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Arrhythmia ECG signal De-Noising by using Discrete Wavelet Transform based on Genetic Algorithm

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***Abstract*:**
ECG is a series of waves and deflection recording the hearts electrical activity from different view, these waves can be used to diagnosis different arrhythmia cardiac disease .ECG is characterized by QRS complex, which provide the fundamentals of the heart electrocardiogram signal so the enhancement of the signal and detection of QRS is necessary for automatic determine the heart conditions, Different research and studies were proposed for this purpose. In this paper , we have proposed an algorithm for ECG signal enhancement ,de-noising and detection of QRS complex based on discrete wavelet transform with different filters, that can be used to convert input signal into different sub-band according to the frequency, each sub-band have coefficient with different significant, which is enhanced with different threshold methods and thresholds. We have proposed anew threshold method based on wavelet level, the value of threshold is change according to the wavelet level. Also genetic algorithm was used to determine the best parameters that are used in the de-noising methods, in which, the binary encoding was used by represent the chromosome with ten bits, two bits to select threshold method, one bit is used to select threshold function, four bit to chose wavelet filter type and three bits to select the best wavelet level . The result are compared with other works, and the comparison show that the proposed work is better.

Keywords: ECG,QRS,GA and DWT.

I. Introduction

Electrocardiogram (ECG) was introduced into practice more than 100 years ago. It is a series of waves and deflections recording the electrical activity of the heart from a certain view. Depending on the ECG results, the specialist can determine whether the heart is performing normally or suffering from abnormalities [1]. ECG is characterized by a recurrent wave sequence of P, QRS and T-wave associated with each beat. The QRS complex is represent the most important part of the waveform within the electrocardiogram (ECG). Since it reflects the hearts electrical activity during the ventricular contraction, its time and shape provide much information about the current state of the heart[2].

However , the data that is acquired from nature is always accompanied with noise. Additive noise is one type of the different noise types. Noise exists in a high or low signal to noise ratio (SNR) due to many conditions or factors and ECG signal is always affected by various noises due to its low frequency-band (0.5-150Hz). For this reason, de-noising and enhancement techniques are required to overcome this problem and to reduce the amount of the noise that exists in the signal because the extraction of information from the signal requires a signal with no or very

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little noise [3]. The source of noises that affect ECG during recording are electrical activity of muscles and instability of electrode skin contact [4]. There are many techniques that are used to perform enhancement and de-noising such as discrete wavelet transform [5][The wavelet transform is considered one of the most efficient and experimented techniques that can be used for this purpose because it can perform a decomposition of signal in the time frequency scale plane. [6][7]. The wavelet transform is used to split the input signal into different sub-band, that are processed individually with different methods such as threshold, contrast etc. In order to select the optimal method, wavelet filter level, type ,threshold and other parameters, Genetic algorithm is used.GA is an optimization technique that is used process of natural selection in living organisms. Optimization is the process of adjusting the inputs parameters to find the minimum or maximum output. Genetic Algorithm is used to select the optimal DWT parameters such as wavelet filter and decomposition level, threshold method , and contrast method , by running a number of iterations and then the optimal enhanced parameters will be given depending on the maximum output of signal to noise ratio improvement.

II.Literature Survey

In (2012) Gaurav Jaswal, Rajan Parmar and Amit Kaul , they used the Discrete Wavelet to detect QRS complex. The DWT approach is found to be better and more accurate than the other common methods when evaluated on MIT/BIH ECG database The maximum points of DWT corresponds to S-points in the input signal and the minimum points of DWT corresponds to the Q-points in the input signal. They used threshold to determine the peaks and the time between two successive peaks represent R-R time interval , then they compare their work with So and Chan method[1].

In (2014) Gaurav Jaswal, Rajan Parmar and Amit Kaul, they used DWT to detect QRS complex, the algorithm idea is based on determine the best coefficient by determine the the best level details of DWT that have maximum correlation with original ECG signal ,then apply DWT with this level to remove the baseline wander in the ECG signal then hard threshold was used to select the 15% from the maximum coefficient and reject the others. The performance of the algorithm of QRS detection is evaluated by using the standard MIT BIH Arrhythmia database[2].

