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Structural Optimization of Adaptive Filter for ECG Extraction (R-Peak)

Priyanka Sahoo, Electronics and Communication Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai, India, priyankasrm2017@gmail.com

Preetha Manohar, Electronics and Communication Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai, India, preetha1999@gmail.com

Abstract - ECG signals comprise a ton of noises like Muscle Artifact, Baseline Wandering, Powerline Interference, and so forth. In this way, to eliminate those commotions we plan to utilize an apparatus called an adaptive channel.

Our proposed framework will identify commotion-free ECG signals by utilizing programming segments like the Physiobank data set and MATLAB Software and by performing underlying streamlining of versatile channels for ECG extraction and distinguishing R-top. We will investigate essential info that is ECG signal for distinguishing R-peak and different irregularities in the heart. Convergence of LMS and NLMS calculation is utilized in building up the specific channel structures. The identification of the R-peak and subsequently of the QRS peak in an ECG signal gives data about the pulse, the conduction speed, the state of tissues inside the heart just as different anomalies. These qualities can be utilized to identify any variety of mind-boggling ordinary qualities. The yield of the framework will be a denoised ECG waveform which is utilized to anticipate noticeable highlights with the assistance of an application produced using MATLAB that would be useful for the advancement of society.

Keywords—ECG, MATLAB, QRS Peak, Physiobank ATM, Adaptive filter, Noise

I. INTRODUCTION

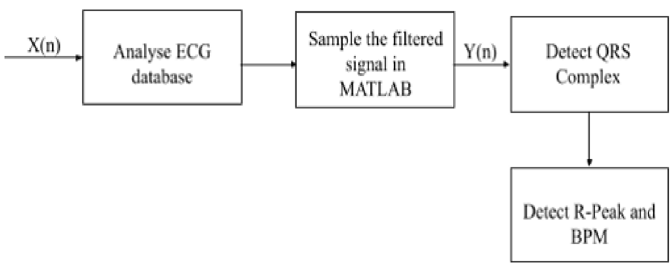
The heart isn't just our generally fundamental, yet in addition our most mind-boggling organ. It is a solid organ about the size of a clenched hand and it is found simply behind and somewhat left of the breastbone. It goes about as a siphon for circling oxygen and blood all through the body through the organization of conduits and veins, along these lines keeping the usefulness of the body flawless. The prospects of heart illnesses, respiratory failures, and numerous heart-related issues have expanded colossally. An ordinary resting pulse for grown-ups goes from 60 to 100 beats each moment. Variety from this worth is a marker of arrhythmia. Numerous components can impact pulse, including age, wellness, action levels, being a smoker, cardiovascular infection, elevated cholesterol or diabetes, Air temperature, body position, feelings, body size, or meds.

An arrhythmia is an issue with the heartbeat, the rate or beat, which is brought about by shifts in perspective tissue or in the electrical signs that control the heartbeat[3]. During an arrhythmia, the heart beats excessively quick, too gradually, or with an unpredictable mood. At the point when a heart beats too quickly, the condition is considered tachycardia and when a heart beats too gradually, the condition is called bradycardia[3]. At the point when the heart has an unpredictable heartbeat, the condition is called shudder or fibrillation. If the resting pulse is reliably over 100 thumps brief its tachycardia and if the resting pulse is under 60 beats per minute, it's bradycardia. Early location and treatment of heart arrhythmias keep the issue from arriving at unexpected passes.

An ECG is the most ideal approach to quantify and analyze unusual rhythms of the heart. There are a few reasons why we go for an ECG, which incorporates unpredictable heartbeat, chest torment, windedness, fundamentally hypertension, and so on Electrocardiography is the way toward creating an electrocardiogram (ECG or EKG).

