

Signal Quality Indicators for ECG signal

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This code was developed by Miodrag Bolic for the book PERVASIVE CARDIAC AND RESPIRATORY MONITORING DEVICES: <https://github.com/Health-Devices/CARDIAC-RESPIRATORY-MONITORING>

Acknowledgements

This notebook uses modified code written by **Hooman Sedghamiz** to compute fiducial points of the ECG signal. In addition it uses modified ensemble averaging code from [A practical guide to wave intensity analysis](#) by **Kim H. Parker**.

Dependencies: ecg.mat, MTEO_qrst.m, ens_averaging.m

```
% Changing the path from main_folder to a particular chapter
main_path=fileparts(which('Main_Content.mlx'));
if ~isempty(main_path)
    %addpath(append(main_path, '/Chapter2'))
    cd (append(main_path, '/Chapter4/Signal Quality'))
    addpath(append(main_path, '/Service'))
end
SAVE_FLAG=0; % saving the figures in a file
```

Introduction

In this notebook, we are going to load ECG signal that is pretty clear and show the SQI based on 3 metrics:

- Kurtosis
- Spectral power ratio

- Template waveform

The signal is sampled at 2,500 samples per second and it is of high quality.

After that we will add Gaussian noise and impulse noise to the original signal and estimate the quality. Therefore, we will consider 3 cases:

Case 1: High quality ECG signal

Case 2: ECG signal with Gaussian noise and 60 Hz noise

Case 3: Impulse noise and high SNR

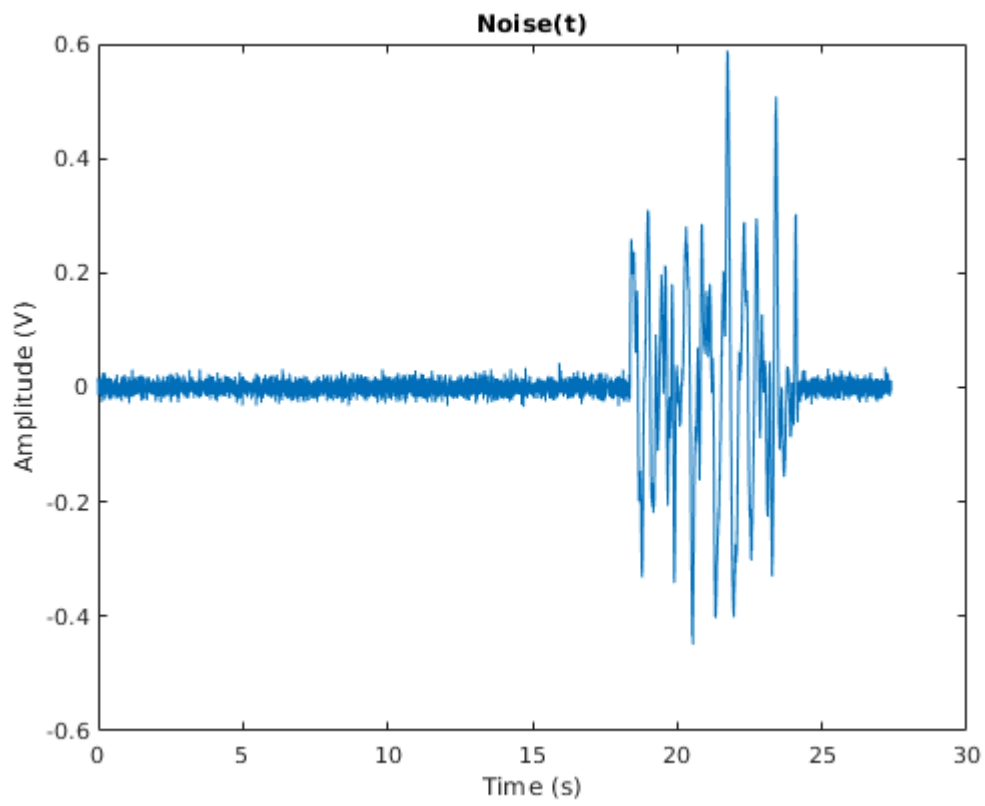
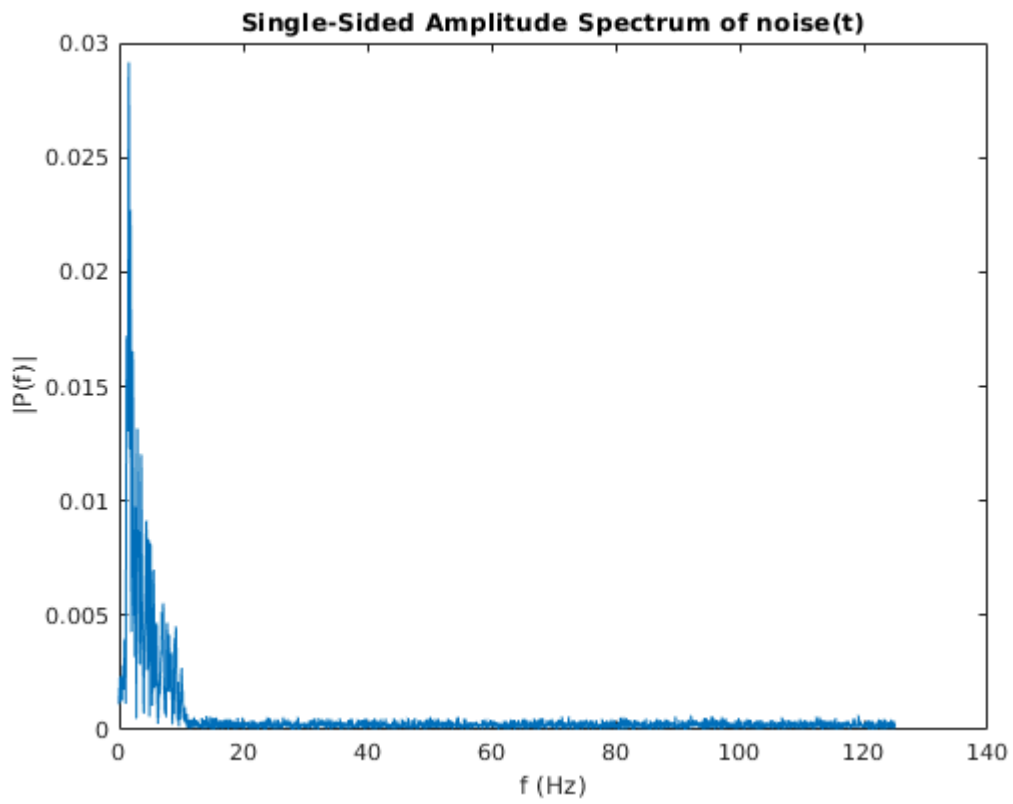
```
case123=3; % modify this number and run simulation for cases 1, 2 and 3
load('ecg.mat')
ratio=10;
