A Novel Approach of ECG Signal Enhancement Using Adaptive Filter Based on Whale Optimization Algorithm

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An Electro cardiogram is commonly used in biomedical signal processing. It is used to monitor minor electrical changes in the human body. The electrical changes originate due to the function of heart. The anomalies of heart are found by ECG. In this work the Whale optimization algorithm is used to de-noising the ECG signal. The Whale optimization algorithm is used with Adaptive filter which filter the corrupted ECG signal. The performance of the ANC will be improved by calculating the optimum weight value. The WOA technique gives the best result on the different fidelity parameter compare to PSO, MPSO and ABC. The WOA technique gives the significant improvement in accuracy. It gives a good SNR, MSE, ME result compare to PSO, MPSO and ABC. The WOA gives 80% improvement in SNR 88% in MSE and 89% in ME as compared to PSO. So, by using WOA we get a desired ECG component. The WOA reduces the noise in ECG signal and improves the quality of signal.

Keywords: AF; ECG; MSE; ME; MPSO; PSO; SNR; WOA.

The ECG is a very important screening tool. ECG provides the information about the human heart condition. It's provides the information about electrical changes in the heart. It detects the anomalies of heart rate. ECG is pivotal detection of cardiac activities. It detects different types of disease related to heart. ECG is also finding the non-cardiac disease as emboli and electrolyte disorders. It records the heart rate. The different component is present in an ECG signal as the P wave, QRS wave, and T wave. These waves provide firm information about the ECG signal. To find the ECG signal the electrodes are placed on the human body and it finds the waveform of heart. The multiple view of heart activity is recorded by the ECG machine. The electrodes are also playing an important role to find out the multiple views in[1-4]. The major problem of ECG signal measurement is that ECG signal is degraded with noise. So to obtain a pure ECG signal right diagnosis of the signal is important. ECG is filtering and de-noising is important to clinical application. The important information of the waveform is affected by the noise. The noise is present due to different reason in the ECG signal.

ECG Artifacts

The noise present in ECG signal occurs by different cause. The noise is called artifacts in ECG signal. In the Power Line interference are occurs high frequency noise which is generated by respiration and body movement. The base Line wander consist low frequency noise which is generated by power lines at 50Hz to 60Hz frequency. The ECG signal is sensitive to SNR. The sensitivity is caused by the low frequency component of ECG signals. The low frequency band has some different internal and external noise. Internal noise commonly generated by the different function of the human body as- EMG. The external noise generated by the device used to measure the ECG signal as-Base line wandering. The signal filtering is very necessary to get the pure ECG signal. Because different noise is present in ECG signal so filtering of signal is a difficult task.

Several methods are used to de-noising the ECG signal. The adaptive filter gives a good result over the different type of filter. The WOA technique is used to find good convergence or better fidelity parameter over PSO, MPSO and ABC in[4-7].

Adaptive filter

The adaptive filter coefficients are varying according to some condition. Its coefficient is changeable and adjustable according to requirement. The performance of the system has improved by these characteristics. Its characteristics adapt the change in parameters so it has a self-adjustable quality. The adaptive filter is widely used in biomedical signal enhancement. The adaptive filter is a very good method to remove noise or artifacts from ECG signal. It is used where the signal to noise occupies a proper distinct frequency band. The conventional filters are basically used to extract the signal but to remove the noise or
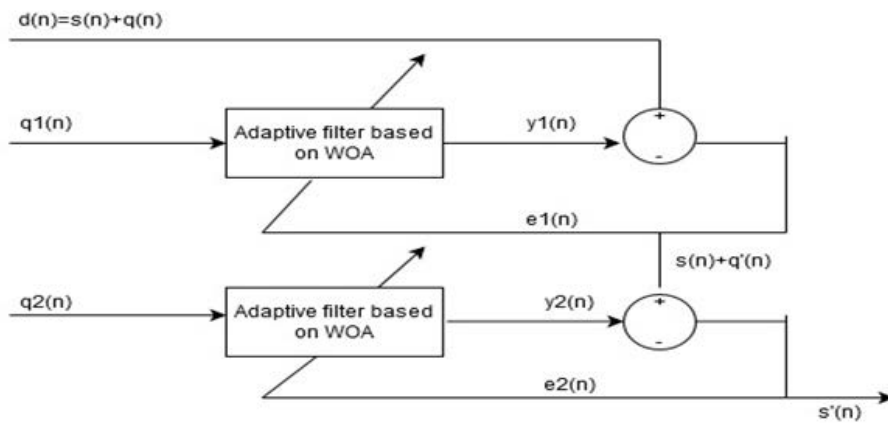

