Embedding Patient Database in ECG Signal using Slantlet Transform for Holter Monitoring Data Transmission

Priti B. Patil[1], Prof. N. C. Patil[2]

Department of Electronics & Telecommunication
D. N. Patel College of Engineering, Shahada ,India

Abstract-- **In the application of telemedicine, ECG signal without any patient details is sent to the Doctor end. Consequently, confusion is arisen between signal and patient's identity. To avoid this confusion, it is necessary to combine ECG signals with patient confidential information when sent. In this paper, the Slantlet Transform based technique has been introduced to protect patient confidential data. The proposed method allows ECG signal to hide patient confidential data and other physiological information. For embedding patient confidential data in ECG signal, the Least Significant Bit watermarking algorithm is used. To evaluate the effectiveness of the proposed technique on the ECG signal and diagnosability measurement of watermarked ECG, some metrics have been used such as Peak Signal to Noise Ratio, Percentage Residual Difference and Bit Error Rate.**

Keywords: **Slantlet Transform; ECG; telemedicine; Least Significant Bit, Holter monitoring data transmission.**

I. INTRODUCTION

The number of elderly patients is increasing dramatically due to the recent medical advancements. Accordingly, to reduce the medical labor cost, the use of remote healthcare monitoring systems and point-of-care (PoC) technologies have become popular. Monitoring patients at their home can drastically reduce the increasing traffic at hospitals and medical centers. Moreover, PoC solutions can provide more reliability in emergency services as patient medical information (e.g., diagnosis) can be sent immediately to doctors and response or appropriate action can be taken without delay. However, remote health care systems are used in large geographical areas essentially for monitoring purposes, and, the Internet represents the main communication channel used to exchange information. Typically, patient biological signals and other physiological readings are collected using body sensors. Next, the collected signals are sent to the patient PDA device for further processing or diagnoses. Finally, the signals and patient confidential information as well as diagnoses report or any urgent alerts are sent to the central hospital servers via the Internet. Doctors can check those biomedical signals and possibly make a decision in case of an emergency from anywhere using any device.In frequency domain, the host signal is decomposed using transforms such as Discrete Cosine Transform (DCT), Short Time Fourier Transform (STFT), Fast Fourier Transform (FFT), Discrete Fourier Transform (DFT) and Integer Wavelet Transform (IWT) etc. Discrete Wavelet Transform (DWT) based ECG steganography scheme is proposed in Ibaida A et al.'s work [1] where DWT is used to decompose the host ECG, and scrambling matrix based LSB watermark embedding algorithm is used to embed the secret information into the DWT coefficients. The inverse transform of watermarked coefficients gives the watermarked ECG signal. Distortion less data hiding based on Slantlet Transform (SLT) for image steganography is proposed in Thabit R et al.'s work [3]. Robust reversible watermarking scheme using SLT matrix is presented in Kumar S et al.'s work[4]. Image watermarking using slantlet transform is presented in Mohammed RT et al.'s work[5]. In [6], the ECG signal is used as a secret data, and embedded inside medical images like CT and MRI. Other researchers [7] implemented a wavelet based watermarking technique for ECG signal. In [8], authors proposed the method to insert an encrypted version of the electronic patient record (EPR) in the LSB (Least Significant Bit) of the gray scale levels of a medical image. Similarly, [9], propose a LSB technique where the host image authenticates the transmission origin with an embedded message composed of various patient data (e.g ECG record), the diagnosis report and the doctor‟s seal.

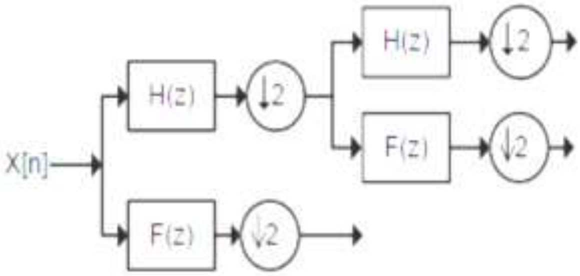
Kai-meiZheng and XuQian [10] proposed a fresh technique for data hiding which is reversible and depending on wavelet transform. Furthermore, this method dose not used user define key, so in this algorithm the security is depends only on algorithm. At last, this algorithm is not useful for the abnormal ECG signal because in it QRS complex is absent. However this algorithm is depending only on normal ECG signal were QRS complex can be easily find. Golpira and Danyali [11] proposed a reversible blind watermarking for medical images based on wavelet histogram shifting. In this paper, medical images such as MRI is used as host signal. A 2-D wavelet transform is applied to the image. Then, the histogram of the high-frequency subbands is determined. Next, two thresholds are selected, the first is in the beginning and the other is in the last portion of the histogram. For each threshold, a zero point is created by shifting the left histogram part of the first threshold to the left, and shifting the right histogram part of the second threshold to the right. The locations of the thresholds and the zero points are used for inserting the binary watermark data. This algorithm performs well for MRI images but not for ECG host signals. Moreover, the capacity of this algorithms is low. Moreover, no encryption key is involved in its watermarking process.

