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2. R-PEAK DETECTION OF ECG

AIM: To detect the R-peak using a simulator based on MATLAB.

OBJECTIVE: R-peak detection of ECG signal using the concept of Shanon energy envelope.

APPARATUS REQUIRED: MIT-BIH-arrhythmia database**,** MATLAB Software.

THEORY: An electrocardiogram records the electrical signals of the heart. It's a common and painless test used to quickly detect heart problems and monitor heart health. A single period of an ECG signal contains P, Q, R, S, T and U waves**.**

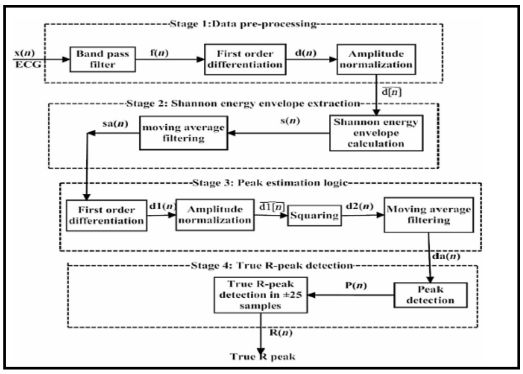
1. The P wave is caused by electrical potentials generated when the atria depolarize before an atrial contraction begins.
2. The QRS complex is caused by potentials generated when the ventricles depolarize before contraction, that is, as the depolarization wave spreads through the ventricles. Therefore, both the P wave and the components of the QRS complex are depolarization waves. The PR interval represents the time taken for an electrical activity to move between the atria and the ventricles.
3. The T wave is caused by potentials generated as the ventricles recover from the state of depolarization. The T wave is known as a repolarization wave.
4. The U wave follows the T wave. The exact cause is uncertain, though it has been suggested that it represents inter-ventricular septal repolarization.

R-peaks in electrocardiogram (ECG) play a vital role in diagnosis of heart rhythm irregularities and also estimating heart rate variability. However, the main challenge in R-peak detection is the nonstationary of both QRS morphology and noise.

METHODOLOGY:

Here we have used the Shannon Energy Envelope method for R peak detection in ECG signals. For this process we are going to follow a specific block diagram mentioned below and after that we will analyze the all the steps individually.

BLOCK DIAGRAM:



DATA PREPROCESSING:

Data preprocessing is very important step in our experiment. Because our pathological ECG signals are generally corrupted with a lot of noises like

- Powerline interference
- Skin interference
- Motion artifacts due to electrodes
- Patient breathing

But our only requirement is to extract the QRS complexes after removing all the noises. Above all there can be a lot of inconsistencies, noises present in our present data. For that reason, we have to execute some filtering operation. We generally will prefer Band Pass Filter (Chebyshev type I) [range: 6-18 Hz]. After filtering operation, we have got enhanced QRS complex attenuating other components. Next, we will undergo first order differentiation (High pass filter) to get high frequency components (QRS complex) more. But, to perform Shannon Energy Envelope computation we have to normalize the output signal in order to scale 1.

SHANNON ENERGY ENVELOPE EXTRACTION:

After data pre-processing stage, ECG signal becomes bipolar signal but for peak detection we have to transform that unipolar one. For that we have chosen Shannon Energy Envelope method because using that middle intensity components are emphasized which will be instrumental for better detection of R-peaks. After passing through this block, we transformed it into an unipolar signal but noise is also present in that unipolar signal. To remove those noisy counterparts, we will have to add a moving average filter for smoothening operation otherwise peak detection will be very difficult. After this operation, we have got a comparatively smoother waveform.

PEAK ESTIMATION LOGIC:

The smooth signal what we have got finally from the previous step, that is basically a combination of both true and false peaks. But, our objective is to detect the actual and true R peaks. For that, we have to perform first order differentiation for storing the slope information of true peaks keeping reduced the slope information of false peaks. But, again unipolar signal is converted into bipolar one for this differentiation operation. For that pupose we have to square it for making it again unipolar one. For further smoothening operation we have to apply one moving average filtering operation again. Then, it will be ready for true R peak detection.