ecg = decimate(ecg,ratio);

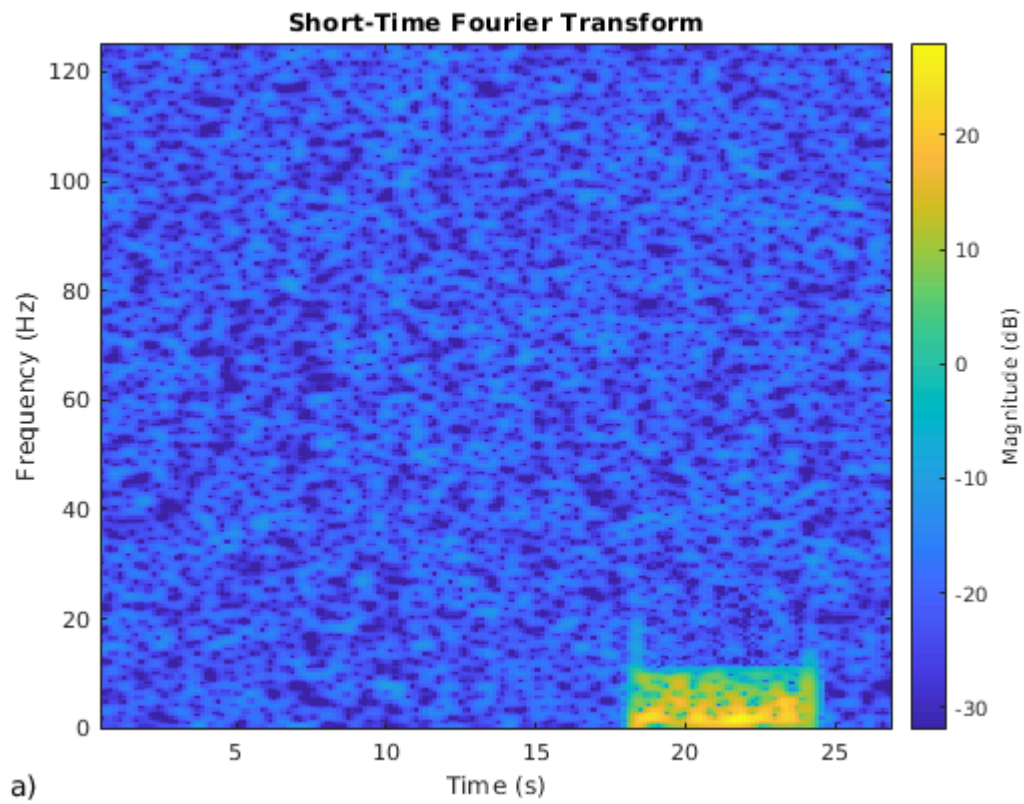
fs=2500/ratio;
N=length(ecg);
T=1/fs;
t = (0:N-1)*T;

if case123 == 1

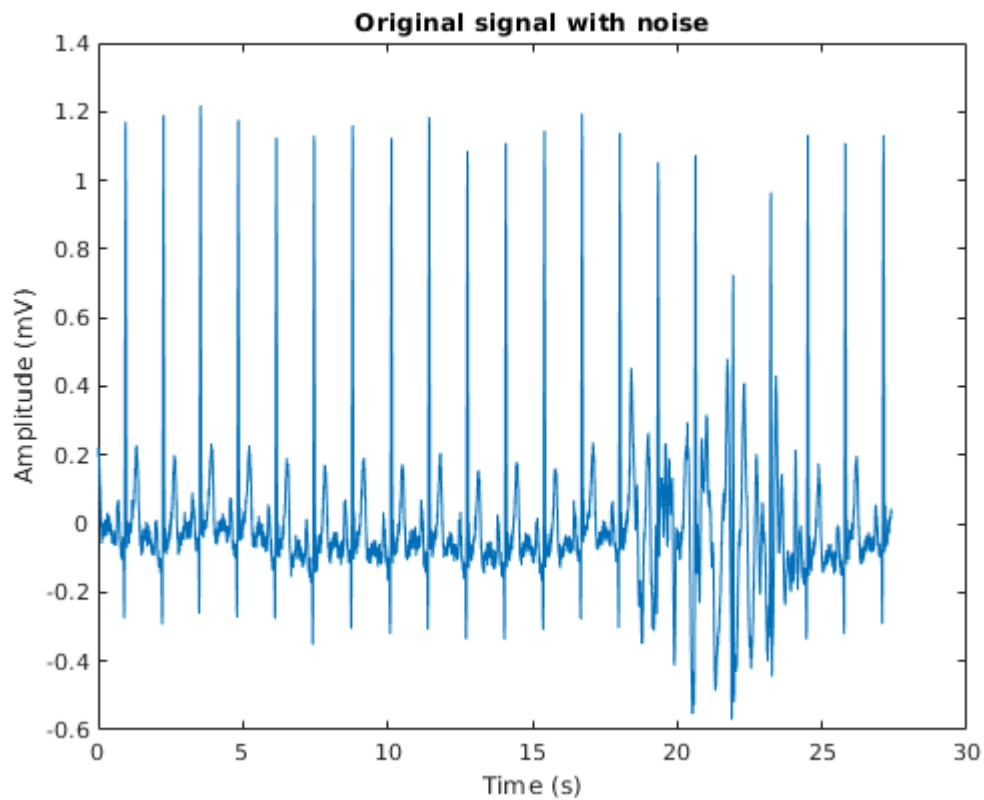
elseif case123 ==2
    noise=additive_noise_model(N, fs, 'Gaussian', [0, 0.1], '60 Hz', [0.1], 'Plotting')
    ecg=ecg+noise;
    snr(ecg,noise)
elseif case123 ==3
    noise=additive_noise_model(N, fs, 'BandLimited Impulse', [2, 1, 10], 'Gaussian', [0.1], 'Plotting')
    ecg=ecg+noise;
    snr(ecg,noise)
end
```

```
ans = 7.1513
```





```
plot(t,ecg);  
title('Original signal with noise')  
xlabel('Time (s)')  
ylabel('Amplitude (mV)')
```



