

Medical Image Watermarking based on SVD-DWT technique

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Abstract. This paper presents a new semi-blind digital watermarking technique using demographic text data and iris code for identification as multiple watermarks. The original image is decomposed into 2-level wavelet transform. In the second level of wavelet transform, the two sub-bands with higher energy are selected as a place to embed the watermark bits. These sub-bands are divided into 8*8 pixels blocks and then singular value decomposition (SVD) is computed to each block. The singular values of host image are modified by the singular values of the watermarks. Experiments conducted on four types of medical images prove that these modifications are visually imperceptible while it has a good robustness against some common attacks such as compression, filtering, and noise.

Keywords: Medical image, Singular Value Decomposition, Wavelet transform, Watermark;

1. Introduction

Nowadays most physicians rely on Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasonic and the traditional X-Ray images to diagnose their patient accurately, therefore the exchange of medical images between hospitals has become common in order to share the information for diagnostic, on the other hand, this process needs a considerable amount of memory and bandwidth. One way to overcome this problem is to have the complete medical information of a patient available in one entity rather than over several information systems. This exchange of medical images shows three advantages [1] 1: Confidentiality means that only entitled persons have access to the information since some patients do not like to expose their information to the public. 2: Reliability which includes: Integrity means the information has not been modified by unauthorized users and Authentication, which is a proof that the information belongs to the correct patient and is issued from the right source. 3: Availability which means the access to the information for authorized persons. Different kinds of watermarks meet the parameters of imperceptibility, robustness and capacity to different degrees, these parameters usually conflict with each other. Therefore, an application-dependent trade-off between them is necessary.

Medical images are usually comprised of region of interest (ROI) and region of non interest (RONI)[2]. The portions of an image which include the significant information for diagnosis are called ROI and therefore should be remained intact during the watermarking (embedding) process. The rest of image is called RONI and hence the watermark may be included in such region.

It has been shown that employing digital wavelet transform (DWT) in watermarking of image information shows priority over other data hiding algorithms, especially when DWT is combined with other techniques to improve the robustness [3, 4]. Singular value decomposition (SVD) is one of the most convenient tools of linear algebra with several applications in image compression, watermarking and other areas of signal processing. Most SVD- based watermarking schemes modify the singular values of host image by the singular values of watermark.

This paper presents a watermarking algorithm for medical images in which DWT and SVD are exploited to produce a robust watermarking method. Section 2 provides a brief review on Watermarking techniques and SVD concept. In section 3, proposed embedding and extracting algorithms are presented. This is followed by

experimental results in section 4 and discussion on results and concluding remarks are presented in the last section.

2. Watermarking methods

2.1. Domain selection

Watermarking method can be distinctly divided into two basic categories[5]: 1: Spatial domain and 2: Frequency domain. Spatial domain schemes embed watermarks in pixels of an image directly. The least significant bit (LSB) scheme is the most common method to embed watermarks in an image[6]. The main advantage of this approach is its simplicity while it presents a low robustness which is its main disadvantage. 2: Frequency domain watermarking, for example, using the DFT (Discrete Fourier Transform), DCT (Discrete Cosine Transform) and DWT (Discrete Wavelet Transform) which are difficult to detect the watermarks. Discrete Wavelet Transform has excellent spatial localization, frequency spread, and multi-resolution characteristics similar to the theoretical models of the human visual system (HVS). The HVS splits an image into several frequency channels, which each channel processes the corresponding signals independently, the dyadic wavelet decomposition performs the similar image resolution by dividing the image into different bands with different frequency. 2-D DWT process the image by 2-D filters in each dimension. The filters divide the input image into four non-overlapping multi resolution sub-bands LL, LH, HL and HH. HH, HL and LH contain the diagonal, horizontal and vertical details of the image, respectively while the LL sub-band contains the coarse details of the image. To obtain the next coarser scale of wavelet coefficients, the LL sub-band is further decomposed until L-level wavelet coefficients are produced. Fig. 1 illuminates 2-level decomposition.