In (2015) Roopali D Pai, Srinivas Halvi andBasavaraj Hiremath, they used wavelet transform to decompose the medical image by use haar filter for high frequency sub- band. Later they used contrast method to adjust the contrast of the image . Filters are applied to identify the edges,this image is subtracting from the original image to get resulting enhanced image. They show by experiments that this method can not only enhance an image's details but can also preserve its edge features effectively [8].

In (2016) Dharmendra Gurve , Alok Kumar Srivastava , Kingsuk Mukhopadhyay N Eswara Prasad, Sachin Shukla1 and H. Muthurajan they have developed algorithm to read the ECG images and algorithm to remove the background grids and extract the numerical co-ordinates of individual points of ECG curve. The numerical data extracted from ECG are highly useful for high precision diagnosis. The method can be applied in image processing.[9]

In (2018) Alan S. Said Ahmad, Majd S. Matti2 , Omar A.M. ALhabiband Sabri Shaikhow they used WT , that is applied with Genetic algorithm to select the best DWT filter type, levels, threshold methods and to denoise ECG Arrhythmia signals corrupted by AWGN. The proposed work was based on applying DWT to the original ECG signal with different levels, filter types ,then wavelet coefficients are the resholded

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by different methods and functions , then they reconstruct the signal by apply the invers wavelet transform . the Genetic algorithm is used to find the optimal parameters for transform and threshold [6].

III.Methodology

In order to remove the noise from ECG signal and enhanced it, and to detect the QRS complex to find its interval R-R time, we have used DWT to split the coefficient of the original signal and used different threshold method to to detect the features of the signal with different threshold method ,that is used according to the significant of the sub-band of wavelet transform. Also genetic algorithm(GA) is used to select the best parameters and method.

1. Discrete Wavelet Transform

The Signals consist of different features but there is difficult to analysis these features , so frequency domain is required would have shorter time duration than their low-frequency components[10][11]. In order to achieve a good time resolution for high-frequency transients and good frequency resolution for low-frequency components discrete wavelet transform is used . The DWT computation requires four types of filters. Fig. (1) show the structure of the decomposition and reconstruction of wavelet transform[12][13].

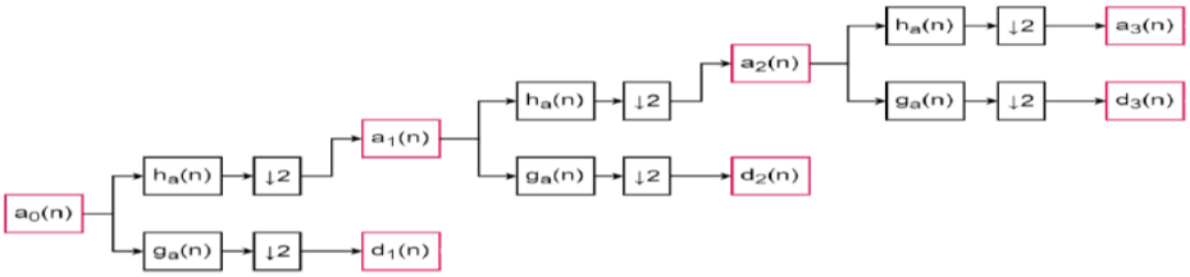

Fig (1-a) decomposition of wavelet transform.

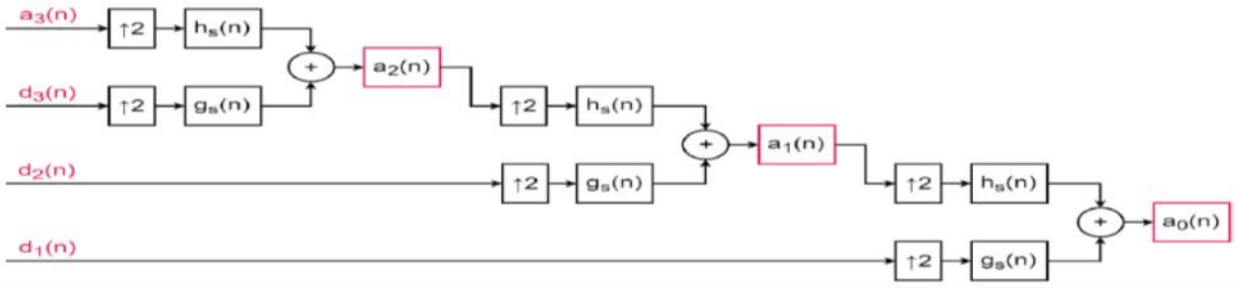

Fig (1-b) reconstruction of wavelet transform.

