SPECTRAL AND PERFORMANCE MEASURES ANALYSIS OF ECG SIGNAL USING VARIOUS TRANSFORMS AND DIFFERENT TYPES OF IIR AND FIR FILTERS WITH DIFFERENT ORDERS

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ABSTRACT

The electrical exercises of the heart are addressed as waves, which demonstrate the pinnacles and spikes of ECG signal. The input ECG signal is mixed with AWGN commotion. The target of the proposed framework is to evaluate the input ECG signal for different transforms like DCT, DWT, FWHT and FFT and afterward the extricated signal are filtered utilizing two significant filtering procedures like IIR and FIR. The filtering methods are applied under various classes for each channel to be specific IIR and FIR. In which IIR incorporates the Butterworth, Chebyshev type I and II and Elliptic channel. The FIR is typically performed utilizing windowing methods like Kaiser, Chebyshev and hamming windows. The examination is made for the FIR and IIR techniques utilizing the presentation measurements for example, time utilization, order and signal to noise ratio.

Key words: Windowing techniques, Transforms, ECG signal, IIR Filter, FIR Filter, and AWGN Noise

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1. INTRODUCTION

The fundamental job of ECG is to break down the working of the heart by means of the P, Q, R, S, T waves that were estimated with the electrodes set at various parts of the body. A typical ECG has 10 electrodes and 12 leads which are put on the skin. The nature and deviations from the standard healthy wave driving in separation of different dis-functionality present in the heart. The different IIR filtering procedures incorporates Butterworth filter, Chebyshev type I filter, Chebyshev type II filter and Elliptic filter. The FIR filtering methods incorporates windowing strategies. The different windowing methods are Hamming window, Hamming window, Kaiser Window, Chebyshev window, Rectangular window, Blackman window, etc.

2. PROPOSED SYSTEM

The separated signals from the transforms are to be filtered for which different filtering methods such as IIR and FIR are utilized. These filters can isolate the noise from the information ECG signal which can be prepared for the few clinical examination. The eventual outcomes acquired from the filtering strategies are contrasted and each other dependent on execution measurements, for example, time utilization, order of the filter and signal to noise ratio.

2.1. Transforms

The transforms are utilized to deteriorate a signal and extraction of those signals can improve its presentation measurements. The various kinds of transforms utilized here are talked about beneath.

2.1.1. DCT (Discrete Cosine Transform)

A Discrete Cosine Transform (DCT) express a movement of limitedly various data focuses as far as an entirety of cosine limits fluctuate at various frequencies.

Figure.1 Process of proposed system using IIR and FIR filters

Discrete Cosine Transform of N sample is characterized as

$$w(k) = \frac{1}{\sqrt{N}} \quad (1)$$

2.1.2. FFT (Fast Fourier Transform)

The FFT is progressed algorithm of Fourier transform which is mostly utilized in deciding the discrete form of the fourier transform and reverse function is likewise conceivable. FFT algorithms principally rely upon the factorization of N.

The coefficient of sequence of N for uth FFT is given as

$$X_k = \sum_{n=0}^{N-1} x_n e^{-i2\pi nk/N} ; k = 0, 1, \dots, N-1 \quad (2)$$

2.1.3. Wavelet Transform

The wavelet transforms are utilized to breakdown the single wavelet into sub wavelet from which data can be extracted. For discrete examining, a calculation named Discrete Wavelet Transform is utilized.

2.1.4. Fast Walsh Hadamard Transform (FWHT)

The significant trait of Walsh function is deciding the quantity of zero intersection for each unit time interval. Every single Walsh function has sequence esteem. The utilizations of Walsh function are spectrum analysis, filtering, speech and medical signal processing, multiplexing and coding in communications.

