International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Particle Swarm Optimization algorithm based Adaptive filter for Removal of Baseline Wander Noise from ECG signal

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Accepted 05 May 2015, Available online 11 May 2015, **Vol.5, No.3 (June 2015)**

Abstract

Electrocardiogram (ECG) is very much susceptible to the Noise and Interference, these are may be other different noise sources. Due to the different types of Noises and Interferences ECG Signal gets corrupted and hence data will be lost. Different types of Noises and Interferences like Power Line Noise (50 Hz), Base Line Wonder Noise (0.05 Hz), Muscle contraction or External High Frequency Noise etc. This Paper focus on the Base line Wonder Noise Which is having very small frequency component of 0.05 Hz to 5 Hz. This small frequency components overlap with that of the ECG Signal, due to the overlap ECG signal information gets corrupted. Hence removing the Base Line Wonder Noise we use newly developed Swarm optimization algorithm based on Adaptive Filter. Swarm Optimization Algorithm minimize the noise signal which is present in the noisy ECG signal.

Keywords: *Baseline Wander Noise, Adaptive Filter and Swarm Optimization algorithm.*

1. Introduction

WHO (World Health Organization) survey: There are 80% of human deaths occurred due to the heart related diseases. Information about the cardiac status, respirational rates positions of the Heart chambers and ventricular triggering is getting from the ECG signal (Chang C-Y *et al*, 2010). Electrocardiogram (ECG) signal is susceptible to the interference and noise signal which are present in the surrounding environment. These external noise and interference added with ECG signal and hence necessary information is loss from ECG signal (J. Mahil *et al*, 2013).

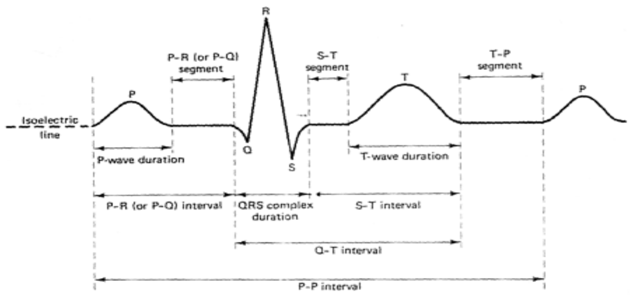

Fig.1 ECG signal with different wave and signals

ECG signal having different waves and intervals like P, Q, R, S, T and U as shown in fig-1 above. These waves gives information of different positions and issues related to the heart. This information is getting from the Electrodes which are externally attached to the body. There are mainly 12 lead system is used for acquisition of ECG signal from human body.

There are different noise and interference signals: Power line Noise, Baseline Wander Noise, Electromagnetic interference and Motion artifacts. These different types of interferences and noises are added in the ECG signal at the time of ECG acquisition or recording. Due to addition of interferences and noises ECG signal gets corrupted and loss clinically important data. Hence we need to remove these noises from the ECG signal for the further processing.

Baseline Wander Noise having low frequency component of 0.5 Hz to 5 Hz and varying amplitude considerably affect information of ECG signal (J.M. Leski *et al*, 2004). This low frequency Baseline Wander Noise is overlap with ECG signal. Baseline Wander noise causes due to patients movement of hands and legs muscles or breathing. It might be induced due to misleading measurement and annotation of the signal information. Hence it is necessary to remove Baseline Wander noise from the ECG signal.

Denoising of Baseline Wander Noise is done with the Adaptive filter based on Swarm algorithm. Adaptive filter provides feature of automatic adjusting coefficients. These coefficients of Adaptive filter calculated using swarm algorithm. Simulation of the model is done on the MATLAB and hardware cosimulation is done on Sparten-3a board by using

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System generator. It gives better efficiency than FIR and IIR digital filters. It removes noise signal from ECG with less no. of stages as compared to the other FIR and IIR techniques.