II. METHODOLOGY

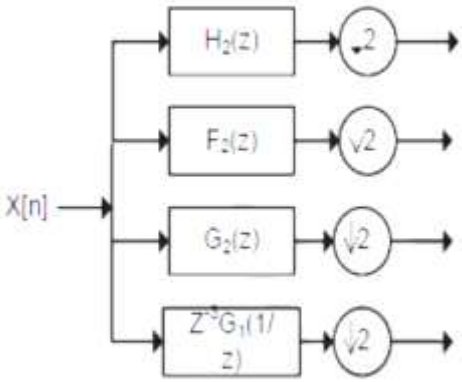
Slantlet Transform:

The Slantlet Transform (SLT) is a recently developed multiresolution technique especially well-suited for piecewise linear data. The Slantlet transform is an orthogonal Discrete Wavelet Transform (DWT) with 2 zero moments and with improved time localization. It also retains the basic characteristics of the usual filterbank such as octave band characteristic and a scale dilation factor of two. However, the Slantlet transform is based on the principle of designing different filters for different scales unlike iterated filterbank approaches for the DWT. The filters used to design the Slantlet filter bank are $h_i(n)$, $f_i(n)$ and $g_i(n)$. The L scale filter bank has $2L$ channels. $h_L(n)$ is the lowpass filter and $f_L(n)$ filter is adjacent to the lowpass filter. The required down sampling order after the filters $h_L(n)$ and $f_L(n)$ are 2^l [1]. The output of filters is computed by equation 1:

$$y_i(n) = \sum_{k=0}^{2^{i+1}-1} x(2^{i+1}n + k)g_i(k) \qquad (1)$$



(a)



(b)

Fig.1 Filter Bank Structure of (a) DWT (b) SLT

SLT provides better time localization that causes the degradation of frequency selectivity because of shorter length of SLT filter bank causes less frequency selective than the DWT filter bank. Slantlet filter banks are orthogonal and has two zero moments. The slantlet filters are piecewise linear. In ECG signal steganography, Slantlet transform is applied to the host ECG signal using convolution with the coefficients of SLT filter bank. The selected embedding algorithm is applied to the SLT coefficients to embedding the personal information and applying inverse slantlet transform results the embedded ECG signal.

LSB Data Embbeding:

The patient information is embedded into the high frequency Slantlet Transform (SLT) coefficients of host ECG signal. Least Significant Bit (LSB) embedding algorithm is applied to embedding the patient information into the SLT coefficients of host ECG as shown in the Fig. 3, taking inverse SLT gives the embedded ECG. The embedding algorithm:

1. Patient's ECG data is selected as host signal for steganography.
2. On host ECG, apply Slantlet transform
3. Find high frequency coefficient
4. Select patient information needed to be sent, confidential data
5. Replace the higher coefficient with normalize ASCII value of patient information.
6. Take inverse Slantlet transform after data embedding algorithm.
7. Evaluate performance of ECG watermarking.

