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Online Suppression of Motion Artifacts During Treadmill ECG

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Abstract:
The electrocardiogram (ECG) is widely used for diagnosis of heart diseases. Cardiac stress test/Treadmill ECG stress test is carried out during treadmill exercise usually involves walking on a treadmill or paddling bicycle Ergometer while heart rhythm, blood pressure and breathing rate are monitored. If one has coronary artery disease, or an irregular heart rhythm (arrhythmia) then the patient is suggested for cardiac stress test. Putting stress on the heart with exercise or certain medications makes the heart work harder. The acquired stress ECG signal is degraded due to motion artifacts as the body is continuously in motion. ECG morphology gets strongly affected by movement artifacts (MAs), which must be therefore effectively removed for proper diagnosis of coronary artery disease, arrhythmia or heart attack. This paper describes the real time suppression of motion artifacts that occurs in the ECG during treadmill exercise with the help of Discrete Wavelet Transform using MATLAB.

Keywords: Cardiac stress test, Discrete Wavelet Transform, Motion artifacts, Real time suppression, Treadmill ECG.

I. INTRODUCTION

Treadmill stress test is a test used in medicine and cardiology to measure the heart's ability to respond to external stress in a controlled clinical environment. In recent days, cardiovascular diseases (CVD) are the leading cause of death. There is a need for early identification and improved treatment of CVD. The treadmill ECG stress test is commonly used as a screening test to identify myocardial ischemia. The treadmill ECG stress test compares the coronary circulation while the patient is at rest with the same patient's circulation during maximum physical exertion. It shows any abnormal blood flow to the myocardium (heart muscle tissue) [8]. The Treadmill ECG stress test is done with heart stimulation, either by exercise on a treadmill, pedaling a bicycle ergo meter with the patient connected to an electrocardiogram. The treadmill ECG stress test is recommended to:

1. Diagnose coronary artery disease.
2. Diagnose a possible heart-related cause of symptoms such as chest pain, shortness of breath.
3. Predict risk of dangerous heart-related conditions such as a heart attack.

The real time ECG signal recording is disturbed by several artifacts. Baseline Wandering due to respiration, power line interference and motion artifacts are some of them. In order to obtain a good quality of ECG which can be utilized by physicians for interpretation and identification of physiological phenomena, artifacts should be suppressed. So a system developed, in which a real time ECG is acquired when a person is performing exercises on a treadmill. The acquired ECG is corrupted by motion artifacts and noise as the subject is constantly moving. In order to obtain clean and artifacts free ECG, Discrete Wavelet Transform technique is applied to ECG containing artifacts in MATLAB software. Various solutions have been proposed for reduction of noise from ECG signal. G. Umamaheswara Reddy used Thresholding techniques for removal of noise from ECG in September 2009 [2]. In September 2011, Malte Kirst used DWT for ECG motion artifact reduction [3]. Chitrangi Sawant, and Harishchandra T. Patil denoised ECG signal using Discrete Wavelet Transform in 2014 [5]. In 2015 Novel Algorithm was tested on horses for suppression of motion artifacts in the ECG [10]. In 2015 Adaptive filtering technique was used to remove Baseline wandering noise from ECG [8]. These are some of the techniques used earlier to remove noise and suppress motion artifacts in the ECG.

MOTION ARTIFACTS

The real time ECG signal recording is disturbed by several artifacts. ECG artifacts can be classified into different categories, including power line interference, electrode pop or contact noise, patient-electrode motion artifacts, electromyographic (EMG) noise, and baseline wandering. Among these noises, the power line interference and the baseline wandering (BW) are the most significant and can strongly affect the ECG signal analysis. The frequency spectrum of motion artifacts overlaps the spectrum of the ECG [3]. With proper electrode positioning and a good hardware design, motion artifact can be minimized, but can never be removed completely.