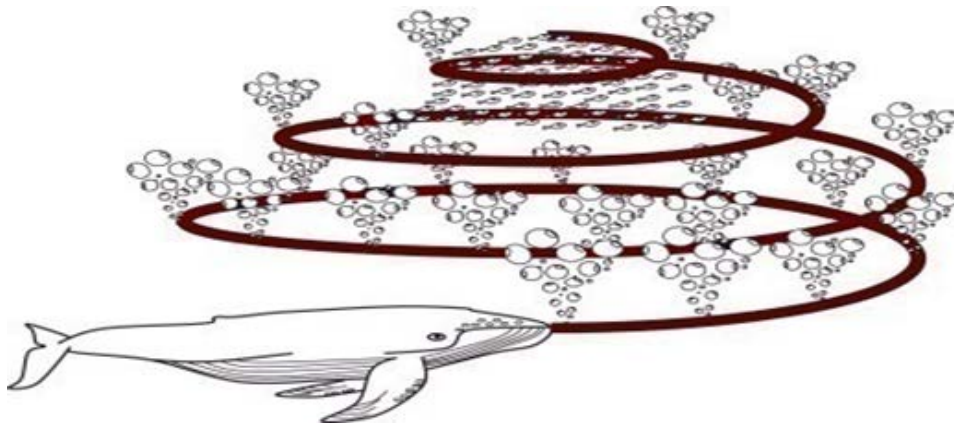**Fig.1.** ANC filter using WOA block diagram

Fig. 2. Bubble Net Attacking Method

artifacts the adaptive filter gives the better result. In many cases the coefficient of filter needs to be changeable. The adaptive filter is changing the signal characteristics according to need. Adaptive filter is mainly used by this reason:

1. When it compulsory to change the filter coefficient according to requirement.
2. When the signal and noise frequency overlap.
3. When the frequency occupied by the artifact is changing according to time.

The use of conventional filter is cause of distortion in the desired signal. Adaptive filter used like a noise canceller to produce a optimum result in corrupted signal. So by using the adaptive filter the accurate result of desired signal obtain in[7, 8]. The feedback network updates the filter coefficient and it reduces the noise until the desired response is obtained. The d(n) is the corrupted ECG signal, s(n) is pure signal and q(n) is noise signal which consist the high frequency component as-power line interference and low frequency component as muscles noise. So the $q_1(n)$ is high recurrence noise and $q_2(n)$ is low recurrence noise. The $q_1(n)$ and $q_2(n)$ is are not correlated with s(n). The ANC filter used to generate the output signal y(n). The error signal e(n) is obtained by subtraction of d(n) and y1(n). Error signal feedback to the every cycle. This process is continued until the desired output obtain. The $e_1(n)$ is feedback until the high frequency component reduce in the first

circuit. The final signal s'(n)+q'(n) consist low frequency component. Error signal e_2 is generated by subtraction of s'(n)+q(n) and y2(n). The $e_2(n)$ is also feedback every instant until the $e_2(n)$ is reduce. The final stage gives s'(n) signal which is similar to s(n). The error signal is described by the following equation-

$$E(n) = \frac{1}{N}\sum_{i=1ij}^{N}(e(n)^2)$$

... (1)

The e_{ij} is i_{th} sample of n repetition. N is the total number of samples. To get optimum results in each iteration we used WOA technique. This algorithm gives the better rate of convergence, better global search, better fidelity parameter or easy to execute in[9, 10].

