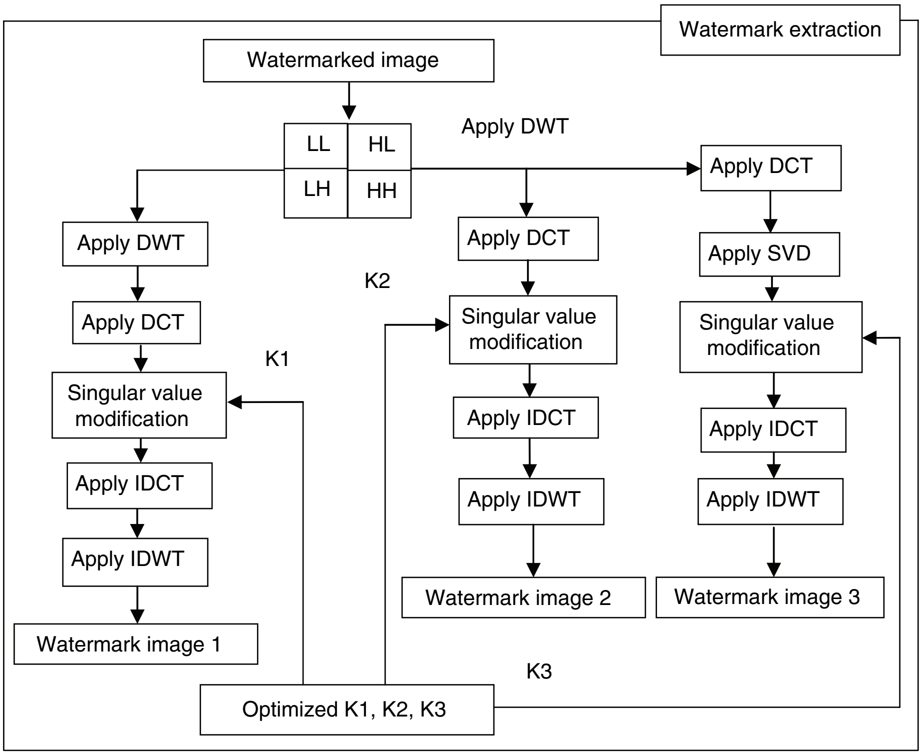

Fig. 6. Proposed method of watermarking extraction in detail.

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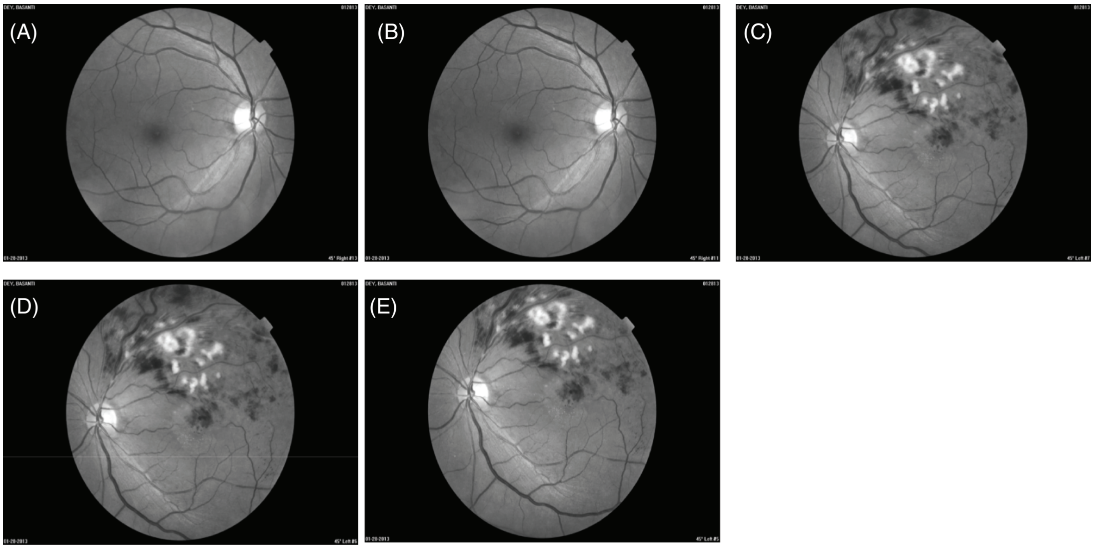