2. Genetic Algorithm

Genetic algorithms simulate the process of natural selection, Genetic Algorithms(GAs) are adaptive heuristic search algorithms that belong to the larger part of evolutionary algorithms. Genetic algorithms are based on the ideas of natural selection and genetics. The basic idea of it is depend on initialize populations and fitness of population then repeat Select parents from population, Crossover , Perform mutation and Calculate fitness for new population. it is used to select the best parameter in the proposed work such as the wavelet types, filter, threshold etc.

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3. Proposed Threshold Method

We have proposed anew adaptive threshold method to determine the threshold value, this method can by summarized by the following algorithm(Fig. 2):

1. *Chose initial threshold th=median(details),i=1,n=1,k=1,S=size(detail)*
2. *While (i ≤ S)*
   If detail(i)> th th1(n)=detail(i), n=n+1,
   Else th2(k)=detail(i), k=k+1
   End
   End While
3. *A1=absolute (th1)*
   M1=mean(A1)
   Segment1=(M1/ 0.6745)
   A2=absolute (th2)
   M2=mean(A2)
   Segment2=(M2/ 0.6745)
4. *Segment=(Segment1 + Segment2)/2*
5. *Threshold=* $\frac{segment * \sqrt{2 * log10(detail)}}{2^j}$

Where j wavelet level, detail is detail coefficient of wavelet transform

Fig(2) Proposed Threshold method.

4. Proposed Algorithm

In this paper , we have proposed algorithm for ECG de-nosing, enhanced and QRS complex detection based on DWT and genetic algorithm that can be shown in figure(2) and summarized by the following steps:-

1. Read input ECG signal
2. Add noise to the signal.
3. Apply DWT to the signal to split it into approximation and details sub-bands.
4. Calculate the threshold according to proposed adaptive threshold method.
5. Apply the proposed threshold method to detail coefficient.
6. Reconstruct the signal by using invers wavelet transform.
7. Calculate the signal to noise ratio improvement(SNRimp) by using equation(3).
8. Use SNRimp as fitness function in GA
9. Apply Genetic algorithm and repeat steps(4 through best method and parameters) by find MSE.
10. Calculate the performance measure. The flowchart of the proposed system is shown in Fig. (3).

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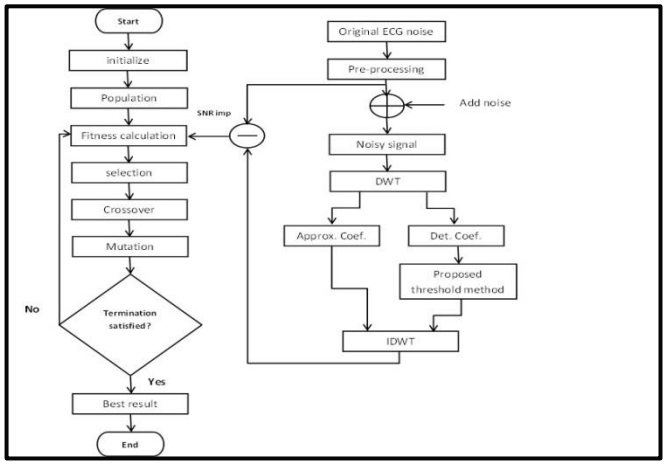


Fig(3) proposed system flowchart.

