Robust transmission of medical records using dual watermarking and optimization algorithm

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Abstract. Nowadays, security of medical records is an important issue for tele-health system. Motivated by importance of such critical issue, we propose a robust watermarking method in the DWT-SVD-optimization domain. To solve the security issue, traditional watermarking schemes use manual scaling factor to manage balance between imperceptibility, robustness and capacity. However, selection of manual scaling factor loses their optimize trade-off between these important parameters of watermarking. The suggested scheme encourages protection of medical data via techniques of dual watermarking and optimization scheme. In our scheme, the data owner imperceptibly embeds the dual watermarks in the medical cover image for extra level of security. Here, appropriate optimization schemes are used to find the scaling factor for embedding purpose. Further, the performance of this scheme is examined and compared. Moreover, the patient text data is coded via hamming code before inserting in to the cover so that bit error rate can be avoided or eliminated, if any. We show that the suggested scheme not only offers the high imperceptible but also robust for various attacks. Compared with existing schemes, our work offers more robustness while imperceptible and good capacity at the same time.

1. Introduction
In tele-health, there has been an exponential increase in the communication of medical images through open network systems [1]. These services use information and communication technology (ICT) tools for effective storage, management and communication of the medical records for various purposes [2]. While transferring the medical images might bring many issues including being tampered by intruders, identity theft problem and privacy leakage. Further, all the medical records are transmitted using Digital Imaging and Communication in Medicine (DICOM) standard [3]. It can be seen that this standard is not much effective for reliable healthcare system [2] [3]. Additionally, identity theft and privacy leakage of healthcare data is a growing crime which results in a huge damage to finances of the individual [4]. Presently, a lot of significant patient information is stored in the local server of the medical centre and distributed over the network in Coronavirus periods [5]. On the other hand, this may lead to high risk of data security and privacy in the current advanced healthcare systems [6]. To overcome such legal and ethical issues, watermarking is used to secure medical contents [1]. It facilitates embedding sensitive information into digital content such that it can later be extracted by authorized party only [4]. Notably, robustness, invisibility and capacity are the primary requirements of any watermarking method [1], which is difficult to balance the trade-off between these requirements [7].
Therefore, suitable nature inspired optimization scheme is used to offer the appropriate balance between these requirements [7], [8]. The major contributions of the suggested approach are listed as follows.

- The suggested method utilizes discrete wavelet transform (DWT)- singular value decomposition (SVD) to enhance the robustness of dual watermarking method. It can be seen that the combination of DWT-SVD offered better results than the schemes based on DWT or SVD individually.
- Dual watermarking and appropriate optimization scheme are used to increase the confidentiality and robustness of the method, respectively.
- Prior to embedding, Hamming code is utilized to encode the patient watermark so that bit error rate can be avoided or eliminated, if any
- In-depth robustness analysis of the method is conducted over varying attacks. Further, compared with existing scheme, our work offers more robustness while imperceptible and good capacity at the same time.

The article is organized as follows: In Section 2, we discuss the related works. Section 3 discusses the proposed methodology, while results are given in Section 4. Some conclusion is made in Section 5.

2. Literature Review

Some of the notable approaches are presented under this section.

Anand and Singh [2] employed a secure watermarking for medical records in DWT-SVD domain. Further, Hamming code is utilized to encode the patient watermark. The concept of Encryption then Compression is applied to achieve robust, secure and bandwidth efficient watermarking for medical application. Compared with existing schemes [3], the suggested work offers more robustness. Ali et al. [8] uses optimization scheme to propose a watermarking for medical data. In this approach, the scaling factor is optimized using Artificial Bee Colony (ABC). This optimized value is used to embed the watermarks into the singular matrix of the redistributed invariant wavelet transform (RIWT) coefficient of the cover image. Apart from being robust and imperceptible, this technique overcomes the problem of false problem detection. An adaptive and efficient watermarking technique is proposed by Chaturvedi and Shukla for efficient transmission of digital multimedia [9]. The watermark image is encrypted using sanitization algorithm, enhancing the security. Further, Oppositional Grasshopper Optimization Algorithm (OGAO) is used to find the optimal area in wavelet coefficients of the cover image to embed these encrypted bits. This technique provides good imperceptibility and robustness.

In [10], Thakur et al. uses chaotic encryption and combination of DWT- Discrete Cosine Transform (DCT)-SVD to develop a watermarking method for the protection of medical data. Compared with existing schemes [11], the suggested work offers more robustness while secure and imperceptible at the same time. SVD based color image watermarking is described in [12] in which Particle Swarm Optimization (PSO) is used to select the embedding factor, which maintains a stability between robustness and imperceptibility. This technique offers dual watermarking by embedding two watermarks into the selected areas of the different DWT-SVD coefficients of the cover image. Compared with existing schemes [13] [14], the suggested work offers good results.

