ROBUST MEDICAL IMAGE MULTIPLE WATERMARK USING 4-LEVEL DWT

[1]Swapnil R. Suke, [2]Dr.Prof. Vibha Vyas
E&TC Department COEP
Email:[1]swapnilsk8@gmail.com, [2]vsv.extc@coep.ac.in

Abstract— In this paper we propose a novel approach for medical image security during their transmission over the network. Medical images like CT, MRI, X-ray contain the patients' vital and confidential information. During transmission over network, it may face different attacks. To prevent such mishaps, embedding of watermark technique is used. In the proposed method, we propose to embed multiple watermarks in the input image for more security and robustness. The method first extracts the detected feature points from the input image by Weber law descriptors (WLD) to insert the watermarks in the optimal location in the input image. Then after insertion of watermarks, the watermarked image is transmitted over network and then at the receiving end, the multiple watermarks are extracted. The robustness of the algorithm is checked by the weighted peak signal to noise ratio (WPSNR) calculation and the efficiency is checked by normalized correlation NC calculation.

Index Terms—Medical image, Multiple watermark, DWT, Weber.

I. INTRODUCTION

Recently because of huge advancement in technologies like internet, telecommunication, we are moving towards digital era. Digital information is easy to handle, easy to store and it also provides ease of transfer and manipulation. Because of these advantages it also becomes the subject of interest in medical image applications. Generally the medical images include patients' personal information. The patients' information is stored digitally in database. The information should be kept very securely so that only authorized person can see the information. During transfer of this information over the public network there are always some chances of attacks, forgery etc. So, now- a-days security of medical images has become huge area of interest among researchers. This is the need of time to secure the transfer of all the medical information through electronic media without any change in the medical image. We can secure this information by using techniques such as cryptography, authentication, etc. There is one more powerful method by which we can add low level signal into these images. This low level signal is known as watermark. This low level signal provides the better security without changing the original information of the image and it can be extracted from image easily. The process of adding low level signal information in digital image is called digital image watermarking. The watermark can be of any type like image, logos, audio or video. The watermarking technique is better over the cryptography technique because in cryptography after the encryption, the resultant image may not be properly visible also at the time of retrieval the information of the host image is lost which is not the problem in watermarking. In watermarking, we can add more than one watermark at a time. This process of adding more than one watermark into the image is called multiple watermarking.

Giakaumaki et al.[1] proposed the method of embedding the multiple watermark into the image by using wavelet transform. This method used 4-level discrete wavelet transform and performed result on ultrasound image. In this technique, the capacity issue is not taken into account and just main focus is on robustness. The doctors' identification code is added in the 4th level. Index watermark is embedded into 3rd level. The method embeds the caption of patients' information in the second level. Even if it gives better integrity and security to the image, there are chances to improve image quality by increasing peak signal to noise ratio (PSNR).

Wakatani[2] presented the watermarking technique by which embedding of watermark is done in region of non interest of image. The technique used is embedded zero tree wavelet (EZW). The disadvantage of this method is that the embedded information can be extracted easily.

Hyung-Kyo Lee[3] proposed the method of watermarking by which the watermark is added in region of non interest of image .The separated region of interest itself used as a watermark .The method is used to prevent the illegal forgery. The disadvantage of this method is the value of similarity measurement between inserted watermark and extracted watermark which is called normalized correlation (NC) values are very less as compared to our method.

II. PROPOSED METHOD

A. Algorithm

In this algorithm for medical image security multiple watermarks are embedded in the medical images, where, depending upon the quantization of selected coefficients, multiple watermarks embedding procedure is used.

Image acquisition:

The first step is image acquisition. The medical image in which the watermark is to be embedded is first acquired from the user and then resized to a fixed size. This image is then converted to grayscale image for further processing and then assigned as reference image.

Four level Haar decomposition:

According to working domain, watermark can be applied in spatial domain or frequency domain. In spatial domain the watermark is added directly in the host data. Though it is simple method of addition of watermark, it is less robust. Watermark can be removed easily by applying some basic operations. So, we are moving towards the frequency domain. Some famous transform domains are DFT, DCT and DWT. The DFT gives the information about the frequency and amplitude. But in some applications like Synthetic aperture RADAR, there is need of time information also. Because of this reason the DWT becomes the most suitable transform among the researchers as it gives the frequency, amplitude information along with information of at which time the signal is applied. The DWT converts the image from spatial domain to frequency domain. The wavelet stands for an orthogonal basis of vector space.