5. Performance Metrics

1. Mean Square Error (MSE)

Mean square error (MSE) is the quality measuring parameter , that is founded by the following equation:

$$\mathrm{MSE} = \frac{1}{\mathrm{N}} \sum_{k=1}^{\mathrm{N}} (\mathrm{Xin} - \mathrm{Xo})^2 \text{---------- -(1)}$$

2. Root mean square error (RMSE)

Root mean square error (RMSE) is obtained by taking square root over mean square error (MSE).

$$\mathrm{RMSE} = \sqrt{\frac{1}{\mathrm{N}} \sum_{k=1}^{\mathrm{N}} (\mathrm{Xin} - \mathrm{Xo})^2} \text{ ------- (2)}$$

3. Signal to Noise Ratio (SNR)

Signal to Noise Ratio (SNR) is widely used quality metric. It is measured in logarithmic scale in decibels (dB).

$$\mathrm{SNR\ imp(dB)} = \mathrm{SNR\ out} - \mathrm{SNR\ inp} \text{ -(3)}$$

$$\mathrm{SNR\ inp(dB)} = 10 * \log 10 \frac{\sum_{k=1}^{\mathrm{N}} (\mathrm{Xin})^2}{\sum_{k=1}^{\mathrm{N}} (\mathrm{Xno} - \mathrm{Xin})^2} \quad (4)$$

$$\mathrm{SNR\ out(dB)} = 10 * \log 10 \frac{\sum_{k=1}^{\mathrm{N}} (\mathrm{Xin})^2}{\sum_{k=1}^{\mathrm{N}} (\mathrm{Xo} - \mathrm{Xin})^2} \quad (5)$$

4. Percent RMS Difference (PRD)

The quality of the reconstructed signal can be calculated by percent value of root mean square of error as following:

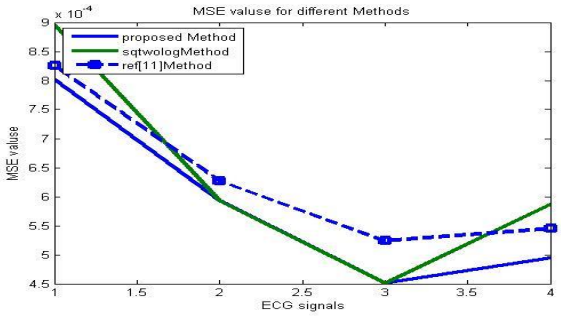
$$\mathrm{PRD} = \sqrt{\frac{\sum_{k=1}^{\mathrm{N}} (\mathrm{Xin} - \mathrm{Xo})^2}{\sum_{k=1}^{\mathrm{N}} (\mathrm{Xin})^2}} * 100\ \% \text{ ---------(6)}$$

Where Xin input signal, Xo noisy signal ,Xo reconstructed signal and N number of samples of the signal.[15].

IV. Experimental Results and Discussion.

1-proposed Method Result

In this paper , we have proposed a new system for ECG signal de-noising based on DWT, that is used to divides the signal into



different sub-band according to its significant, the details coefficient of DWT are applied to proposed a new threshold method. Table(1) and (2) show the result of applying the sqtwolog and ref [11]respectively, while Table (3) show the results of the proposed adaptive threshold method.

Table(1) performance for sqtwolog method

Filter	MSE	RMSE	PRD	SNR
db2	0.00084514	0.029071	12.8858	0.86858
db4	0.00065077	0.02551	11.3074	2.0036
db6	0.00059264	0.024344	10.7906	2.4099
db8	0.0007054	0.026559	11.7724	1.6535
Bior4.4	0.00059814	0.024457	10.8405	2.3699

Table(2) performance for ref(11) method

Filter	MSE	RMSE	PRD	SNR imp
Db2	0.00045	0.021379	10.6274	3.3581
DB4	0.00054	0.023334	11.5987	2.5984
Db6	0.00065	0.025605	12.7278	1.7915
Db8	0.00056	0.023808	11.8345	2.4236

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Bior4.	0.00058	0.024259	12.0588	2.2605

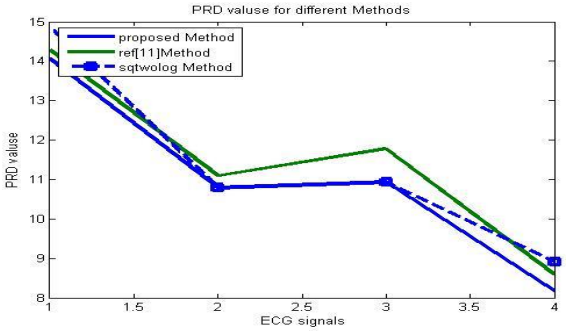
Table(3) performance of proposed method

Filter	MSE	RMSE	PRD	SNR
db2	0.00052332	0.022876	11.3713	2.7704
db4	0.00041323	0.020328	10.1048	3.7961
db6	0.00050046	0.022371	11.1202	2.9643
db8	0.00072293	0.026887	13.3652	1.367
Bior4.4	0.00061343	0.024767	12.3115	2.0804