2. Theory and Concept

2.1 MIT-BIH Arrhythmia database

Electrocardiogram (ECG) signal is required for signal processing, which is achieved from the MIT-BIH Massachusetts Institute of Technology/ Beth Israel Hospital) Arrhythmia Database.

MIT-BIH Arrhythmia Database contain mainly 48 recording of ECG signals, each of them is of more than 30 minutes recording (Ying-Wen Bai *et al*, 2004). This all 48 recordings are selected from the 4000 recordings, out of these 23 are of 100 series and other 25 are of 200 series. In100 series all the recorded ECG signals are of random patients and normal ECG signal. Other 25 are of 200 series are unique ECG signals, each of them are different from the others.

2.2 Swarm Optimization Algorithm

Swarm Algorithm is an optimization technique for maxima and minima of the function, which is used in various industries or business. There are mainly two types of Swarm optimization algorithm Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO), but PSO algorithm is mostly used for optimization due to its simplicity in implementation and does not required more information for processing than other optimization technique.

Particle Swarm Optimization (PSO) Algorithm is first introduced by Dr. Kennedy and Dr. Eberhart. It required only few parameters to adjust. PSO algorithm is faster, cheaper and efficient as compared with other optimization techniques.

Particle Swarm Optimization (PSO) Algorithm is implemented on the Adaptive filter. This is used for the minimization of the Baseline Wander noise signal present in the ECG signal. Adaptive filter based on the PSO algorithm block diagram is shown in the fig-(2) below.

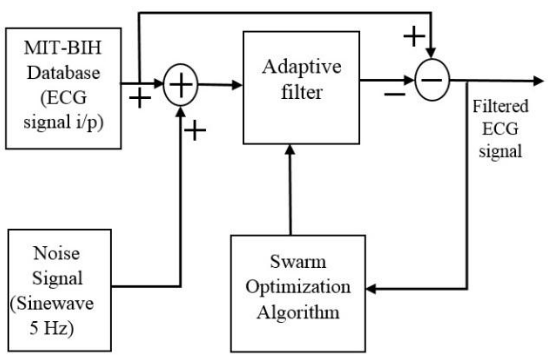

Fig.2: Block diagram of Particle Swarm Optimization (PSO) algorithm based Adaptive filter.

There are mainly two equations of PSO algorithm. One is used for the updation of the velocity of the particle and other for updation of position of the particle. These equations are updated depends upon the present input signal. The output of the PSO algorithm is acting as a coefficient for Adaptive filter,

Depends upon no of stages it changes each stage. This equations are given below:

Equation for the Velocity updation:

V in (n + 1) = V in (n) + C1 * R1 * (Gbest – X (n)) + C2 * R2 * (Gbest – X (n)) (1)

Vin (n) = Initial condition of the signal.

C1 , R1 ,C2 and R2 = Constants of values between 0 to 1.
Gbest = Error signal.
X (n) = Initial input considered as zero.
Equation for the Position updation:
P in (n+1) = P in (n) + V in (n) (2)
Pin (n + 1) = Coefficient of Adaptive filter.

As we seen in Eq-(1) C1, C2, R1 and R2 are constant, where C1 = C2 for every stages and R1 ≠ R2 are vary with respect to stages. Gbest is error signal of the particle and X (n) is input signal to the PSO algorithm. The standard values of the C1, C2, R1 and R2 are varies from 0 to 2. Mainly filtered output of the PSO based Adaptive filter is depends on the values of the R1 and R2. The updated values of variables P in (n + 1) and V in (n + 1) are updates coefficients of the adaptive filter with different stages.

Particle Swarm Optimization algorithm based Adaptive filter working flow shown in figer below.

