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Digital Watermarking for Medical Images using Biorthogonal Wavelet Filters and Transformed Watermark Embedding

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Abstract

In recent years, data protection is one of important aspect because of cases like piracy, copyright and ownership issues. Digital watermark seems to be solution to the problem. In our paper, we proposed a method of invisible watermark to medical image using Biorthogonal wavelet filter and transformed domain watermark embedding. Generally watermark is embedded in original image either directly or in transform of original image. In our method, we transformed both original image and watermark using discrete wavelet transform and Biorthogonal wavelet filter coefficients. We specifically follow this method considering the case of medical images. As medical images are low contrast images and are taken at high precision with special equipment, so it is not expected that any one will claim for its ownership. Hence we tried to develop a method which will recover watermark through medical image considering any kind of attacks. We tested our method on multiple medical images and listed down results and comparison is made on basis of PSNR and normalised correlation (NC). From the values of NC, we concluded that our method gives better recovery of watermark from watermarked image.

Keywords

Invisible Watermark, medical images, DWT, BWT, PSNR, NC, Watermark Attacks.

1. Introduction

Today due to advancement in internet and printing technology, it is needed to preserve ownership of multimedia signals such audio, image and video signals and text from being copied and getting misused. Digital watermarks are marker embedded in audio, image and video signal for protecting ownership of copyright of that audio, image and video signal.

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Watermarking is the process of hiding information into original signal and that hidden information may or may not be related with original signal. Digital watermark may be audio, image, video and text. Digital watermark have properties such as Robustness, Impeccability, capacity, security [1]. Robustness is measure of resistance to any attack, Perceptibility gives amount with which watermark is visible. Capacity is number of bits used for representing watermark. Watermarking is passive tool which preserves ownership of that particular signal but also allow access to that signal without loss of any original information. Watermarks are classified in two class namely visible watermarks and invisible watermarks. In visible case image is represented by distinctive unique message which can be a logo of company.

In invisible watermarking system invisibilities are maintained such that original and watermarked image are seen alike. The main requirement of this system is that invisibility of watermark should be maintained over any kind of attack. Invisible watermark provides security against unauthorized detection and extraction of invisible watermark is carried out via computer program. Invisibility of watermark increases with increase in frequency. As human eyes are very sensitive to low frequency noise, invisible watermarking system uses higher frequency range to improve invisibility. At higher frequency robustness of system decreases and so there is tradeoff between robustness and invisibility [2].

Digital watermarking finds a major application in medical field to protect authentication, integrity and reliability of medical images [3]. Medical images are transmitted over internet for diagnostic aspects and can be corrupted, pirated so overcome this problem medical filed needs robust watermarking techniques which can sustain any attack on watermarked image.
General block diagram of digital watermarking is given in figure 1. In digital watermarking input image, watermark and key are given to embedding function. Embedding function inserts watermark into input image using key. Key may be sequence number, scaling parameter. Watermarked image may be attacked by external noise which is random in

nature. Sometimes watermarked image undergo cropping and rotation which are most dangerous attacks. For extracting watermark form image, watermarked image is given to recovering function. Key provided to recovering function must be same as key given at embedding function.

In our paper, Section 2 gives information about wavelet transform. Section 3 and 4 will discuss Biorthogonal wavelets and Biorthogonal wavelet filters respectively. Section 5 includes literature survey. Section 6 includes our proposed method and section 7 will show respective experimental results. Section 8 will discuss about conclusion and future scope.

