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Quality Controlled ECG Signal Compression using Genetic Algorithm

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Abstract: In this paper, calculations of threshold using genetic algorithm (GA) is studied. From the results, it can be found that the threshold value calculated using GA is such that the actual PRD (Percent root mean square difference) after threshold is almost equal to the UPRD (User specified PRD). First ECG signal is transformed using wavelet transform (WT) and discrete cosine transform (DCT). The transformed coefficients (TC) are then thresholded by genetic algorithm. The thresholding is done in a way so that error between actual PRD and UPRD remains within the specified limits.

Keywords: ECG Signal, quality controlled compression, Discrete Cosine Transform, Wavelet Transform, Genetic Algorithm.

I. INTRODUCTION

Many quality controlled ECG compression algorithms have recently been developed that gives good performance [1]-[8]. Among the reported algorithms [1]-[8], the threshold value is calculated by the bisection algorithms (BA) in order to match the UPRD within the tolerance. Most of them are using the WT. In 2003, Benzid *et al.* [5] presented quality controlled ECG compression based on wavelet transform, after decomposition the resultant coefficients are subjected to an iterative threshold until a fixed percentage target of wavelet coefficients to be zeroed is reached. Then, the Look-up table is made to store the zero and non-zero coefficients (NZC). NZC are quantized by linear quantizer. The NZC and look up table encoding is done by Huffman coding. Blanco-Velasco *et al.*, [3] developed a filter bank-based algorithm for quality controlled ECG compression. The procedure is same as [5] but here the bisection algorithm (BA) is used for calculation. And this method for threshold calculation found to be better than [5]. In 2006, Benzid *et al.* [1] used wavelet transform and Max-Lloyd quantizer. Chen *et al.* [8] presents quality controlled ECG compression based on wavelet transform, these coefficients are quantized with a uniform scalar dead zone quantizer and Exp-Golomb and Golomb-Rice coding is used to code the lengths of runs of the zero coefficients and nonzero coefficients respectively. Benzid *et al.* [2] proposed the effective method of ECG compression based on the adaptive wavelet coefficients quantization combined with a modified two-role encoder.

The algorithm is same as explained in [1] but the NZC are encoded by two role encoder and here quantizer is linear. Blanco-Velasco *et al.* [4] methodology is same as [5] this paper used the Wavelet Packet transform instead of wavelet transform. Benzid *et al.*, [6] represents ECG compression using block-based DCT. To identify the optimal threshold value the combination of False Position (Regula Falsi) and bisection technique is used. Here the linear quantizer is used and encoding is done by arithmetic coding. In this paper the threshold value is calculated by the GA. GAs are computational models inspired from biological evolution, which is based on the mechanics of natural genetics and natural selection. The back- bone of every GA is the reproduction of an original population, the performance of crossover and mutation and the selection of the best [9]. For the performance analysis, the metrics like compression ratio (CR) and PRD are used. CR is defined as the ratio of the number of bits used to represent the original signal to the number of bits used to represent the compressed signal [4] and PRD is calculated as [5]:

$$PRD = 100 \times \sqrt{\frac{\sum_{i=1}^{N}(x_i - \hat{x}_i)^2}{\sum_{i=1}^{N} x_i^2}} \qquad (1.1)$$

Where x_i and $\hat{x}_i$ are the i[th] sample of original and reconstructed ECG signal of length N [5].

II. METHODOLOGY

The proposed technique is implemented in three steps: (i) the TC are thresholded using genetic algorithm and (ii) the thresholded coefficients are quantized and (iii) Final stage is the entropy coder that provides the final compressed bitstream. The pseudo code for the algorithm is explained as follows [1][2].

Step 0: Initialization; Get the UPRD; Select the threshold in the range [THmin, THmax] where the range may be initialized by [*TCmin, **TCmax]. Where *TCmin is minimum value of TC and **TCmax is maximum value of TC. Get the convergence precision $\epsilon = 0.01$. Calculate the mean. Subtract the mean from the original signal. Transform the zero mean ECG signal using DCT and WT .