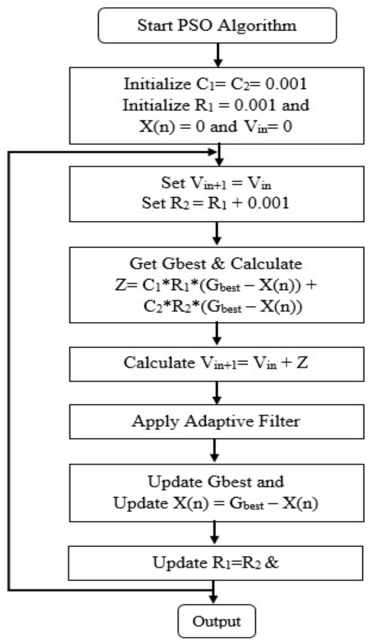

Fig.3 Operation of Particle Swarm Optimization based Adaptive filter

Adaptive filter equation is:

$$Y(x) = \sum_{K=0}^{\infty} P(k) * X(n-K) \quad (3)$$

Here P(K) acting as a coefficient of the Adaptive filter. Different stages of Adaptive filter is value of the P(K) is changes with respect to input signal present.

3. Implementation Methodology

Particle Swarm Optimization (PSO) algorithm is implemented on the Adaptive filter by using Xilinx System generator tool. Software simulation is done on the Matlab 2013(b) software. Matlab simulation model is implemented on the Spartan-3E kit.

MIT-BIH arrhythmia database contains no of recoded ECG signals in the file three format. Matlab software is used for the extracting ECG signal from the MIT-BIH arrhythmia database. ECG signal extracted from the MIT-BIH is pure ECG signal that is noise free ECG signal. This is used as input for PSO algorithm. Baseline Wander Noise (i.e. sinusoidal wave of frequency of 0.05 to 10 Hz) added in the pure ECG signal and resultant wave is applied to the input of Adaptive filter.

Matlab Simulation model is implemented by using Xilinx System Generator 14.5 tool. Here we are implementing single stage PSO based Adaptive filter. This simulation model is implemented on the kit of Spartan-3E. For implementing swarm algorithm on hardware it required minimum 6 adders, 4 multipliers and 2 constant multipliers. Depending upon these requirements and minimum cost Spartan-3E board is selected.