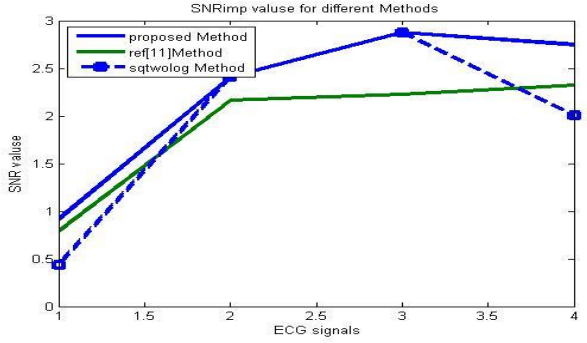
From Tables, we note the differences between RMSE,MSE,PRD and SNR imp. It clear that the proposed method give better results than other approaches. Also the proposed method give less values of MSE , RMSE and PDR values by use db4 and db6 filters with better SNR imp as shown in Table(3). We can note the improvement in the

Levels	MSE	RMSE	PRD	SNRimp
One	0.00063	0.025112	12.4829	1.9602
Two	0.000413	0.020328	10.1048	3.7961
Three	0.00064	0.0253	11.6492	2.2885
Four	0.00066	0.0257	12.79	1.74
five	0.00066	0.0257	12.78	1.7514

performance of the proposed method, it give low



values of MSE and PRD as shown in Fig. (4) and (5)respectively, while Fig.(6) show the



improvement in the SNR by use the proposed method compared with others.

Fig.(4) MSE of different signals for proposed and other methods.

Fig.(5) PRD values for different signals for proposed and other methods.

Fig.(6) SNRimp values for different signals for proposed and other methods.

The best results in terms of SNRimp,RMSE and PRD can be get by using wavelet level two and three as shown in Fig. (7),(8) and (9) respectively , also its clear that db4 filter give best result at level two and to lesser extent at level three as described at table (4), db6 give better results at level two as shown in table (5) , while db2 filter give better results at level three as shown in in Table(6) .Table (4) result of db4 filter for different levels.

Table (4) result of db4 filter for different levels.
Table (5) result of db6 filter for different levels.

Levels	MSE	RMSE	PRD	SNRimp
One	0.0008	0.028	14.07	0.92
Two	0.0005	0.0223	11.12	2.96
Three	0.00060	0.024526	12.1914	2.1655
Four	0.00071	0.0266	13.259	1.4358
five	0.00071	0.00266	13.259	1.8622

Table (6) result of db2 filter for different levels.

Levels	MSE	RMSE	PRD	SNRimp
One	0.00075	0.0274	13.65	1.18
Two	0.00052	0.022	11.3713	2.7704
Three	0.00034	0.0185	13.79	3.93
Four	0.00056	0.0237	11.8	2.44
Five	0.00056	0.023	11.8	2.44

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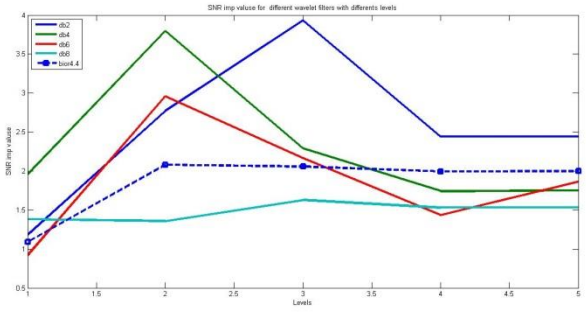

Fig (7) SNRimp values for different wavelet levels

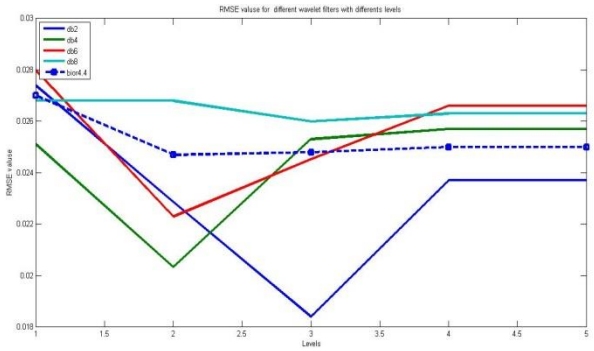

Fig.(8) RMSE values for different wavelet levels.