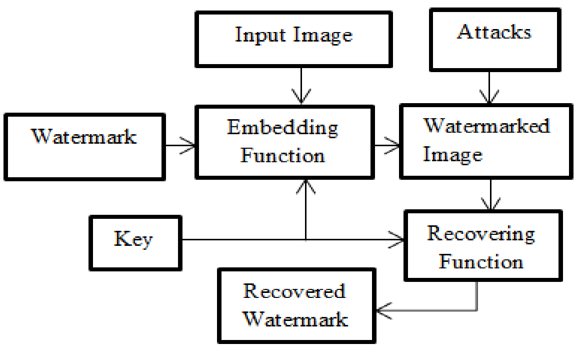


Fig. 1: General digital watermarking process

2. Wavelet Transform

Wavelets means small wave and wavelet transform deals with analysis of signal with short duration energy function. Wavelets are a special kind of functions which exhibits oscillatory behaviour for a short period of time and then die out. Thus wavelet transform allows time and frequency localization. Time and frequency localization is the main advantage of wavelet transform on Fourier transform. In general, wavelet transform is categorised in two types, Continuous wavelet transform (CWT) and Discrete Wavelet Transform (DWT). CWT being continues and function of parameters called scaling and translation, it contains large amount of redundant information when analysing a function. To avoid the problem of redundancy, we analyse the signal with a small number of scales with varying number of translations at each scale [4]. This is the discrete wavelet transform. The discrete WT (DWT) is digital representation of the CWT, and it is given by

$$\psi_{(j,k)} = \psi(a^{-j}t - kb) * a^{-\frac{j}{2}} \qquad (1)$$

Where in general a = 2 and b = 1 turning it to dyadic sampling grid as

$$\psi_{j,k}(t) = 2^{-j/2} * \psi(2^{-j}t - k) \qquad j,k \in Z \qquad (2)$$

Where j defines scaling and k defines translation of wavelet function.
Two dimensional DWT can be used to decompose the given image into four components called as multi-resolution analysis. In general it is represented as shown below.
LL represents approximate low frequency content of image which contains maximum information regarding image, we further make use of LL content to recover our watermark from processed image. LH, HL, HH are horizontal, vertical and diagonal frequency content of image.

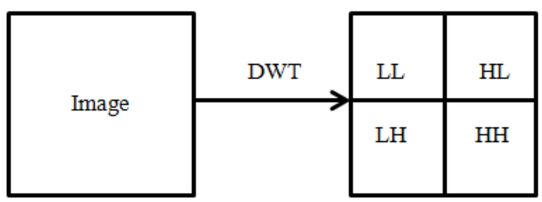


Fig. 2: Decomposition structure using DWT

This is achieved using wavelet decomposition filter which are defined in term of scaling function and wavelet function given in general as follows

$$\Phi(t) = \sum_k h(k)\sqrt{2}\,\Phi(2t-k) \qquad (3)$$

$$\psi(t) = \sum_k g(k)\sqrt{2}\,\psi(2t-k) \qquad (4)$$

Where $\Phi(t)$ is scaling function, $\psi(t)$ is wavelet function, h(k) is low pass scaling filter coefficients and g(k) is high pass wavelet filter coefficients.

3. Biorthogonal Wavelets

In case of filtering applications, to have linear phase response it is expected to have filters with symmetrical coefficients [5]. Excluding Haar wavelet, all orthogonal wavelets have asymmetric filter coefficients. Because of sharp transitions in response of Haar wavelet, it is not applicable for many practical applications. So Biorthogonal wavelet systems can be designed to have this property. It makes use of a set of low pass and high pass filter for reconstruction and decomposition which satisfy properties like symmetric wavelet and perfect reconstruction. Also Biorthogonal wavelet transform is invertible transform.

Let consider a scaling function $\Phi(t)$ and its dual scaling function $\tilde{\Phi}(t)$ as

$$\Phi(t) = \sum_{k=0}^{N-1} h(k)\sqrt{2}\,\Phi(2t-k)$$

$$\tilde{\Phi}(t) = \sum_{k=0}^{N-1} h(k)\sqrt{2}\tilde{\Phi}(2t-k) \qquad (5)$$

These two will be orthogonal if $\Phi(t)$ and its translates are not orthogonal among themselves but orthogonal to translates of $\tilde{\Phi}(t)$. In similar way wavelet function $\psi(t)$ and its dual $\tilde{\psi}(t)$ also follow scaling relation. In orthogonal wavelet system, $\Phi(t)$ is orthogonal to $\psi(t)$ and it's translates. In Biorthogonal system $\Phi(t)$ will be orthogonal to $\tilde{\psi}(t)$ and it's translates.