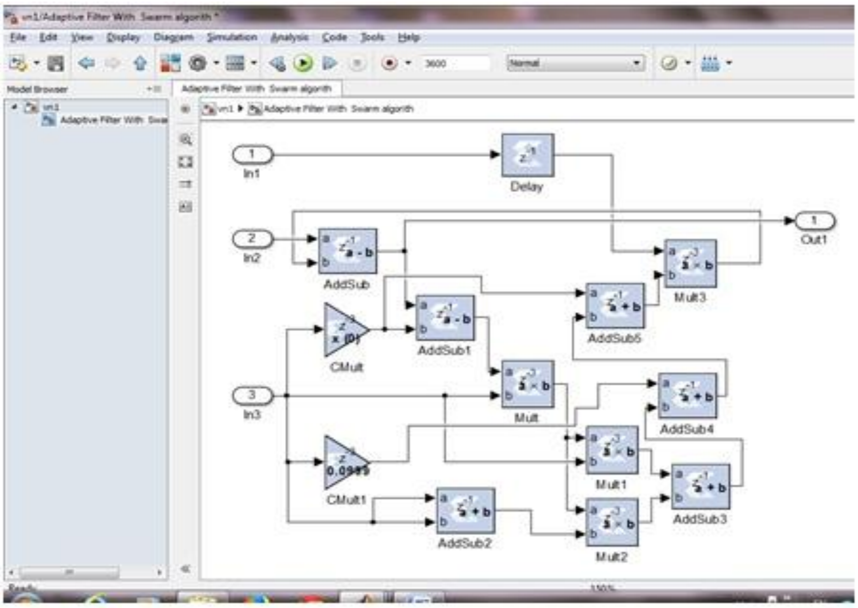

Fig.4 Internal structure of Particle Swarm Optimization based Adaptive filter

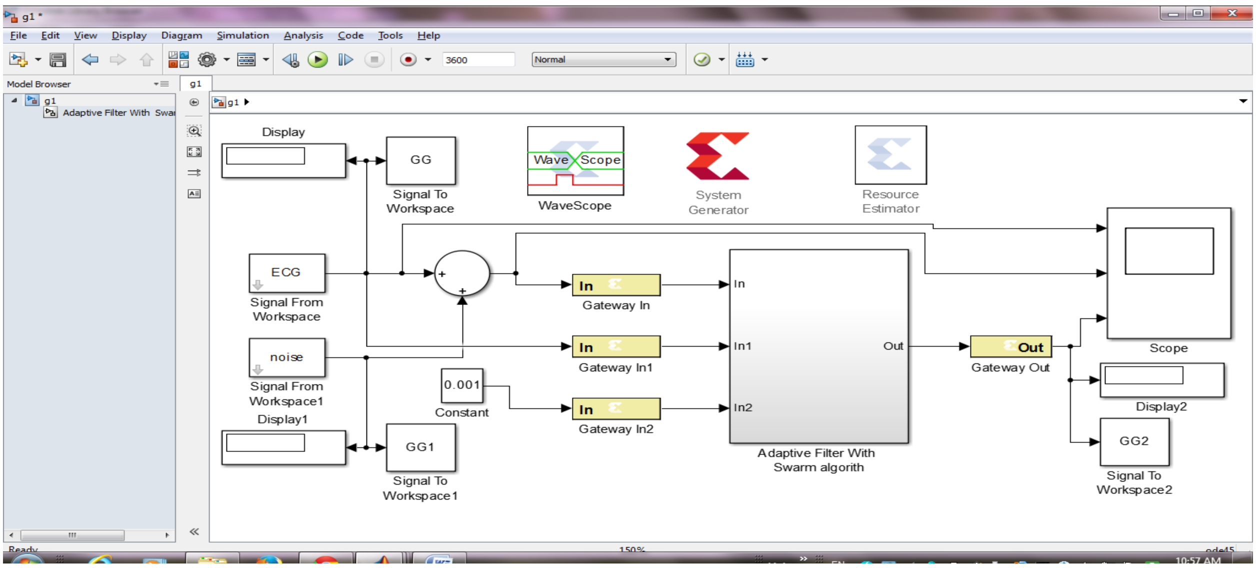

Fig.5 Simulation model of Particle Swarm Optimization algorithm based Adaptive filter

