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ECG SIGNAL DENOISING USING EMD WITH NOTCH FILTER AND MORPHOLOGY FILTER

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Abstract-*In this paper, a novel scheme for Electrocardiogram (ECG) denoising is proposed based on Notch filter, Morphology Operations and Empirical mode decomposition (EMD). Firstly, we pre-process the noisy ECG by making the model passing through a Notch filter and then by applying some Morphological Operations , in order to preserve the important morphological features, especially the QRS complex. After that, the model is then decomposed using EMD and denoised by discarding the noise components from the decomposition results. Finally, the resultant ECG is obtained.*

Key Words: ECG, Morphology, Notch, EMD.

1. INTRODUCTION

Electrocardiogram (ECG) signal may be a recording of the bioelectric capability made with the help of syncopated internal organ sports. ECG has been significantly used for heart sickness prognosis in treatment room, additionally to affected person monitoring at domestic, only if it is going to provide valuable data of the coronary heart practical things. However, reliable and economical scientific applications square measure exceptionally dependent on the accuracy of statistics extracted from the ECG recording, for ECG signals square measure typically corrupted with varied artifacts.

The supply of cardiogram artifacts are going to be cardiac-related, for example, reduction or disappearance of the isoelectric interval, prolonged repolarization, or chamber flutter; extra cardiac noise sources embody respiration, changes of electrode position, contraction, and transmission line interference [1]. Therefore, the goal of cardiogram denoising is to separate the valid viscus components from the background noises thus on acquire a sign that allows reliable interpretation.

During its acquisition, the electrocardiogram signal is corrupted with differing types of noises. Noises a bit like the power line interference (50 Hz), the muscle object as a results of the graph (electromyogram), the baseline wandering as a results of the rhythmical inhalation and exhalation throughout respiration samples of noises that corrupt the electrocardiogram signals [1-2]. So on scale back the noise in electrocardiogram signals several techniques out there such a digital filters (FIR or IIR), adaptive technique, wave work on thresholding and Empirical Mode Decomposition strategies [3]. However, digital filters and adaptive strategies is applied to signal whose math's characteristics square measure stationary in several cases. Recently the wave work on has been tried to be Associate in Nursing helpful gizmo for non-stationary signal analysis [4]. Thresholding is employed in wave domain to eliminate or to urge obviate some coefficients of wave work on sub signals of the measured signal. The noise content of the signal is reduced, effectively, with among the nonstationary atmosphere. Donoho [5-6] has planned the denoising technique that applies thresholding in wave domain. It's been verified has been verified that the Donoho's technique for noise reduction works well for an honest category of one-dimensional and one or two of dimensional signals. Numerous approaches for threshold price estimators is found in [7-10]. VisuShrink [9, 11] utilizes the universal threshold portable computer that's 2log (N) for a vector i d of the detail coefficients of length N. positive Shrink depends on Stein's unbiased risk portable computer [12]. Positive shrinks serious drawbacks in things of most poorness of the wave coefficients [13]. In [11], scientist Shrink was used for the sting portable computer that may be a data-driven sub and adaptive technique littlest quantity Mean sq. adaptive rule (LMS) [9]. However, this rule is not able to track the speedily varied non-stationary signals like electrocardiogram signal among every heartbeat; this causes excessive low pass filtering of mean parameters like QRS troublesome. The electrocardiogram signal is outlined by 5 peaks and valleys labeled by the letters P, Q, R, S, T as shown in figure one. The QRS troublesome is that the foremost distinguished wave 0.5 among the graph. It reflects the electrical activity of heart throughout the cavity contraction and therefore the time of its incidence. A beautiful vary of strategies were planned for detection of the waves of electrocardiogram signal [1-7]. The bulk of those techniques square measure supported filtering or the thresholding adaptive, that shows the limitation of the appliance. Alone variety of algorithms perform well for the detection of all the landmarks a bit like the begin and therefore the tip of the P wave, the T wave and QRS troublesome (also noted below the name: extremes of the waves of electrocardiogram signal).