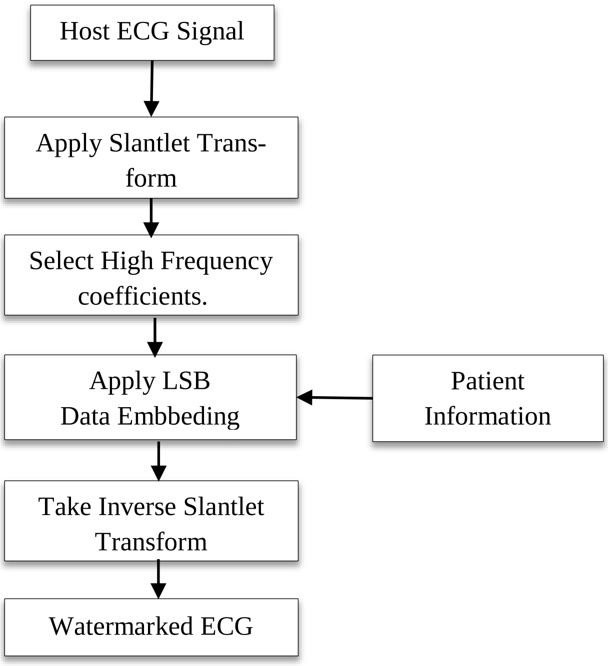


Fig.2. SLT based ECG steganography

Data Extraction:

This phase of the proposed technique is to retrieve the patient information from the reconstructed ECG Data. So again slantlet transform is applied on watermarked ECG signal. Extraction algorithm is as follows:

1. Apply SLT on watermarked ECG
2. Select high frequency coefficients
3. Extract secret information from LSB bits
4. Rearrange the extracted data

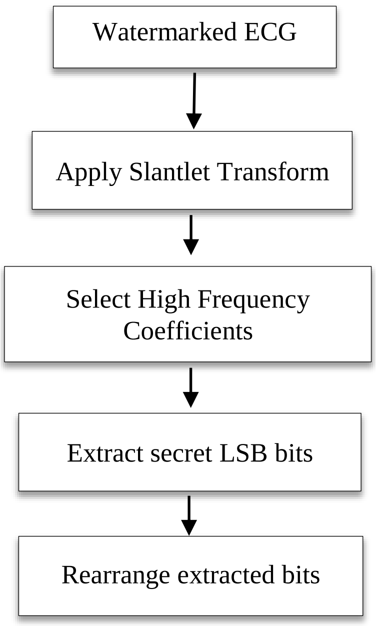


Fig.3. Data Extraction

III. Performance Analysis

The performance of proposed method is evaluated using various validation metrics such as PSNR, PRD and BER, where PSNR and PRD are calculated from the amplitude values of host and watermarked ECG directly.

1. Percent Root Mean Square Difference (PRD):

The PRD is a measure of error loss. This measure evaluates the distortion between the original ECG host signal and the reconstructed ECG signal. In this proposed method different types of ECG signals are used for the experimentation. ECG samples used for the experimentation are 10 s long with 360-Hz sampling frequency each. To evaluate the proposed model, the PRD is calculated as:

$$\text{PRD} = \sqrt{\frac{\sum_{i=1}^{N}(x_i - yi^2)}{\sum_{i=1}^{N} x_i^2}} \qquad (2)$$

where *x* represents the original ECG signal and *y* is the reconstructed signal. The lower the PRD, the closer the reconstructed signal is to the original ECG signal.

2. Bit Error Rate (BER):

To evaluate the reliability of the extracted information bit error rate has been used. The BER, that is the ratio of bit errors to the total transferred bits, is usually expressed as a percentage and can be formulated as:

$$\text{BER} = \frac{B_{err}}{B_{total}} \times 100\% \qquad (3)$$

where BER represents the bit error rate in percentage, *B*err is the total number of erroneous bits, and *B*total is the total number of bits.

3. Peak Signal to Noise Ratio (PSNR):

The PSNR is concerned with class of watermarked signal. The output of imperceptibility testing is a value in decibel scale. The PSNR is calculated as below:

