A Semi-Fragile Blind Digital Watermarking Technique for Medical Image File Authentication using Stationary Wavelet Transformation

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ABSTRACT
Electronically stored health information enhances resource sharing, help us to reduce the number of errors, speed up clinical communication and assist doctors in diagnosis and treatment. Medical image watermarking is a special type of watermarking technique where the watermarked medical images should not differ perceptually from the original images, because the diagnosis must not be affected due to the presence of watermark. This paper presents a new blind watermarking technique for medical image using Stationary Wavelet Transformation (SWT). In the proposed method multiple watermarks containing patient's information are embedded and original image is not needed for the extraction of those watermarks.

General Terms
Watermarking, Medical Image, SWT

Keywords
SWT, Pseudo Random Noise, SNR, ISWT.

1. INTRODUCTION
Medical image watermarking [3, 5, 6, 8 and 9] is used to authenticate, investigate the integrity of medical images. The biggest challenge in medical image watermarking is that, the image may not undergo any major degradation that will affect the quality of images with visible alteration to their original form.

Medical image watermarking systems can be broken into three broad categories: robust, fragile, and semi-fragile. Robust watermarks are robust under most image processing methods and can be extracted from heavily attacked watermarked image. Fragile watermarks are destroyed by random image processing methods. The change in watermark is easy to be detected, thus can provide information for image completeness. Semi-fragile watermarks combine the properties of both robust and fragile watermarks like robust methods; they can tolerate some degree of change to the watermarked image.

There are different watermarking technologies both in spatial [4, 7 and 14] and frequency-domain [13]. Compared to spatial-domain watermarking, frequency domain watermarking are more popular because of robustness and imperceptibility. Embedding watermarks within DCT coefficients [10, 13 and 15] or DWT coefficient [10, 11, and 17] is a common approach. Multiple watermark embedding [8, 16 and 18] has also been used by a number of researchers. Multiple watermarking systems have the advantages that different watermarks can be applied for different purposes. In the blind [12] watermarking technique original image is not needed for the extraction of the watermarks.

1.1 Discrete Stationary Wavelet Transform
Discrete Stationary wavelet transform or SWT [1, 2, 11 and 19] provides efficient numerical solutions in the signal processing applications. It was independently developed by several researchers and under different names, such as undecimated wavelet transform, the shift invariant wavelet transform and the redundant wavelet transform.SWT performs a multilevel stationary wavelet decomposition using either a specific orthogonal wavelet or specific orthogonal Wavelet decomposition filters.
SWT is almost similar to the Discrete Wavelet Transform (DWT) where the high-pass and low-pass filters are applied to the input signal at each level (3 and 6). However, in the SWT, the output signal is never down sampled (not decimated). Instead, at each level the filters are up sampled. Figure 1 illustrated the block diagram of SWT decomposition.

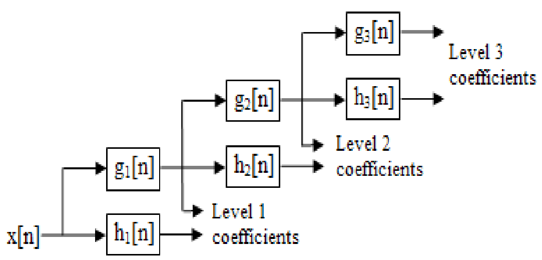


Fig 1: Block Diagram of SWT Decomposition

The second section gives the proposed algorithm and the third section explains the algorithm in detail. Fourth section shows the experimental results and the fifth section discussed about the proposed method.

2. PROPOSED ALGORITHM
2.1 Watermark Embedding Process
Step 1: Color medical image is decomposed into RGB color components.
Step 2: Two-Dimensional SWT is applied on individual color components (R, G, & B).
Step 3: Three binary images, one containing patient's name in short form; second containing patient's blood group and third

containing date of birth of the patient are taken and converted into three one-dimensional message vectors separately.

Step 4: A two-dimensional pseudo random noise matrix is generated from the session key.

Step 5: Three 1-D vectors are embedded within the diagonal sub bands of the three color components separately using the pseudo random noise.

Step 6: Two-Dimensional ISWT is applied on sub bands (A, H, V & D) of individual color components.

Step 7: Three color components are combined to generate the watermarked image.

2.2 Watermark Extraction Process

Step 1: Watermarked image is decomposed into RGB color components.

Step 2: Two-Dimensional SWT is applied on individual color components (R, G & B).

Step 3: Pseudo random noise matrix is regenerated from the session key.

Step 4: Using the correlation function between the diagonal band and pseudo random noise hidden 1-D message vectors are generated.

Step 5: Reshape operation is performed on 1-D vector to get back the watermark images.