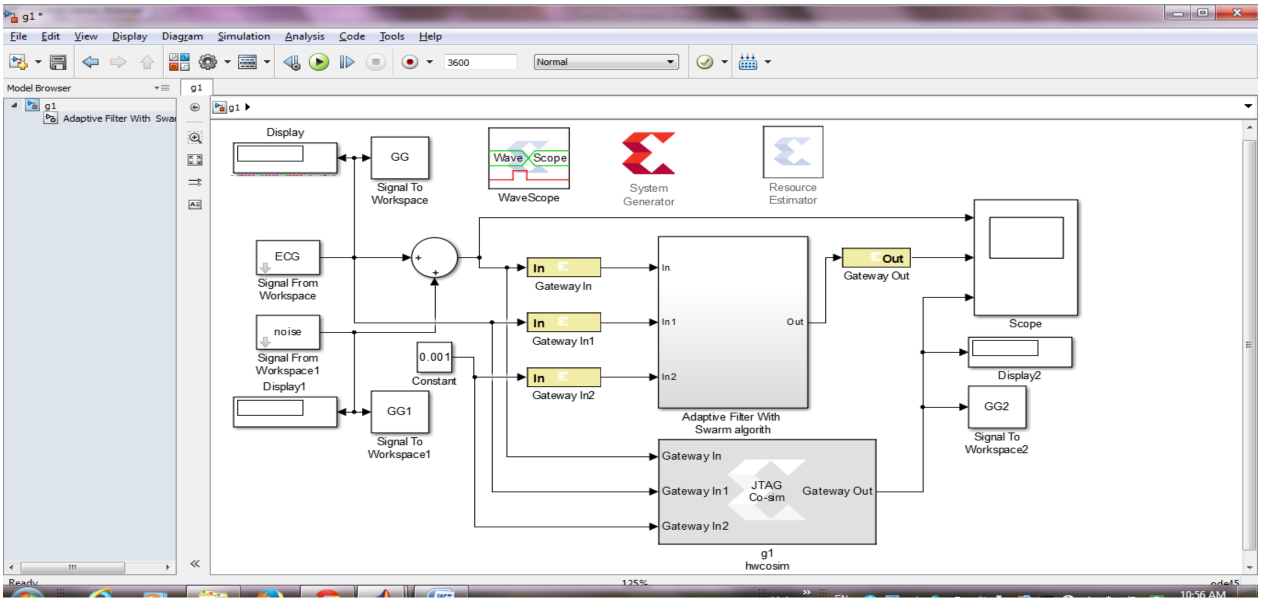

Fig.6 Hardware cosimulation model of Particle Swarm Optimization algorithm based Adaptive filter

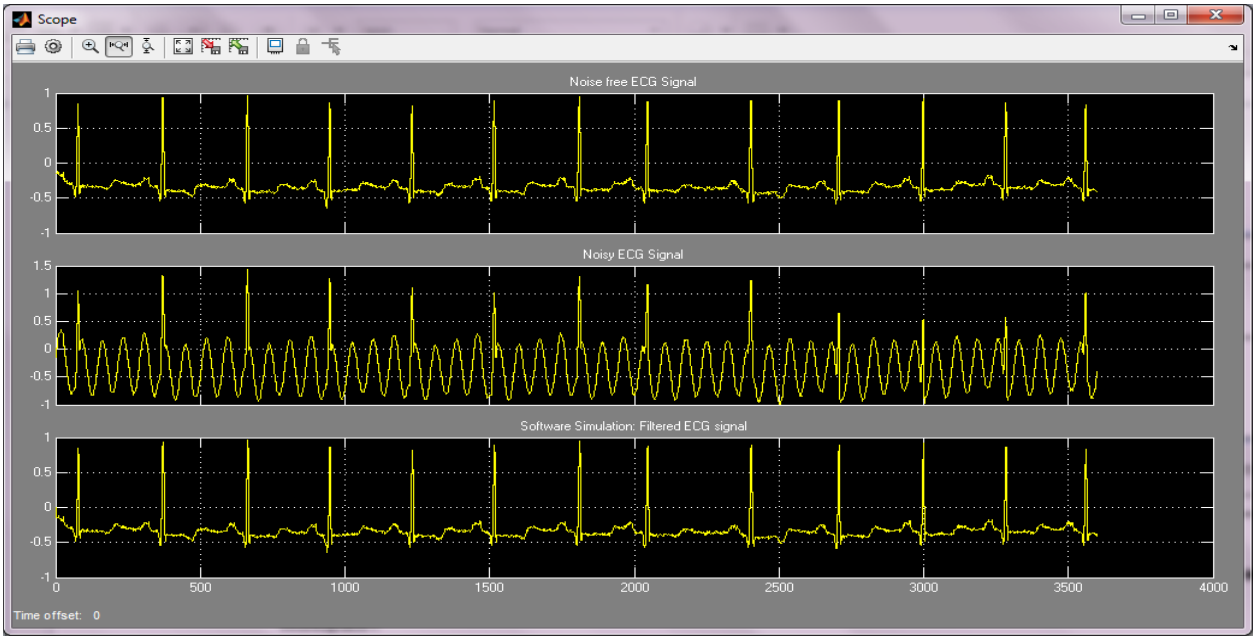

Fig.7 Simulation: Filtered ECG signal by using Particle Swarm Optimization algorithm based Adaptive filter

Communication between Matlab software and Spartan-3E kit is done by using JTAG cable. System generator of the Xilinx block set generate JTAG block for compatible signal for Spartan-3E kit.