II. RELATED WORK

A. System Model Description



X(n)= Input ECG signal
Y(n)=Filtered Signal

Fig. 1: System Architecture

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The block- diagram depicts the overall process of the proposed framework and they are :

1. Acquisition of the ECG signal utilizing a Software apparatus like PhysioNet data set.
2. Use of fell design with LMS calculation to perform dynamic clamor undoing.
3. Getting a denoised yield waveform.
4. Use the calculation to identify QRS calculation
5. Predict the R-peak and BPM.

B. System Analysis

The discovery of the R-pinnacles and thus of the QRS edifices in an ECG signal gives data about the pulse, the conduction speed, the state of tissues inside the heart just as different anomalies. These qualities can be utilized to distinguish any variety from typical qualities. The yield of the framework will be a denoised ECG waveform that is utilized to anticipate conspicuous highlights with the assistance of an application produced using MATLAB that would be useful for improving society.

C. LMS Algorithm

The least mean squares (LMS) calculations are a class of versatile channels used to emulate the ideal channel by discovering the channel coefficients to deliver the most un-mean square of the noise signal (the distinction between the ideal and the real sign).

The least mean square calculation is an iterative method used to limit MSE among essential and reference input[1]. LMS doesn't need any connection work estimation or framework reversal which simplifies it and is simpler when contrasted with another calculation.

D. R-Peak and BPM

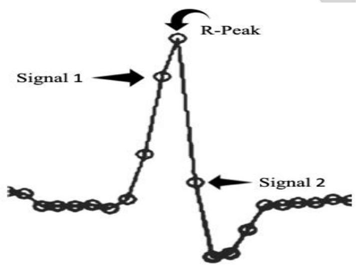

Fig. 2: Peak of ECG signal

In Fig. 2, we will recognize that the peak is more prominent than the adjoining esteems:

$$sig(x) > sig(x+1) \text{ and } sig(x) > sig(x-1)$$

- sig(x) - Current signal
- sig(x-1)= signal 1
- sig(x+1) - signal 2
- To identify BPM

$bpm = beat / duration\ in\ minutes$is utilized.

III. CONTRASTING ALGORITHMS

1**)** Pan Tompkins: The Pan–Tompkins calculation is regularly used to identify QRS peaks in electrocardiographic signs (ECG). The Pan–Tompkins calculation applies a progression of channels to feature the recurrence substance of this fast heart depolarization and eliminates the foundation clamor. At that point, it squares the sign to intensify the QRS complex. At last, it applies versatile edges to distinguish the pinnacles of the sifted signal [4].

2) Symlet4: ECG Signal is dissected utilizing the capacity of Wavelet Transforms to figure the pulse [10]. The typical worth of heartbeat lies in the scope of 60 to 100 thumps/minute.

- Each wave has various frequencies, for instance, the P wave has f1 recurrence, the R wave has f2 recurrence, and the S wave has f3 recurrence. Our goal is recurrence containing R tops (f2) should be saved while different frequencies should be stifled. In this way, a bandpass activity is required.
- That can be accomplished by wavelet change. The wavelet changes separate signs into various recurrence groups. The bandpass channel can be carried out by taking out some recurrence groups.
- When an ECG signal is gone through a bandpass channel it stifles the low and high recurrence wavelets and allows just R top [4]. Thus, a reasonable ascent of the R pinnacle will be noticeable. With the assistance of the standard pinnacle location calculation, the R top is recognized.
- Also, the complete number of R pinnacles can be recognized from a given time frame from which Heart Rate can likewise be distinguished. A slower rate than the typical pulse is called bradycardia (Slow heart) and a higher rate is called tachycardia (Fast heart) [3].

$$\text{Pulse:}(1/RR\ stretch\ in\ sec) * 60$$

3) LMS Calculation**:** The LMS calculation plays out the accompanying activities to refresh the coefficients of a versatile FIR channel[9]:

The LMS Algorithm comprises two essential cycles

1. Separating measure: Calculate the yield of the FIR channel by convolving information and taps. A certain assessment blunder by contrasting the yield with a wanted sign.