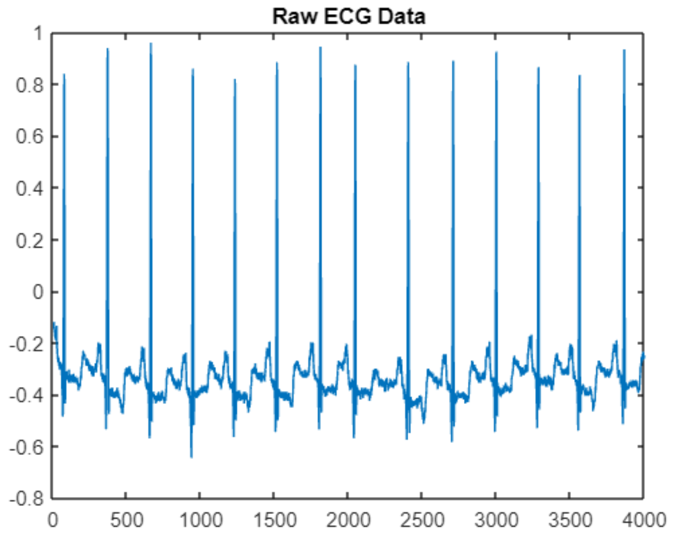
MATLAB CODES:

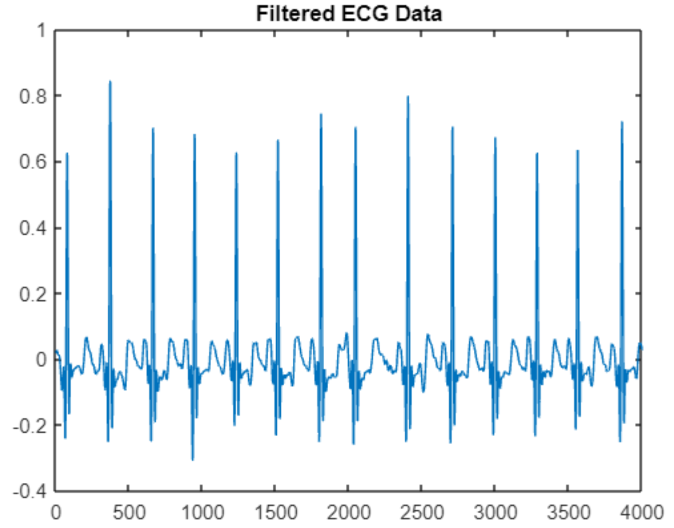
```
% Load ECG data
ecg_data = load("F:\IITM\Mtech 2_sem\Advanced_Modelling_Simulation_Lab\Exp2- R peak detection of ECG\100m.mat");
og = ecg_data.val(1, 1:4000) ./ 200;
plot(og);
title('Raw ECG Data');


% Define sampling frequency
fs = 360;


% Bandpass filter parameters
fl = 5;  % Low cutoff frequency in Hz
fh = 20; % High cutoff frequency in Hz


% Design the bandpass filter
[b, a] = cheby1(4, 0.0001, [fl fh]/fs, 'bandpass');


% Apply the filter to the ECG signal
filtered_ecg = filtfilt(b, a, og);
figure;
plot(filtered_ecg);
title('Filtered ECG Data');


% Differentiation
different = diff(filtered_ecg);
plot(different)
title("diffrentiated ECG")


% Amplitude normalization
norm = different / max(abs(different));
plot(norm)
title('normalised amplitude')


% Shannon energy envelope
norm_squared = norm.^2;
log_norm_squared = log(norm_squared);
shannon = norm_squared .* log_norm_squared * (-1);
plot(shannon)
title("shannon energy envelope")


% Moving average
ma1 = (1/65) * ones(65, 1);
```

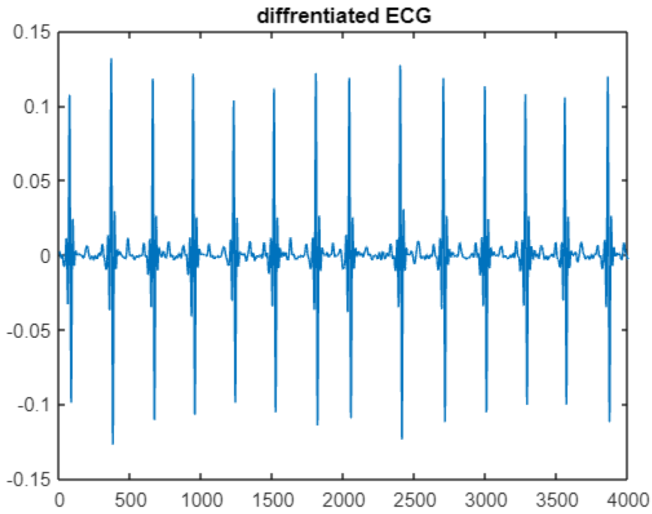
```
moving_avg = filtfilt(ma1, 1, shannon);
plot(moving_avg);
title("manual moving avg")


% Second differentiation
s2 = diff(moving_avg);
plot(s2);
title("first order after moving average")


% Squaring
osqr = s2.^2;
plot(osqr)
title("squaring")


% Second moving average
q = (1/85) * ones(85, 1);
ma2 = filtfilt(q, 1, osqr);


% Find peaks in the second moving average
[pks, locs] = findpeaks(ma2);


% Preallocate the output array
o = zeros(size(locs));


% Find the true R peak in the neighborhood (25 samples) of detected points
for v = 1:numel(locs)
    j = 1;
    search_start = max(locs(v) - 25, 1);
    search_end = min(locs(v) + 25, length(og));
    for i = search_start:search_end
        t(j) = og(i);
        j = j + 1;
    end
    [mag, pos] = max(t);
    o(v) = (pos - 1) + search_start;
end


% Display the final true position of R-peaks
disp('Final true position of R-peaks:')
disp(o);


% Plot ECG R peak locations
g = 1:length(og);
```