Proposed method

ANC Filter Using Whale Optimization Algorithm

The Adaptive filter designed with whale optimization algorithm on noisy ECG signal gives a good performance. In the proposed work, the random noise is generated using Matlab 2013(a) which has a length of 18000. The fidelity parameters such as output Signal-to-Noise Ratio (SNR), Mean Square Error (MSE) and maximum error (ME) are varying according to, input Signal to noise ratio in [9,10]The different fidelity parameters are calculated using following mathematical terms:

$$SNRi = 10\log10\frac{(ECGpure)^2}{(ECGnoisy-ECGpure)^2}$$

...(2)

$$SNRo = 10\log10\frac{(ECGpure)^2}{(ECGfiltered-ECGpure)^2}$$

...(3)

$$MSE = \frac{1}{N}\sum_{j=1}^{n}(ECGfiltered - ECGpure)$$

...(4)

$$ME = \max[abs(ECGfiltered - ECGpure)$$

...(5)

The whale optimization algorithm is a meta-heuristic algorithm. It has two basic elements namely, exploration and exploitation. The exploitation is used for local search, which finds the information about the best search agent. The

```
1.Initialize the whale population Xj=(j=1,2,3...........n)
2.Calculate the fitness of each agent,X*=best search agent
3.while(t<maximum no. of iteration)
4.if 1(p<0.5)
if (|A|<1)
update the position of current search agent by eq 2.5 & 2.6
else if
Select a random search agent (X rand)
Update the position of current search agent by eq 2.11 & 2.12
end if 2
5.else if 1(p>0.5)
Update the position of the current search space & amend it by
eq 2.9 & 2.10
6.Calculate if any search agents goes beyond the search space
& amend it
7.Calculate the fitness of each search agent
8.Update X* if there is a better solution
   t=t+1
   end while
9.return X*
```

Fig. 3. The ANC filter using WOA Pseudo code

exploration is used to search the global optimum value. WOA technique uses killing nature of humpback whales. Which is analyzed and the process is completed by following two important methods:

1. The preys are chased by the random or best search agent.
2. Then the bubble net attacking method is used.

The humpback whale swims around the target, forming a thin shaped circle. It makes a winding path and creates distinct bubbles along the circle formed. The humpback whale uses two methods when they search for the prey. In mathematical terms for these 50% to choose among these two method to refresh the position of whales as follow-

$$X(t + 1) = \{X^*(t) - A.D \quad \text{if } p < 0.5$$
$$\{D.e^{bl}.Cos(2\Pi l) + X^* \quad \text{if } p > 0.5$$