2. Transformation measure: Adjust tap loads dependent on the assessment mistake.

Execution of Least Mean Square Algorithm: For the Implementation of every emphasis of the LMS calculation requires three unmistakable strides in the accompanying request:

1. The yield of the FIR channel,$y(n) = wT(n)\ x(n)$

2. The worth of the blunder assessment is determined utilizing,

$$e(n) = d(n) - y(n)$$

3. The tap loads of the FIR vector are refreshed in anticipation of the following cycle,

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$w(n+1) = w(n) + 2\mu e(n)\, x(n)$. For every emphasis, the LMS calculation requires 2N augmentations and 2N+1 duplication

4) NLMS Calculation: It is an improvement over the LMS calculation with the additional computation of step size boundary for every emphasis [7].

1. The yield of the versatile channel is determined as

$$y(n) = wT(n)\ x(n)$$

2. The mistake signal is determined as the contrast between the ideal yield and the channel yield given by:

$$e(n) = d(n) - y(n)$$

3. The progression size and channel tap weight vectors are refreshed utilizing the accompanying conditions in anticipation of the following cycle: For i=0,1,2,… … .N-1; $\mu i(n) = \alpha/(\ c + ||\, xi\ (n)\ ||^{2}$ with α =0.02 and c=0.001, every emphasis of the NLMS calculation requires $3N +$ 1duplication activities.

5) Proposed Algorithm:

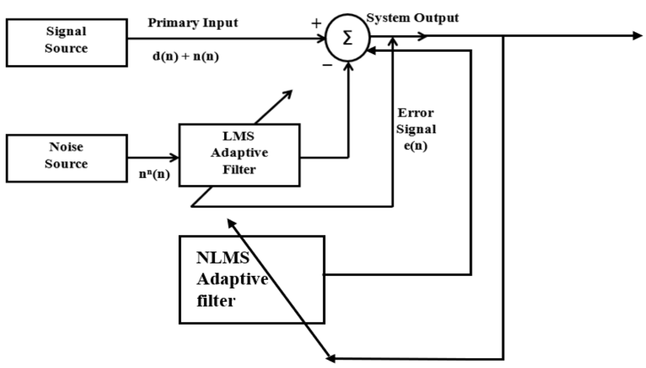

Fig. 3: Convergence of LMS and NLMS

n*(n)= Noise signal

d(n) + n(n) = Primary Input

e(n) = Error signal

In this custom algorithm as depicted in Fig . 3, a convergence of LMS and NLMS is made to get the best efficient output. The LMS system Y(n) output is fed as input to the NLMS filter to get a more efficient clean ECG signal [6].

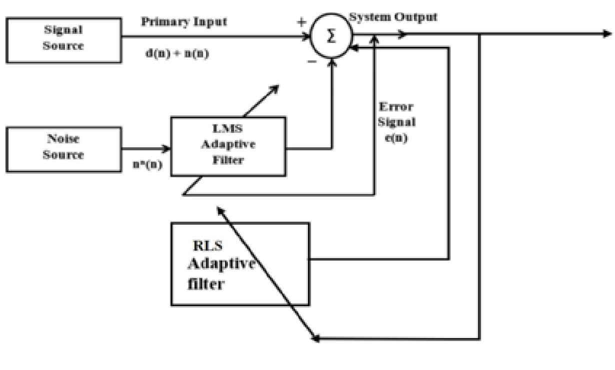

Fig. 4: Convergence of LMS and RLS

n*(n)= Noise signal

d(n) + n(n) = Primary Input

e(n) = Error signal

In this custom algorithm depicted in Fig.4, a convergence of LMS and RLS is made to get the best efficient output. The output of LMS system Y(n) is fed as input to the NLMS filter to get a more efficient clean ECG signal.

E. Software Specifications

1. PHYSIONET: It is an online discussion for scattering and trade of recorded biomedical signals and open-source programming for dissecting them, by giving offices an agreeable examination of information and assessment of proposed new calculations.