When we apply 2D-DWT on the image, the image is divided into four levels LL, LH, HL and HH. The level LL contain low frequency information, it is the level where most of the image information is stored. The level LH contain the medium frequency information, it is the level where horizontal detail of image is stored. The next level i.e. HL contain the vertical detail. Final level HH contain the high frequency information of image. Further you can increase the level by using decomposition of the low frequency band.

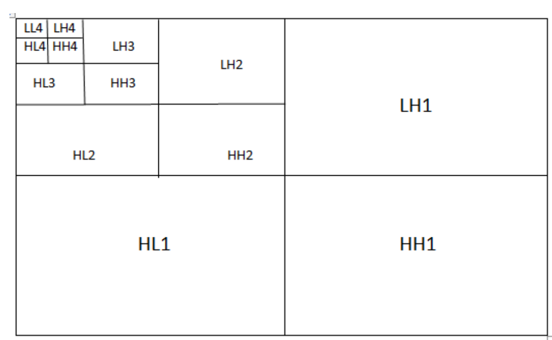


Fig. 1

Haar Wavelet Transform:

Haar wavelet is discontinuous and it resembles the unit step function. This property is advantageous for analysis of signal with sudden transition. It can be represented mathematically as follows:

$$\psi(x) = \begin{cases} 1 & x \in [0,0.5) \\ -1 & x \in [0.5,1] \\ 0 & x \in [0.5,1] \end{cases}$$

and

$$\psi_i^j(x) = \sqrt{2^j}\,\psi(2^j x - i) \qquad (1)$$

Haar is the difference and averaging phenomenon of neighboring pixels. This can be explained by following example. We took 1-D image with 8 pixels.

[4 3 -2 -3 4 1 5 1]

By applying the Haar wavelet on this image we get two types of coefficient i.e. transformed coefficient and detailed coefficient. The transformed coefficient is obtained by taking the average of two consecutive pixels. The detailed coefficient can be obtained by taking the difference of two consecutive pixels at a time and dividing the difference by 2. The detailed coefficient is used for the reconstruction of image. So, after applying one time Haar wavelet transform, the obtained image is:

Transformed coefficient= [3.5 -2.5 2.5 3]

Detailed coefficient= [0.5 0.5 1.5 2]

Feature Point Detection using Weber Local Descriptor:

For feature point detection from the reference image at level 3 and level 4 in H3 and H4 coefficients of the Haar DWT Weber local descriptor [6] is used. The Weber's law states that the ratio of increment threshold and the original stimulus intensity remains constant. The increment threshold represents the just noticeable difference. To extract the feature points from the reference image we calculate the two WLD components i.e. differential excitation (ε) and orientation (θ). First step is to calculate the differential excitation ε. Considering the 3 x 3 mask as shown in Fig. 2 (a), the value of the center pixel is subtracted from the value of each of its neighbor as shown below in Fig. 2 (b). This difference gives us the increment threshold mentioned in the Weber's law. The original stimulus intensity is nothing but the value of the center pixel considered in the above 3 x 3 mask. The original pixel intensity value can be obtained by applying another 3 x 3 mask as shown below in Fig. 2 (c).

P0	P1	P2
P3	P4	P5
P6	P7	P8

(a)Input image

+1	+1	+1
+1	-8	+1
+1	+1	+1

(b) mask 1

0	0	0
0	+1	0
0	0	0

(c) mask 2

Fig. 2

According to the Weber's law, the ratio of the difference between the neighboring and center pixel to the original pixel intensity is constant. The difference between the center and neighboring pixels is calculated by following formula:

$$\mathrm{v1} = \sum_{k=0}^{n-1} (\mathrm{P_k} - \mathrm{P_4}) \qquad (2)$$

The difference image obtained after applying mask 2 is referred as V2. And the ratio V1/V2 is constant. Then the arctangent function is employed to this ratio to compute the differential excitation ε. Thus the differential excitation is calculated by the following formula:

$$\varepsilon(\mathrm{P_4}) = arctan\left[\frac{V1}{V2}\right] = \arctan\left[\sum_{k=0}^{n-1}\left(\frac{\mathrm{P_k} - \mathrm{P_4}}{\mathrm{P_4}}\right)\right] \qquad (3)$$

Because of the delimitation property of arctangent function to limit the output even though the input fluctuates, the arctangent function is used here.