$$...(6)$$

It also forms a path which is similar to the shape 9. They have a very different hunting method which is often called as the bubble net
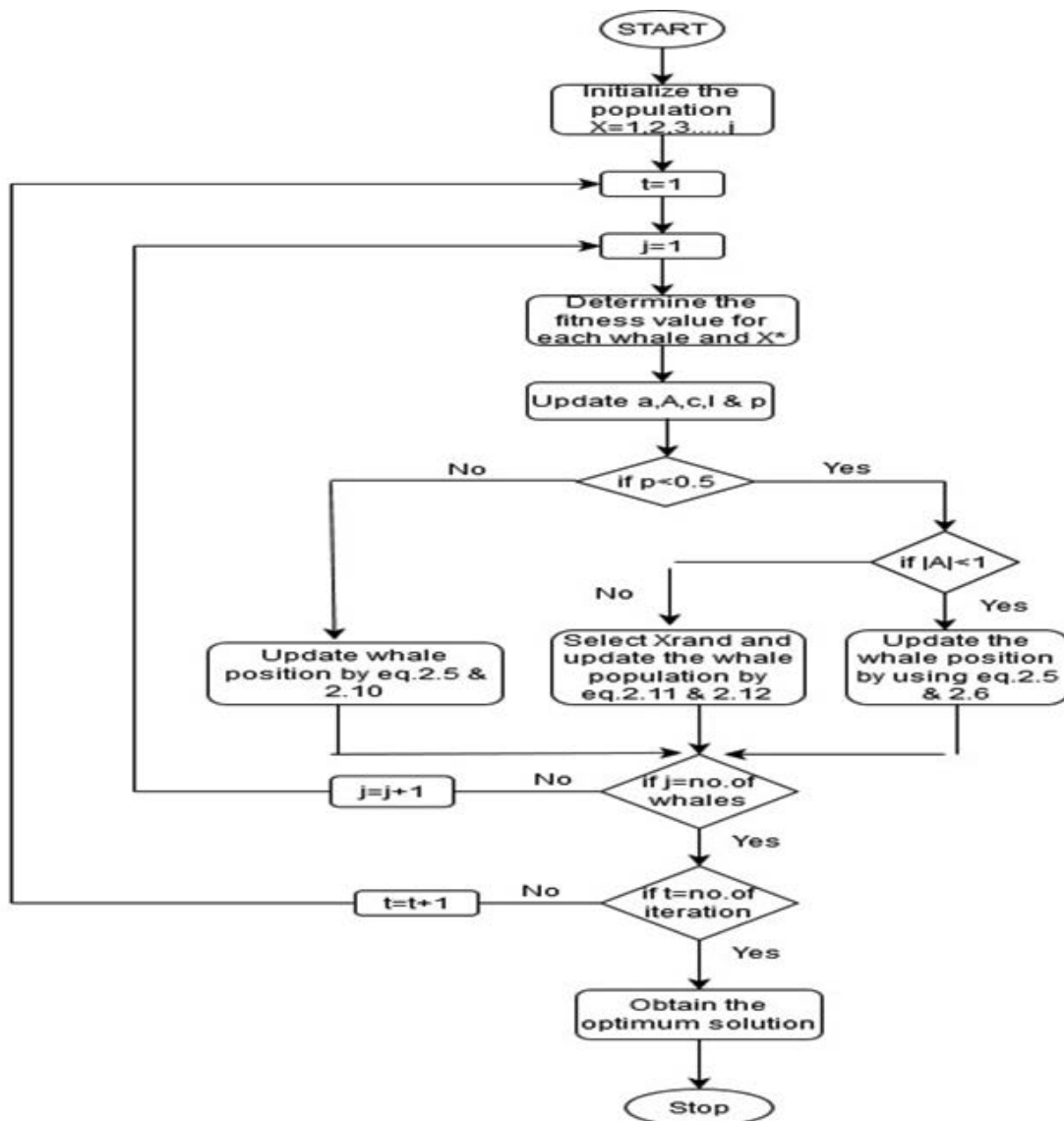

Fig. 4. The Flow chart of WOA

feeding method in[11] WOA consist of two major phases described as follow-

Encircling the prey

In encircling, the whale finds out the position of the prey and encircles them. In this method, we assume that the best solution is the target prey. The other search candidate continues to refresh the position. The mechanism is described by the following equation

$$X(t+1) = X^*(t) - A.D$$

...(7)

$$D = |C.X^*(t) - X(t)|$$

...(8)