4. Biorthogonal Wavelet Filter

Biorthogonal filters define a superset of orthogonal wavelet filters and can be used in virtually all areas where wavelets are utilized. As there is lot of variety in available Biorthogonal wavelets, it is not unlikely that different have somewhat different properties. Biorthogonal filters are used for decomposition (analysis) and reconstruction (synthesis) same as subband filtering method. General decomposition and reconstruction is shown in figure 3.

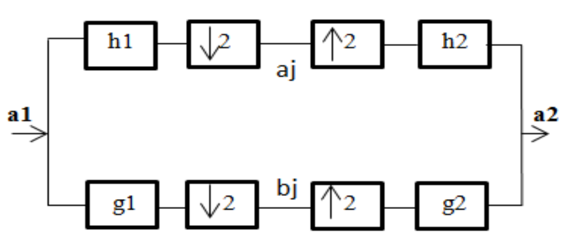


Fig. 3: Decomposition and reconstruction process

From figure,
aj(n) = h(2n)*a1(n) and bj(n) = g1(2n)*a1(n)

Coefficients h and g are defined by following functions

$$\tilde{\Phi}(t) = \sum_{k=0}^{N-1} h(k)\sqrt{2}\tilde{\Phi}(2t-k)$$

$$\tilde{\psi}(t) = \sum_{k=0}^{N-1} g(k)\sqrt{2}\tilde{\psi}(2t-k)$$

If a1 = a2; perfect reconstruction will occur provided that h1 = h2 and g1 = g2.

5. Literature Survey

In the literatures mainly two types of watermarking techniques are discussed, watermarks are embedded in image either in spatial domain or in frequency domain. The spatial domain is simple and less costly but it is very sensitive to noise attacks. Frequency domain embedding is comparatively complex but robust against various noise attacks.

Cong Jin et.al [6] described watermarking scheme using wavelet transform and Human Visual System (HVS). In this method watermark is embedded using adaptive embedding based on Human Visual System. It considers sensitivity of human eye towards noise, luminous and textures. Watermark is inserted using adaptive gain factor which is calculated from noise sensitivity, luminosity, edge distance and texture area. This method is robust against noise, cropping.

Error correcting codes [7] are used for watermark in Hamming and cyclic codes are major error correcting codes used in communication system and also useful in watermarking for recovery of corrected watermark in noisy environment. Use of DWT and singular value decomposition is discussed by Prof. Mahendra M. Dixit et.al [8]. DWT is applied to original image and its SVD are calculated then SVD of watermark is added with SVD of original image and IDWT is taken to get watermark image.

LSB modification and Run length encoding for compression for watermark embedding is discussed by Tjokorda Agung et. al [9]. Watermarks are scaled and embedded in LSB of original image and Run length Encoding is used to compress the Watermark image and due to RLE embedding capacity increases.

Dong-Gyu Yeo et.al [10] discussed method of shifting histogram used for embedding watermark. In this method histogram is shifted to make space for message embedding. Histogram of message is added to shifted version of original image histogram. In [11] authors have used two Fibonacci based algorithm for image scrambling. This method has many applications in real time applications and performs well for various attacks. Min Li, Ting et. al [12] a powerful scrambling algorithm of Arnold Transform is discussed. In Arnold transform we come to original image after certain number of iterations. The number of iterations is related with size of image and it is key for unscrambling the watermark. Rajendra S. Shekhawat et.al [13] discussed watermarking mechanism based on Pseudo Noise (PN) sequence. In this method watermark gray values are added with scaled version of PN sequence number. At recovery time same PN sequence is generated to get original watermark.

In 2012, B. Rajendra Prasad et.al [14] proposed method of watermarking using Biorthogonal Transform. They use biorthogonal wavelet transform for digital watermarking. For cropping and rotational attack their algorithm gives less performance.