Rayachoti et al. described another watermarking technique for medical data using Slantlet transform (SLT) and SVD [15]. The proposed work can efficiently recognize and recuperate any tamper in the ROI of the image. It performed better in terms of ROI tamper detection, its correction and robustness when compared to similar watermarking techniques [16]–[19]. In [20], a color image watermarking is developed using Lifting Wavelet Transform (LWT) and SVD. Further, Arnold transform is employed to secure the watermark. Authors also use Grey Wolf Optimization (GWO) technique to improve the performance of the scheme. Other research has optimized the multiple scaling factors (MSF) through firefly scheme in [21]. The method employs SVD on DWT coefficients to embed the sensitive information through optimized Scaling Factor (SF) into cover.
Wavelet based adaptive and robust watermarking approach is proposed by Gangadhara et al. [22] for securing the healthcare applications. The cover is decomposed using modified DWT and SVD. Further, PSO is implemented to optimize the scaling factor, which is then used to embed the watermark into region with maximum entropy.

3. Design of the proposed scheme
Our scheme mainly comprises of the following phases, a. Embedding and recovery of the concealed watermarks b. Optimization of the scaling factor. Forthcoming subsections explain both the phases in details. Figure 1 illustrates the concealing of the multi-watermarks and optimizing the scaling factor (SF) using ABC algorithm.
3.1. Embedding and extraction of multi-watermarks

Listing 1 describes the embedding process in detail. In this process, second level DWT-SVD is applied on the cover image. Prior to embedding, the image watermark is subdivided into two equal parts, making the technique more imperceptible [23]. After, and sub-images of the image watermark are concealed using optimized SF (refer listing 2) in the resultant singular component of the specified sub-bands of the cover. Additionally, hamming code is utilized to encode the patient watermark (character form) so that bit error rate can be avoided or eliminated, if any.

The encoded bits of the patient watermark are hidden in the higher-level sub-band of the cover. Finally, inverse of SVD-DWT is utilized to obtain the final marked image. For extracting the watermarks, exact reverse embedding procedure is to be followed.

Listing 1: Embedding procedure

Input: Text watermark \( w_{\text{text}} \), Cover and watermark image \( c_{\text{img}} \) and \( w_{\text{img}} \), respectively

Output: final_img (Marked image)

Step 1. Read \( c_{\text{img}} \) of size 512×512.
Step 2. Decompose \( c_{\text{img}} \) using DWT.

\[
\text{DWT}(c_{\text{img}}, \text{\textquoteleft\text{Haar\textquotepright}}) = [LL1, HL1, LH1, HH1] \tag{1}
\]

\[
\text{DWT}(LL1, \text{\textquoteleft\text{Haar\textquotepright}}) = [LL2, HL2, LH2, HH2] \tag{2}
\]

Step 3. Determine singular value of \( LH1 \) and \( HL1 \) components.

\[
\text{SVD}(LH1) = [U_{LH}, S_{LH}, V_{LH}] \tag{3}
\]

\[
\text{SVD}(HL1) = [U_{HL}, S_{HL}, V_{HL}] \tag{4}
\]

Step 4. Read watermark image \( (w_{\text{img}}) \) of size 256×256 and divide it equal parts

\[
w_{\text{img}} = w_{\text{img}1} + w_{\text{img}2} \tag{5}
\]

Step 5. Embed \( w_{\text{img}1} \) and \( w_{\text{img}2} \) into \( S_{LH} \) and \( S_{HL} \) sub-bands using gain factor \( \alpha \).

\[
w_{S_{HL}} = S_{HL} + \alpha \times w_{\text{img}1} \tag{6}
\]

\[
w_{S_{LH}} = S_{LH} + \alpha \times w_{\text{img}2} \tag{7}
\]

Step 6. Apply inverse SVD to attain the marked \( LH1 \) and \( HL1 \).

\[
w_{LH1} = U_{LH} \times w_{S_{LH}} \times (V_{LH})^T \tag{8}
\]

\[
w_{HL1} = U_{HL} \times w_{S_{HL}} \times (V_{HL})^T \tag{9}
\]

Step 7. Read \( w_{\text{text}} \) and convert it into ASCII format.

\[
w_{\text{binary}} = \text{Binary}(w_{\text{text}}) \tag{10}
\]

Step 8. Encode \( w_{\text{binary}} \) using Hamming code.

\[
w_{\text{encoded}} = \text{Encode}(w_{\text{binary}}) \tag{11}
\]

Step 9. Replace \((1,0)\) with \((1, -1)\) in \( w_{\text{encoded}} \).

\[
w_{\text{final}} = \text{Replace}(w_{\text{encoded}}) \tag{12}
\]