Where the current iteration is represented by t, the coefficient Vectors represented by A and C, the position vector of best solution is represented by X*, and the position vector of a solution is
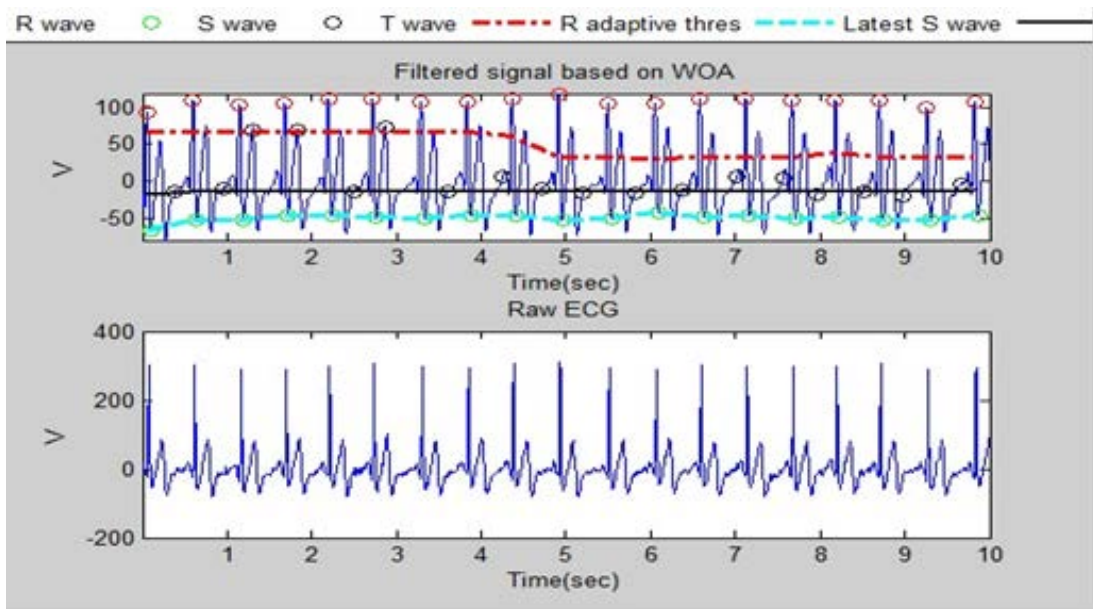
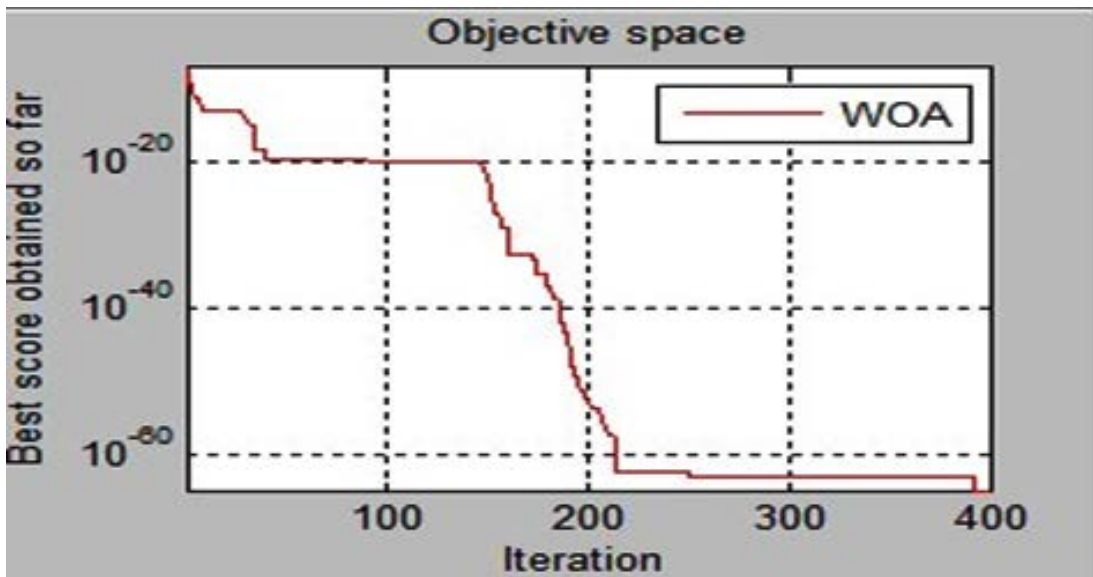

Fig. 5. ECG signal filtering using WOA

Fig. 6. Representation of unimodal benchmark function F1 in objective space

represented by X,| | is the absolute value.The vectors A and C are determined by the following equation:

$$A = 2.a.r - a \qquad ...(9)$$

$$C = 2.r \qquad ...(10)$$

Where components are linearly reduced to a from 2 to 0 in each cycle and the random vector r is in the range of [0, 1].

Bubble Net Hunting Method

The bubble net hunting method has two approaches to design a mathematical model.