Step 1: Take a copy of TC. $\mathrm{x} = [\mathrm{THmin\ THmax}]$

$$\text{Fitness function} = 100 \times (\mathrm{x}(1)^2 - \mathrm{x}(2))^2 + (1 - \mathrm{x}(1))^2$$

And select threshold using GA

Step 2: Inverse TC. Add the mean to the inverse coefficients.

Step 3: Compute the PRD

Step 4: if $abs(PRD - UPRD) \geq \epsilon$. Then go to Step 1

Step5: Construct the binary lookup table to represent the zero and non-zero coefficients obtained after thresholding in Step1. This binary lookup table is encoded using Huffman coding.

Step6: The non-zero coefficients are quantized using Max-Lloyd algorithm followed by Arithmetic coding.

Step7: End.

III. RESULTS

The efficiency of the proposed algorithm is tested by well known ECG database, MIT-BIH Arrhythmia. Each record contains 11 bit resolution and 360 Hz a sampling frequency. In the WT, ECG signal is decomposed to four levels using biorthogonal swapped filters. The results presented in Table 1, 2, 3 and 4 represents the CR at fixed PRD=0.5, PRD=1, PRD=2 and PRD=3 respectively for different ECG signals using BA and GA. From the numerical results, it can be observed that PRD before quantization (BPRD) is nearly equal to fixed PRD (UPRD) and PRD after quantization (QPRD) using BA and GA. Table 5 and Figure 1 compares the proposed method to that compression methods reported in the literature which is best threshold-based ECG compression. For comparison the average CR and the average PRD of the proposed method are taken according to that reported in the literature. Testing dataset is of 2 min duration long (43200 samples) lead extracted from records 100, 101, 102, 103, 107, 109, 111, 115, 117, 118 and 119. This dataset has been chosen for Table 5 and Figure 1 because it has been used in the literature. Figure 1 , Table 5 and Table 6 conclude that the proposed method gives better CR as compared to that reported in [2]-[8].

But as far as BA is concerned the CR of the proposed method using GA is almost same. For example, in case of record MIT-BIH 121 at UPRD =0.5, QPRD= 0.52, CR is 17.85 for DCT from Table 1 and at UPRD= 0.5, QPRD= 0.50, CR is 15.67 for WT from Table 2 with BA and with GA at UPRD=0.5, QPRD=0.50, CR is 18.21 for DCT from Table 3 and at UPRD=0.5, QPRD= 0.50, CR is 15.67 for WT from Table 4. It can be observed from the result that in case of GA the actual PRD is very close to the UPRD. So, in general GA is recommended over BA. But during the implementation of GA based threshold calculations it has been observed that GA based method requires more time for calculations of threshold at high UPRD. Therefore, it is recommended that GA method for threshold calculation should be used in case of low UPRD.

IV. CONCLUSION

In this paper, to calculate the threshold value with the help of genetic algorithm has been studied. The method of calculating threshold value is very good and it gives final PRD which is within the specified error as compared to UPRD. But computational time is more in case of GA as compared to that of BA for higher values of UPRD. So, GA is recommended for low PRD ECG compression. So, GA is recommended for low PRD ECG compression.

The method gives high performance for ECG compression due to the combined effect of transforms (DCT and WT), thresholding algorithm, non-uniform quantizer, look-up table encoded by Huffman coding and non-zero quantized coefficients are encoded by Arithmetic coding. But computational time is more in case of GA as compared to that of BA for higher values of UPRD.

V. REFERENCES

[1]. R. Benzid, F. Marir and N. E. Bouguechal, “Quality-controlled compression method using wavelet transform for electrocardiogram signals”, Int. J. of Biomed. Sciences, 2006, **1**, (1),pp. 28-33.

[2]. R. Benzid, F. Marir and N. E. Bouguechal, “Electrocardiogram compression method based on the adaptive wavelet coefficients quantization combined to a modified two-role encoder”, IEEE Signal Process. Lett., 2007, 1-4.

[3]. M. Blanco-Velasco, F. Cruz-Roldan, J. I. Godino-Llorente and K. E. Barner, “ECG compression with retrived qualtiy guranteed”, Electron. Lett., 2004, **40**, (23).