Step 10. Using gain factor \( \alpha_{\text{text}} \), conceal \( w_{\text{final}} \) into \( HH2 \) sub-band.

\[
w_{HH2} = \text{Embed}(HH2, w_{\text{final}}, \alpha_{\text{text}}, \text{len}) \tag{13}
\]

Where, \( \text{len} \) is the length of \( w_{\text{final}} \).
Step 11. final_img is obtained via inverse DWT.

\[ w_{LL1} = \text{IDWT}(LL2, w_{HL2}, LH2, w_{HH2}) \]  

\[ \text{final_img} = \text{IDWT}(w_{LL1}, w_{HL1}, w_{LH1}, HH1) \]  

3.2. Optimization of the scaling factor

Any general watermarking system need to maintain the balance between two major characteristics, namely imperceptibility and robustness [7]. It can be seen that the larger and smaller value of SF offer good robustness and imperceptivity, respectively [2]. So, an optimal value of SF is required to maintain a trade-off between the two. In this context, ABC algorithm [24] is used to find the optimal value of the SF for embedding and extraction process of the mark data. Fig. 2 shows the detail working process of ABC optimization scheme. It has been proven that the suitable range for a confined initialization of random swarms is 0.005-0.06 [21]. The basic optimization parameters for the scheme are illustrated in Table 1. Further, fitness function is defined as [25]:

\[
\text{Fitness Value} = [\alpha \times (BER + \frac{1}{PSNR})] + \left[\frac{1}{N} \times \sum_{i=1}^{N} \frac{1}{NC(W,W_i)} + \frac{1}{N} \times \sum_{i=1}^{N} \text{BER}_i\right]
\]  

Table 1. Control parameters of ABC optimization technique

| Parameter                          | Value          |
|------------------------------------|----------------|
| No. of bees (swarm)                | 20             |
| No. of iterations                  | 15             |
| No. of onlooker and employed bees  | half of the swarm |
| No. of scout bees                  | Changeable     |

Listing 2. Determination of optimal scaling factor

Input: ‘w_img’, ‘w_text’ and ‘c_img’

Output: Optimal ‘SF’
Step 1: Determine PSNR, NC and BER values without attack as illustrated Listing 1.
Step 2: Determine NC and BER values with n-attacks.
Step 3: Determine fitness value using the above steps

\[
\text{fitness\_value} = \text{Fitness}(\text{PSNR, NC, BER}_1, (\text{NC, BER}_2, \ldots, (\text{NC, BER}_n))
\] (17)

Step 4. Optimize SF using fitness\_value and ABC optimization scheme

4. Results
Experimental analysis of the proposed work is done using MATLAB R2017a on a 64-bit, 2.10 GHz processor, 8 GB RAM system. The experimental parameters are: size of the cover medical image is 512×512 [26], and patient report and medical image are considered as mark data of size 11 characters and 256×256, respectively. Robustness of the proposed watermarking approach is verified against different attacks listed in Table 2.

| Considered Attack with Noise Intensity | Notation |
|--------------------------------------|----------|
| Without attack                       | atck_0   |
| Salt and pepper noise of intensity 0.001 | atck_1 |
| Gaussian noise of intensity 0.001     | atck_2   |
| JPEG Compression with Quality Factor of 50 | atck_3 |
| Speckle noise of intensity 0.005      | atck_4   |
| Cropping attack with crop rectangle [20 20 400 480] | atck_5 |
| Median filter with neighbourhood size of [2 2] | atck_6 |
| Sharpening Mask of intensity 0.1      | atck_7   |
| Histogram Equalization                | atck_8   |

PSNR and NC are used to estimate the distortion and robustness, respectively. On the other hand, BER is used to calculate the error (if any) in received bits i.e. for text watermark. Further, optimized SF value is determined via ABC algorithm, which makes the good balance between trade-off parameters.

The PSNR, NC and BER value against considered attacks are recorded in Table 3, where the suggested technique obtained satisfactory performance. It can be seen from the table, NC value is greater than 0.7, BER is zero (except for atck_5 (cropping attack)), and PSNR value is 35.8651 dB. Further, NC and BER value for varying cover images and attacks are recorded in Table 4. It can be recorded that maximum values of PSNR and NC are 39.9559 dB and 0.9999, respectively for cell image. Refer Table 4, the BER is zero (except for atck_5 (cropping attack)) under the consideration. The results show that the proposed technique is robust and shows versatility since it offered virtuous results when tested with a variety of cover images. Furthermore, the effect of number of iterations under ABC optimization on PSNR, NC and BER value are recorded in Table 5. We noticed that value of SF approaches the optimal value as the number of iterations increases. It has been shown that performance of the system depends of number of iterations. The effect of optimization algorithms (PSO, firefly, and ABC) on NC performance is shown in Figure 3. Notably, ABC provides better results against under consideration. Overall, the objective assessment of the proposed scheme offered good results and also outperformed when compared with similar approach [2]. As shown in this Figure 4, the performance of suggested method is always better except atck_5 (cropping attack).
### Table 3. Performance analysis against various attacks