In 2012, Rashel Sarkar et.al [15] implemented hardware based invisible watermarking scheme using spatial domain embedding method. They use specific embedding function for watermarking which depends upon pixel intensity of watermark. It is low cost and simple to implement but time consuming as it works on pixel by pixel. It has other advantages like secure transmission, high robustness etc.

In 2012, Baisa L. Gunjal et.al [16] explored method of watermark in medical images using ROI method. In this method watermark is embedded in Region of interest only. It gives better recovery of watermark. They use Arnold transform for watermark scrambling and wavelet transform for host image decomposition. This method is robust against various noise attacks.

We have used new technique of embedding watermark in which we have taken Wavelet transform for both original image and watermark and then coefficients of mid frequency regions are modified with coefficients of mid frequency region of watermark. Our proposed method works well for medical image and recovered watermark is nearly identical with original watermark. We have shown Matlab results in coming section.

6. Proposed work

Block diagram of proposed method is as shown in figure 4.

In the proposed method we have taken Biorthogonal wavelet transform of both watermark and original image. We have taken 256x256 original image and 64x64size image for watermark. We have added normalized version of LH component of watermark into the LH component of original image so that the grey level values of original image will remain almost unchanged. To get the watermarked image, we took inverse wavelet transform using Biorthogonal reconstruction filter coefficient.

While recovering the watermark image, we followed same procedure as that of embedding process. We took DWT of watermarked image using Biorthogonal filter coefficient and found LH component of watermarked image. By subtracting LH components of original image from watermarked image, we got LH components of watermark. Then after denormalization the LH components, we took inverse wavelet transform using Biorthogonal reconstruction filter coefficient that we use during construction of watermark image, we recovered the watermark.

The above procedure of reconstruction will remain same in case of any attack to watermarked image. We have tested our proposed algorithm on medical images of knee and brain.

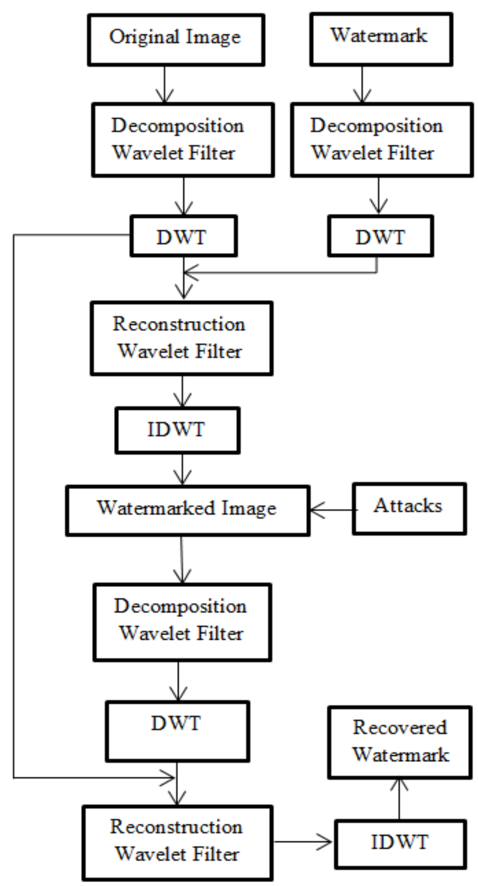


Fig. 4: Proposed method

Detail algorithm of our proposed method is as given below

Watermark embedding Process:

1. Take input image and decompose using biorthogonal wavelet filters.
2. Take watermark image and decompose it using biorthogonal wavelet filters.
3. Take mid frequency components of original image and add normalized mid frequency components of watermark to it.
4. Take inverse wavelet transform using reconstruction filters to get watermark image.

Watermark Extraction Process:

1. Decompose watermark image to get mid frequency components.
2. Subtract mid frequency components of original image from watermarked image to get mid frequency components of watermark
3. Do denormalization and inverse wavelet transform using biorthogonal reconstruction filters to extract watermark

7. Experimental Results

We have used two medical images, test image 1 is MRI scan image of brain [17] and test image 2 is MRI image of knee [18] as shown in table no.2. Watermark image is taken from [14].