[4]. M. Blanco-Velasco, F. Cruz-Roldan, J. I. Godino-Llorente and K. E. Barner, “Wavelet packets feasibility study for the design of an ECG compressor”, IEEE Trans. on Biomed. Eng., 2007, **54**, (4), pp. 766-769.

[5]. R. Benzid, F. Marir, M. Benyoucef and D. Arar, “Fixed percentage of wavelet coefficients to be zeroed for ECG compression”, Electron. Lett., 2003, **39**,(11), pp. 830-831.

[6]. R. Benzid, A. Messaoudi, A. Boussaad, “Constrained ECG compression algorithm using block-based discrete cosine transfrom”, Digital Signal Processing, 2008, **18**, pp. 56-64.

[7]. Z. Lu, D. Y. Kim and W. A. Pearlman, “Wavelet compression of ECG signals by the set partitioning in hierarchical trees algorithm”, IEEE Trans. on Biomed. Eng., 2000,**47**, (7), pp. 849-856.

[8]. J. Chen, J. Ma, Y. Zhang and X. Shi, “ECG compression based on wavelet transform and Golomb coding”, Electronics Letters, 2006, **42** (6).

[9]. N. E. Mastorakis, I. F. Gonos and M. N. S. Swamy, “Design of two-dimensional recursive filters using genetic algorithms”, IEEE Trans. on Circuits and Syst.-I: Fund. Theory and App., 2003, **50**, (5), pp. 634-639.

Table 1: Performance of ECG compression with BA using DCT on different ECG signals

DCT, [1]Qbits=14, Samples=43200, Time=2 min,												
Signal	**[2]UPRD=0.5**			**[2]UPRD=1**			**[2]UPRD=2**			**[2]UPRD=3**		
	[3]BPRD	***[4]QPRD***	***[5]CR***	***[3]BPRD***	***[4]QPRD***	***[5]CR***	***[3]BPRD***	***[4]QPRD***	***[5]CR***	***[3]BPRD***	***[4]QPRD***	***[5]CR***
121	0.49	0.52	17.85	1.00	1.00	37.66	1.99	1.99	50.55	2.99	2.99	51.69
122	0.49	0.53	15.16	0.99	0.99	22.27	2.01	2.01	24.63	3.00	3.00	26.89
205	0.50	0.54	12.60	1.00	1.01	26.47	1.98	1.98	29.72	2.99	3.00	30.18
103	0.50	0.52	10.41	0.99	1.00	13.83	1.99	1.99	19.14	2.98	2.98	20.86
104	0.49	0.55	13.37	0.99	1.02	15.47	1.98	1.98	17.83	2.97	2.97	17.74
221	0.49	0.52	10.33	0.99	1.00	11.79	1.99	1.98	20.57	3.02	3.02	23.94
201	0.50	0.53	11.05	0.99	1.01	12.82	1.98	1.98	23.77	2.98	2.98	28.86
203	0.49	0.51	11.64	1.00	1.01	14.89	2.01	2.01	15.75	2.97	2.97	16.43
233	0.50	0.51	11.49	1.00	1.00	18.36	1.99	1.99	20.06	2.97	2.97	20.61
109	0.49	0.52	11.21	0.99	1.00	17.53	1.99	1.99	23.84	3.00	3.00	27.99
[1]Qbits- bits used for quantization [2]UPRD- user defined PRD [3]BPRD- PRD before quantization [4]QPRD- PRD after quantization [5]CR-Compression ratio												

Table 2: Performance of ECG compression with BA using WT on different ECG signals