Other Xilinx block which are Wavescope and Resource Estimator used for calculating values of signal at different timing and resource used by the simulation model respectively. Resource Estimator is used only when hardware is connected. Simulation and Hardware cosimulation models are shown in the Fig-(2) and Fig-(3) respectively.

Subsystem shown in the Fig-(5) of PSO based Adaptive filter is implemented on the Spartan-3E kit. The internal structure of PSO based adaptive filters subsystem is shown in Fig-(3) below. In this subsystem single stage PSO is implemented with Adaptive filter. Output of the single stage is same as that of the multistage PSO based Adaptive filter.

4. Results

ECG signal extracted from the MIT-BIH Arrhythmia database is noise free signal which is used as input signal for PSO algorithm and Adaptive filter.

PSO based Adaptive filter simulation model is execute on the Matlab software. Output of the simulation model is shown in the scope in Fig-(6). Designed Adaptive filter is of single stage which is considerably removes Baseline Wander Noise from the ECG signal effectively and gives noise free ECG signal.

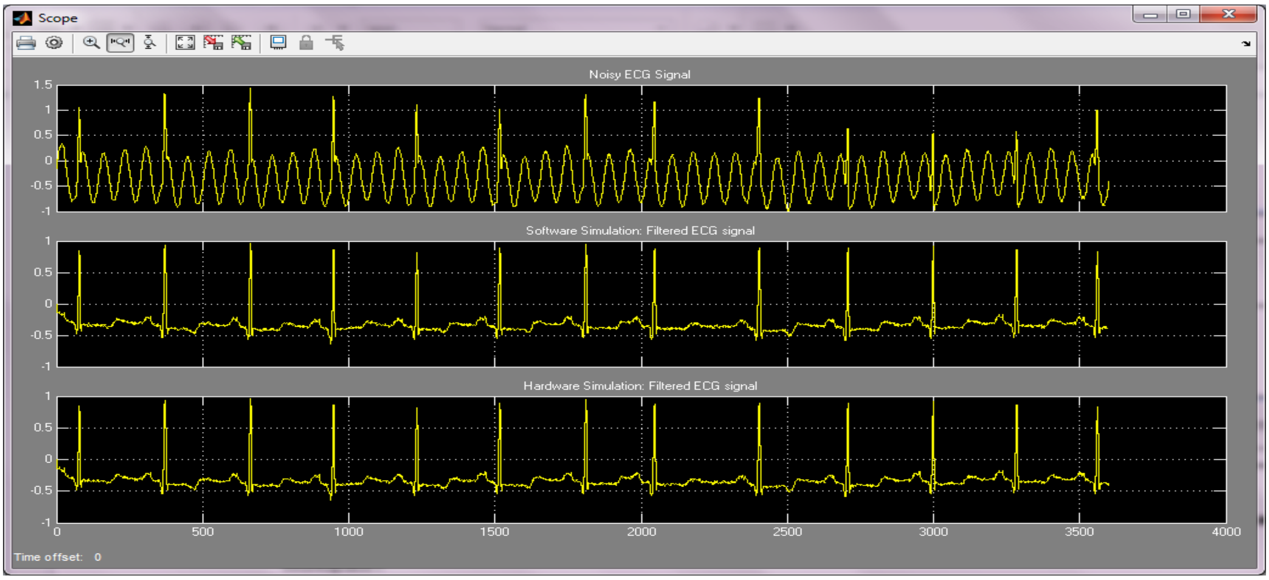

Fig.8 Hardware: Filtered ECG signal of Particle Swarm Optimization based Adaptive filter