| Attack   | NC   | BER  |
|----------|------|------|
| atck_0   | 0.9998 | 0    |
| atck_1   | 0.9693 | 0    |
| atck_2   | 0.8806 | 0    |
| atck_3   | 0.9968 | 0    |
| atck_4   | 0.9776 | 0    |
| atck_5   | 0.9113 | 46.4285 |
| atck_6   | 0.8938 | 0    |
| atck_7   | 0.9374 | 0    |
| atck_8   | 0.7834 | 0    |

PSNR = 35.8651 dB

### Table 4. Performance evaluation on various medical and non-medical images

| Attack   | MRI NC | Kidney stones NC | Head CT scan NC | X-Ray NC | Cameraman NC | Cell NC |
|----------|--------|------------------|-----------------|----------|---------------|--------|
|          | BER    | BER              | BER             | BER      | BER           | BER    |
| atck_0   | 0.9998 | 0.9839           | 0.992           | 0.9867   | 0.9997        | 0.9999 |
| atck_1   | 0.9693 | 0.9796           | 0.9463          | 0.9723   | 0.9922        | 0.9527 |
| atck_2   | 0.8806 | 0.9579           | 0.8619          | 0.9157   | 0.937         | 0.8113 |
| atck_3   | 0.9968 | 0.9685           | 0.9777          | 0.9747   | 0.9983        | 0.9947 |
| atck_4   | 0.9374 | 0.9107           | 0.9527          | 0.9245   | 0.9545        | 0.981  |
| atck_5   | 0.9113 | 46.4             | 0.944           | 45.23    | 0.9477        | 45.23  |
| atck_6   | 0.8378 | 0.938            | 0.9197          | 0.9258   | 0.9367        | 0.9597 |
| atck_7   | 0.9968 | 0.9685           | 0.9777          | 0.9747   | 0.9983        | 0.9947 |
| atck_8   | 0.7834 | 0.7858           | 0.7537          | 0.76     | 0.9658        | 0.9655 |

PSNR (in dB) = 35.865

### Table 5. Performance at varying number of iterations

| Attack   | 10 iterations NC | 15 iterations NC | 20 iterations NC | 30 iterations NC | 50 iterations NC | 80 iterations NC |
|----------|------------------|------------------|------------------|------------------|------------------|------------------|
|          | BER              | BER              | BER              | BER              | BER              | BER              |
| atck_0   | 0.9998           | 0.9998           | 0.9996           | 0.9903           | 0.99   | 0.991 |
| atck_1   | 0.9693           | 0.9656           | 0.9712           | 0.9865           | 0.9876          | 0.9693          |
| atck_2   | 0.8806           | 0.891            | 0.9157           | 0.978            | 0.977           | 0.8806          |
| atck_3   | 0.9968           | 0.9969           | 0.9976           | 0.9892           | 0.9911          | 0.9968          |
| atck_4   | 0.9776           | 0.9797           | 0.9846           | 0.9874           | 0.9886          | 0.9776          |
| atck_5   | 0.9113           | 46.429           | 0.9117           | 46.4285          | 0.9107          | 46.4285         |
| atck_6   | 0.8938           | 0.8922           | 0.8864           | 0.8851           | 0.8816          | 0.8938          |
| atck_7   | 0.9374           | 0.9412           | 0.9536           | 0.9729           | 0.9749          | 0.9374          |
| atck_8   | 0.7834           | 0.7929           | 0.8242           | 0.9288           | 0.9244          | 0.7834          |

PSNR (in dB) = 35.865
5. Conclusion

Based on optimization technique, we developed a non-blind robust watermarking in the DWT-SVD domain. In our scheme, dual watermarks are imperceptibly embedded within the singular matrices of the selected DWT sub-bands of the cover for extra level of security and authenticity. The method uses optimization techniques to make the balance between robustness, imperceptivity and capacity. Out of the three different optimizations techniques, ABC algorithm performed better than PSO and firefly scheme. Moreover, the patient text data is encoded via hamming code before embedding in to the cover so that bit error rate can avoid or eliminate, if any. Our results analysis has indicated that the proposed scheme is efficient for tele-health applications. In future, we will study the performance of proposed scheme with some more appropriate transform and hybrid meta-heuristic technique, which will offer better results. We may also incorporate the concepts of machine learning, neural networks and blockchain to further enhance the performance.
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