WT, [1]Qbits=14, Samples=43200, Time=2 min,												
Signal	**[2]UPRD=0.5**			**[2]UPRD=1**			**[2]UPRD=2**			**[2]UPRD=3**		
	[3]BPRD	***[4]QPRD***	***[5]CR***	***[3]BPRD***	***[4]QPRD***	***[5]CR***	***[3]BPRD***	***[4]QPRD***	***[5]CR***	***[3]BPRD***	***[4]QPRD***	***[5]CR***
121	0.50	0.50	15.67	1.00	1.00	28.58	1.99	1.99	49.66	2.97	2.97	54.29
122	0.50	0.50	11.92	0.99	0.99	16.33	1.98	1.98	28.94	3.01	3.01	33.25
205	0.49	0.49	10.98	1.00	1.00	16.81	1.99	2.00	24.60	3.01	3.01	30.49
103	0.49	0.49	9.92	0.99	0.99	11.58	1.98	1.98	18.62	3.00	3.00	27.77
104	0.50	0.50	10.38	0.99	0.99	11.19	1.99	1.99	15.18	3.00	3.00	20.19
221	0.50	0.50	10.33	0.99	0.99	10.68	1.99	1.99	14.28	2.98	2.99	18.27
201	0.50	0.50	10.83	0.99	0.99	11.15	1.99	1.99	15.86	2.98	2.98	23.18
203	0.49	0.50	10.27	0.99	1.00	11.20	2.00	2.00	14.27	2.99	2.99	18.33
233	0.50	0.50	10.61	0.99	1.00	15.41	1.99	1.99	18.08	2.97	2.97	19.65
109	0.49	0.49	10.34	1.00	1.00	13.61	2.00	2.00	23.42	3.00	3.00	28.61
[1]Qbits- bits used for quantization [2]UPRD- user defined PRD [3]BPRD- PRD before quantization [4]QPRD- PRD after quantization [5]CR-Compression ratio												

Table 3: Performance of ECG compression with GA using DCT on different ECG signals

DCT, [1]Qbits=14, Samples=43200, Time=2 min												
Signal	**[2]UPRD=0.5**			**[2]UPRD=1**			**[2]UPRD=2**			**[2]UPRD=3**		
	[3]BPRD	**[4]QPRD**	**[5]CR**	**[3]BPRD**	**[4]QPRD**	**[5]CR**	**[3]BPRD**	**[4]QPRD**	**[5]CR**	**[3]BPRD**	**[4]QPRD**	**[5]CR**
121	0.5084	0.5067	18.2153	0.9985	0.9997	37.4200	1.9935	1.9945	50.5532	2.9982	2.9983	51.6971
122	0.4912	0.4911	15.1030	0.9944	0.9941	22.2806	2.0097	2.0097	24.6371	3.0017	3.0017	26.8900
205	0.5098	0.5100	12.7222	0.9971	0.9958	26.3531	1.9981	1.9982	29.6259	3.0030	3.0021	30.2444
103	0.5000	0.4989	10.4200	0.9906	0.9899	13.7436	2.0022	2.0045	19.1737	2.9980	2.9967	20.9302
104	0.5061	0.5177	13.3572	0.9989	1.0008	15.4688	1.9909	1.9959	17.8325	2.9974	2.9928	17.7525
221	0.4948	0.4975	10.3466	1.0003	0.9980	11.8091	2.0097	2.0083	20.6681	3.0057	3.0051	24.0194
201	0.5100	0.5057	11.0573	1.0057	1.0012	12.8349	1.9962	1.9948	23.9613	2.9982	2.9956	28.9756
203	0.5086	0.5112	11.6975	1.0065	1.0078	14.9134	2.0035	2.0025	15.7434	2.9964	2.9985	16.4863
233	0.5020	0.5068	11.5027	0.9935	0.9943	18.3107	1.9969	1.9983	20.0743	2.9928	2.9956	20.6322
109	0.4914	0.4973	11.1696	1.0001	1.0004	17.5325	2.0028	1.9999	23.8842	3.0016	3.0018	28.0321
112	0.4961	0.4977	19.7671	1.0005	0.9994	34.1576	1.9974	1.9982	38.8489	3.0100	3.0111	40.5788
217	0.5042	0.5158	12.3160	0.9960	1.0015	17.5948	2.0082	2.0110	18.2882	3.0019	3.0023	19.0568
[1]Qbits- bits used for quantization [2]UPRD- user defined PRD [3]BPRD- PRD before quantization [4]QPRD- PRD after quantization [5]CR-Compression ratio												

Table 4: Performance of ECG compression with GA using WT on different ECG signals