2. PHYSIOBANK ATM: It incorporates information bases of multi-boundary cardiopulmonary, neural, and other biomedical signs from solid subjects and patients with an assortment of conditions with significant general wellbeing suggestions, including abrupt cardiovascular demise, congestive cardiovascular breakdown, epilepsy, step issues, rest apnea, and maturing.

3. MATLAB: It is a restrictive multi-worldview programming language and mathematical registering climate created by MathWorks. MATLAB permits framework controls, plotting capacities and information, execution of calculations, making of UIs, and interfacing with programs written in different dialects.

IV. SIMULATION & RESULTS

ECG signals were made by adding relics to clean the ECG signals. The perfect ECG signal was a brief span of the signal record 100 from the MIT-BIH information base[1]. All relics were additionally acquired from the MIT-BIT data set. The program to produce the boisterous ECG signals.

When the boisterous ECG signals were made, they were taken care of into the principle MATLAB program. In the fundamental program, execution of LMS and NLMS [5]. For the ECG sifting, first PLI and Baseline Wander were sifted through, and afterward, QRS investigation was applied to decide the start of P-wave, an incentive for definite channel phase of muscle relic and movement curio evacuation. This cycle was accomplished for every LMS and NLMS calculation multiple times for every one of 3 loud ECG signals[2]. For QRS discovery, an outsider program was utilized which distinguishes QRS highlights utilizing Wavelet Technique.

By and large, when it comes down to an examination of the signs, the most widely recognized technique for execution investigation is a sign to commotion proportion (SNR). Nonetheless, R examination for an ECG is futile because researchers and Emergency Medical Technicians (EMTs) that work with ECG signals are not keen on its SNR, but instead on its exactness of distinguishing its wave boundaries. Rather than SNR, True positives (TPs), True

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negatives (FNs), False positives (FPs), Sensitivity, and Accuracy of wave boundaries were determined [9].

F. TP, FP, and FN:

True Positive: True positive signifies the quantity of genuine peculiar beats that are effectively distinguished as abnormal. TPs are the pinnacle areas that were distinguished in sifted ECG and coordinated to top areas to clean ECG.

False Positive: It means the number of typical ECG beats that are mistakenly distinguished as peculiar. FP's are top areas that were available in sifted ECG however never existed in clean ECG.

False Negative: False-negative signifies the quantity of genuine peculiar beats that are mistakenly distinguished as expected, feeling the loss of the anomalies of those beats in the location. FNs are the top areas that were identified in clean ECG yet were missing in separated ECG.

G. Quantitative Analysis:

Table I: Quantitative analysis of Pan Tompkins, Proposed Algorithm and Symlet4

	Pan Tompkins	Proposed Algorithm	Sym4
TP(%)	94.90	98.90	96.68
FP(%)	78.85	66.68	70.23
FN(%)	30.63	23.95	40.23
Se(%)	91.20	99.92	97.58
Acc(%)	97.754	99.923	98.987

Quantitative analysis demonstrates the performance of R-peak using various algorithms like the Pan Tompkins algorithm, our proposed algorithm, and symlet4 algorithm which is used for detection of R-peak along with heartbeat conditions and bpm. We can see that our proposed algorithm to find R-peak has better accuracy of 99.923% compared to other algorithms used.

Table II: Quantitative analysis of LMS filter

	μ=0.3	μ=0.5	μ=0.9
TP(%)	98.82	96.15	93.54
FP(%)	52.14	58.54	65.24
FN(%)	58.50	68.54	69.17
Se(%)	95.65	98.97	91.86
Acc(%)	98.78	94.74	96.55

The analysis of the LMS filter with different 'μ' values is done. At first, when 'μ' was 0.9 some noises were present due to which we reduced the 'μ' value and found that with 'μ' of 0.3, the accuracy is 98.78% which is higher compared to the rest ' μ' values.