SQI

Kurtosis

Let us compute the kurtosis of the signal:

```
kurt=kurtosis(ecg);
if kurt > 5
    kSQI=1
else
    kSQI=0
end
```

```
kSQI = 1
```

Spectral power ratio

```
% Define frequency ranges of interest for the signal
Fmask_low_sig=5;
Fmask_high_sig=14;
Fmask_low_all=5;
Fmask_high_all=60;

% Compute periodogram
NyquistF = fs/2;
FResBPM = 0.5;
```

```

Nfft = (60*2*NyquistF)/FresBPM; %number of bins in power spectrum
[Pxx,F] = periodogram(ecg,hamming(length(ecg)),Nfft,fs);

% Compute power in the frequency band of the signal of interest
FMask1 = (F >= Fmask_low_sig)&(F <= Fmask_high_sig);
PowerSig = sum(Pxx(FMask1));

% Compute power in the total frequency band
FMask2 = (F >= Fmask_low_all)&(F <= Fmask_high_all);
PowerAll = sum(Pxx(FMask2));

% Compute signal quality indices = ratio of the power in the
PowerRatio=PowerSig/PowerAll;
if PowerRatio < 0.9 && PowerRatio > 0.5
    pSQI=1
else
    pSQI=0
end

```

```
pSQI = 1
```

Template matching

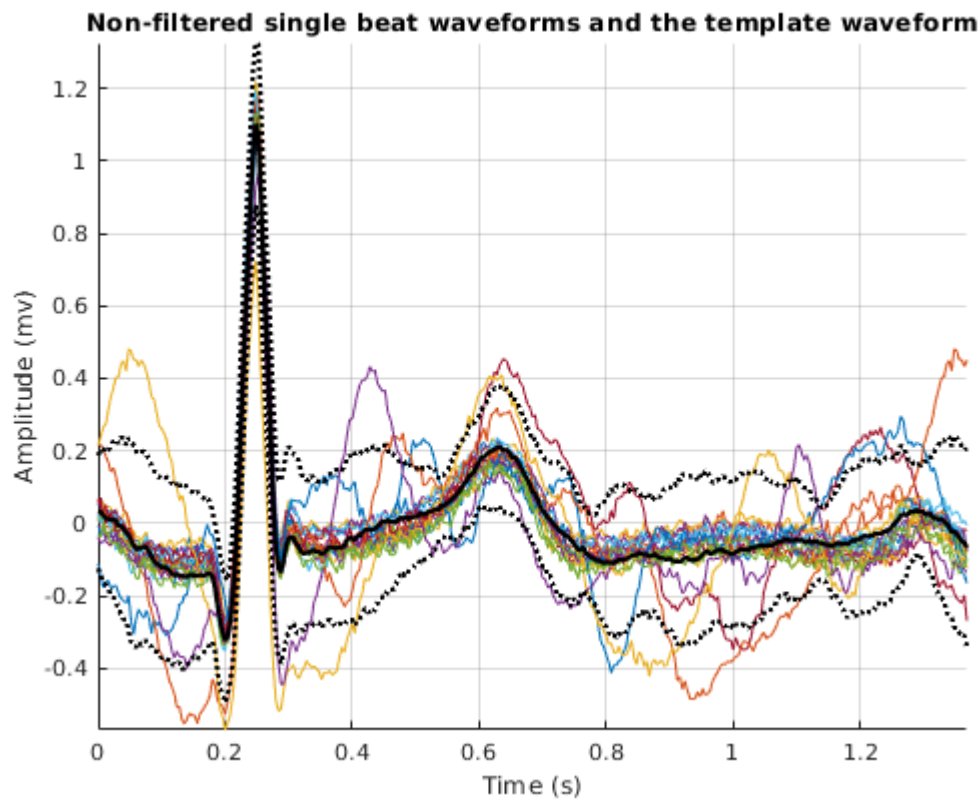
Template matching includes:

1. Filtering the signal
2. Identifying pulses
3. Extracting pulses and averaging them to obtain the template
4. Calculating correlation between each pulse and the template
5. Converting the correlation coefficient into a SQI score

```

%MTEO_qrst find all characteristic waves of ECG and performs low-pass filtering with 15
% R1(:,1) are time instances of R peaks the filtered ecg1 signal while
% R1(:,2) are the amplitudes of the R peaks of the filtered signal ecg1.
[R1,Q,S,T_w,P_w, Te, ecg1] = MTEO_qrst(ecg,fs,0); % steps 1,2
% Ensample average of the non-filtered signal:
[pensavg, penssd, quality, r1]=ens_averaging(ecg, fs, R1(:,1), 1); % steps 3,4,5
title ('Non-filtered single beat waveforms and the template waveform')

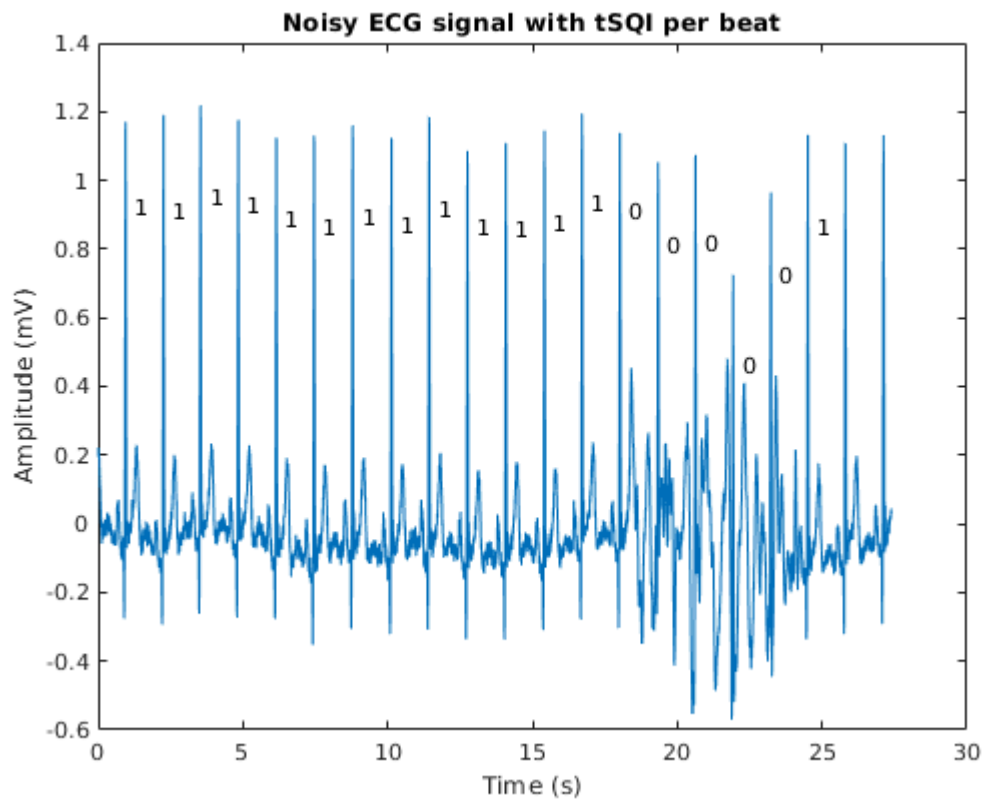
```