$$PSNR = 20 \times \log_{10}\left(\frac{MAX^2}{MSE}\right) \qquad (4)$$

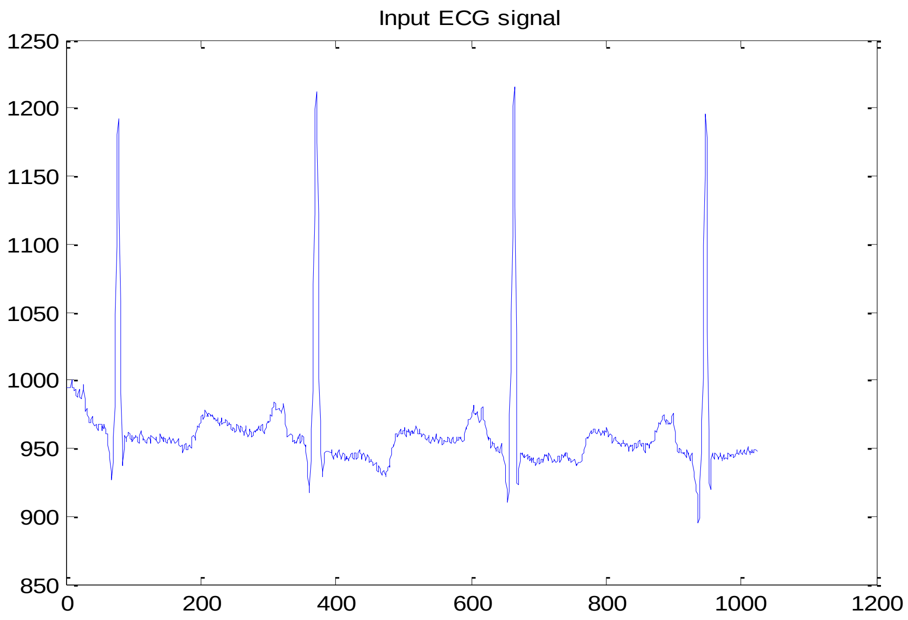
Where, MSE shows the difference between original signal and reconstructed signal. It is calculated as follows:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \qquad (5)$$

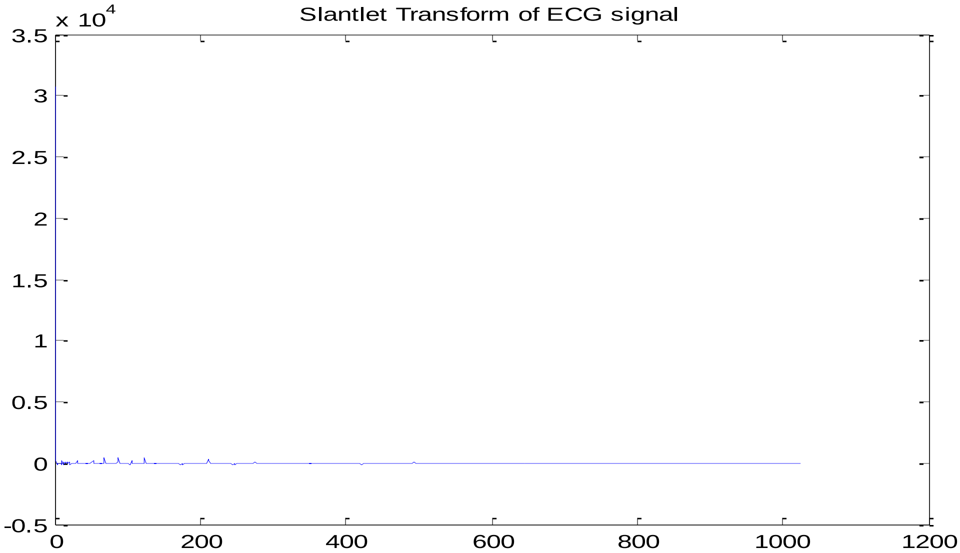
Where, y_i represents original signal and $\hat{y}_i$ represents watermarked signal. Large PSNR indicates that the high watermarked signal quality.

IV. RESULT

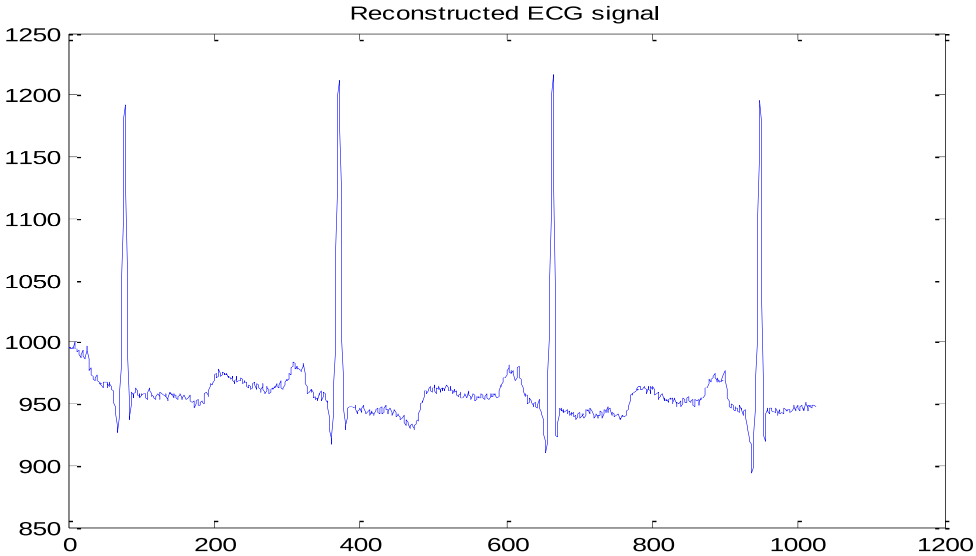
In this paper, a testbed of 10 normal ECG samples is used for experimentation. ECG signal is digitized at 360 samples per second over 10mv range. ECG database is taken from www.physionet.org .We performed the same experiments on 10 ECG samples and PRD, PSNR and BER is calculated for each. Fig 3 shows the experiment on ECG sample no.100.