Fig. 7. (A)–(E) Fundus photography (experiment dataset).

scale Ã in an optimization problem, the parameter γ can typically initialize by the following value:

$$K = \frac{1}{\Gamma^n} \tag{9}$$

For fixed K, characteristic distance will be:

$$\Gamma = K^{-1} \to 1 \quad \text{when} \quad n \to \alpha \tag{10}$$

The distance between any two fireflies i and j at y_i and y_j can be computed by the following equation:

$$r_{ij} = \|y_i - y_j\| = \sqrt{\sum_{k=1}^{d} (y_{i,k} - y_{j,k})^2} \tag{11}$$

Where $y_{i,k}$ is the k-th component of the spatial coordinate y_i of i-th firefly and d denotes the number of dimensions. The movement of a firefly i is attracted to another more appealing (brighter) firefly j which is the relation between the new and old position of firefly i. It is determined by

$$y_i^{t+1} = y_i^t + \beta_0 e^{-Kr_{ij}^2}(y_j^t - y_i^t) + \alpha\varepsilon_i^t \tag{12}$$

$\alpha \in [0, \infty)$ Where, the 2nd term is due to attraction. The 3rd term is randomization with being the randomization parameter, and ε_i^t is a vector of random numbers drawn from a Gaussian distribution or uniform distribution at time t.

The basic steps of firefly algorithm (FA) can be summarized as the pseudo code illustrated in Figure 1.

The main objective of this paper is to use FA in combination with image embedding techniques to achieve medical information hiding with high security and accuracy and robustness.

3. PROPOSED METHOD

By combining the image embedding with the optimal scaling factors using FA, a methodology is proposed for secure biomedical image authentication and information hiding. The DWT-DCT-SVD based proposed watermarking approach using the optimized scaling factors by FA can be outlined as follows:

3.1. Watermark Embedding

Step 1. Original gray cover image size is calculated.

Step 2. Three gray scale watermark images, of the same size as that of the cover image are taken.

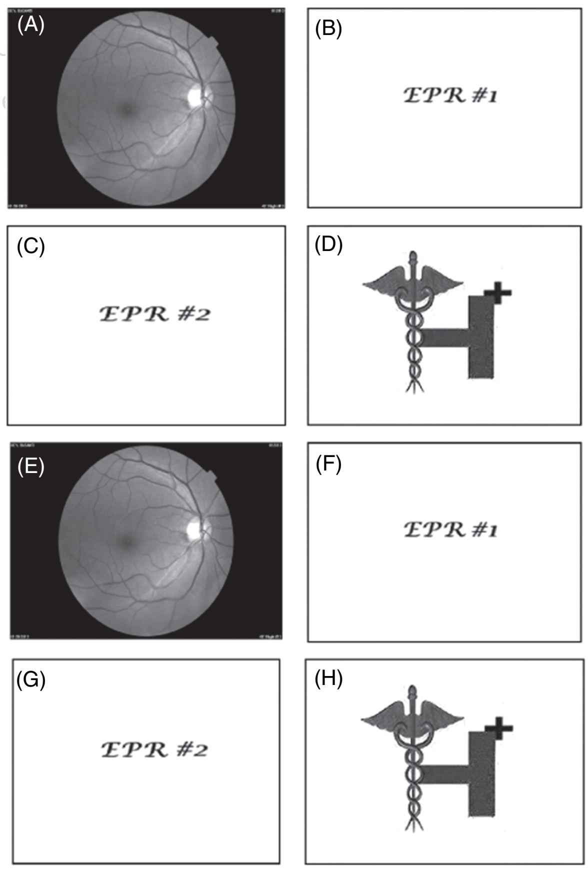

Fig. 8. (A) Original image (dataset (A)), (B) Watermark 1 (EPR1), (C) Watermark 2 (EPR 2), (D) Watermark 3 (hospital logo), (E) Watermarked Image, (F) Recovered watermark 1 (EPR1), (G) Recovered watermark 2 (EPR 2), (H) Recovered watermark 3 (hospital logo).