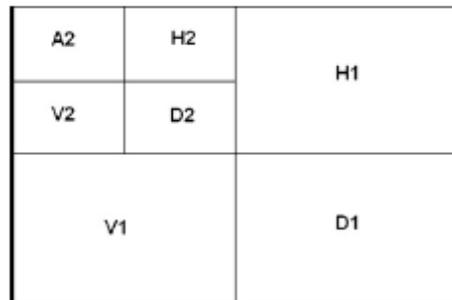


Fig. 1.2- level DWT composition

The approximation sub-band is not selected because manipulation of the low frequency sub-band will impose severe degradations on the reconstructed image as the most of the energy is concentrated in this sub-band. The sub-bands which have higher energy are more robust against common attacks. Therefore, in the second level of wavelet transform, the 2 sub-bands with higher energy are selected as the place to embed the watermark bits. These sub-bands are divided to non-overlapping blocks of 8*8 pixels and then the SVD transform is used to these blocks.

2.2. Singular value decomposition

Singular value decomposition (SVD) is one of the most useful tools of linear algebra with several applications in image compression, watermarking and other areas of signal processing[7]. SVD packs maximum signal energy into a few coefficients as possible. Every real matrix A can be decomposed into a product of 3 matrices $A = U\Sigma V^T$, where U and V are orthogonal matrices, $U^T U = I$, $V^T V = I$, and $\Sigma = \text{diag}(\lambda_1, \lambda_2, \dots)$. The diagonal entries of Σ are called the singular values of A , the columns of U are called the left singular vectors of A , and the columns of V are called the right singular vectors of A . This decomposition is known as the Singular Value Decomposition (SVD) of A , and can be written as

$$A = \lambda_1 U_1 V_1^T + \lambda_2 U_2 V_2^T + \dots + \lambda_r U_r V_r^T \quad (1)$$

Where r is the rank of matrix A . Singular values are organized in decreasing numerical in order from top left to the bottom right of the matrix. It is important to note that the singular value decomposition of digital images presents the following properties [8]:

1: The singular value of image is stable which means that it does not change much after applying common attacks and so watermarked image quality is not reduced and its changes are not noticeable with human eyes. 2: Each singular value specifies the luminance of an image layer while the corresponding pair of singular vectors specifies the geometry of the image layer. An important property of SVD –base watermarking is that the largest of the modified singular values against signal processing attacks change very little.

2.3. Introducing the two watermarks

The Proposed watermarking algorithm is designed to embed the following watermarks:

Details of diagnosis done by the doctor, Electronic Patient Record(EPR), and iris code are embedded in an image as double watermarks. Electronic Patient Record included health history, diagnosis report, sex and age, etc. The second watermark is related to Iris code used for identity authentication. The human iris is a thin circular diaphragm lying between the cornea and the lens. For every person, iris characteristics are unique, stable over the lifetime which make iris particularly useful for personal identification. These following measures are needed to take for reaching iris code:

- 1: Providing appropriate image of iris image
- 2: Segmentation of the image
- 3: Normalizing the image
- 4: Image enhancement
- 5: Feature extraction
- 6: Using Gabor filter to reach binary array.

Iris segmentation is to locate the valid part of the iris biometrics, [9] including finding the papillary and limbic boundaries of the iris, localizing its upper and lower eyelid if they occlude, and detecting and excluding any superimposed occlusion of eyelashes [9], shadows, or reflection. There are some portions in the iris of the human eyes which have the most significant, so to reach lower bits just these portions can be used [10].

3. The proposed algorithm

The proposed watermarking algorithm consists of two procedures; watermark embedding and watermark extraction procedure as described below.

3.1. Embedding process

The embedding process is performed in the following steps.

1. Separate the ROI areas of the host image from RONI areas using the threshold method.
2. Compute 2-level DWT for the host image. The slight modification into LL sub-band is noticeable so it is not used for embedding. In each of level, compute the amount of energy of LH, HL, HH sub-bands according to Equation 2 given below and select two sub-bands with most of the energy.

$$\theta_k = \frac{\sum_i \sum_j |x_k(i, j)|}{M_k N_k} \quad (2)$$

Where M_k and N_k correspond to dimensions of each coefficient matrix x_k of sub-band x at level k .