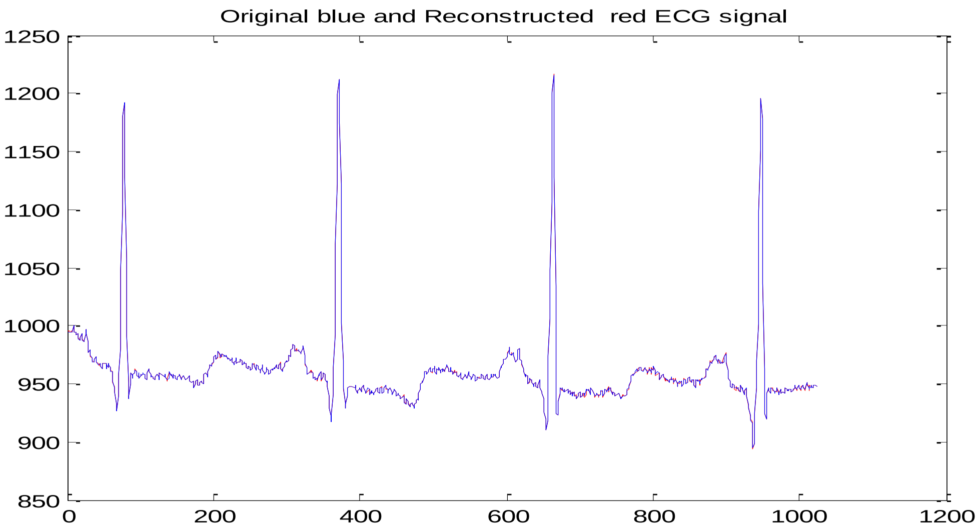
(a)


Slantlet Transform of ECG signal
x 10^4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
0
200
400
600
800
1000
1200

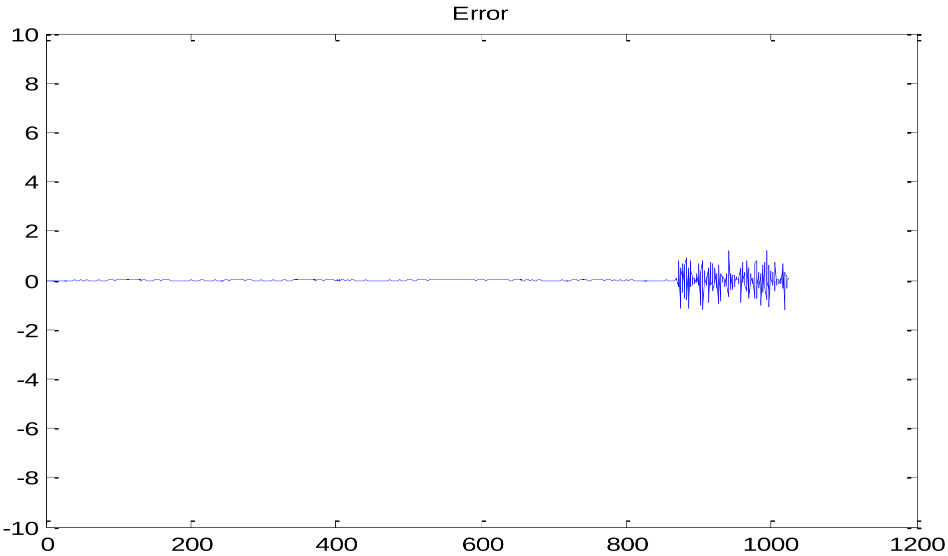
(b)