WT, [1]Qbits=14, Samples=43200, Time=2 min												
Signal	**[2]UPRD=0.5**			**[2]UPRD=1**			**[2]UPRD=2**			**[2]UPRD=3**		
	[3]BPRD	***[4]QPRD***	***[5]CR***	***[3]BPRD***	***[4]QPRD***	***[5]CR***	***[3]BPRD***	***[4]QPRD***	***[5]CR***	***[3]BPRD***	***[4]QPRD***	***[5]CR***
121	0.5041	0.5031	15.6770	1.0049	1.0049	28.5577	1.9937	1.9937	49.5413	2.9939	2.9940	54.4954
122	0.4937	0.4928	11.8350	1.0099	1.0093	16.4315	1.9984	1.9980	29.1319	2.9927	2.9928	32.9817
205	0.4976	0.4993	10.9817	0.9937	0.9938	16.6901	1.9914	1.9917	24.6065	2.9973	2.9973	30.0000
103	0.4905	0.4985	9.9298	0.9947	0.9946	11.5880	2.0031	2.0040	18.8153	3.0013	3.0015	27.7700
104	0.5011	0.5075	10.3810	1.0086	1.0074	11.2160	1.9978	1.9947	15.1840	2.9958	2.9977	20.1698
221	0.4957	0.4985	10.3376	0.9902	0.9856	10.6624	1.9977	1.9945	14.2857	3.0033	3.0025	18.3164
201	0.5018	0.5097	10.8039	0.9908	0.9963	11.1528	2.0009	2.0033	15.9121	3.0020	3.0032	23.4320
203	0.5021	0.5074	10.2786	0.9961	0.9953	11.1907	2.0055	2.0082	14.2754	3.0092	3.0095	18.4186
233	0.4949	0.4951	10.5713	0.9933	0.9942	15.3647	1.9902	1.9909	18.0712	2.9905	2.9897	19.7342
109	0.4945	0.5263	10.4467	1.0014	1.0042	13.6145	1.9964	1.9969	23.3766	3.0011	3.0000	28.5989
112	0.5091	0.5101	16.4270	1.0044	1.0052	25.2122	1.9933	1.9933	38.0525	2.9986	2.9969	43.5484
217	0.4991	0.4957	10.0236	0.9946	0.9944	12.8488	2.0046	2.0046	19.4882	3.0089	3.0090	25.7589
[1]Qbits- bits used for quantization [2]UPRD- user defined PRD [3]BPRD- PRD before quantization [4]QPRD- PRD after quantization [5]CR-Compression ratio												

Table 5: Compression results

Proposed method with DCT	PRD	2.6427	2.8776	3.4578	3.7278	4.1512	4.8009	5.7648
	CR	24.0514	24.2419	24.6988	24.9055	25.2669	25.7487	26.4071
Proposed method with WT	PRD	2.6405	2.8808	3.4575	3.7304	4.1420	4.7945	5.7614
	CR	27.1251	28.1654	30.2581	31.0241	32.2080	33.3796	34.6589
Benzid [6]	PRD	2.66	2.89	3.48	3.77	4.18	4.81	5.79
	CR	10.84	11.46	13.45	14.29	15.43	17.10	19.64
Benzid [2]	PRD	--	2.89	3.51	--	--	4.84	--
	CR	--	10.70	12.61	--	--	15.95	--
Blanco-Velasco [4]	PRD	2.69	2.90	3.45	3.73	4.16	4.80	5.77
	CR	9.62	10.65	12.38	12.98	13.76	14.78	16.05
Chen [8]	PRD	2.72	2.91	3.47	3.73	4.15	4.79	5.75
	CR	11.59	12.48	14.45	15.51	17.12	19.53	22.87
Blanco-Velasco [3]	PRD	2.72	2.91	3.47	3.73	4.15	4.79	5.75
	CR	9.41	10.33	11.84	12.44	13.19	14.13	15.32
Benzid [5]	PRD	2.64	2.88	3.46	3.73	4.15	4.80	5.76
	CR	7.05	8.28	10.89	11.62	12.46	13.49	14.74
Lu [7]	PRD	1.19	1.56	2.46	2.96	3.57	4.85	6.49
	CR	4:1	5:1	8:1	10:1	12:1	16:1	20:1