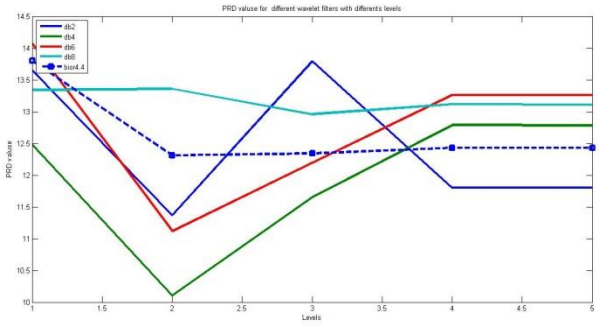

Fig (9) PRD values for different wavelet levels.

From Tables and Figures above, it is clear that level two is the best level that give highest SNRimp value and lowest PRD and RMSE values, at level two db4 and db6 filter give the best result while at level three db2 and db4 filters give best results. The differences between hard and soft threshold function can be shown in table(7) and table(8) for two signals with different characteristics, in table (7) the best result is satisfied by using hard function with wavelet level two, while in the second signal the best result can be satisfied by using soft threshold with level five.

Table (7) performance of db6 filter with hard and soft threshold function for signal 2

Measure	Threshold function	Level1	Level2	Level3	Level4	Leve5
MSE	**Soft threshold**	0.00079439	0.00091295	0.0006131	0.00074982	0.00076429
	Hard threshold	0.00069419	**0.00050046**	0.00060152	0.00064506	0.00064503
RMSE	**Soft threshold**	0.028185	0.030215	0.024761	0.027383	0.027646
	Hard threshold	0.026348	**0.022371**	0.024526	0.025398	0.025398
PRD	**Soft threshold**	14.0103	15.0194	12.3082	13.6116	13.7423
	Hard threshold	13.0969	**11.1202**	12.1914	12.625	12.6247
SNRimp	**Soft threshold**	0.95766	0.35353	2.0827	1.2084	1.1254
	Hard threshold	1.5432	**2.9643**	2.1655	1.862	1.8622

Table (8) performance of db6 filter with hard and soft threshold function for signal 4

Measure	Threshold function	Level1	Level2	Level3	Level4	Leve5
MSE	**Soft threshold**	0.0004383	0.00053795	0.00041091	0.00041668	0.00039908
	Hard threshold	0.00047	**0.00030**	0.00041	0.00040	0.000399
RMSE	**Soft threshold**	0.020936	0.023194	0.020271	0.020413	0.019977
	Hard threshold	0.021	**0.0173**	0.0202	0.020	0.0199
PRD	**Soft threshold**	10.7749	11.9367	10.4324	10.5054	10.2812
	Hard threshold	11.214	**8.99**	10.43	10.3	10.288
SNRimp	**Soft threshold**	2.9996	2.1102	3.2802	3.2197	**3.407**
	Hard threshold	2.65	**4.57**	3.28	3.38	3.4

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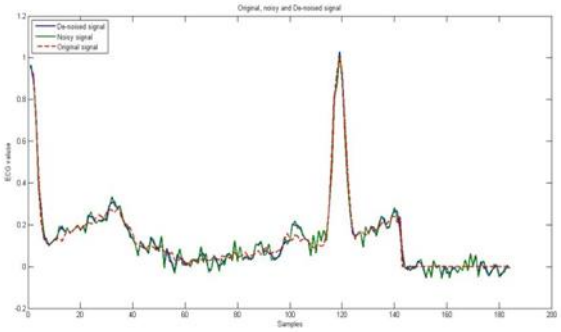
Fig (10) and (11) show the de-noised signal after applying the proposed method with db6 DWT filter with noisy and original ECG signal , there is high improvement in the quality of the signal as shown in figures.



.Fig. (10) Original, noisy and reconstructed ECG signal by using db6 filter .