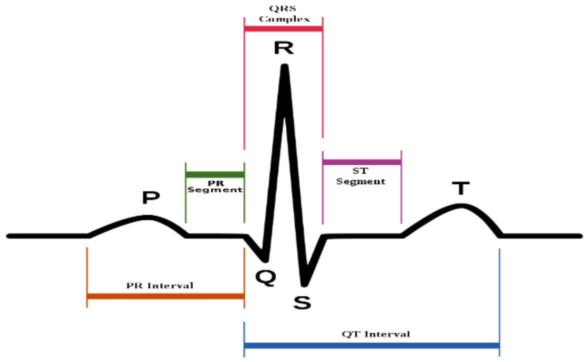

Fig 1: Basic ECG Signal

In this paper, we propose to apply the EMD algorithm to ECG denoising problem along with Notch Filter and Morphology Operations. The contribution of our method is that it not only makes use of the advantage of EMD in processing non-linear and nonstationary signal (e.g. ECG), but also overcomes the potential problem brought by direct ECG denoising with EMD, by utilizing a simple and flexible ECG model to pre-processing the signal.

2. RELATED WORK

2.1. Empirical mode decomposition

Empirical mode decomposition (EMD) is intuitive, a posteriori and adaptive, with basic functions derived totally from the information. Its essence is to spot the intrinsic oscillating modes by their characteristic time scales within the signal through empirical observation, and consequently decompose the signal into intrinsic mode functions (IMFs) by means that of a separation method. Therefore, EMD is very applicable for nonlinear and nonstationary signals, together with EKG.

$$z = \frac{x_i - \mu}{\sigma}$$

z= Standardized value to data.
xi= Real value of data.
μ = Mean.
σ = Standard deviation of data.

EMD Algorithm

1. The successive extrema of X (t) are firstly identified, then the local maxima and minima
2. Calculate the mean m1 (t).
3. The difference between the signal X (t) and the mean m1 (t) is calculated, which can be regarded as the primary description of the first IMF p1 (t).

$$p1\ (t) = X\ (t) - m1\ (t)$$

4. To determine the first IMF more accurately, p1 (t) is treated as a new signal, its upper and lower envelopes, and their new mean m2 (t) are calculated, where p2 (t) is determined.

$$P2\ (t) = X\ (t) - m2\ (t)$$

5. This p2 (t) is again treated as a new signal, and the process, referred to as iteration, is repeated many times designated by k until a stopping criterion satisfies. pk (t) is the first IMF designated by c1(t).

$$pk\ (t) = X\ (t) - mk(t)$$

The whole process can be stopped when $cn\ (t)$ or $rn\ (t)$ is less than a predetermined threshold, or rn (t) becomes a constant or monotonic function.

$$r1\ (t) = X\ (t) - c1\ (t)$$
$$r2\ (t) = X\ (t) - c2\ (t)$$
$$rn\ (t) = X\ (t) - cn(t)$$

p1, p2….pk = prototype of IMF.
X (t) = Original signal.
r1, r2…. rn = residue signal
c1, c2…..cn = New IMF.

$$\mathbf{X\ (t) = \Sigma\ cn\ (t) + rn\ (t)}$$

Original signal is decomposed into *n* IMFs and one residue.

2.2. Notch Filter

In signal methodology, a band-stop filter or band-rejection filter could also be a filter that passes most frequencies unreduced, however attenuates those terribly} specific vary to very low levels.[1] it's the various of a band-pass filter. A notch filter could also be a band-stop filter with a slender stopband (high letter of the alphabet factor).
Narrow notch filters (optical) utilized in Raman qualitative analysis, live replication (public address systems, or PA systems) and in instrument amplifiers (especially amplifiers or preamplifiers for acoustic instruments like musical instrument, mandolin, bass instrument instrumentation, etc.) to chop back or stop audio feedback, whereas having very little noticeable impact on the remainder of the frequency spectrum (electronic or code filters). Completely different names embody 'band limit filter', 'T-notch filter', 'band-elimination filter', and 'band-reject filter'.
Typically, the breadth of the stopband is one to two decades (that is, the foremost effective frequency attenuated is ten to one hundred times very cheap frequency attenuated). However, at intervals the audio band, a notch filter has high and low frequencies that will be solely semitones apart.
A Notch Filter is else spoken as a Band Stop filter or Band Reject Filter. These filters reject/attenuate signals in Associate in Nursing passing specific band named as a result of the stop band frequency vary and pass the signals over and below this band. as Associate in Nursing example, if a Notch Filter contains a stop band frequency from 1500 megahertz per second to 1550 megahertz per

second, it'll pass all signals from DC to 1500 megahertz per second and higher than 1550 megahertz per second. it'll solely block those signals from 1500 megahertz per second to 1550 megahertz per second. When selecting a Band Stop Filter or Notch Filter the next unit very important parameters to evaluate:

Stop Band Frequency: Any signal throughout this frequency vary ar attenuated by the Notch Filter.
Attenuation/Rejection inside the Stop Band: It may be the quantity of attenuation that the filter will offer inside the stop band. This may be generally delineate in decibel.
Power Handling Capability of the Filter: Can be the utmost power that the notch filter will handle.
Package Type: There unit style of kind factors and package varieties throughout that these notch filters unit on the market.
The ideal response for any notch filter would be a completely flat response over the usable vary with the exception of the notch frequency.