Table 6: Comparison with other methods

Method	**Signal**	**CR**	**PRD**
Proposed Method with DCT	117	33.1658	1.1805
		33.8269	2.5446
		33.1658	0.9926
	119	21.0714	5.1280
	232	13.3154	0.3057
Proposed Method with WT	117	25.8036	1.1791
		45.5871	2.5593
		23.94	1.00
	119	32.3353	5.1276
	232	12.7852	0.3040
Benzid [6]	117	21.74	2.54
		9.56	1.18
Benzid [2]	117	16.70	2.15
Blanco-Velasco [4]	232	7.35	5.00
Chen [8]	117	8.31	1.07
		17.45	2.0
	119	18.14	2.65
	232	9.78	4.91
Blanco-Velasco [3]	117	8.24	1.1760
		17.40	2.5359
	119	18.02	5.0474
	232	9.70	6.2806
Benzid [1]	117	27.93:1	1.04
Benzid [5]	117	16.24	2.55
	119	17.43	5.1268
	232	9.04	0.2981
Lu[7]	117	8	1.18

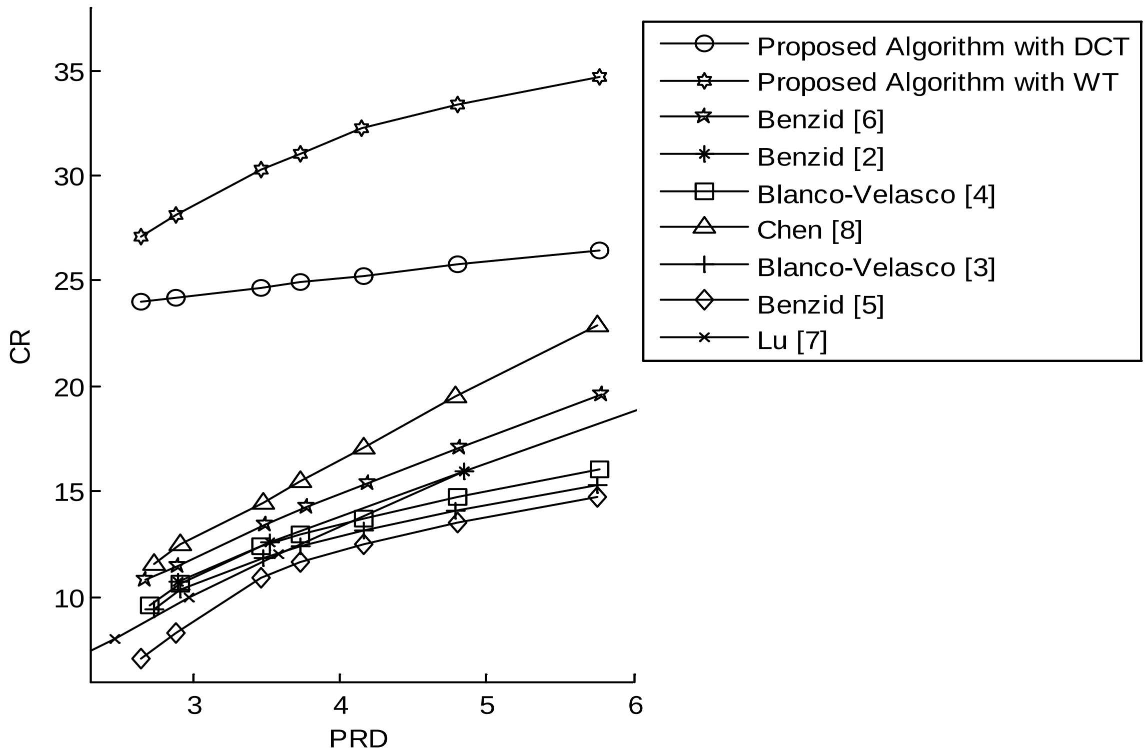

Figure. 1 Performance of proposed algorithm