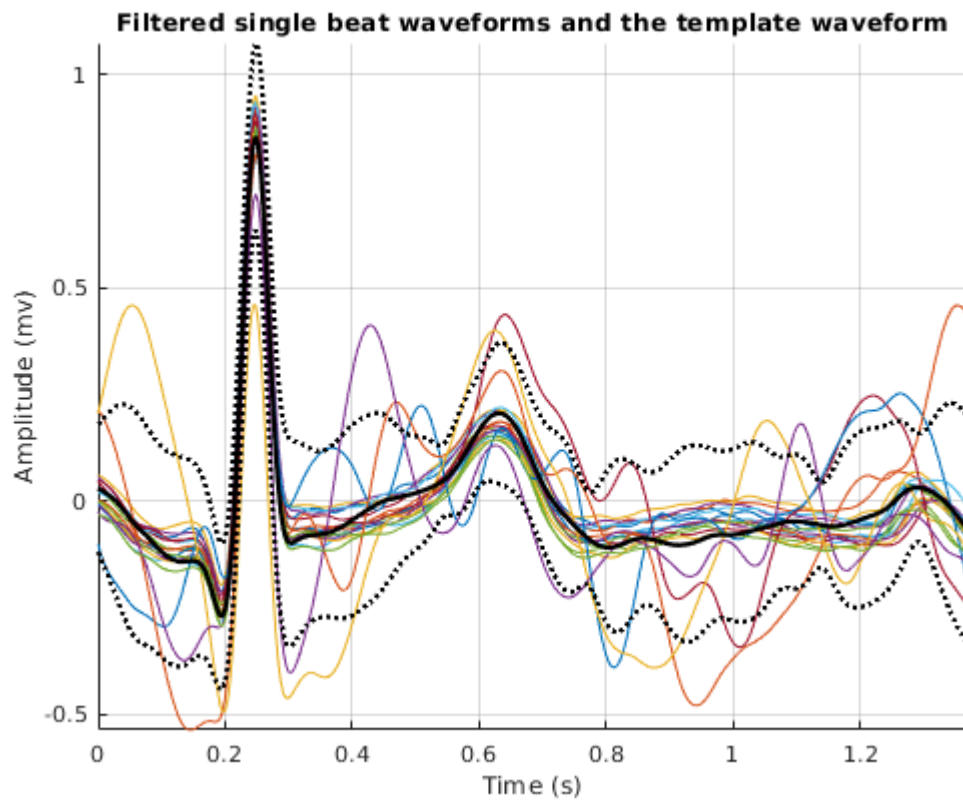
```
DISPL=[ 'No filtering, average corr coef=', num2str(mean (r1))];
disp(DISPL)
```