The next step is to calculate orientation (θ). To calculate the orientation value two different masks are used as shown below in the Fig. 3.

P0	P1	P2
P3	P4	P5
P6	P7	P8

(a)Input image

0	-1	0
0	0	0
0	+1	0

(b) mask 3

0	0	0
+1	0	-1
0	0	0

(c) mask 4

Fig. 3

The masks are represented by the following formulae:

$$V3 = (P_7 - P_1) \;\; and \;\; V4 = (P_3 - P_5) \qquad (4)$$

Then by using these masks, the orientation θ is calculated as

$$\theta(P_4) = arctan\left(\frac{V4}{V3}\right) \qquad (5)$$

The value of this θ falls in the range of [-∏/2, ∏/2]. So the θ is mapped θ' into range [0, 2∏] by using following formulae:

$$\theta' = arctan2(V4, V3) + \prod$$

$$arctan2(V4, V3) = \begin{cases} \theta & V4 > 0 \; and \; V3 > 0 \\ \Pi - \theta & V4 > 0 \; and \; V3 < 0 \\ \theta - \Pi & V4 < 0 \; and \; V3 < 0 \\ -\theta & V4 < 0 \; and \; V3 > 0 \end{cases} \quad (6)$$

Thus by applying the WLD mask to input image, we scan the entire image. The scanning is done in such a way that the mask overlaps the next columns and rows of the input image so that the high intensity feature points are extracted from the input image, thus making the algorithm more robust and efficient. While extracting the feature points from the input image, the no. of feature points are counted so as to calculate the size of the watermark to be inserted. The feature points extracted from the image are from the 3rd and 4th level of the Haar DWT. The locations of the pixels from where the feature points are extracted are saved for insertion of watermark.

Watermark Image Resizing:

The next step after feature point extraction is the watermark resizing. As mentioned above, the scanning is done by overlapping the mask across entire image. Thus the no. of feature points extracted from the input image are in large range of numbers. The watermark image size is decided depending upon these no. of features extracted. To resize the watermark image, the square root of the no. of feature points is taken. The single-level two-dimensional wavelet decomposition with respect to a particular wavelet decomposition filters, low pass or high pass of the watermark image is then computed. The DWT of watermark image is computed for robustness. DWT gives better results than DCT. If we add watermark in low frequency band, then there are chances of loss of data and if we add the watermark in high frequency band, then the process of recovery of watermark becomes tedious. So the watermark is embedded in the medium frequency band. The watermark image is then resized by the square root of the no. of feature points extracted, after applying DWT.

Watermark insertion:

In the pixel locations from where the feature points are extracted, the resized watermark is embedded. As the method proposed here is based on multiple watermarks, two separate watermarks are embedded into the input medical image, by same method explained above. The two watermarks are embedded in the 3rd and 4th level for security and robustness. The watermark can consist of the patient's information, doctor's information, fingerprint or the image of patient or any other logo. In this method, we have embedded patient's and doctor's information as watermark images. After insertion of watermark, before sending the watermarked image on the network, the Inverse DWT of the watermarked image is taken for security purpose. After watermark insertion, single-level two-dimensional wavelet reconstruction with respect to the low pass and high pass filter is performed.

Insertion of reference watermark in Image:

In our proposed method, for checking the robustness of the system, a reference watermark is embedded into the input image. As mentioned earlier, the watermark can be inserted in both spatial and frequency domain. The reference watermark is inserted in the spatial domain to check the efficiency of the system to attacks. The insertion of watermark in spatial domain is more prone to attacks than that of frequency domain. The reference watermark is embedded into the input image by XOR operation on the bits of the watermark image.