Shrinking Encircling Prey

The value of A is a randomly chosen value in this method which lies between range [-a, a].Here, A is reduced by 2 to 0. The position is set to random values in the range of [-1, 1].The new position of **a** lies between the current and original position.

Spiral Position Updating

The spiral shaped mathematical model is used between   position of the prey and the humpback whales. It follows the helix shaped path. The mathematical equation used for the position updating are-

Table 1. Comparative result of SNR by using different technique on ECG signal

Input SNR(db)	O/p SNR(db) LMS[9]	O/p SNR(db) DWT[9]	O/p SNR(db) PSO[9]	O/p SNR(db) MPSO[9]	O/p SNR(db) ABC SF[9]	O/p SNR(db) WOA
-5.0	0.869	1.068	2.567	4.689	5.870	9.560
0.5	12.623	20.348	22.456	339.812	42.246	49.238
3.0	23.310	31.974	33.264	45.810	53.334	58.472
6.0	28.401	34.271	39.434	48.681	59.782	67.326
10	34.523	40.438	47.454	57.584	74.289	79.424

Table 2. Comparative result of MSE by using different techniques on ECG signal

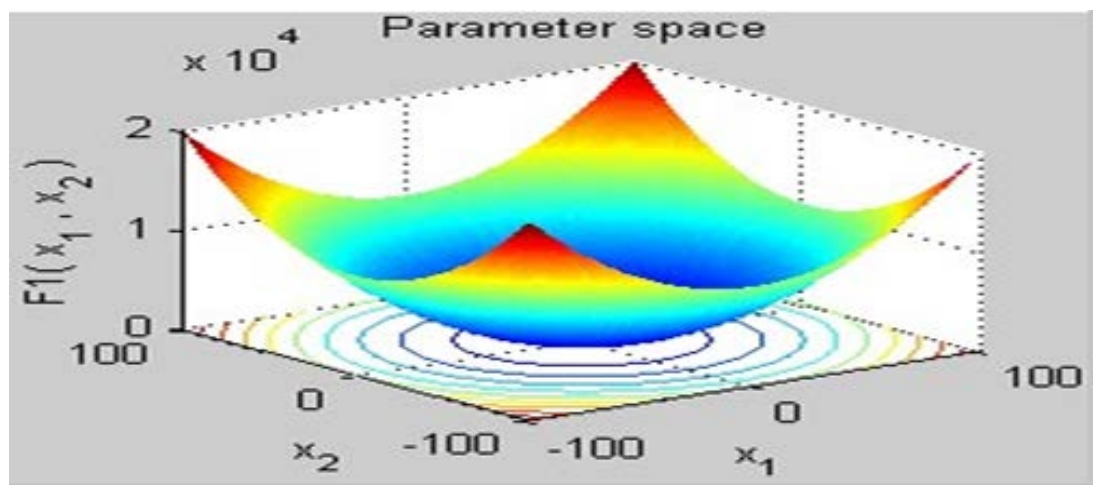| Input SNR(db)	MSE($\times 10^{-6}$) LMS[9]	MSE($\times 10^{-6}$) DWT[9]	MSE($\times 10^{-6}$) PSO[9]	MSE($\times 10^{-6}$) MPSO[9]	MSE($\times 10^{-6}$) ABC[9]	MSE($\times 10^{-6}$) WOA
-5.0	5.854	0.685	0.087	0.0568	0.0421	0.0261
0.5	2.989	0.197	0.120	0.0362	0.0342	0.0142
3.0	1.878	0.106	0.062	0.0225	0.0046	0.0031
6.0	1.154	0.096	0.036	0.0132	0.0010	0.0008
10	1.386	0.087	0.008	0.0002	0.0001	0.0001

Fig. 7. Representation of unimodal benchmark function F1 in parameter space

$$X(t + 1) = D^l e^{bl} . \text{Cos}(2\prod l) + X^* \qquad \ldots(11)$$

D=|C.X*(t)-X(t)| represent the distance between the prey(best solution) and i^{th} whale, b is a constant, l is a random value in the range [-1,1] in[11-15]