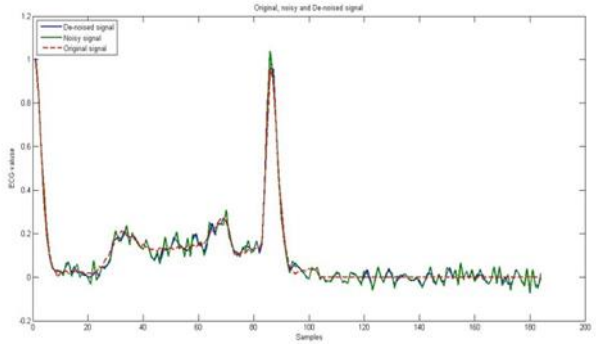


Fig. (11) Original, noisy and reconstructed ECG signal by using db6 filter.

2- Proposed Algorithm results.

When we note the results, that are obtained in the previous section, we note that the characteristics of the signal is different, so the results of de-noising is different, this because there is specific parameters for each signal, in order to get best result, we must determine the best parameters such as best wavelet filter, levels, threshold function and threshold method, for this reasons, we proposed to use genetic algorithm to select the optimum result for each ECG signal.

In the proposed method, binary encoding is used, in which, the proposed chromosome is constructed from 10 bits, two bits is used to select the threshold method, one bit is used to choose the threshold type (hard or soft), four bits are used to select the wavelet filter type and three bits are used to choose the filter levels. The structure of the proposed method is shown in Fig. (12).

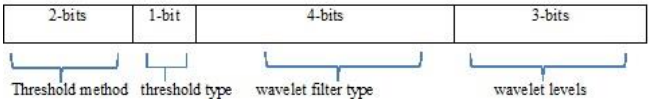


Fig.(12) structure of the proposed chromosome.

The result of genetic algorithm is shown in table (9), which explain the selection of the best parameters that can cab be used to give the best result, for signal 1, the algorithm chose db6 filter, two wavelet level, soft and proposed method to give 5.19 dB in SNRimp.

Table (9) show the best parameter that are selected after applied the GA algorithm.

Signal	Best filter	Best level	Best threshold function	Best threshold method	MSE	RMSE	PRD	SNRimp
1	Db6	Two	Soft threshold	Proposed method	0.00026	0.016	11.9387	5.1909
2	Db10	Five	Hard threshold	Proposed method	0.00049	0.02212	10.9959	3.0619
3	Db6	Three	Hard threshold	Proposed method	0.00055	0.02392	10.3241	2.7938
4	Db5	Two	Hard threshold	Proposed method	0.00029	0.0171	8.781	4.7772
5	Db6	one	Soft threshold	Proposed method	0.00054	0.02317	8.5289	2.3891

It clear that the result with GA is better than other result . For signal(1),the best value of SNRimp is(5.19 dB) and the best chromosome was (010 0110 110),which means that the best result can be obtained using(db6,two level, proposed threshold method and soft threshold function) as shown in table(10),while signal (5),the best chromosome is (1 01 1100 011) which means (soft threshold function , proposed threshold method, db6 filter and level three) that give (2.79 dB, 8.528 and

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0.023) in terms of SNRimp,PRD and RMSE respectively, as shown in table (11).

Table (10) results of db6 filter with hard and soft threshold function for signal 1

Measure	Threshold function	Level1	Level2	Level3	Level4	Leve5
MSE	**Soft threshold**	0.00049	0.000358	0.00029	0.000256	**0.000256**
	Hard threshold	0.00048157	0.000336	0.00044	0.000415	0.000415
RMSE	**Soft threshold**	0.02235	0.018919	0.01696	0.01601	**0.016001**
	Hard threshold	0.021945	0.018313	13.27	0.02038	0.02038
PRD	**Soft threshold**	16.6751	14.1156	12.6512	11.945	**11.9387**
	Hard threshold	16.3727	13.6632	16.1139	15.2051	15.2051
SNRimp	**Soft threshold**	2.2887	3.7361	4.6874	5.1863	**5.1909**
	Hard threshold	2.4476	4.019	2.844	3.0903	3.0903

Table (11) results of db6 filter with hard and soft threshold function for signal 5