No filtering, average corr coef=0.91528

```
figure
plot(t,ecg)
hold on
%plot(R1(1:end-1,1)*T,R1(1:end-1,2),'o')
text(R1(1:end-1,1)*T+0.3,R1(1:end-1,2),num2str(quality))
title('Noisy ECG signal with tSQI per beat')
xlabel('Time (s)')
ylabel('Amplitude (mV)')
```



```
% Ensample average of the filtered signal:  
[pensavg, penssd, quality,r2]=ens_averaging(ecg1, fs, R1(:,1), 1);  
title ('Filtered single beat waveforms and the template waveform')
```

```

annnotation_save('b','Fig4.12b.jpg', SAVE_FLAG);
DISPL=['Bandpass filtering, average corr coef=', num2str(mean (r2))];
disp(DISPL)

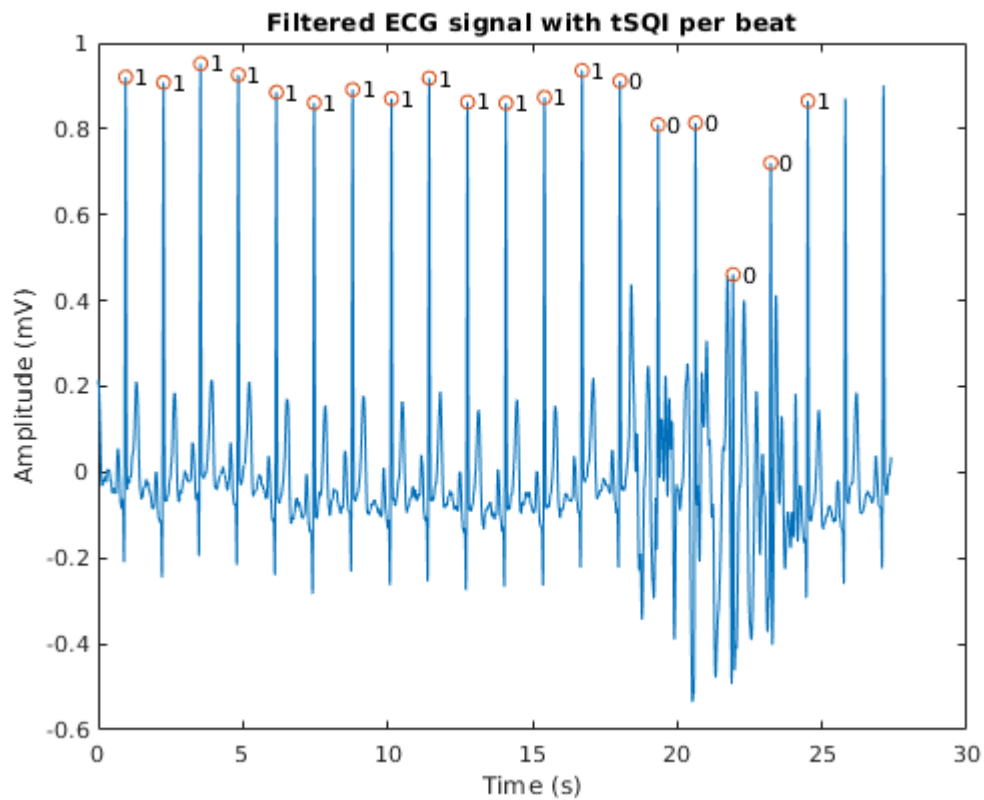
```

Bandpass filtering, average corr coef=0.90861

```

figure
plot(t,ecg1)
hold on
plot(R1(1:end-1,1)*T,R1(1:end-1,2),'o')
text(R1(1:end-1,1)*T+0.3,R1(1:end-1,2),num2str(quality))
title('Filtered ECG signal with tSQI per beat')
xlabel('Time (s)')
ylabel('Amplitude (mV)')

```



```
annotation_save('a') , "Fig4.12a.jpg" , SAVE_FLAG);
```

Exersizes

Excercise 1: repeat the analysis for cases 1, 2 and 3 and comment on the SQI indicators. Modify SNR in lines 14 and 18 to see the effect of noise on the signal quality indicators.

Excercise 2: Analyze effects of baseline drift on the quality indicators. Then filter out the baseline signal and observe the SQI again.