Calculation of WPSNR:

The weighted peak signal to noise ratio (WPSNR) [5] is the image quality metric. It is an extension of peak signal to noise ratio (PSNR). WPSNR is especially useful where geometric distortions are observed, in our case, the attacks like rotation, scaling may cause the geometric distortions in the input image. The difference between PSNR and WPSNR is the Noise Visibility Function (NVF) which is included in WPSNR. The NVF enables us to know the best location in the input image for embedding watermark and its strength for embedding process. PSNR does not take into account the flat and textured regions of the image so WPSNR is more advantageous than PSNR. So we have calculated WPSNR value of the watermarked image. The results are mentioned in the result section. Following is the formula used for calculation of WPSNR:

$$WPSNR = 10\log_{10}\left(\frac{Maximum\ Pixel\ value}{\sqrt{MSE}\ \times NVF}\right)^2 \quad (7)$$

Where MSE is mean square error which is calculated as follows:

$$\mathrm{MSE} = \frac{1}{\mathrm{xy}}\sum_{\mathrm{m}=0}^{\mathrm{x}-1}\sum_{\mathrm{n}=0}^{\mathrm{y}-1}\|\mathrm{img}(\mathrm{m},\mathrm{n}) - \mathrm{img\_v}(\mathrm{m},\mathrm{n})\|^2 \quad (8)$$

And NVF is calculated by following formula:

$$\mathrm{NVF}(\mathrm{m},\mathrm{n}) = \frac{1}{1+\theta.\,\sigma_{\mathrm{x}}^2(\mathrm{m},\mathrm{n})} \quad (9)$$

Where $\sigma_{\mathrm{x}}^2(\mathrm{m},\mathrm{n})$ represents the local difference between the neighbouring pixels and θ controls the value of NVF. The value of θ is dependent on the image variance as given by following formula:

$$\theta = \frac{\mathrm{D}}{\sigma_{\mathrm{Maximum}}^2(\mathrm{m},\mathrm{n})} \quad (10)$$

Recovery of watermark:

At the receiving end, the reference watermark is recovered to check the effect of attacks. The procedure for the recovery of reference watermark is as explained in this section. First the watermarked image is XORed with the input image as we are working in spatial domain. Then the 4-level DWT is applied on the watermarked image for recovery of the reference watermark. The extraction process is exactly reverse of that of the insertion of the watermark. Again in the received image, for the extraction of other two watermarks, the WLD is used to find out the feature points in 3rd and 4th level. By using these feature points and the size of the watermark image, the watermark is recovered from the received image. This recovered watermark is then resized by the size of square-root of the no. of feature points extracted. The inverse DWT is applied to the resized watermark image. As the proposed method consists of multiple watermarks, the same procedure is applied twice for the two different watermark extraction processes.

Calculation of Normalized correlation (NC):

The NC computes the similarity measurement between the original watermark and the extracted watermark. NC is calculated for both the watermarks. The computed values of NC for the medical images are tabulated in the results section. The formula used for computation of NC is given as follows:

$$NC = \frac{\sum_{x=1}^{N}\sum_{y=1}^{N} w(x,y) * w'(x,y)}{\sum_{x=1}^{N}\sum_{y=1}^{N} w(x,y)^2} \quad (11)$$

where w(x,y) represent the original and w'(x,y) represent the recovered watermark.

III. Experiments and results

The proposed method is applied on different types of medical images like CT scan images, MRI, X-ray and ultrasound images. The images are taken from http://www.nlm.nih.gov/research/visible.