Measure	Threshold function	Level1	Level2	Level3	Level4	Leve5
MSE	**Soft threshold**	**0.00054**	0.000749	0.00065	0.000705	0.000719
	Hard threshold	0.00060	0.00070	0.00054	0.00066	0.00066
RMSE	**Soft threshold**	**0.02316**	0.027377	0.02558	0.026569	0.026806
	Hard threshold	0.0245	0.0265	0.023	0.025	0.025
PRD	**Soft threshold**	**8.5289**	10.0787	9.42	9.781	9.8683
	Hard threshold	9.032	9.78	8.559	9.466	9.47
SNRimp	**Soft threshold**	**2.3891**	0.93885	1.5259	1.1993	1.1221
	Hard threshold	1.8911	1.2	2.359	1.48	1.478

Table (9) above shows that the best values of SNRimp, RMSE and PRD which are(4.57 dB, 8.99 and 0.017 respectively)can be obtained using (db6 filter, hard function, proposed threshold method and level two), but the genetic algorithm proves that we can get better results using db5 filter (SNRimp=4.78dB, PRD=8.7 and RMSE=0.017).

Obviously , the use of GA is very important in obtaining better results because its use can get the best parameters of the system, Fig. (13),(14) and (15) illustrate the differences between the use of GA and its not use, in terms of SNRimp, PRD and MSE respectively.

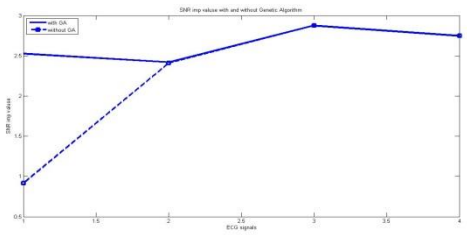

Fig.(13) SNR imp value for some signal with and without GA

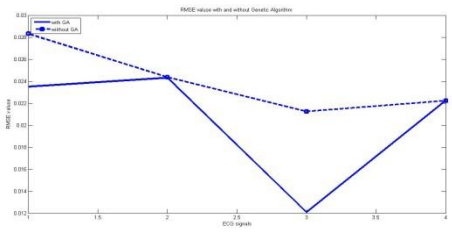

Fig.(14) RMSE value for some signal with and without GA

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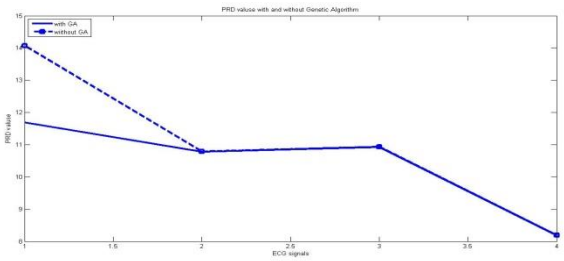

Fig.(15)PRD value for some signal with and without GA.

V.Conclusion

In this paper, we have proposed a new system for ECG signal de-noising based on a new efficient adaptive threshold method with discrete wavelet transform and genetic algorithm, the main contribution of this work is design anew threshold method that determine threshold value for each signal depending on its characteristics, which can result in effective threshold value of ECG signal, this threshold value is applied on the detail coefficient. Different DWT filter types with different function of threshold rule were used in the proposed system and the efficiency of the system was tested by different metric to evaluate the quality of the de-noised signal along with its difference as compared with the original signal, these metric were MSE,RMSE, SNR imp and PRD. The best result are satisfied by use db2,db4 and db6 filters, also the highest value in terms of SNR obtained by using second and third of wavelet level .

ECG signals have different characteristics, therefore ,there are different parameters for each signal according to its characteristic. In order to satisfied best enhancement , different method should be used, So, Genetic algorithm was used to determine the best parameters of the system such as threshold function, threshold methods, wavelet level and wavelet filter types according to the characteristic of the input signal. In this work, binary encoding was used to represent the chromosome with ten bits, two bits to select threshold method, one bit is used to select threshold function, four bit to choose wavelet filter type and three bits to select the best wavelet level. The results show that , the proposed system give better results by terms of the performance metrics, the system provide the best result when used the proposed adaptive threshold method as shown in tables and figures. It is clear from the tables and figures that, the proposed system provide better results than other approaches.

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