3. EXPLANATION OF THE ALGORITHM

3.1 Watermark Embedding Process

Color medical image is broken into Red, Green and Blue color components as shown in figure 2.

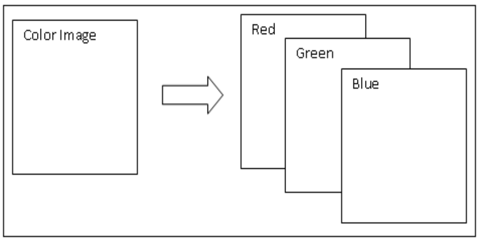


Fig 2: Decomposition into RGB color components

As shown in figure 3, Two-Dimensional SWT (Stationary Wavelet Transformation) is applied on color components separately to decompose each color component into four sub bands (A, H, V and D).

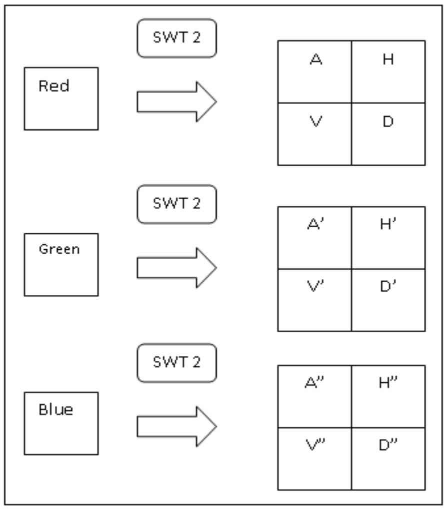


Fig 3: Decomposition of RGB color components using SWT2

2-Dimensional pseudo random noise is generated from the session key as shown in figure 4.

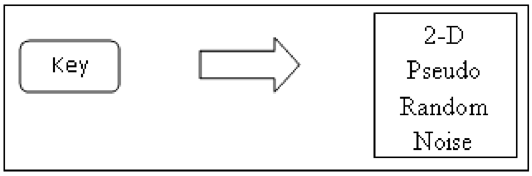


Fig 4: Pseudo random noise generation from the session key

As depicted in figure 5, watermark images are converted into corresponding 1-D message vectors

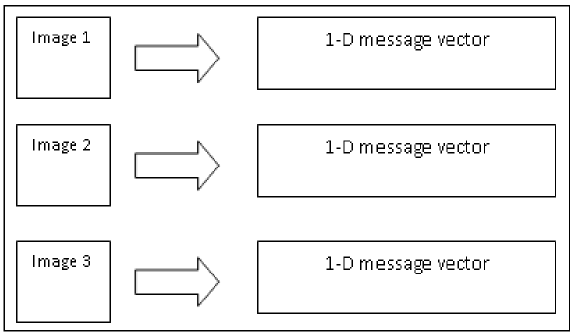


Fig 5: Generation of three message vectors from three watermarking images.

Message vectors are embedded within each of the diagonal sub band (D) of the color components using 2-D pseudo random noise as shown in figure 6. The general equation used to embed the secret image is:

$$IS(x, y) = I(x, y) + k \times S(x, y) \quad (1)$$

In which I(x, y) representing the selected SWT sub band of the cover image, IS (x, y)) is the modified sub band of the cover image, 'k' denotes the amplification factor that is usually used to adjust the invisibility of the secrete images in corresponding sub bands. S (x, y) is the pseudo random sequences.

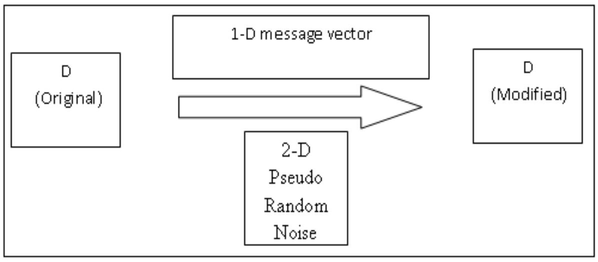


Fig 6: Sub band (Diagonal) modification.

Figure 7 shows, how ISWT2 is applied separately to regenerate color components with modified D sub band.

