Signal Quality Indicators for breathing 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

Dependencies: files PEX_T1.mat, Free_T1.mat and Irregular_T1.mat. Code: br_rate_est.m

Acknowledgements

```
% 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,'/Chapter9/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 respiratory belt and temperature sensor data and to show the waveforms as well as to compute several signal quality indicators.

Loading breathing data

```
% Loading breathing data obtained after exercize
load('PEX_T1.mat')
```

```matlab
figure
fs=100;
lim=105*fs:115*fs;
t=1/fs:1/fs:length(mp36_s(1,:))/fs;
[m,i_max]=findpeaks(mp36_s(4,lim));
[m,i_min]=findpeaks(-mp36_s(4,lim));
i_all=[i_min,i_max];
%plot(t/60,mp36_s(1,:))
subplot(211)
hold on
plot(t(lim)-t(lim(1)),smooth(mp36_s(2,lim),25))
for i=1:length(i_all)
    plot([i_all(i)/fs, i_all(i)/fs],ylim.*ones(1,2),'b')
end
hold off
text(i_min/fs,-1*ones(1,length(i_min)),'Expiration')
text(i_max(1:end-1)/fs,ones(1,length(i_max(1:end-1))),'Inspiration')

xlabel('Time(s)')
ylabel('Amplitude(mV)')
title('Breathing signal from the respiratory belt')
subplot(212)
hold on
plot(t(lim)-t(lim(1)),mp36_s(4,lim))
xlabel('Time(s)')
ylabel('\DeltaT (degrees)')
title('Breathing signal from the temperature sensor')
for i=1:length(i_all)
    plot([i_all(i)/fs, i_all(i)/fs],ylim.*ones(1,2),'b')
end
hold off
exportgraphics(gcf,"Fig9.3.jpg", 'Resolution',600)
```

Breathing signal from the respiratory belt

Breathing signal from the temperature sensor
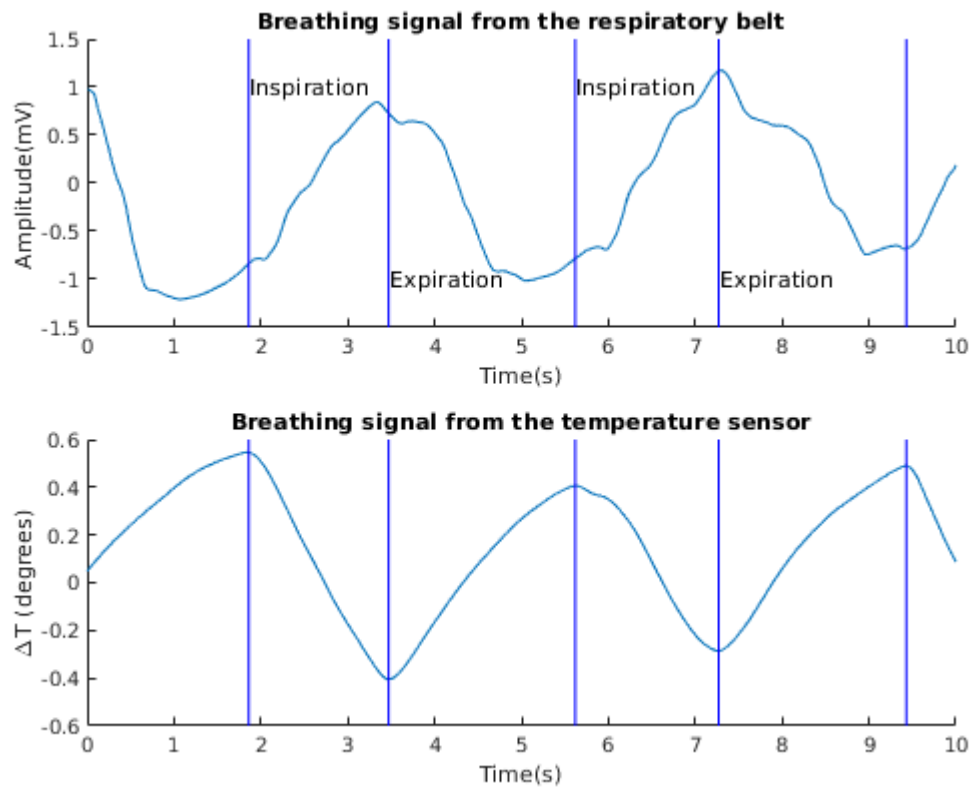
```
%text(i_min/fs,ylim*ones(1,length(i_min)),'expiration')
%text(i_max/fs,-ylim*ones(1,length(i_max)),'inspiration')
```

SQI

Loading signal after exercise

```
load('PEX_T1.mat')
%load('Free_T1.mat')
t=1/fs:1/fs:length(mp36_s(1,:))/fs;
```

```
resp=mp36_s(4,:);
% Define frequency ranges of interest fot the signal
Fmask_low_sig=br_rate_est(resp',fs)/60-0.1;
Fmask_high_sig=br_rate_est(resp',fs)/60+0.1;
Fmask_low_all=0.05;
Fmask_high_all=1;