Fig no.5 shows the result for reconstruction of watermark image in case of no attack to watermarked image. Fig no.5 a & b represent original host image and watermark to embed respectively. Fig no.5 c & d represent the watermarked image and recovered watermark respectively.

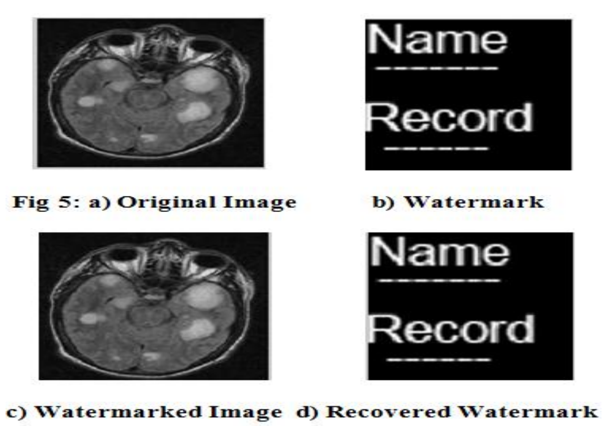


Fig 5: (a) Original Image (b) Watermark (c) Watermarked Image (d)Recovered Watermarked

We tested our proposed method on various attacks like Gaussian noise, speckle noise, salt and pepper noise etc.; we also tested it against attacks like cropping of image, rotation of image. We also performed high pass filtering, low pass filtering and median filtering on watermarked images. Comparing of results is done on basis of following performance measures.

Performance measures: To evaluate algorithms on digital watermark mainly two performance measures are used which are Peak signal to noise Ratio (PSNR)

PSNR [14] is used to calculate amount of distortion in original and watermarked image due to insertion of watermark and generally given in dB

$$PSNR=10*\log_{10}(Imax*Imax) / (MSE) \qquad (6)$$

Where, MSE is mean square error

Imax is maximum grey value of image.

MSE is calculated as follows,

$$MSE=\frac{1}{M*N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[I(i,j)-X(i,j)\right]^2 \qquad (7)$$

Where, I is original image

X is watermarked image.

M and N are dimensions of original image

Normalized Correlation (NC)

Normalized correlation [19] gives degree of similarity between original watermark and recovered watermark and it is given by

$$NC=\frac{1}{M*N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} W(i,j)*W'(i,j) / A \qquad (8)$$

Where, $A=\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}[W(i,j)]^2$

W (i, j) =original watermark

$W'(i,j)$ =recovered watermark

Table 1: Different Watermark attacks

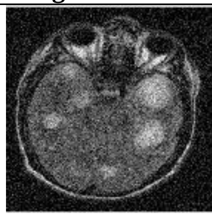
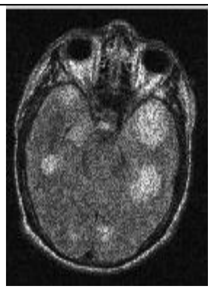
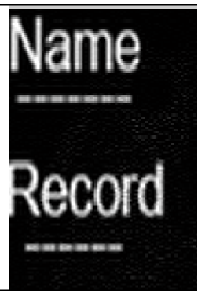
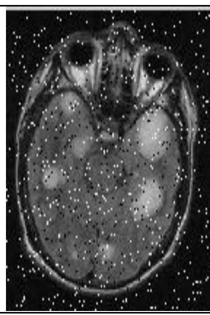
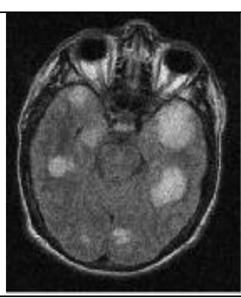
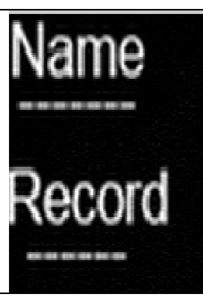
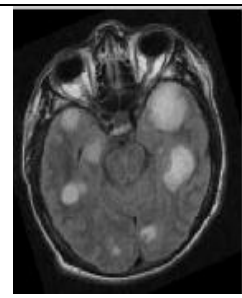
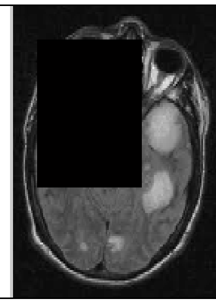
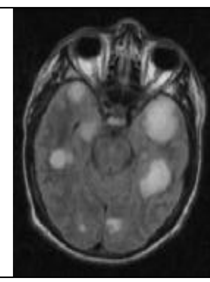
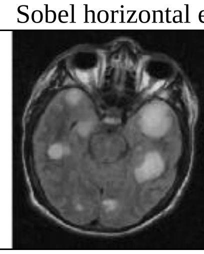
Attack	Watermarked Image	Recovered watermark
Gaussian		
	Mean = 0 with Variance = 0.01	
Speckle		
	Multiplicative noise of variance = 0.04	
Salt and Pepper		
	Noise density = 0.05	
Poisson		
	Mean = 10	
Rotation		
	10 degree rotation	
Cropping		
	25 % cropping	
LPF		
	Averaging Filter of 3x3 block size	
HPF		
	Sobel horizontal edge-emphasizing filter	
Median		
	Median filtering of 3x3 neighborhood	