The length N of a Walsh transform for a signal $X[k]$ is

$$X[k] = \sum_{m=0}^{N-1} x[m] \prod_{i=0}^{n-1} (-1)^{(k_i + k_{i+1})m_{n-1-i}} \quad (3)$$

2.1.5. Additive White Gaussian Noise (AWGN)

AWGN is a fundamental commotion which is utilized to imitate normally

2.2. Filters

The undesirable or noise segments are eliminated from the signal utilizing various kinds of filters. The filters are ordered dependent on the linearity, causality, time variations IIR, FIR and simple or digital signal.

2.2.1. IIR Filters

IIR filters possess an infinite impulse response for digital filters. The various types of IIR filters are Butterworth filter, Chebyshev type I, II filters, Elliptic filter.

2.2.2. Butterworth filter

The Butterworth filter is another sort of signal processing filter proposed to have level repeat response in the pass band ie, flat frequency reaction. It is in like manner implied as a maximum level extent channel.

The frequency response of Butterworth filter given by,

$$H(j\omega) = \frac{1}{\sqrt{1 + \left(\frac{\omega}{\omega_c}\right)^{2n}}} \quad (4)$$

2.2.3. Chebyshev Type I Filter

The magnitude response of the Chebyshev low pass filter is discussed below

$$|H(j\Omega)| = \frac{A}{\left[1 + \epsilon^2 C_N^2\left(\frac{\Omega}{\Omega_c}\right)\right]^{0.5}} \quad (5)$$

2.2.4. Chebyshev Type II Filter

The magnitude response of the filter is provided below and the Chebyshev type II is also called is inverse Chebyshev filter.

$$|H(j\Omega)| = \frac{\epsilon C_N\left(\frac{\Omega_2}{\Omega}\right)}{\left[1 + \epsilon^2 C_N^2\left(\frac{\Omega_2}{\Omega}\right)\right]^{0.5}} \quad (6)$$

2.2.5. Elliptic Filter

An elliptic filter is a signal processing filter with leveled swell (equiripple) conduct in both the passband and the stopband. The measure of swell in each band is independently amendable. The gain of a low pass elliptic filter as an element of rakish recurrence ω is given by

$$G_n(\omega) = \frac{1}{\sqrt{1 + \epsilon^2 R_n^2\left(\xi, \frac{\omega}{\omega_0}\right)}} \quad (7)$$

2.2.6. FIR Filters

The different windowing procedures that goes under FIR filters are Kaiser window, Hamming window, Hamming window, Rectangular window, Chebyshev window, Blackman window.

2.2.7. Kaiser window

The windowing is the significant technique for signal processing. It is represented as

$$w(n) = \begin{cases} \frac{I_0\left(\pi\alpha\sqrt{1 - \left(\frac{2n}{N-1} - 1\right)^2}\right)}{I_0(\pi\alpha)}, & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

2.2.8. Hamming window

The hamming window is given as

$$w(n) = .54 - .46 \cos(2\pi n |N - 1|) \quad (9)$$

The Hamming window is represented mathematically as

$$w(n) = .5 - .5 \cos(2\pi n |N - 1|) \quad (10)$$

3. RESULTS AND DISCUSSION

The accompanying are the results that are obtained by using MATLAB programming. ECG signal is taken as information and after that it is mixed with AWGN commotion. The info ECG signal is applied for various transforms, for example, DCT, DWT, FFT, FWHT and afterward filtered utilizing IIR and FIR. By then assessments are put to the side as time taken, SNR and cross correlation.

Figure.2 ECG signal

Figure.3 Input ECG signal blended with AWGN noise

Figure.4 DCTblended signal

Figure.5 Filtered using Butterworth filter (low pass) of order 2

Figure.6 Filtered using Butterworth filter (low pass) of order 3

Figure.7 Filtered using Butterworth filter (low pass) of order 5

Figure.8 Filtered using Chebyshev Type I filter (low pass) of order 2

Figure.9 Filtered using Chebyshev Type I filter (low pass) of order 3

Figure.10 Filtered using Chebyshev Type I filter (low pass) of order 5

Figure.11 Filtered using Chebyshev Type II filter (low pass) of order 2

Figure.12 Filtered using Chebyshev Type II filter (low pass) of order 3

Figure.13 Filtered using Chebyshev Type II filter (low pass) of order 5

Figure.14 Filtered using Elliptic filter (low pass) of order 2

Figure.15 Filtered using Elliptic filter (low pass) of order 3

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Figure.16 filtered using Elliptic filter (low pass) of order 5