WAVELETS

Wavelets are mathematical functions with an oscillatory nature similar to sinusoidal waves. Due to the finite oscillatory nature of the wavelets, it is extremely useful in real time non stationary signal processing. A wavelet transform is a mathematical function which decomposes a signal and provides us with time frequency representation of signal [11]. Wavelet transforms are classified as Continuous wavelet transforms (CWT) and Discrete wavelet transforms (DWT) [5]. DWT is used to decompose a signal into approximate and detail coefficients that helps to examine the signal at different frequency bands with different resolutions.

II. METHODS

The system developed consists of a treadmill ECG, which is acquired from the skin surface with the help of clamp electrodes (RA, LL, RL) and it is given to Instrumentation amplifier. As the ECG signal is quite low in amplitude Instrumentation amplifier is used to produce an output signal which is readable and measurable. In instrumentation amplifier the output of the buffer is given to differential amplifier which amplifies the difference between two input signal voltages while rejecting any signals that are common to both the inputs. Second order Butterworth High Pass Filter (HPF) and Low Pass Filter (LPF) are used with desired cutoff frequencies of 0.05 Hz and 150 Hz respectively. The ECG signal is then given to the ADC of a microcontroller which digitizes the ECG data and then transmit it to Bluetooth module. The signal is then transferred to the PC by Bluetooth module and processed in MATLAB using Discrete Wavelet Transform technique. After processing the signal, motion artifacts suppressed ECG signal is displayed on the monitor. The block diagram of a system used for online suppression of motion artifacts during treadmill ECG is shown below in Figure I.

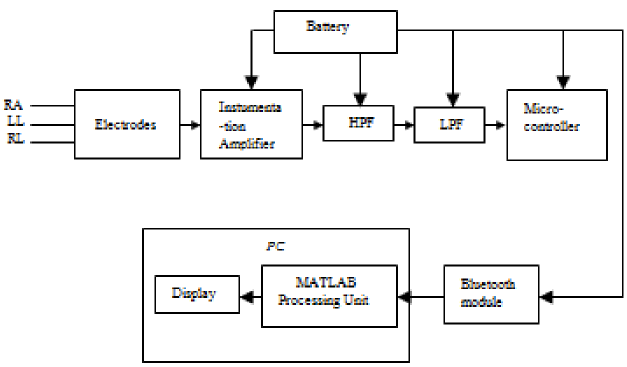

Figure.1. Proposed Block Diagram For Online Suppression Of Motion Artifacts During Treadmill ECG

WAVELET BASED MOTION ARTIFACTS SUPPRESSION:

Using wavelet transform motion artifacts present in ECG can be suppressed. Decomposition, Thresholding and Reconstruction are the three steps used for suppression of motion artifacts [4]. Flow chart for Motion artifact suppression in the ECG is shown in Figure II.

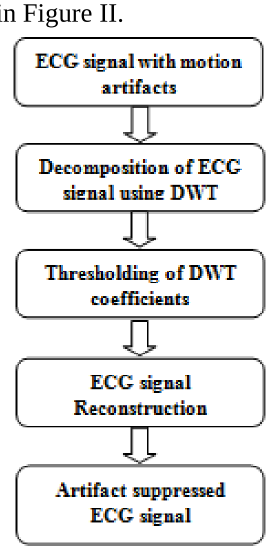

Figure.2. Flowchart Of Dwt Algorithm

1. Decomposition: Wavelet transform is applied to the ECG signal containing motion artifacts up to a certain level in order to produce the wavelet approximation coefficients.
2. Thresholding: Appropriate threshold limit is selected for each level, soft or hard thresholding is applied to the detail coefficients to remove the noise.
3. Reconstruction: The signal is reconstructed by subtracting the thresholded signal from raw ECG signal and thus motion artifacts gets suppressed from ECG signal.

III. RESULTS

Presence of motion artifacts in ECG signal mostly affects ST segment. ST segment depressions like up sloping and down sloping is observed in ECG signal. The recorded treadmill ECG when the person is in motion is processed in MATLAB using Discrete Wavelet Transform technique. Below given figures shows that motion artifacts get reduced from ECG signal.

