



# ECG signal enhancement using S-Transform



Samit Ari\*, Manab Kumar Das, Anil Chacko

Department of Electronics and Communication Engineering, National Institute of Technology, Rourkela, India

## ARTICLE INFO

### Article history:

Received 16 May 2012

Accepted 15 February 2013

### Keywords:

Baseline wander

Denosing

Electrocardiogram (ECG)

Electrode motion

Gaussian noise

Muscle artifacts

Signal enhancement

S-Transform

## ABSTRACT

Electrocardiogram (ECG), which is a noninvasive technique, is used generally as a primary diagnostic tool for cardiovascular diseases. In real-time scenario, noises like channel noise, muscle artifacts, electrode motion and baseline wander are often embedded with ECG signals during acquisition and transmission. In this paper, an automatic ECG signal enhancement technique is proposed to remove noise components from time–frequency domain represented noisy ECG signal. Stockwell transform (S-Transform) is used in this work to represent the noisy ECG signal in time–frequency domain. Next, masking and filtering technique is applied to remove unwanted noise components from time–frequency domain. The proposed technique does not require any prior information like R-peak position or reference signal as auxiliary signal. This method is evaluated on ECG signals which are available in MIT-BIH Arrhythmia database. The experimental results demonstrate that the proposed method shows better signal to noise ratio (SNR) and lower root means square error (RMSE) compared to earlier reported wavelet transform with soft thresholding (WT-Soft) and wavelet transform with subband dependent threshold (WT-Subband) based technique. To quantify the significant difference among all methods, the performances of different ECG enhancement techniques at 1.25 dB input SNR level are compared using analysis of variance (ANOVA) based statistical evaluation technique and it is seen that the proposed method yields superior performance compared to other methods. R-peak detection test is also conducted on enhanced ECG signal in addition to SNR and RMSE to evaluate the quality of biology-related information preserved in the enhanced ECG signal. The performance of R-peak detection for denoised ECG signals, in terms of sensitivity and positive predictivity using proposed enhancement method, is also better than WT-Soft, WT-Subband methods, and validates the superiority of the proposed method.

© 2013 Elsevier Ltd. All rights reserved.

## 1. Introduction

Electrocardiogram (ECG) is a noninvasive technique that is used as a diagnostic tool for cardiovascular diseases [1]. ECG signal is widely used as a fundamental tool for detection and diagnosis of heart disorders. Since, ECG is the most commonly recorded signal for the patient monitoring and examination process, it is important to be able reliably and quickly detect the cardiac disorders. ECG would be much more useful as a diagnostic tool if unwanted noise embedded in the signal is removed. For wireless and telecardiology application, the efficient transmission of ECG signals over telephone lines, mobile communication, and satellite communication is becoming more and more important. During acquisition and transmission, ECG signals are generally affected by different noises like channel noise, muscle artifacts, electrode motion and baseline wander [2,3].

Muscle artifacts are introduced due to muscle activity and electrode motion is caused by the shift in electrode location [2]. Baseline wander is the variation in isoelectric line of ECG which can occur during respiration. Poor channel conditions can also introduce noise in the ECG signal during its transmission [2]. All these noises can corrupt the signal thereby making its analysis difficult and error prone. Hence noisy ECG signals should be enhanced by removing the noise components for further processing.

Various techniques have been reported in the literature for enhancement of ECG signal [3–11] including techniques like fuzzy multiwavelet denoising [4], independent component analysis [5], wavelet denoising [6,7] and least mean square (LMS) algorithm based adaptive filter [3]. However, most of these reported techniques generally concentrated only on one kind of noise type [4,5,7–11]. Few reported techniques [2,3] show significant performance for enhancement of ECG signals embedded with different types of noises. However, these techniques require prior information of the signal to work efficiently such as the position of the R-peak for empirical mode decomposition (EMD) based technique [2] and a reference signal for the least mean square

\* Corresponding author. Tel.: +91 661 2462464.

E-mail addresses: [samit.ari@gmail.com](mailto:samit.ari@gmail.com) (S. Ari), [manabster@gmail.com](mailto:manabster@gmail.com) (M.K. Das), [anilchacko84@gmail.com](mailto:anilchacko84@gmail.com) (A. Chacko).

(LMS) algorithm based method [3]. This kind of information is difficult to obtain when the noise level is very high. The wavelet transform (WT) based techniques [4,6,7] are more popular and widely used because of its ability to characterize time–frequency domain information of a time domain signal. Ercelebi [6] reported an ECG signal enhancement technique based on 4th level decomposed coefficients of Daubechies wavelet with soft thresholding when the ECG signal is corrupted with base line wander, muscle artifact, electrode motion noises. In an another reported literature Poornachandra [7] proposed an ECG signal enhancement technique using 3rd level decomposed coefficients of Daubechies wavelet with subband dependent thresholding. This reported work applied on baseline wander, muscle artifact, electrode motion and Gaussian noises. However, the amplitude of the wavelet transform is dependent on the frequency. Wavelet transform also has other limitations [12] such as having better frequency resolution and poor time resolution for low frequencies and vice versa for high frequencies. It also has locally referenced phase.

