SLT based ECG Signal Steganography for Telemedicine Application

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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 ECG signal steganography 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 MSE is used.

Keyword: Slantlet Transform; ECG; steganography; Least Significant Bit watermarking; MSE.

I. INTRODUCTION

Steganography is a technique used to embed secret information into a host signal. In ECG steganography patient’s ECG signal is used as host signal and personal information of the patient like name, age and locations are the secret data. Classically, the secret data is embedded into the host signal using watermarking algorithms. Least Significant Bit (LSB), threshold level, patchwork and assignment based algorithms are the few existing watermark embedding algorithms. Performance of each watermark embedding algorithms varies with selection of host signal and size of secret information. Upon embedding the secret data, the host signal is prone to distortion. One of the performance metric of watermarking algorithms is to measure the distortion between the host and watermarked signal. Lesser the distortion, better it is.

Telemedicine is defined as the “use of computers and telecommunications equipment to provide health care over long distances” (Larkin, 1997). It can be beneficial to patients living in isolated communities and remote regions, who can receive care from doctors or specialists far away without the patient having to travel to visit them. 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-mei Zheng and XuQian [10] proposed a fresh technique for data hiding which is reversible and depending on wavelet transform. Furthermore, this method does not use 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.

Finally, Kaur et al. [12] proposed new digital watermarking of ECG data for secure wireless communication. In their work, each ECG sample is quantized using 10 bits, and is divided into segments. The segment size is equal to the chirp signal that they use. Therefore, for each ECG segment a modulated chirp signal is added. Patient ID is used in the modulation process of the chirp signal. Next, the modulated chirp signal is multiplied by a window-dependent factor, and then added to the ECG signal. The resulting watermarked signal is 11 bits per sample. The final signal consists of 16 bits per sample, with 11 bits for watermarked ECG, and 5 bits for the factor and patient ID.

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 \( h_l(n) \), \( f_l(n) \) and \( g_l(n) \). 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 as follows:

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

![Fig.1 Filter Bank Structure of (a) DWT (b) SLT](image)
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 Embedding:**

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. Apply LSB data embedding algorithm on,
6. Take inverse Slantlet transform after LSB data embedding algorithm.
7. Evaluate performance of ECG watermarking by MSE

![Fig.2. SLT based ECG steganography](image)

The performance of SLT based ECG steganography using LSB data embedding algorithm is evaluated using the metric MSE. MSE shows the difference between original signal and reconstructed signal. It is calculated as follows:

\[
MSE = \frac{1}{n} \sum_{i=1}^{n} (y_i - \hat{y}_i)^2
\]  

(2)

**III. 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
To evaluate the proposed model, the MSE (Mean Squared Error) is used. It is evaluated as the difference between the amplitude of original and reconstructed ECG signal. We performed the same experiments on 10 ECG samples and MSE is calculated for each. Fig 3 shows the experiment on ECG sample no.100.

![Input ECG signal](image)

![Reconstructed ECG signal](image)

![Original blue and Reconstructed red ECG signal](image)
Fig. 3 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 I MSE VALUES FOR NORMAL ECG SAMPLES**

<table>
<thead>
<tr>
<th>ECG Sample No.</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.0687</td>
</tr>
<tr>
<td>101</td>
<td>0.0888</td>
</tr>
<tr>
<td>102</td>
<td>0.0734</td>
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<tr>
<td>103</td>
<td>0.0725</td>
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<tr>
<td>104</td>
<td>0.0832</td>
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<tr>
<td>105</td>
<td>0.0839</td>
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<tr>
<td>106</td>
<td>0.0744</td>
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<tr>
<td>107</td>
<td>0.0782</td>
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<tr>
<td>108</td>
<td>0.0794</td>
</tr>
<tr>
<td>109</td>
<td>0.0888</td>
</tr>
</tbody>
</table>

Table III shows the MSE 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.
IV. CONCLUSION

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

REFERENCES