Table I. Obtained optimized K_1, K_2, K_3 value using FA up to 80 iteration (Dataset A).

Iteration	No of fireflies	K_1	K_2	K_3	Correlation 1	Correlation 2	Correlation 3	PSNR	Fitness
10	20	2.1558	0.3943	0.622	0.9978	0.987	0.9788	46.9556	343.3105
15	20	0.3134	0.4025	0.422	0.9954	0.987	0.9778	58.101	354.118
20	20	0.1014	0.1	0.1	0.9816	0.9872	0.9698	70.8826	364.7372
25	20	0.252	0.1	0.3005	0.9945	0.9871	0.978	62.5142	358.4631
30	20	0.5643	0.7459	0.4327	0.9969	0.9868	0.9761	54.1809	350.1635
35	20	0.2	0.6751	0.2242	0.9917	0.9868	0.9704	57.5389	352.439
40	20	0.141	0.1	0.1	0.9816	0.9872	0.9698	70.8826	364.7372
45	20	0.2023	0.44	0.2097	0.9923	0.9869	0.9731	60.6086	355.8497
50	20	0.1813	0.2946	0.1451	0.9914	0.9869	0.9706	63.7634	358.6613
55	20	0.141	0.1	0.1104	0.9816	0.9872	0.9712	70.5947	364.5895
60	20	0.1	0.1	0.11	0.9816	0.9872	0.9698	70.8826	364.737
65	20	0.1	0.1	0.11	0.9816	0.9872	0.9698	70.8826	364.737
70	20	0.1014	0.1	0.1	0.9816	0.9872	0.9698	70.8826	364.737
75	20	0.141	0.1	0.1	0.9816	0.9872	0.9698	70.8826	364.737
80	20	0.141	0.1	0.272	0.9844	0.9872	0.9698	70.8826	364.737

Step 3. Cover image is decomposed into four sub bands LL_1, LH_1, HL_1 and HH_1 by applying DWT.
Step 4. DCT is applied on the HH_1, HL_1 and LH_1, sub bands individually.
Step 5. SVD is applied on all the resultant sub bands.
Step 6. Each watermark image is decomposed into four sub bands (LL_1, LH_1, HL_1 and HH_1) by applying DWT.
Step 7. DCT is applied on all sub bands of the decomposed watermark images.
Step 8. After applying DCT on the four sub bands of the decomposed watermarks, SVD is applied on each resultant sub band.
Step 9. DWT and DCT are applied on the image using optimal scaling factors (K_1, K_2, K_3). Singular values of all the resultant sub bands obtained from the cover image are modified using singular value of the corresponding HH1 sub bands of the watermark images.
Step 10. To generate the final watermarked image, IDCT is applied followed by IDWT.

3.2. Watermark Extraction

Step 1. Watermarked image is decomposed into four sub bands by applying DWT. (LL_1, LH_1, HL_1 and HH_1).
Step 2. Discrete cosine transformation (DCT) is applied on the HH_1, LH_1, HL_1 sub bands.
Step 3. SVD is applied on the resultant sub bands.
Step 4. Singular values of the watermarked image are modified. Optimal scaling factors (K_1, K_2, K_3) are used to extract the watermarks from the modified singular values of the watermarked image.
Step 5. To extract the watermark image from the watermarked image, IDCT is applied followed by IDWT on the resultant image.