Table III: Quantitative Analysis of NLMS filter

	μ=0.3	μ=0.005	μ=0.9
TP(%)	98.32	99.08	80.78
FP(%)	60.59	52.50	68.94
FN(%)	50.20	50.12	50.30
Se(%)	94.58	98.98	92.33
Acc(%)	96.658	98.926	94.564

Table III shows an analysis of the NLMS filter with different 'μ' values. At first, when 'μ' was 0.9 some noises were present due to which we reduced the 'μ' value and found that with 'μ' of 0.005, the accuracy is 98.926% which is higher compared to the rest 'μ' values.

Table IV: Quantitative Analysis of Convergence of LMS and NLMS filter

	μ=0.3	μ=0.05	μ=0.9
TP(%)	98.92	99.15	96.54
FP(%)	52.14	54.54	60.24
FN(%)	58.50	52.54	59.17
Se(%)	95.65	98.97	91.86
Acc(%)	98.782	99.897	96.550

In Table IV we can see the quantitative analysis of the Convergence of LMS and NLMS filters with different 'μ' values. Convergence of LMS and NLMS is structurally optimized, that is the output of the LMS filter is given to the error signal of the NLMS filter, and the error signal of the LMS filter is used as input of NLMS filter to estimate the best output. Over here we can see that 'μ' of 0.05 has better accuracy of 99.897% compared to the other 'μ' values.

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Table V: Quantitative Analysis for all Tables:

	Pan Tompkins	Symlet4	LMS	NLMS	Convergence of LMS and NLMS	Convergence of RLS and LMS	Proposed algorithm
TP(%)	94.90	96.58	98.75	99.98	98.90	97.50	98.90
FP(%)	78.85	70.23	52.14	52.20	66.56	56.23	66.68
FN(%)	85.26	87.23	58.45	50.12	89.95	80.15	23.95
Se(%)	91.20	97.58	98.97	98.98	99.92	92.45	99.92
Acc(%)	97.754	98.987	98.74	98.92	99.897	99.7	99.923

In Table V, the analysis proves that the Convergence of LMS and NLMS which is used to get denoised ECG signal, and our proposed algorithm which is used to detect R-peak along with heart-beat condition and beat-per-minute has the highest accuracy of 98-99%, when compared with Pan Tompkins, symlet4, LMS and NLMS algorithm.