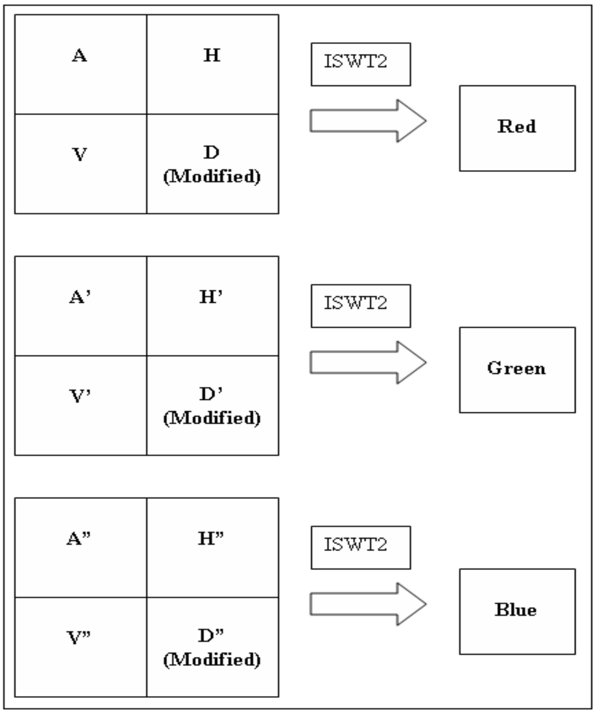


Fig 7: Application of ISWT2 to regenerate R, G and B components.

As shown in figure 8, finally color components are combined to generate the watermarked image

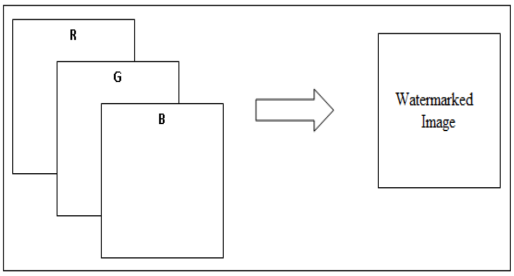


Fig 8: Modified R, G and B components are combined to get watermarked image.

3.2 Watermark Extraction Process

For the process of authentication watermarked image is decomposed into color components as shown in figure 9.

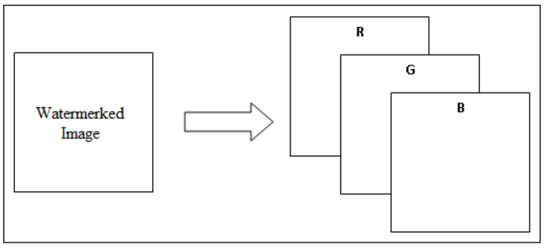


Fig 9: Decomposition of watermarked image into RGB color components

As shown in figure 10, SWT2 is applied to individual color component to get back modified diagonal sub band.

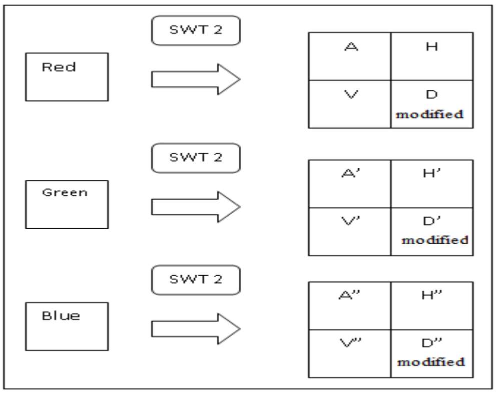


Fig 10: SWT2 applied on the three components separately.

Same 2-D pseudo random sequence is generated from the key as depicted in figure 11

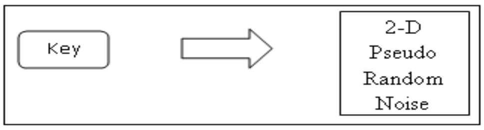


Fig 11: Pseudo random noise generation from the session key.

Finally as shown in figure 12, water mark images are extracted from diagonal sub band of individual color component.

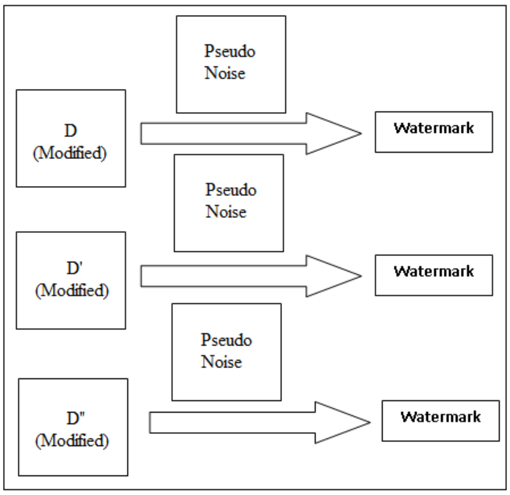


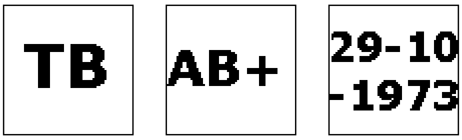
Fig 12: Extraction of watermarks from D sub band and Noise.