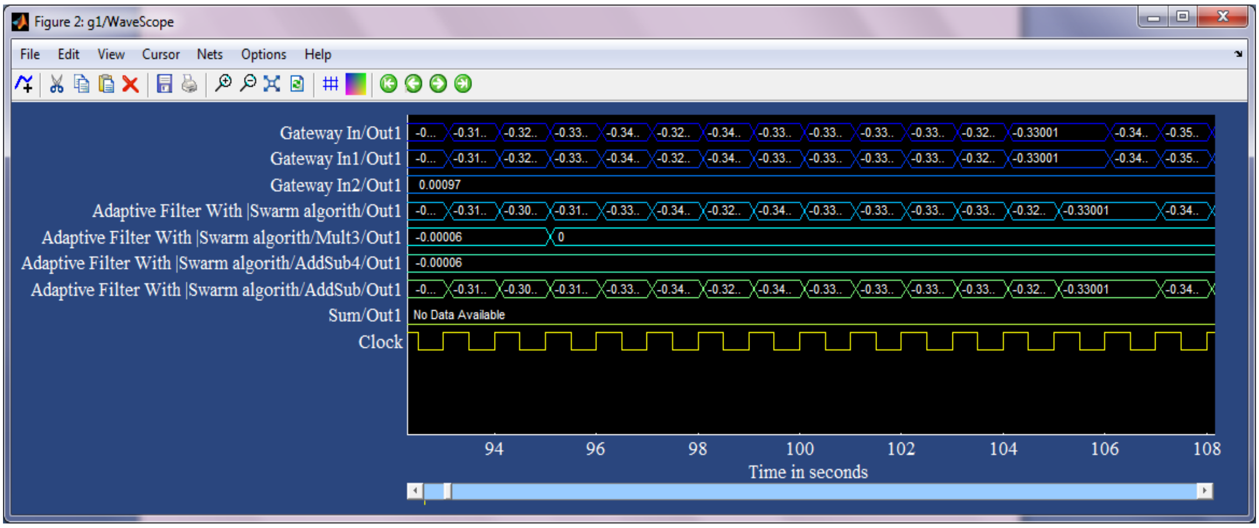

Fig.9 Wavescope values at different positions of implemented model of PSO based Adaptive filter.

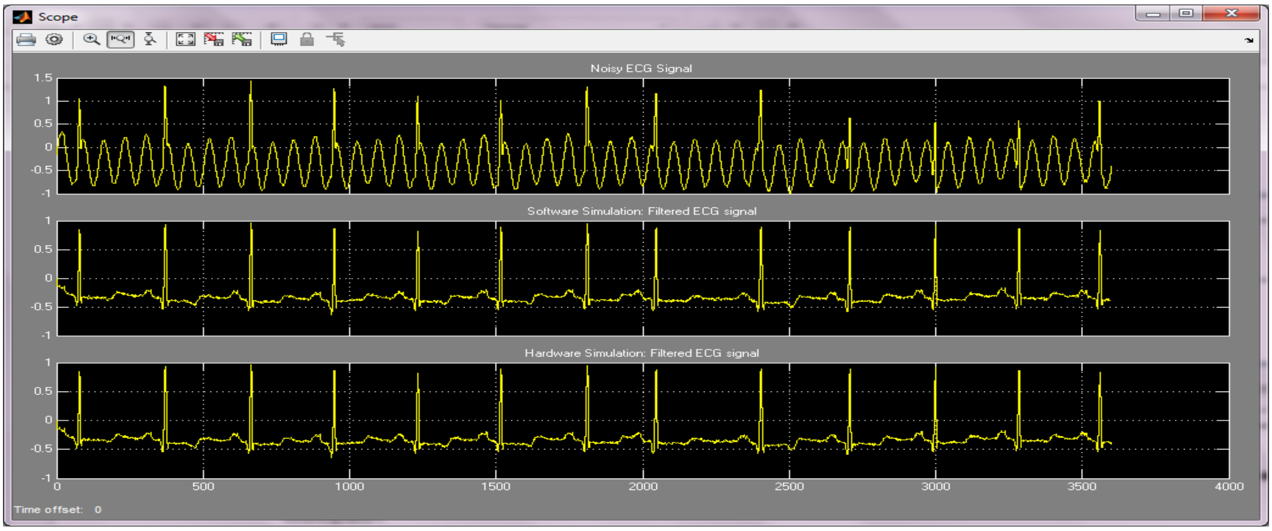

Fig.10 Two stage Particle Swarm Optimization algorithm based Adaptive filter Simulation and Hardware cosimulation results