2.3. Morphology Operations:

Morphological operators like dilate, erode, open, and close, can be applied through image filtering to grow or shrink image regions, still on take away or relief image region boundary pixels.
These basic operators that method objects within the input image supported the characteristics encoded within the elite structuring part, area unit represented below. Additional morphology filters embody top-hat transforms, Morphological gradient and morphological Laplace.

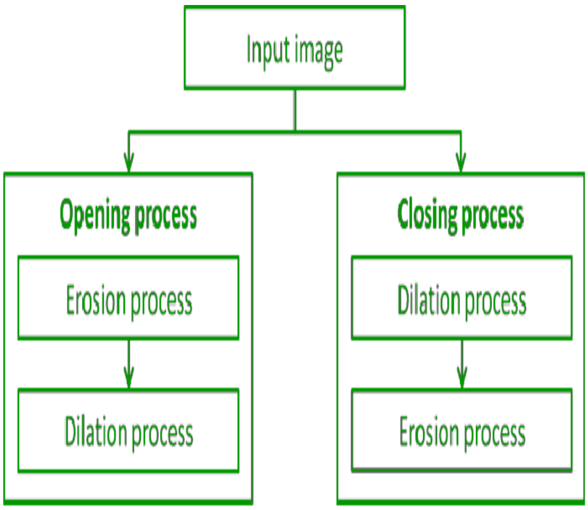

Fig 2: Morphology Operation

In this paper two types of Morphology operations like Top hat transform and Bottom hat transform are used.

2.3.1. Top-hat transformation

Top-hat transform is an operation that extracts little components and details from given pictures. Top – hat transform (S_{TH}) is obtained by subtracting opening of the signal from original signal. Opening of a signal has Erosion and Dilation process in it.

$$S_{TH} = S - S_0$$

S_{TH} = Top hat transform.
S = Original Signal.
S_0 = Opening Signal.

2.3.2. Bottom-hat transformation

Bottom-hat transform is similar to that of Top-hat transform instead of opening we use the closing signal. Bottom-hat transform (S_{BH}) is obtained by subtracting closing of the signal from original signal. In Closing of signal, Dilation process is seen first then Erosion is considered.

$$S_{BH} = S - S_c$$

S_{BH} = Bottom hat transform.
S = Original Signal.
S_c = closing Signal.

2.4 Proposed Method for ECG Denoising

In this section, we explain our method for ECG denoising. The ECG is considered and a error or noise is added to the signal, we consider Gaussian noise and muscle associated noise.
Error occurring in the signal:

$$X(t) = X^{\wedge}(t) + W_K.$$

X^ (t) - Informational signal.
X (t) - Acquired signal.
W_k are measurement and process noise vector at the time step *k.*
The noisy ECG signal is gone through pre-processing by passing through Notch filter and then through Morphology filter, so that pre-processing or pre- filtering takes place to further reduce the noise output signal is pass through EMD (Empirical Mode Decomposition) where the ECG signal is decomposed into parts called IMFs the ECG signal is represented as sum of IMFs and its residue, then further filtering is seen.

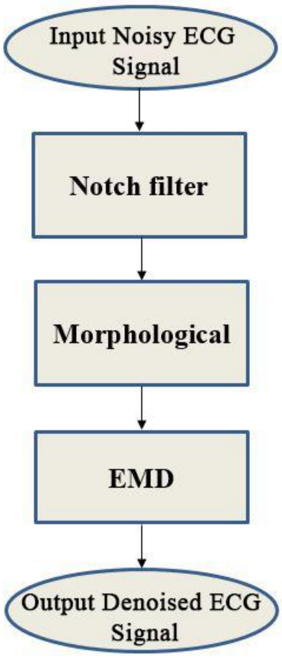

Fig 3: Working procedure

3. SIMULATION RESULTS

The planed approach is recreated with a broadly speaking took on reenactment climate, MATLAB 2021a. An error is introduced to ECG signal (fig 4) then preprocessing is done by using Notch and Morphology filters.