Table 2: Comparison of PSNR (in dB) for BWT and DWT for various Attacks

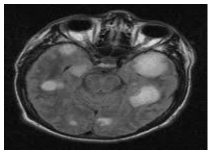
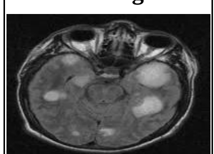
Attacks	Test image 1		Test image 2	
				
	BWT	DWT	BWT	DWT
No attacks	51.874	44.635	46.500	43.284
Gaussian	20.704	20.717	20.593	20.580
Speckle noise	23.701	23.690	19.065	19.059
Salt and PepperNoise	17.520	17.511	17.657	17.628
Poisson	30.344	30.237	27.759	27.680
Rotation	37.370	37.380	24.492	24.495
Cropping	29.410	29.410	28.523	28.523
LPF	33.403	33.318	32.605	32.553
HPF	11.481	11.483	6.229	6.292
Median	35.441	35.160	35.298	35.108

Table 3: Comparison of NC for BWT and DWT for various Attacks

Attacks	Test image 1		Test image 2	
				
	BWT	DWT	BWT	DWT
No attacks	0.989	0.979	0.989	0.979
Gaussian	0.989	0.978	0.989	0.978
Speckle noise	0.952	0.961	0.952	0.962
Salt and PepperNoise	0.952	0.962	0.952	0.962
Poisson Noise	0.951	0.962	0.951	0.962
Rotation	0.951	0.962	0.951	0.962
Cropping	0.951	0.962	0.951	0.961
LPF	0.951	0.962	0.951	0.961
HPF	0.951	0.962	0.951	0.961
Median	0.9517	0.962	0.9518	0.961

8. Conclusion and Future Scope

From experimental results and comparison it is shown that our proposed method is well suitable for medical images. Our system works well for Poisson noise and rotation of about 10-20 degrees. Our proposed method also yields good PSNR for cropping up to 25%. For median and low pass filtering our proposed method shows quite good result. From table of Normalized Correlation we can say that recovered watermark by our proposed method is very similar with original watermark. We also tested our proposed method by taking discrete wavelet filter coefficients also. The value Normalized Correlation is nearly same for both BWT and DWT if watermarked image is attacked by external noise. In case of no attack, BWT gives better results. In case of PSNR we found that BWT yields better results than DWT in case of no attack on watermarked image. Our Proposed method yields less PSNR values for Gaussian, Speckle and salt and pepper noise. Our future aim is to modify our algorithm to get better PSNR in case of Gaussian, Speckle and Salt and Pepper noise using Multilevel Embedding, as with the use of multilevel embedding we will embed watermark at different subband of decomposed image. Also we can improve NC by embedding block by block watermark in multilevel decomposition of original image.

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