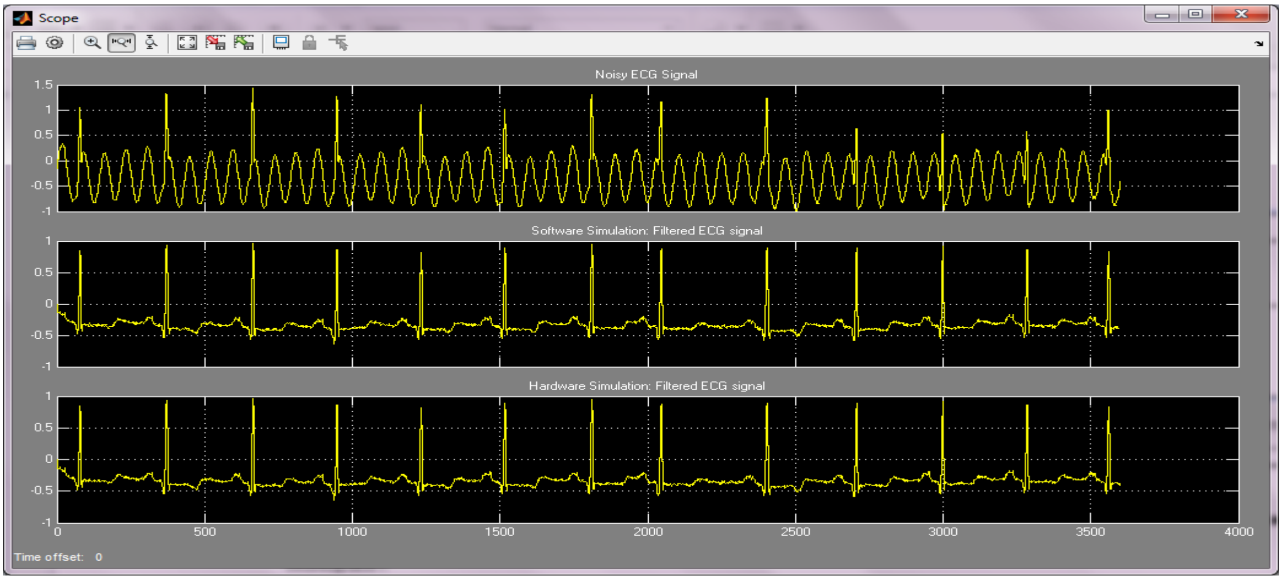

Fig.11 Three stage Particle Swarm Optimization algorithm based Adaptive filter Simulation and Hardware cosimulation results

Simulation model implemented Spartan-3E kit by using JTAG cable. JTAG cable makes Matlab signal compatible with Spartan-3E kit for processing signal on hardware and create JTAG block by using System generator tool. Output taken from the hardware cosimulation and software simulation is having no difference. Hardware cosimulation result is shown in the Fig-(7) and wavescope result shows the different signal values at different timing in Fig-(8). Single stage PSO based Adaptive filter removes Baseline Wander Noise effectively.

Conclusions

In this paper Particle Swarm Optimization (PSO) Algorithm is implemented on the Adaptive filter for removing Baseline Wander Noise from the ECG signal. Hardware cosimulation is done on Spartan-3E kit, which having faster speed and performance and low cost for digital signal processing. PSO based Adaptive filter is simple to build in Matlab environment and removes maximum noise from ECG. Single stage PSO based Adaptive filter is sufficient to remove noise from ECG signal. Outputs of multistage filters are same as that of the single stage, hence it is not required to design multistage filter. PSO based Adaptive filter effectively removes Baseline Wander Noise from the ECG signal.

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