3.3. Optimal Scaling Factors Generation Using Firefly Algorithm

Step 1. A set of n fireflies (solutions) are dislocated randomly in Three-dimensional (K_1, K_2, K_3 plane) search space (S) within a specific range.
Step 2. For each firefly (possible solution), watermarking is performed and its corresponding fitness value is computed using PSNR. Correlation values are then calculated.
Step 3. Solution with the best light intensity (fitness) is stored as the best solution for scaling factors.
Step 4. The position of the other fireflies is adjusted according to the best-fit solution, which means firefly starting with the highest light intensity.
Step 5. The new firefly position is updated and the best solution is found.
Step 6. Step 2 to Step 4 is repeated t no. of iterations.

Final value of K_1, K_2, and K_3 indicates the optimal scaling factors. Figures 2 and 3 shows that basic block diagram for the

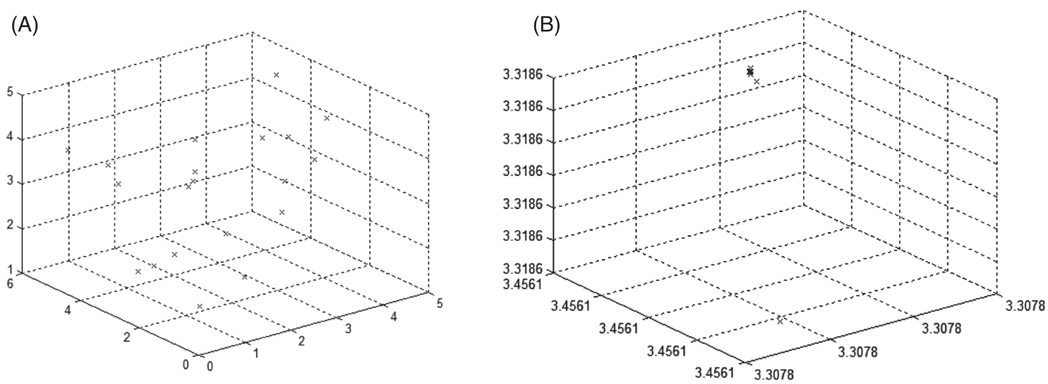

Fig. 9. (A) In PSO based approach, 20 particles are dislocated randomly in the initial search space (S), (B) particles after 80th iteration in S (dataset A).