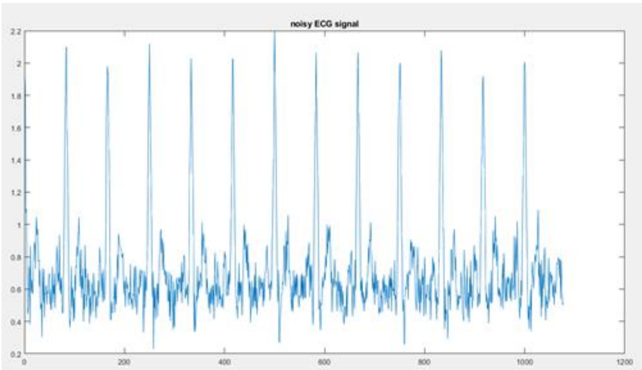

Fig 4: Noisy ECG signal

After passing the Noisy ECG signal through pre-processing it is further processed by EMD to get residues at a particular frequency and IMF as shown in (fig 5).

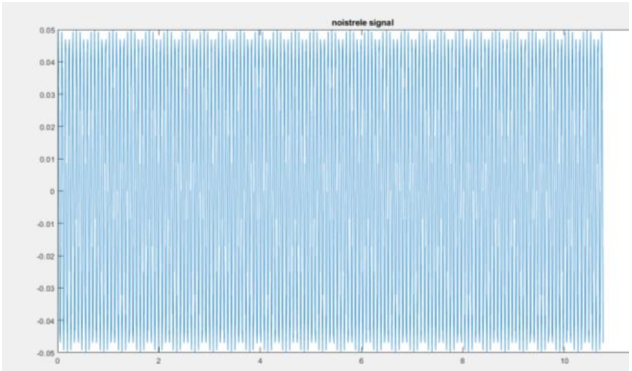

Fig 5. IMF output

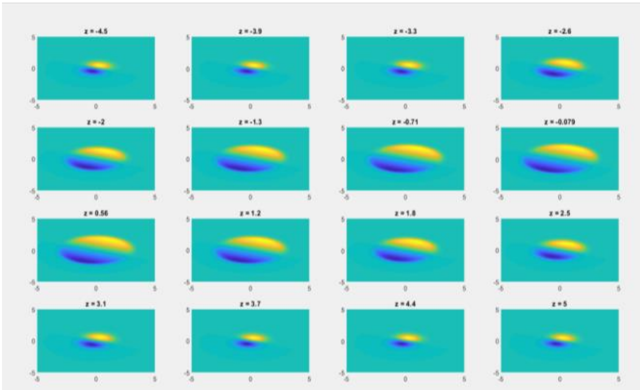

Fig 6: Residue at different frequencies

After decomposing the signal to IMF and residue, (fig 6) the noise is removed in the system to get finalized denoised signal.

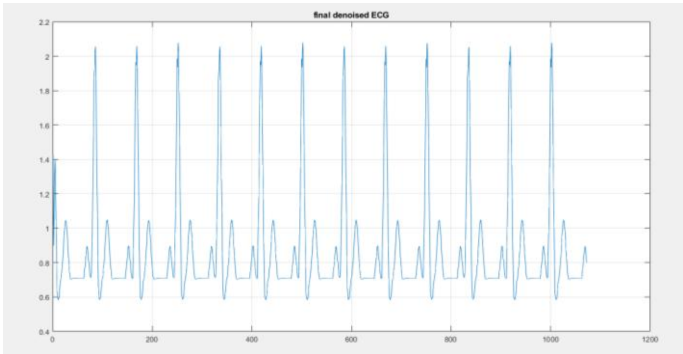

Fig 7: Denoised ECG signal

Parameters	Values
RMSE	0.0928
MEAN	0.8696
PSNR	99.9072
STD	0.03151

Table 1: Calculated results

CONCLUSIONS

EMD method is proposed for processing ECG signals. This method consists of a new method for grouping the IMFs of ECG signals, a Notch filtering and morphological filtering.

The simulated results show that the proposed paper offers good performance on IMF grouping and baseline wandering elimination for ECG signals.

The proposed paper determined is more reasonable, and the effect of filtering high-frequency noise is better than the previous paper denoising methods.

The SNR is improved, and the waveform of the QRS complex remains intact.

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