- 3: Divide the selected sub-band into blocks of 8*8 pixels.
- 4: Select 32 blocks with highest energy in each of the sub-band. So the total blocks are 64.
- 3: Apply singular value decomposition (SVD) to each block

$$A_s = U_s S_s V_s^T \quad (3)$$

- 4: Applying SVD to watermark blocks.

$$W = U_w S_w V_w^T \quad (4)$$

5: Modify the singular value of the host image in each sub-band with the singular values of watermark using the following equation:

$$S_S^W = S_S + aS_W S_S \quad (5)$$

5: Obtain the 2 sets of modified DWT coefficients.

$$A_S^W = U_S S_S^W V_S^T \quad (6)$$

6: Apply 2-level inverse wavelet transform to reach the watermarked image. Fig. 2 shows the MRI, CT-SCAN, ultrasound and X-RAY original image and watermarked image respectively.

3.2. Extracting process

Extracting process after facing watermarked image with different attacks is as follows:

1. Compute 2-level DWT for the watermarked image. Select two sub-bands in the same way as embedding process, Do step1, 2 in the same way as embedding process.

2: apply singular value decomposition (SVD) to each block

$$A_S^* = U_S^* S_S^* V_S^{T*} \quad (7)$$

3: Extracting singular values from each sub-band:

This method does not need the original image, it just needs the matrix of the SVs of the original image

$$S_S^W = \frac{S_S^* - S_S}{a} \quad (8)$$

4: Producing 1000 sample signal denoted by Y_k , k 1: 1000 containing the original watermark, and then applying SVD to each signal

$$Y_k = U_k S_k V_k^T \text{ for } k, 1: 1000 \quad (9)$$

Compute correlation between these two matrixes of singular value S_S^W, S_k for extracting the watermark, the signal with largest correlation value is assumed to be the original watermark.

4. Experimental Result

4.1. Experimental results

This section describes the experimental results of the proposed scheme. All the images used are 256*256 gray-scale images. The proposed method embeds a couple of watermarks into different types of medical images. All the watermarks were used are binary arrays from the sets {0, 1}. Text file was read first and each character converted into ASCII code. An 8 bits representation has been used to convert them to a binary array. EPR contained total of 256 characters, which were converted into binary form resulting in 2048 bits. After using Gabor filter to reach a binary array, the used Iris code is 2048 bits. These 2 watermarks are combined to reach 4096 bits. This array is converted to 64 blocks of 8*8 pixels. The SVs of 64 selected blocks of original image are modified with SVs of these 64 blocks. Performance of the proposed algorithm is evaluated using four types of medical images. Fig.2 shows the original images of MRI, Ct-scan, Ultrasound, X-ray and the related watermarked images respectively.

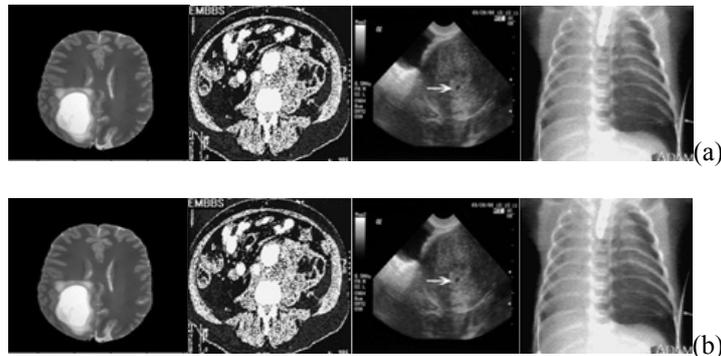


Fig. 2. (a) original images; (b) watermarked image.