4. RESULTS

Experiment was carried out with Matlab-2009. Original and watermarked medical images are shown in figure 13 and 14. Figure 15 shows three different watermarks about the patient. These watermarks are patient's name, blood group and date of birth. Extracted watermark images are shown in figure 16.

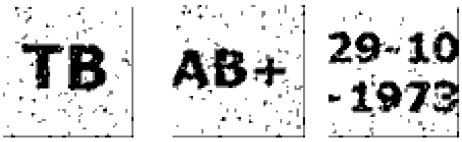
Fig 13: Original Medical image (Iris).

Fig 14: Watermarked Medical image.



a) b) c)

Fig 15: Watermark images a) Patient's Name (Short), b) Blood Group, c) Date of Birth



a) b) c)

Fig 16: Recovered watermark images a) Patient's Name (Short), b) Blood Group, c) Date of Birth

Table 1 gives a comparison of performance of the proposed method with other frequency domain watermarking techniques like DCT and DWT. Figure 17 shows the corresponding graphical representation. Detail comparison has been shown in table 2. In Table 3 robustness test results of the proposed approach is shown.

Table 1. Comparison with DCT and DWT based watermarking approaches

Algo.	Color Medical Image	Watermark Images	SNR	PSNR
DCT	180X180	Three (64 X 64)	12.7135	18.4312
DWT	180X180	Three (64 X 64)	25.8846	31.6023
SWT (Proposed)	180X180	Three (64 X 64)	28.8232	34.5409

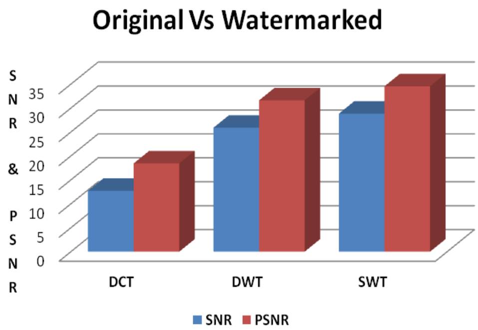


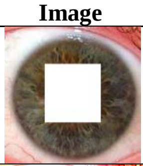
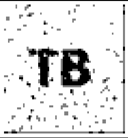
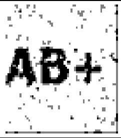
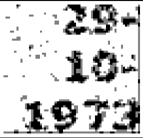
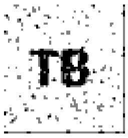
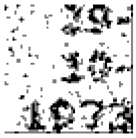
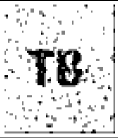
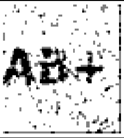
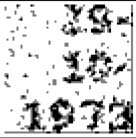
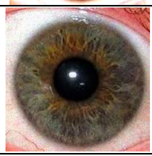
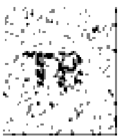
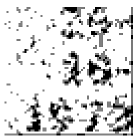
Fig 17: Graphical representation of Table 1 data

Table 2. Detail comparison with DCT and DWT based watermarking approaches

Method	DCT	DWT	SWT (Proposed)
MSE	624.03281	222.38105	215.11710
MSSIM	0.329486	0.596276	0.605527
Accuracy	59.734568	63.264275	63.363426
Correlation	0.932994	0.975913	0.976614
Bit Error Rate	104368	95219	94962
Average Difference	9.111265	5.854938	5.850123
Mean Absolute Error	19.19176	11.42407	11.18580
EME (Original image)	16.00763	16.00763	16.00763
EME (Noisy image)	30.90245	19.68274	19.52168

Universal Image Quality Index	0.35017	0.59177	0.60081
Normalized Cross-correlation	0.999797	0.999199	0.999089
Normalized Absolute Error	0.080598	0.051793	0.051750
Pearson Correlation Coefficient (Original Image vs. Noisy Image)	30228.06958	31618.59	31641.32235

Table 3. Sustainability against various attacks

Attacks	Watermarked Image	Water mark1	Watermark2	Watermark3
Cropping				
Contrast Stretching				
Both				
Noise (Poisson)				

5. CONCLUSION

Imperceptibility is a very important feature for medical image watermarking. Any kind of major visual change can hamper the diagnosis process. As shown in Table 1, proposed method gives higher SNR and PSNR values than other popular watermarking methods. Table 2 also depicts the merit of the proposed technique in detail. Table 3 shows that this technique, can also sustain some popular attacks. But resistance to noise attack is very poor. The proposed method used patient's information as watermarks so this technique will also help to store and maintain medical image archive. This method can also be applied for sharing medical image in telemedicine application.

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