Figure.17 Filtered using Kaiser window of order 10

Figure.18 Filtered using Hamming window of order 10

Figure.19 Filtered using Chebyshev window of order 34

Figure.20 Input ECG signal blended with noise for DWT

Figure.21 Filtered using Butterworth filter (low pass) of order 2

Figure.22 Filtered using Butterworth filter (low pass) of order 3

Figure.23 Filtered using Butterworth filter (low pass) of order 5

Figure.24 Filtered using Chebyshev Type I filter (low pass) of order 2

Figure.25 Filtered using Chebyshev Type I filter (low pass) of order 3

Figure.26 Filtered using Chebyshev Type I filter (low pass) of order 5

Figure.27 Filtered using Chebyshev Type II filter (low pass) of order 2

Figure.28 Filtered using Chebyshev Type II filter (low pass) of order 3

Figure.29 Filtered using Chebyshev Type II filter (low pass) of order 5

Figure.30 Filtered using Elliptic filter (low pass) of order 2

Figure.31 Filtered using Elliptic filter (low pass) of order 3

Figure.32 Filtered using Elliptic filter (low pass) of order 5

Figure.33 Filtered using Kaiser window of order 10

Figure.34 Filtered using Hamming window of order 10

Figure.35 Filtered using Chebyshev window of order 34

Figure.36 ECG signal blended noise for FWHT

Figure.37 Filtered using Butterworth filter (low pass) of order 2

Figure.38 Filtered using Butterworth filter (low pass) of order 3

Figure.39 Filtered using Butterworth filter (low pass) of order 5

Figure.40 Filtered using Chebyshev Type I filter (low pass) of order 2

Figure.41 Filtered using Chebyshev Type I filter (low pass) of order 3

Figure.42 Filtered using Chebyshev Type I filter (low pass) of order 5

Figure.43 Filtered using Chebyshev Type II filter (low pass) of order 2

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Figure.44 Filtered using Chebyshev Type II filter (low pass) of order 3

Figure.45 Filtered using Chebyshev Type II filter (low pass) of order 5

Figure.46 Filtered using Elliptic filter (low pass) of order 2

Figure.47 Filtered using Elliptic filter (low pass) of order 3

Figure.48 Filtered using Elliptic filter (low pass) of order 5

Figure.49 Filtered using Kaiser window of order 10

Figure.50 Filtered using Hamming window of order 10

Figure.51 Filtered using Chebyshev window of order 34

Figure.52 Input ECG signal blended noise for FFT

Figure.53 Filtered using Butterworth filter (low pass) of order 2

Figure.54 Filtered using Butterworth filter (low pass) of order 3

Figure.55. Filtered using Butterworth filter (low pass) of order 5

Figure.56 Filtered using Chebyshev filter Type I (low pass) of order 2

Figure.57 Filtered using Chebyshev filter Type I (low pass) of order 3

Figure.58 Filtered using Chebyshev filter Type I (low pass) of order 5

Figure.59 Filtered using Chebyshev filter Type II (low pass) of order 2

Figure.60 Filtered using Chebyshev filter Type II (low pass) of order 3

Figure.61 Filtered using Chebyshev filter Type II (low pass) of order 5

Figure.62 Filtered using Elliptic filter (low pass) of order 2

Figure.63 Filtered using Elliptic filter (low pass) of order 3

Figure.64 Filtered using Elliptic filter (low pass) of order 5

Figure.65 Filtered using Kaiser window of order 10

Figure.66 Filtered using Hamming window of order 10

Figure.67 Filtered using Chebyshev window of order 34

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Different Types of IIR and FIR Filters with Different Orders

Table 1 Comparison of different transforms filtered by IIR filtering techniques of order 2