Reconstructed ECG signal
1250
1200
1150
1100
1050
1000
950
900
850
0
200
400
600
800
1000
1200

(c)


Original blue and Reconstructed red ECG signal
1250
1200
1150
1100
1050
1000
950
900
850
0
200
400
600
800
1000
1200

(d)



(e)

Fig.4 shows (a) Input ECG Signal (b) Slantlet transform of ECG signal (c) Reconstructed ECG Signal (d) Original Blue and Reconstructed Red ECG Signal (e) Plot of Error

Table 1 Metrics Values for Normal ECG Samples

ECG Sample No.	MSE	PSNR	PRDN	BER
100	0.0340	351.78	0.0192	0
101	0.0452	347.41	0.0219	0
102	0.0485	344.37	0.0223	0
103	0.0474	350.68	0.0193	0
104	0.0359	350.83	0.0207	0
105	0.0404	349.73	0.0216	0
106	0.0460	352.18	0.0192	0
107	0.0373	355.59	0.0193	0
108	0.0345	344.68	0.0223	0
109	0.0432	344.72	0.0226	0

Table 1 shows the different metrics values obtained for 10 normal ECG samples. It can be seen from the table that the difference is very small. Accordingly, this proves that the embedding process does not affect the diagnosability.

V. Conclusion

Personal information security of a patient is offered by LSB embedding algorithm in transform domain using SLT. For diagnosability measurement, the embedded ECG has been evaluated using the various metrics such as MSE, PSNR, PRDN and BER. LSB embedding gives less distortion in embedded ECG signal result shows that the better similarity and diagnosis measurement of embedded ECG is possible using slantlet transform.

References

[1] Ibaida A, Khalil I, Wavelet-Based ECG Steganography for Protecting Patient Confidential Information in Point-of-Care Systems. IEEE Trans. Biomed. Eng, 60(12):3322–3330, 2013.

[2] Selesnick I W, The Slantlet Transform. Proceedings of the IEEE-SP International Symposium on Time-Frequency and Time-Scale Analysis, 1998.

[3] Thabit R, Khoo B E, Robust reversible watermarking scheme using Slantlet transform matrix. J Syst Software, 88:74–86, 2014.

[4] Kumar S, Muttoo S K, Distortionless Data Hiding Based on Slantlet Transform. 2009 International Conference on Multimedia Information Networking and Security, 2009.

[5] Mohammed RT, Bee Ee Khoo, Image watermarking using slantlet transform, 2012 IEEE Symposium on Industrial Electronics and Applications (ISIEA), 281-286, 2012
[6] Nambakhsh.M, Ahmadian.A, Ghavami.M, Dilmaghani.R, and Karimi-Fard.S. „A novel blind watermarking of ECG signals on medical images using EZW algorithm‟. In Conference proceedings: Annual International Conference of the IEEE Engineering in Medi6yhn cine and Biology Society. Volume 1, 2006
[7] Engin.M, Cidam.O, and Engin.E. „Wavelet Transformation Based Watermarking Technique for Human Electrocardiogram (ECG)‟. Journalof Medical Systems, 29(6):589–594, 2005.
[8] Anand.D and Niranjan.U.C. "Watermarking Medical Images with Patient Information". In Proceedings IEEE/EMBS Conference, Hong Kong, China, October 1998, pp. 703-706.
[9] Miaou.S,Hsu.C,Tsai.Y,Chao.H " A Secure Data Hiding Technique with Heterogeneous Data-Combining Capability for Electronic Patient Records," in Proceedings of the World Congress on Medical Physics and Biomedical Engineering, Session Electronic Healthcare Records, IEEE-EMB, ed.,Chicago, USA, July 2000.
[10] K. Zheng and X. Qian, "Reversible Data Hiding for Electrocardiogram Signal Based on Wavelet Transforms," in *International Conference on Computational Intelligence and Security, 2008. CIS'08*, vol. 1, 2008.
[11] H. Golpira and H. Danyali, "Reversible blind watermarking for medical images based on wavelet histogram shifting," in *Proc. IEEE Int. Symp. Signal Process. Inf. Technol.*, Dec. 2009, pp. 31–36.