A. *LMS Filter Output:*

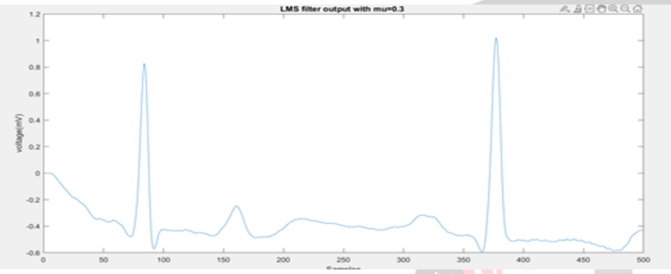

Fig.5:Output of LMS filter for μ = 0.3

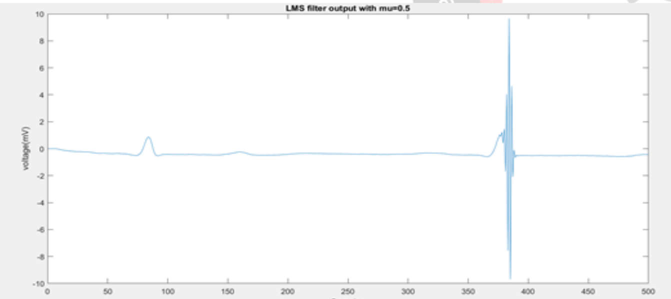

Fig. 6:Output of LMS filter for μ=0.5

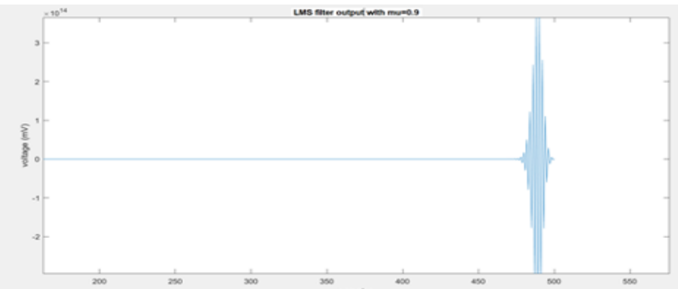

Fig. 7: Output of LMS filter for μ=0.9

Three distinct ECG signals are simulated with different ‘μ’ values to yield better results.

We can derive that Fig.5 that is the result for μ=0.3 yields a better result in the case of the LMS filter.

B. *NLMS Filter Output:*

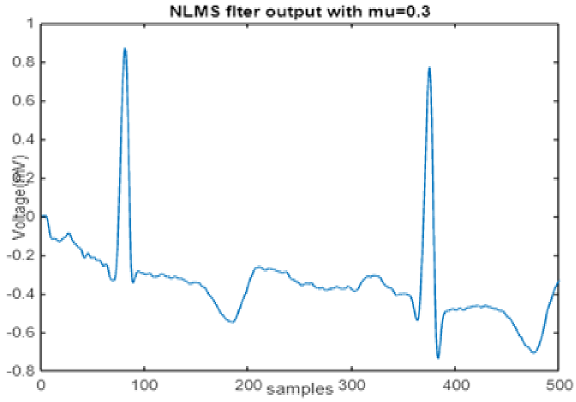

Fig. 8: Output of NLMS filter for μ=0.3

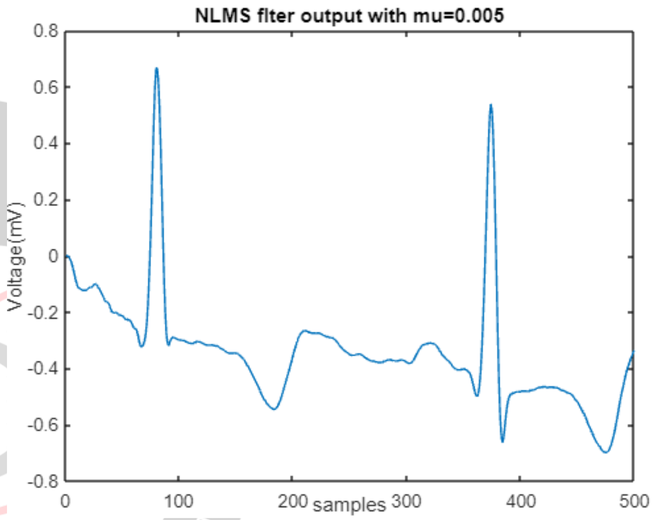

Fig. 9: Output of NLMS filter for μ = 0.005

Three different ECG signals are simulated in MATLAB with different "μ" values to yield better results.

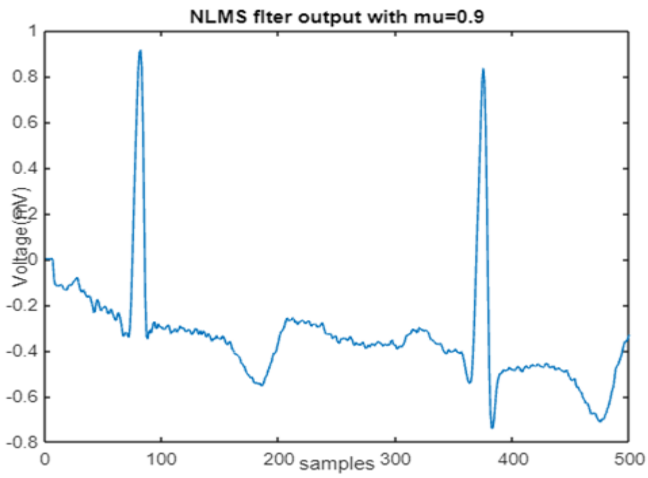

Fig. 10: Output of NLMS filter for μ=0.9

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We can derive that μ=0.005 yields a better result in the case of the NLMS filter as showcased in Fig.9.