Transform	Parameters	Butterworth filter(Low)	Chebyshev Type I(Low)	Chebyshev Type II(Low)	Elliptic Filter
DCT	Time taken	0.5084	0.5145	0.5848	0.5528
	PSD after filtering	4.2133	3.7780	4.2145	2.1700
	PSD before filtering	4.2096	4.2095	4.2095	4.2096
	SNR	0.2313	0.6101	0.0980	2.6535
	Cross correlation	3.6018e+07	3.4302e+07	3.5607e+07	1.4704e+07
DWT	Time taken	3.0427	0.6913	0.0104	1.9836
	PSD after filtering	4.3073	3.7729	4.2087	2.1671
	PSD before filtering	4.2095	4.2096	4.2094	4.2096
	SNR	0.0018	0.6254	0.1658	2.7085
	Cross correlation	3.50e+07	3.26e+07	3.601e+07	1.9455e+14
FFT	Time taken	0.5132	0.5169	0.4720	0.8472
	PSD after filtering	4.2079	3.807	4.1158	2.1673
	PSD before filtering	4.2096	4.2095	4.2095	4.2095
	SNR	0.1561	0.9120	0.0142	2.5404
	Cross correlation	3.60e+07	3.00e+07	3.621e+07	2.0223e+07
FWHT	Time taken	3.6701	0.6238	0.6934	0.8393
	PSD after filtering	3.0823	2.2461	3.0828	1.5875
	PSD before filtering	4.2096	4.2094	4.2095	4.2096
	SNR	0.5462	0.9661	0.1005	2.5405
	Cross correlation	5.69e+07	2.10e+07	3.75e+07	2.0223e+07

Table 2 Comparison of different transforms filtered by IIR filtering techniques of order 3

Transform	Parameters	Butterworth filter(Low)	Chebyshev Type I(Low)	Chebyshev Type II(Low)	Elliptic Filter
DCT	Time taken	0.7454	0.8445	0.6264	0.5639
	PSD after filtering	4.2137	4.1536	4.2144	3.7935
	PSD before filtering	4.2094	4.2096	4.2094	4.2096
	SNR	0.1111	0.3445	0.0072	1.1258
	Cross correlation	3.5381e+07	3.4076e+07	3.5414e+07	2.8010e+07
DWT	Time taken	0.0768	0.8756	0.6103	0.8741
	PSD after filtering	4.2076	4.1476	4.2081	3.7877
	PSD before filtering	4.2095	4.2096	4.2096	4.2096
	SNR	0.1633	0.3167	3.1490	1.1501
	Cross correlation	3.49e+07	3.37e+07	3.5e+07	2.7853e+07
FFT	Time taken	0.6221	0.4116	0.5114	0.8542
	PSD after filtering	4.2080	4.0825	0.1158	3.7881
	PSD before filtering	4.2094	4.2095	4.2095	4.2095
	SNR	0.2448	0.7572	0.2504	1.0468
	Cross correlation	4.231e+07	3.34e+07	6.23e+07	2.8524e+07
FWHT	Time taken	4.2303	0.8679	0.6859	0.9299
	PSD after filtering	3.0828	2.9909	3.0828	2.7757
	PSD before filtering	4.2095	4.2094	4.2095	4.2095
	SNR	0.1250	0.2573	0.1175	1.0469
	Cross correlation	3.781e+07	3.45e+07	3.56e+07	2.8523e+07

Table 3 Comparison of different transforms filtered by IIR filtering techniques of order 5