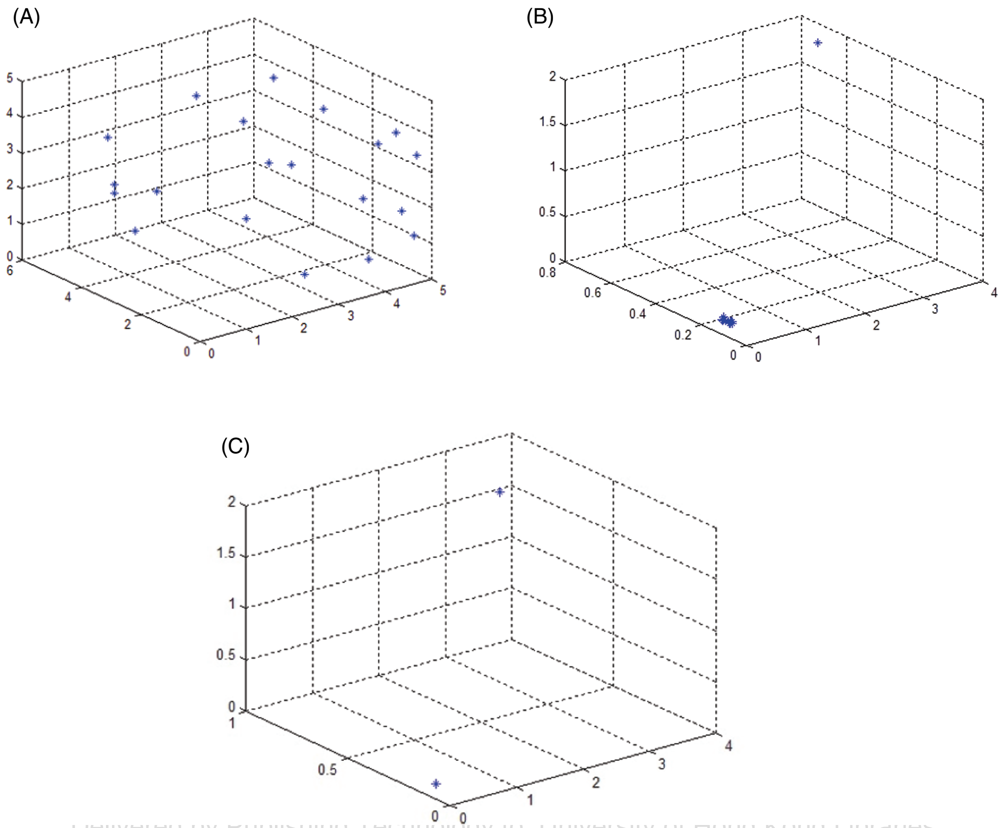

Fig. 10. (A) In FA based approach, 20 fireflies are dislocated randomly in the initial search space (*S*), (B) fireflies after 35th iteration in *S*, (c) swarm after 80th iterations in *S* (after convergence) (dataset A).

proposed watermarking embedding and extraction procedure and Figures 4, 5 reports the detail architecture of the proposed system. Figure 6 reports the overall system design.

4. RESULTS AND DISCUSSION

The proposed method was implemented in MATLAB 7.0.1. Our algorithm was successfully tested on 5 fundus patient photographs, diagnosed for retinal stroke. Typical output images achieved in the result set are illustrated in Figure 7 through Figure 8.

Peak signal to noise ratio (PSNR) is the ratio between the maximum achievable power of a signal and power of the corrupting noise that affects the reliability of the signal representation. This ratio can be used as an evaluation of the quality of a watermarked image. Therefore, it can be used as a performance metric to find out perceptual transparency of the watermarked image with respect to the cover image. Therefore, this ratio also measures the invisibility of the embedded watermark. The high PSNR value implies better invisibility of the watermark. The PSNR ratio can be defined as

$$PSNR = \frac{XY \max_{x,y} P_{x,y}^2}{\sum_{x,y} (P_{x,y} - \bar{P}_{x,y})^2} \tag{13}$$

Where, X and Y are the numbers of rows and columns, respectively, in the input image, $P_{x,y}$ is the original signal, and $\bar{P}_{x,y}$ is the watermarked image. The similarity of the recovered logo (x') and the original logo (x) can be determined by using the standard correlation coefficient (C), once the hospital logo/EPR embedding process is complete.

$$C = \frac{\sum_m \sum_n (x_{mn} - x')(y_{mn} - y')}{\sqrt{(\sum_m \sum_n (x_{mn} - x')^2)(\sum_m \sum_n (y_{mn} - y')^2)}} \tag{14}$$

where, y and y' are respectively the transforms of x and x'. m, are the size of the image.

Initially, a set of n fireflies which can be considered as n number of distinct solutions are dislocated randomly in

Table II. **Comparative study of PSNR and fitness function between PSO based watermarking approach and FA for dataset A.**

Iterations	No of fireflies/ particles	PSO		FA	
		PSNR	Fitness	PSNR	Fitness
10	20	39.4835	335.7657	46.9556	343.3105
15	20	41.3932	337.5866	58.101	354.118
20	20	40.6422	337.0849	70.8826	364.7372
25	20	37.1690	333.5631	62.5142	358.4631
30	20	48.1457	344.5014	54.1809	350.1635
35	20	43.0724	339.2854	57.5389	352.439
40	20	39.6558	335.8636	70.8826	364.7372
45	20	38.7154	335.0606	60.6086	355.8497
50	20	46.9576	343.1579	63.7634	358.6613
55	20	43.0903	339.1574	70.5947	364.5895
60	20	39.7960	336.2310	70.8826	364.737
65	20	44.6577	340.0234	70.8826	364.737
70	20	37.3902	333.7997	70.8826	364.737
75	20	40.6246	337.0576	70.8826	364.737
80	20	39.3876	335.7366	70.8826	364.737

Table III. Obtained optimized K_1, K_2, K_3 values using FA after 80 iteration for all the dataset.