C. *Convergence of Both LMS and NLMS:*

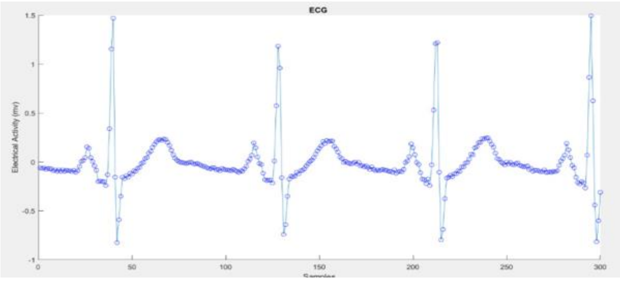


Fig. 11: Convergence Output

The QRS complex is detected in the ECG signal for the convergence of LMS and NLMS as depicted in Fig .11.

D. *PAN TOMPKINS:*

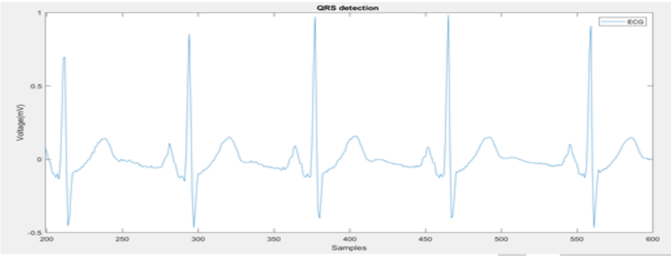


Fig. 12: QRS Detection for Pan Tompkins Algorithm

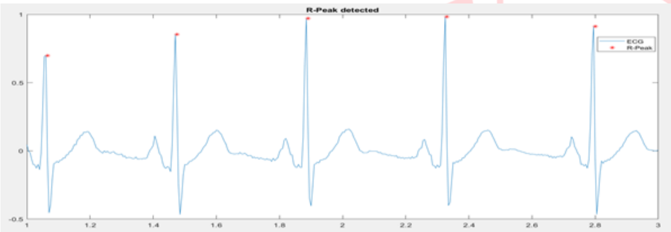


Fig. 13: R-Peak for Pan Tompkins Algorithm

The simulation results of QRS detection and R-peak are achieved through MATLAB for Pan Tompkins Algorithm that is showcased in Fig. 12 and Fig. 13.

E. *SYMLET4:*

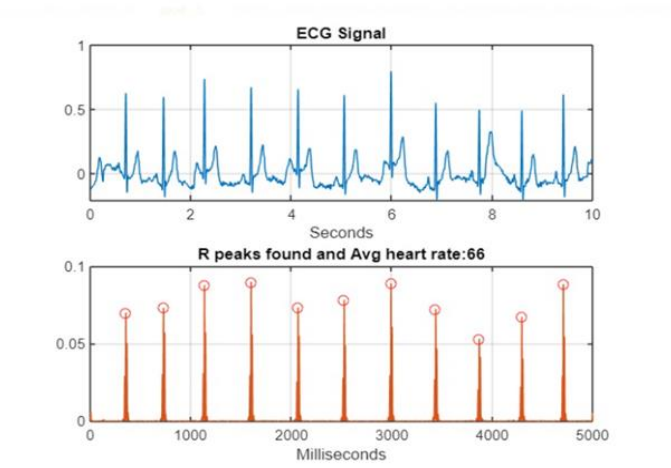


Fig. 14: QRS Detection and R-peak for Symlet4 Algorithm

Fig.14 shows the simulation results for QRS complex and detection of R-peak along with average heart-beat is achieved using MATLAB software for Symlet4 algorithm.