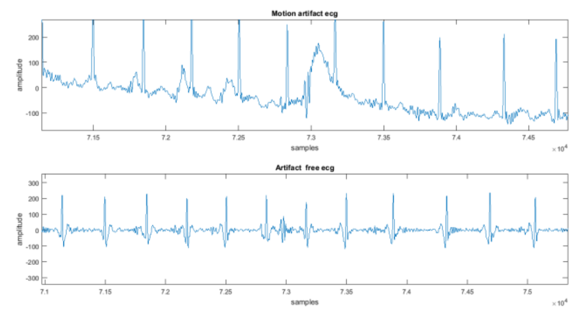

Figure .3. matlab output after processing

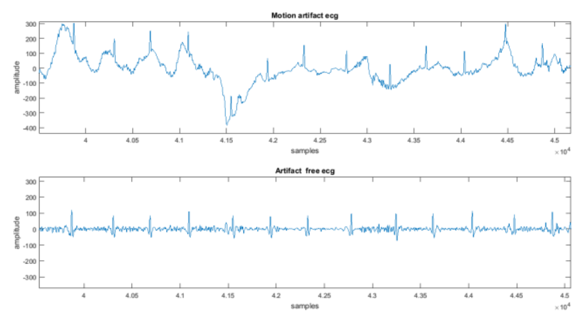

Figure.4. matlab output after processing

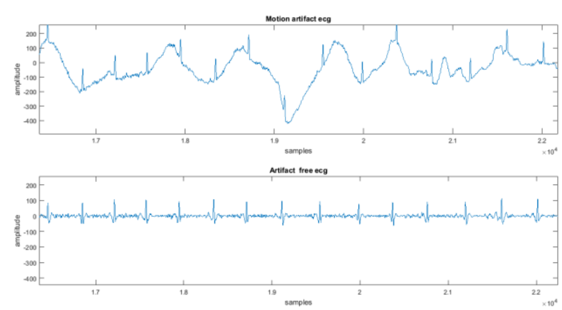

Figure.5. matlab output after processing

In above shown results the up sloping and down sloping of ST segment is restored and baseline wandering noise is also reduced.

IV. DISCUSSION

The SNR ratio is signal to noise ratio. The quality of the signal depends on SNR value. The batter is the SNR value better will be signal quality and less will be noise present in the signal. Wavelet families include Biorthogonal, Coiflet, Haar, Symmlet, Daubechies wavelets [13], etc. For motion artifact suppression in ECG, the selection of the wavelet family is done by observing the SNR values during wavelet thresholding. Below given table shows the SNR values for wavelet thresholding.

Table.1. Values Of Snr Using Wavelet Thresholding

Sr No.	Name of Wavelet	SNR before thersholding	SNR after thresholding
1	Db2	2.891798043	19.18994582
2	Db3	2.891798043	19.77960659
3	Db4	2.891798043	17.75376594
4	Db5	2.891798043	19.09497654
5	Db6	2.891798043	18.7900743
6	Db7	2.891798043	21.04079503
7	Db8	2.891798043	18.56113473
8	Sym2	2.891798043	22.0221397
9	Sym3	2.891798043	22.18971839
10	Sym4	2.891798043	22.07640749
11	Sym5	2.891798043	22.08709051
12	Sym6	2.891798043	22.11690941
13	Sym7	2.891798043	22.21938973
14	Sym8	2.891798043	22.18880674

It is noticed that using Symmlet order-7 wavelet, better SNR value is obtained as compared to other wavelet. The ECG signal contains less artifacts after denoising.

V. CONCLUSION

This paper represents a system which is used to acquire clean ECG, suppressing the motion artifacts in health care centers and clinics. The ST segment elevation and depression is restored, which makes physicians easy to detect the coronary artery diseases. Thus, using exercise testing, ischemic conditions are detected and treated to prevent infarction or other serious complications. In this paper, hardware system is designed to acquire ECG during treadmill exercise and the acquired ECG is processed in MATLAB using Wavelet Transform algorithm.

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