Dataset	Iterations	No of fireflies	Optimal K_1	Optimal K_2	Optimal K_3	Correlation 1	Correlation 2	Correlation 3	PSNR	Best fitness
A	80		0.141	0.1	0.272	0.9844	0.9872	0.9698	70.8826	364.737
B	80	20	0.1	0.1	0.1	0.9813	0.9872	0.9713	71.0417	365.0286
C	80	20	0.1	0.1	0.141	0.9788	0.9873	0.9587	71.0494	363.5262
D	80	20	0.1	0.1	0.1061	0.9799	0.9873	0.9563	71.8079	364.1547
E	80	20	0.1001	0.1	0.1	0.9807	0.9874	0.9744	72.0314	366.2871

three-dimensional (K_1, K_2, K_3 plane) search space (S) within a specific range. For each solution (firefly), watermarking is performed and the fitness function for each of the n solutions can be computed, based on the obtained PSNR and C values. The solution set with the best light intensity (fitness value) are then selected and stored as the best solution for the obtained scaling factors (K_1, K_2 and K_3). The following fitness function (FT) is used:

$$FT = PSNR + \rho \tag{15}$$

where, ρ is $100 * C$. Here, the correlation factor is ρ. Since the normal values of the correlation value (C) falls in the range 0 $\sim$1, C has been multiplied by 100, while PSNR values[34] might reach the value of 100. Our simulations show that this fitness function works well. The position of the other fireflies is adjusted according to the best fit solution (firefly starting with the highest light intensity) and new firefly position is updated accordingly to obtain the best solution. This process repeated t no of iterations and finally the optimized K_1, K_2 and K_3 value (scaling factors) are obtained.

Following result sets are obtained for 20 fireflies, where maximum iteration is 80 and K_1, K_2, K_3 ranges within 0.1 to 5.

Table I reports that, obtained K_1, K_2 and K_3 values using FA based approach are respectively 0.141, 0.1 and 0.272 after 80 iterations (Fig. 10). Obtained best fitness is 364.737, best PSNR is 70.8826 and the correlations are 0.9844, 0.9872 and 0.9698 respectively. A comparative study has been done between FA and particle swarm optimization (PSO) based approach. By using particle swarm optimization technique (PSO) for 20 particles and 80 iterations (Fig. 9) for the same watermarking algorithm, obtained K_1, K_2 and K_3 are 3.3078, 3.4561, 3.3186 respectively. Obtained best fitness is 335.7366, best PSNR is 39.3876, and the correlations are 0.9978, 0.9869, 0.9788 respectively. Table II clearly shows that for all 5 experimental test retinal images the obtained fitness using PSO based approach is less significant than the FA based approach. Table III reports that the obtained PSNR and correlation values for all test images in 80th iteration using FA based approach is remarkably high. This effective result (high PSNR) claims the efficacy of the robustness of the technique. The correlation values amongst multiple original watermarks and recovered watermarks are also within acceptable limits.

5. CONCLUSION

The proposed method of content authentication by embedding hospital logo as well as multiple medical data within the retinal image is more trustworthy than the classical method of transmitting the content. In this paper, the image embedding with optimal scaling factor generation has been done by FA. It has also been shown that the proposed method is secure and accurate in the applications of medical image authentication by watermarking with a hospital logo as the ownership data and at a time, manifold medical information can be hidden. Comparative study shows that, using firefly algorithm, better fitness and PSNR values were produced during optimization of scaling factors. In this paper, particle swarm optimization is used for comparative studies, which is a well-known optimization technique. Obtained results using FA based approach yields much more significant results than PSO based approach. Also, the main advantage of our proposed method is gray multiple image embedding with a very high payload. The sizes of all watermarks are of the same size as the original medical image. Thus, during extraction, the size of the watermark is not required to be sent to the recipient's end. All the obtained recovered watermarks are having high correlation values apart from obtained high PSNR value between the watermarked image and the original image, which is truly encouraging. The scope for further improvement is to work with color retinal images. Overall, the proposed method can serve as a secure and strong authentication system and information hiding.

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