We have tested our algorithm on medical images of size

CT scan images 512 x 512

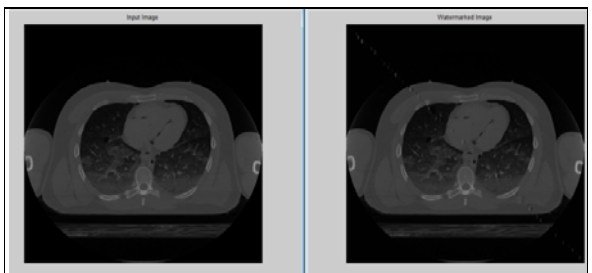
MRI images 512 x 512

X-ray images 416 x 596

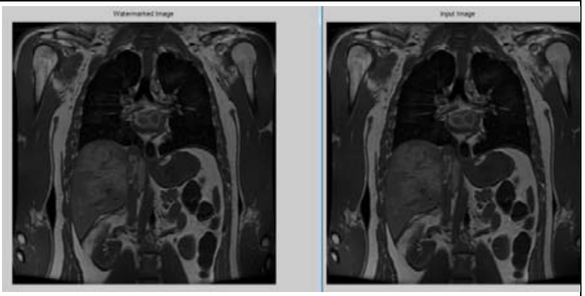
Ultrasound 358 x 256

A. Experiments and results without attack:

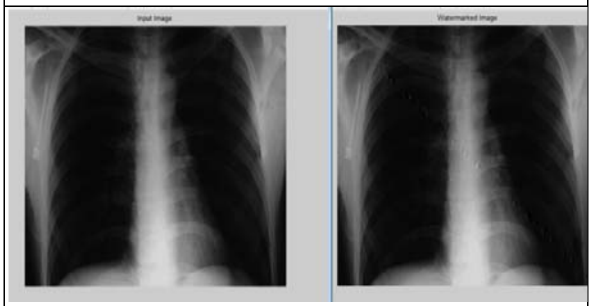
The algorithm was tested on the above images and the resulting images for the experiments without attack are as shown below:



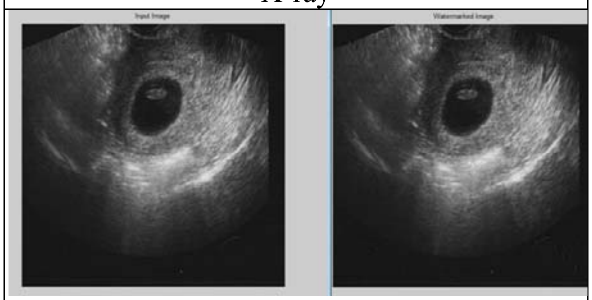
CT



MRI



X-ray



Ultrasound

Fig. 4

The following table shows the values of WPSNR and NC for all the medical images without attack:

Types of images	WPSNR	NC for watermark1	NC for watermark 2
CT Scan	69.34 db	0.9875	0.9986
MRI	51.97 db	0.9903	0.9988
X-Ray	58.63 db	0.9908	0.9986
Ultrasound	55.27 db	0.9925	0.9989

Table 1

B. Experiments and results without attack:

The following attacks were added to the input medical images:

1. Median Filtering attack
2. Noise:
   - Speckle Noise
   - Poisson Noise
3. Rotation attack
4. Translation attack

The results after adding attacks were as follows:

Types of attacks	WPSNR	NC for watermark1	NC for watermark 2
Median Filtering	63.70 dB	0.9884	0.9987
Speckle Noise	53.00 dB	0.9879	0.9985
Poisson Noise	47.03 dB	0.9914	0.9985
Rotation attack	54.73 dB	0.9882	0.9987
Translation Attack	39.20 dB	0.9978	0.9988

Table 2

IV. CONCLUSION AND FUTURE WORK

For the security of medical images over network, there are many methods proposed. The proposed system makes use of embedding of multiple watermarks. The system embeds the watermark using WLD and DWT method. Use of WLD and DWT makes the system robust and efficient to attacks. The results i.e. the values of WPSNR and NC show the robustness of the system. For the future work, the combination of DCT and DWT can be used to make the system more robust.

REFERENCES

[1] Aggeliki Giakoumaki, Sotiris Pavlopoulos, and Dimitris Koutsouris, "Multiple Image Watermarking Applied to Health Information Management," IEEE Trans. Information Technology in Biomedicine, vol. 10, No. 4, October 2006.

[2] A. Wakatani, "Digital Watermarking for ROI Medical Images by Using Compressed Signature Image," Proceedings of 35th International Conference on System Sciences, Jan. 2002.

[3] Hyung-Kyo Lee, Hee-Jung Kim, "ROI Medical Image Watermarking Using DWT

and Bit-plane," Asia-Pacific Conference on Communications, Perth, Western Australia, October 2005.

[4] Makoto Miyahara, Kazunori Kotani, and V. Ralph Algazi, "Objective Picture Quality Scale(PQS) for Image Coding," IEEE Trans. Communications, vol. 46, No. 9, September 1998.

[5] Sonika C. Rathi, Vandana S. Inamdar, "Medical Images Authentication through Watermarking Preserving ROI," Health Informatics - An International Journal (HIIJ), vol. 1, No. 1, August 2012.

[6] Jie Chen, Shiguang Shan, "WLD: A Robust Local Image Descriptor," IEEE Trans. Pattern Analysis and machine intelligence, TPAMI-2008-09-0620, 2009.