PSNR is Peak Signal to Noise ratio in decibels which is quality measurement between the original and watermarked image. The higher the PSNR, the better quality of watermarked image. The PSNR is computed by:

$$PSNR = 10 \log_{10} (x_{peak}^2 / MSE), \quad MSE = \frac{\sum_i \sum_j (S_{ij} - \hat{S}_{ij})^2}{MN} \quad (10)$$

Where x_{peak} is the maximum gray value of the original image, and \hat{S} and S are watermarked image and original image respectively. Experimental results as Table I shows these modifications are visually imperceptible in terms of PSNR and also the extracted watermarks show good robustness against some common attacks such as compression, filtering, and noise.

Table 1. Imperceptibility shown in the original and watermarked images in the terms of PSNR.

Image	PSNR
X-Ray	41.59
Ultrasound	39.83
Ct-Scan	36.40
MRI	38.28

This method is robust against compression attack and it can detect the original watermark from 1000 signals with a good accuracy. Fig. 3 shows the detector response of detected watermark in jpeg compression with Quality factor 30.

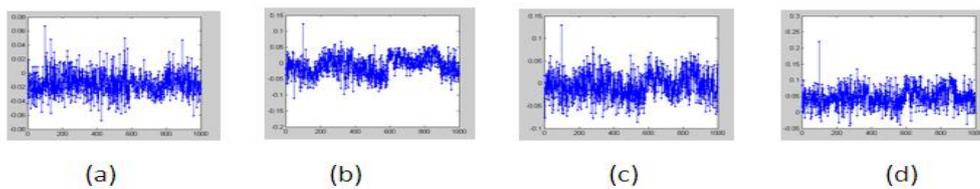


Fig. 3. Detector response of detected watermark in jpeg compression with Quality factor 30. (a) MRI image (b) Ct-scan image (c) Ultrasound image (d) X-ray image

This method is also robust against scaling and filtering attacks. Figure 4 shows the detector response of detected watermark against scaling attack. In a other test, the watermarked image was filtered with Gaussian filter with window mask sizes of 7×7 . The collected results show that method is robust against filtering and it can detect the original watermark from 1000 signals with a good accuracy too.

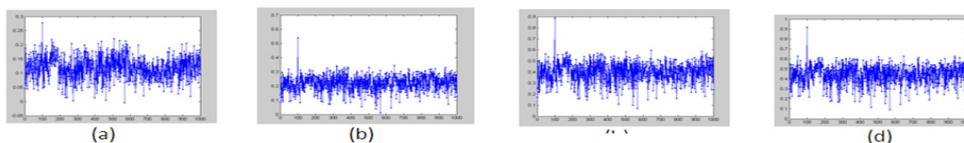


Fig. 4. Detector response of detected watermark in against scaling (a) MRI image (b) Ct-scan image (c) Ultrasound image (d) X-ray

Fig.5 referred to shows the detector response of detected watermark against Gaussian filtering with mask size 7×7 . After the examination of results, it can be proved that the x-ray image has the best detector response and it is the most robust against intentional attacks and image processing and the MRI image is the least robust.

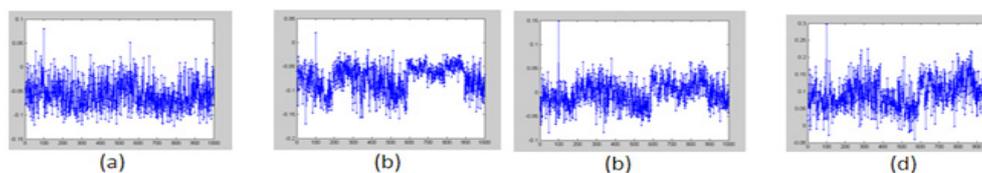


Fig.5. Detector response of detected watermark in against Gaussian filtering with mask size 7×7 (a) Mri image (b) Ct-scan image (c) Ultrasound image (d) X-ray image.

5. Conclusion

Singular value decomposition has become one of the most popular watermarking algorithms. In this paper a novel watermarking scheme, that uses the combination of digital wavelet transform and SVD has been presented. Experiments proved that the algorithm can embed the watermarks into images and the detector can retrieve the original signal between 1000 existed signals. The good characteristics of proposed method is a good performance in terms of imperceptibility, data payload, robustness against common signal processing attacks such as JPEG compression, Gaussian filtering and scaling.

6. References

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