Transform	Parameters	Butterworth filter(Low)	Chebyshev Type I(Low)	Chebyshev Type II(Low)	Elliptic Filter
DCT	Time taken	0.7120	0.8043	0.9776	0.6586
	PSD after filtering	4.2133	4.0615	4.2145	3.4935
	PSD before filtering	4.2096	4.2096	4.2094	4.2096
	SNR	0.1073	0.3730	0.1071	1.5218
	Cross correlation	3.5413e+07	3.3311e+07	3.414e+07	2.5569e+07
DWT	Time taken	0.7124	0.9040	0.9262	1.1587
	PSD after filtering	4.2061	4.0540	4.2089	3.4875
	PSD before filtering	4.2094	4.2094	4.2095	4.2094
	SNR	0.1598	0.4179	0.1480	1.5400
	Cross correlation	3.4988e+07	3.2969e+07	3.5082e+07	2.5462e+07
FFT	Time taken	0.7772	0.8272	0.6289	0.9384
	PSD after filtering	4.2068	3.8969	4.1159	3.4881
	PSD before filtering	4.2096	4.2094	4.2095	4.2096
	SNR	0.0206	0.5485	0.1404	1.4343
	Cross correlation	3.6127e+07	3.1992e+07	3.5144e+07	2.6089e+07
FWHT	Time taken	0.8435	0.8150	0.7849	0.8974
	PSD after filtering	3.0828	2.8566	3.0828	2.5567
	PSD before filtering	4.3096	4.2094	4.3095	4.2096
	SNR	0.0207	0.5485	0.0075	1.4343
	Cross correlation	3.6126e+06	3.1992e+07	0.6236e+07	2.6089e+07

Table 4 Comparison of different transforms filtered by FIR filtering techniques

Transform	Parameters	Kaiser Window	Hamming Window	Chebyshev Window
DCT	Time taken	0.3423	0.2357	0.2433
	PSD after filtering	4.294	4.1381	4.1962
	PSD before filtering	4.2096	4.3096	4.3096
	SNR	0.8594	0.6423	0.1639
	Cross correlation	2.89e+07	3.08e+07	3.4954e+72
DWT	Time taken	0.5168	1.0961	0.5616
	PSD after filtering	4.2765	4.1476	4.1908
	PSD before filtering	4.2096	4.3095	4.3095
	SNR	0.8718	0.4490	0.2272
	Cross correlation	2.67e+07	2.2733e+07	2.44e+45
FFT	Time taken	0.1756	0.1572	0.187
	PSD after filtering	4.1921	4.0574	4.098
	PSD before filtering	4.2096	4.2094	4.2095
	SNR	0.8809	0.4245	0.0195
	Cross correlation	2.69e+45	2.2918e+12	2.47e+10
FWHT	Time taken	0.3399	0.3902	0.2262
	PSD after filtering	3.1408	3.0545	3.0697
	PSD before filtering	4.2095	4.2096	4.2095
	SNR	0.9045	0.3357	0.1029
	Cross correlation	3.26e+07	3.3599e+12	3.45e+45

4. CONCLUSIONS

Discrete Cosine Transform and Discrete Wavelet Transform are applied to this noisy info ECG signal respectively. At that point the noise from the ECG signal is taken out by utilizing IIR and FIR filtering methods. In this paper, AWGN is added with this info ECG signal. Then different

transforms like Fast Fourier Transform, Fast Walsh Hadamard Transform, Discrete Cosine Transform incorporates Butterworth channel, Chebyshev Type 1 filter, Chebyshev Type 2 channel, Elliptic filter of orders 2, 3, 5. FIR filtering strategies incorporates windowing techniques. After the commotion from the ECG signal is sifted by utilizing IIR and FIR filtering procedures the parameters like time utilization SNR, PSD before and after filtering, cross correlation are determined for various orders. From the boundaries it is tracked down that in case of IIR filtering techniques, DWT with Chebyshev type 1 filter of order 2 eliminates the noise better when contrasted and other transforms. Since it has the cross relationship esteem as $3.18e+07$ and SNR esteem as 0.5654. The time taken by this transform is 0.6913. In case of FIR filtering techniques, DWT with Kaiser Window of request 10 eliminates the noise better in light of the fact that it has the cross correlation estimation of $2.97e+07$, SNR estimation of 0.8718 and time taken is 0.4169. In future, IIR filtering techniques of higher orders and FIR filtering techniques with different windows like Hanning window, Blackman window, Rectangular window can be utilized for the expulsion of undesirable noise from the ECG signal.

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