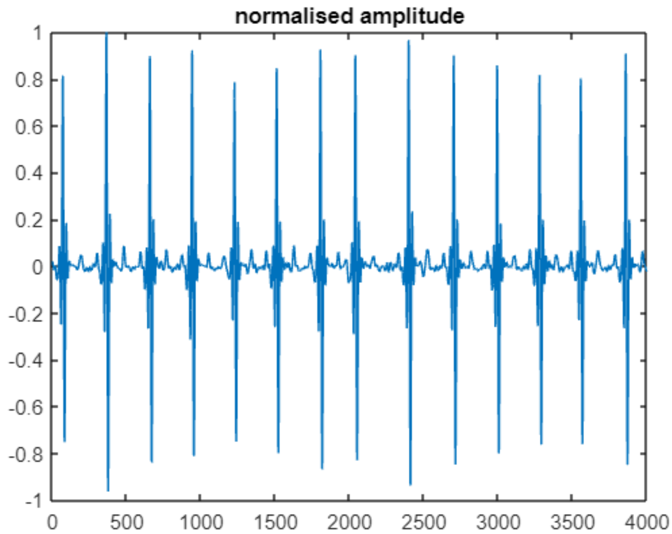
```
figure;
plot(og);
hold on;
stem(g(o), og(o), 'r');
title('ECG True R Peak Locations');
xlabel('Sample');
ylabel('Amplitude');
hold off;
```

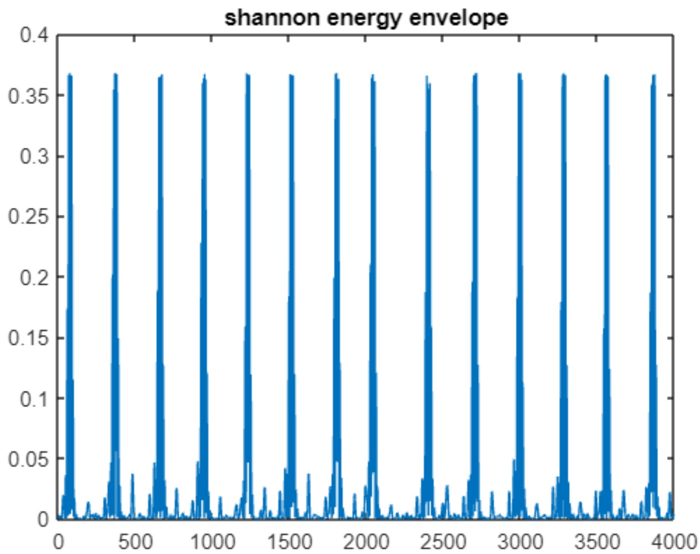
OUTCOMES:

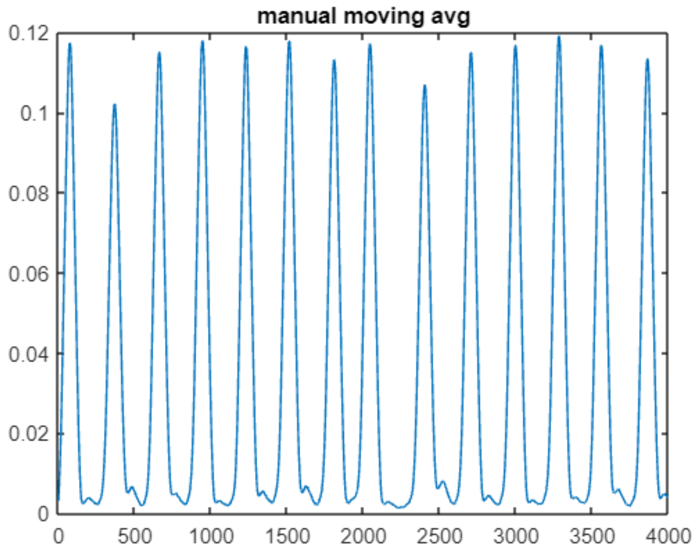


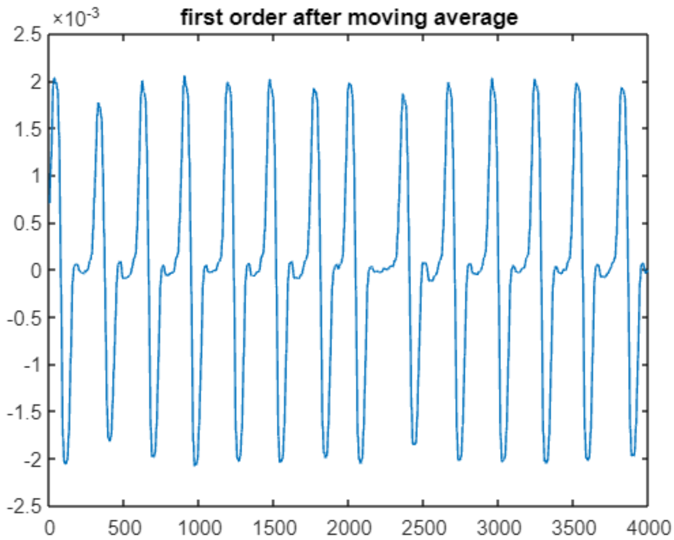


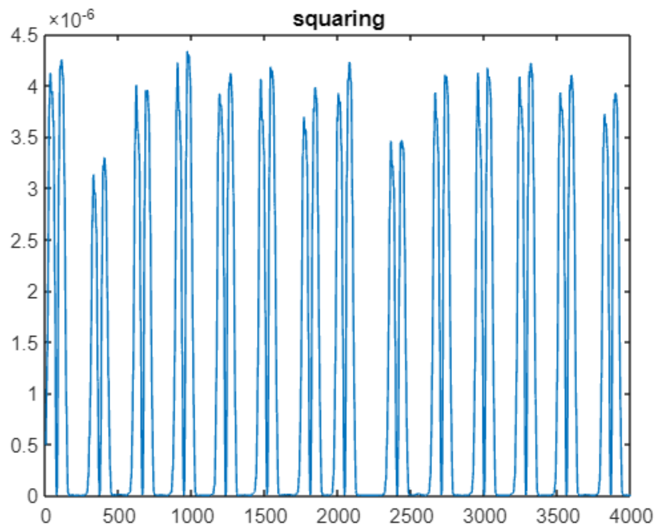

diffrentiated ECG
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
500
1000
1500
2000
2500
3000
3500
4000


normalised amplitude
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
500
1000
1500
2000
2500
3000
3500
4000


shannon energy envelope
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
500
1000
1500
2000
2500
3000
3500
4000

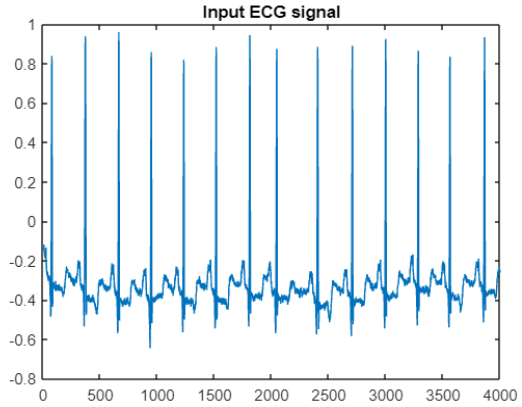

manual moving avg
0.12
0.1
0.08
0.06
0.04
0.02
0
0
500
1000
1500
2000
2500
3000
3500
4000

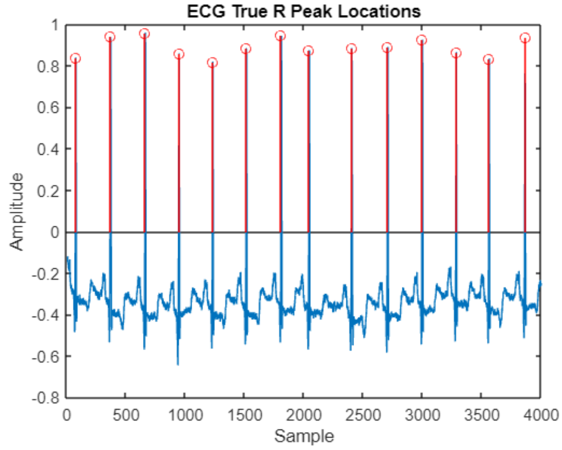

first order after moving average
×10^-3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
500
1000
1500
2000
2500
3000
3500
4000


squaring
×10^-6
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
500
1000
1500
2000
2500
3000
3500
4000

Final true position of R-peaks:

78 371 664 948 1232 1516 1810 2046 2404 2707
2999 3284 3561 3864





CONCLUSION:

Using the Shannon energy envelope idea, the model-assisted in the detection of R Peaks by carefully examining and monitoring each step.