Search for prey

The search stage is also called exploration phase. The whales discover the prey by their random search. The whales change their position according to other whales. To oblige the search agent to relocate distant away from the reference whale, here we choose A with values greater than 1 or less than 1 in {16-25} The mathematical equation for the exploration is described as

$$X(t + 1) = X^*(t) - A. D \qquad \ldots(12)$$

$$D = |C. X^*(t) - X(t)| \qquad \ldots(13)$$

The random position vector chosen by current population is represented by X_{rand} in[11-25]. The pseudo code and flow chart of WOA is shown below in fig 3 and fig.4

RESULT AND DISCUSSION

The ANC filter using WOA gives improved amplitude of P, Q, R, S pulse. The WOA technique gives more optimum result compare to PSO, MPSO and ABC technique as it detects ECG signal more accurately in[9]

The WOA technique gives high quality improvement in output SNR, MSE and ME with respect to input SNR. It is by far better than the other PSO, MPSO and ABC technique. By using unmoral benchmark function F1 we obtain good SNR, MSE and ME for ECG signals. The best

Table 3. Comparative result of ME by using different technique on ECG signal

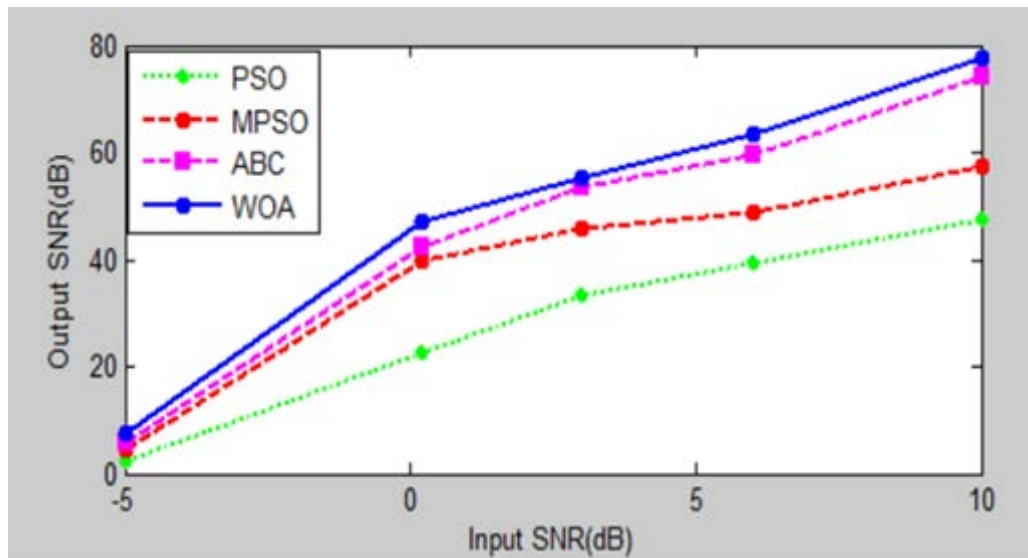| Input SNR(db)	ME($\times 10^{-2}$) LMS[9]	ME($\times 10^{-2}$) DWT[9]	ME($\times 10^{-2}$) PSO[9]	ME($\times 10^{-2}$) MPSO[9]	ME($\times 10^{-2}$) ABC[9]	ME($\times 10^{-2}$) WOA[9]
-5.0	28.5400	18.560	0.1032	0.0682	0.0208	0.0115
0.5	29.8900	19.780	0.0168	0.0045	0.0038	0.0025
3.0	18.7800	17.680	0.0084	0.0021	0.0009	0.0007
6.0	11.5450	0.9690	0.0059	0.0014	0.0006	0.0003
10	13.8600	0.3720	0.0022	0.0004	0.0002	0.0001