In this paper, a novel method for ECG signal enhancement is proposed using Stockwell transform (S-Transform) to overcome the afore-mentioned limitations. This method can be applied to enhance the ECG signal from different noises which often get embedded with ECG signal during its acquisition and transmission [2]. During acquisition of ECG signal in real time environment, the different types of noises such as channel noise, muscle artifacts, electrode motion, and base line wander are often embedded with ECG signal. Muscle artifacts are due to movement of muscle between skin and electrode. Motion artifacts are transient baseline change due to electrode skin impedance with electrode motion. Base line drift may be caused in chest-lead ECG signals by coughing and breathing with large movement of the chest, or when an arm or leg is moved in the case of limb-lead ECG acquisition. This work proposes an automatic and generalized approach for ECG signal enhancement technique. Beside this, the proposed method does not require any prior information like R-peak position or reference signal as auxiliary signal. The S-Transform, derived by Stockwell et al. [13], is closely related to the Wavelet transform (WT) and short time Fourier transform (STFT). The S-Transform (ST) has a similar form to the STFT except that the width of window varies with frequency [12]. The S-Transform has three characteristics that distinguishes it from wavelet transform: (i) frequency invariant amplitude response, (ii) progressive resolution and (iii) absolutely referenced phase information. Besides, the ST uses time–frequency axis rather than the time–scale axis used in the WT [12]. Therefore, the interpretation on the frequency information in the ST is more straight forward than in the WT, which will be beneficial to remove noise components. ST is used to represent the noisy ECG in time–frequency domain. An automatic mask window and morphological filtering technique is applied to this time–frequency domain represented noisy signal for removing the noises. The proposed algorithm is evaluated for noises such as white Gaussian noise, muscle artifact, electrode motion, and baseline wander. Performance of the proposed algorithm is evaluated by means of signal to noise ratio (SNR) and root mean square error (RMSE). Experimental results show that the proposed method yields superior performance compared to commonly used wavelet transform

with soft thresholding (WT-Soft) [6] and wavelet transform with subband threshold (WT-Subband) based techniques [7]. The performance of different ECG enhancement techniques at 1.25 dB input SNR level is also compared using analysis of variance (ANOVA) based statistical evaluation method to quantify the significant difference among all methods, and the proposed method yields superior performance compared to other methods. The performance of R-peak detection for denoised ECG signals in terms of sensitivity and positive predictivity using proposed enhancement method is also better than WT-Soft, WT-Subband methods and it validates the superior performance of the proposed method.

This paper is organized as follows: Section 2 presents the proposed methodology, Section 3 shows the experimental results and performance of the proposed enhancement technique, Section 4 gives discussion, and finally the conclusion is given in Section 5.

## 2. Proposed methodology

The objective of the proposed algorithm is to achieve enhanced signal by selecting the required frequencies and removing the noise components. The block diagram of proposed S-Transform based ECG enhancement is shown in Fig. 1 and the different steps are explained below.

**Step1: Time–frequency domain representation:** The S-Transform [14] is used to obtain the time–frequency representation of a time domain noisy ECG signal. The continuous S-Transform  $S(\tau, f)$  of a noisy ECG signal  $h(t)$  at time  $t = \tau$  and frequency  $f$  is defined as

$$S(\tau, f) = \int_{-\infty}^{\infty} h(t) \frac{|f|}{\sqrt{2\pi}} e^{-((\tau-t)^2 f^2)/2} e^{-i2\pi ft} dt \quad (1)$$

A voice  $S(\tau, f_0)$  is defined as a one dimensional function of time for a constant frequency  $f_0$ , which shows how the amplitude and phase for this exact frequency changes over time. If the time series  $h(t)$  is windowed (or multiplied point by point) with a window function (Gaussian function)  $g(t)$  then the resulting spectrum is

$$H(f) = \int_{-\infty}^{\infty} h(t)g(t)e^{-i2\pi ft} dt \quad (2)$$

where generalized Gaussian function is

$$g(t) = \frac{1}{\sigma\sqrt{2\pi}} e^{-t^2/2\sigma^2} \quad (3)$$

and then allowing the Gaussian to be a function of translation  $\tau$  and dilation (or window width)  $\sigma$

$$S(\tau, f, \sigma) = \int_{-\infty}^{\infty} h(t) \frac{1}{\sigma\sqrt{2\pi}} e^{-(t-\tau)^2/2\sigma^2} e^{-i2\pi ft} dt \quad (4)$$

This is a special case of the multi-resolution Fourier transform because there are three independent variables in it, it is also impractical as a tool for analysis. Simplification can be achieved by adding the constraint restricting the width of the window to  $\sigma$  to be proportional to the period (or inverse of the frequency)

$$\sigma(f) = \frac{1}{|f|}$$

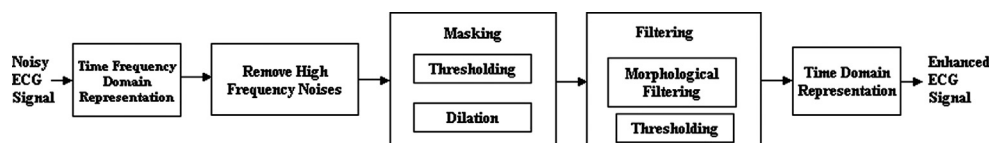


Fig. 1. Block diagram of proposed ECG enhancement technique.

Download English Version:

<https://daneshyari.com/en/article/505089>

Download Persian Version:

<https://daneshyari.com/article/505089>

[Daneshyari.com](https://daneshyari.com)