F. *PROPOSED ALGORITHM:*

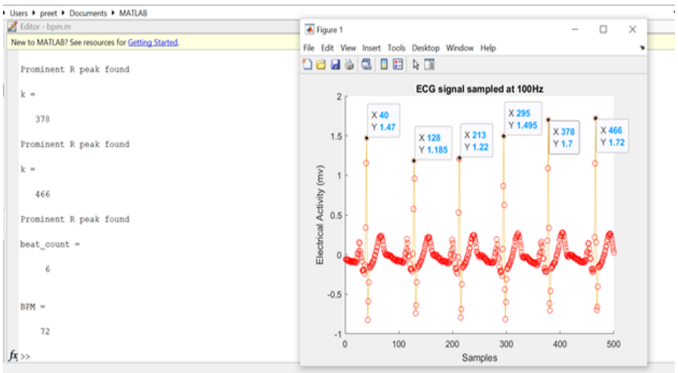
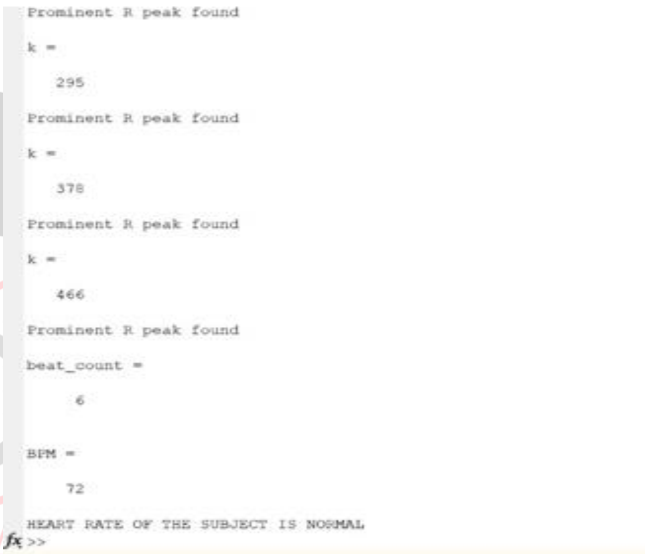


Fig. 15: ECG Signal Sampled at 100Hz



```
Prominent R peak found
k =
  295
Prominent R peak found
k =
  378
Prominent R peak found
k =
  466
Prominent R peak found
beat_count =
    6
BPM =
   72
HEART RATE OF THE SUBJECT IS NORMAL
```

Fig 16: Condition of heart along with bpm

Fig. 15 shows the simulation of ECG Signal sampled at 100Hz. Over here we have considered three heart-beat conditions: Tachycardia (ie; heartbeat greater than 100 beats per minute), Bradycardia (ie; heartbeat below 60 beats per minute), and normal heartbeat.

In Fig. 16, we can see that it clearly shows that for bpm = 72, the heart rate condition is normal.

V. CONCLUSION

In light of results from charts and tables, it may very well be seen that the Convergence of both LMS and NLMS found in Fig.16 and the proposed calculation of R-peak found in Fig. 20 have much-preferred execution over the LMS, NLMS, Pan Tompkins, and Symlet4 calculations. All these examples and techniques that are discussed here can be really useful for experimental/lab purposes even if we don't have any ECG data we still can simulate and analyze it. We can see that our convergence of LMS and NLMS, the convergence of LMS and RLS has better accuracy with 96%-98% for different mu. We can see that our proposed algorithm to find

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the R-peak has a better accuracy of 99.923%. For improving the outcomes, one can execute variable advance size calculation which can help on quicker assembly of calculation toward the beginning. Quicker transformation permits the sign to be investigated by more modest portions. The presentation of Convergence is better founded on Accuracy that we accomplished while ascertaining TP, FP, and FN.

The work further can be extended to eradicate the noise from ECG using different Adaptive filters. We can use ML and AI techniques to detect congenital heart defects and can also display the data in a customized app.

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