Fig. 8. Performance analysis of output SNR with respect to input SNR by using PSO,MPSO,ABC and WOA
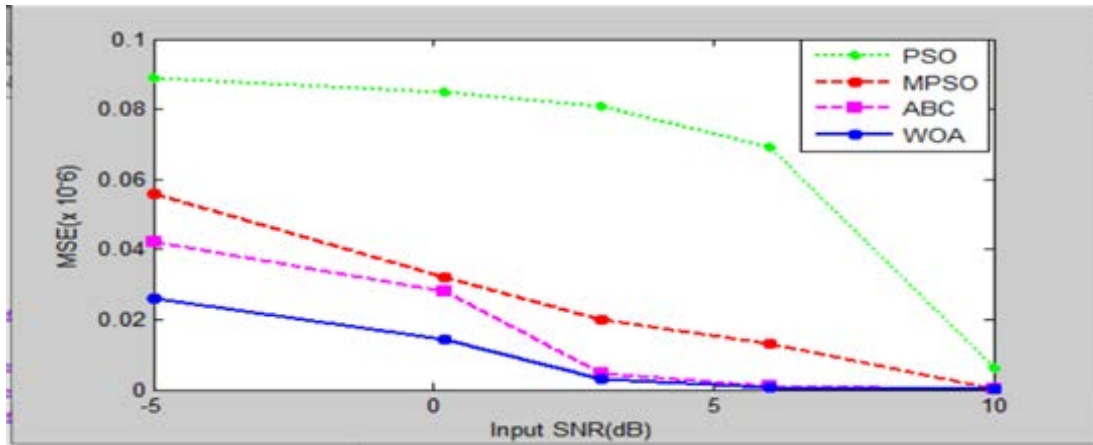
Fig. 9. Performance analysis of MSE with respect to input SNR by using PSO, MPSO, ABC and WOA
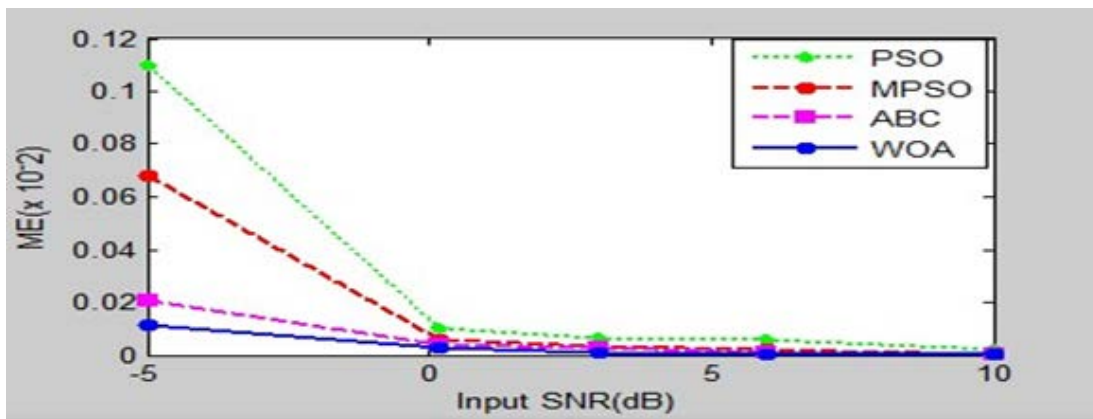

Fig. 10. Performance analysis of ME with respect to input SNR by using PSO,MPSO, ABC and WOA

solution in objective space by using F1 is 2.7329e-28 and the best optimal value for F1 is 1.572e-65.

The comparative analysis of output SNR with respect to input SNR on different ECG signals is shown in the table1:

The comparative analysis of MSE with respect to input SNR are given in the table2

The comparative analysis of ME with respect to input SNR are given in the table3

CONCLUSIONS

The efficient ANC filter using WOA is developed for de-noising of ECG signal. The WOA gives better result for different fidelity parameters such as SNR, MSE and ME compared to PSO, MPSO and ABC technique. The ANC filter using WOA gives optimum solution compare to PSO, MPSO and ABC technique. This makes it a

very attractive approach to find out better results for SNR, MSE and ME in comparison to PSO, MPSO and ABC for future prospective. The WOA gives a good convergence rate compare to swarm optimization such as PSO, MPSO and ABC so it is used for further comparison with the other technique.

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