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

```matlab
FResBPM = 0.5;
Nfft = (60*2*NyquistF)/FResBPM; %number of bins in power spectrum
[Pxx,F] = periodogram(resp,hamming(length(resp)),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
```
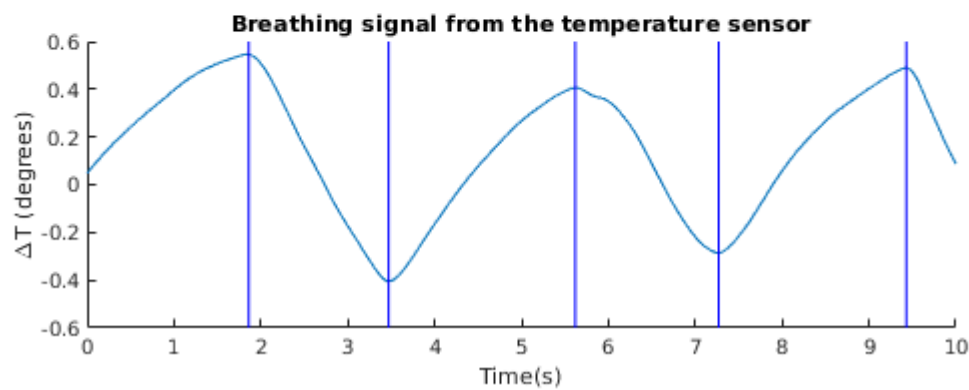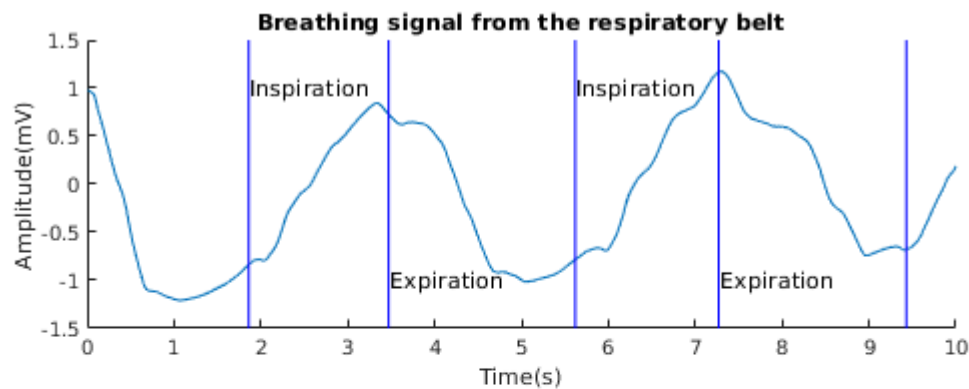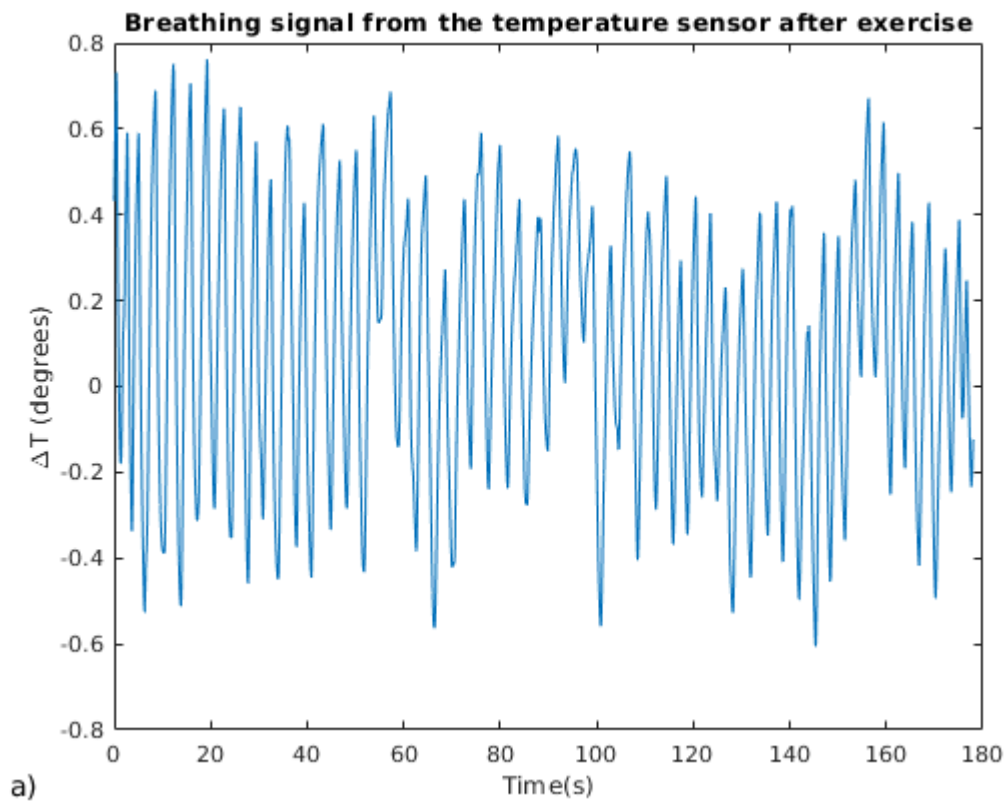
pSQI = 1

```matlab
figure
% subplot(211)
% plot(t,mp36_s(2,:))
% xlabel('Time(s)')
% ylabel('Amplitude(mV)')
% title('Signal from respiratory belt')

plot(t,mp36_s(4,:))
xlabel('Time(s)')
ylabel('\DeltaT (degrees)')
title('Breathing signal from the temperature sensor after exercise')
annonation_save('a)',"Fig9.4a.jpg", SAVE_FLAG);
```
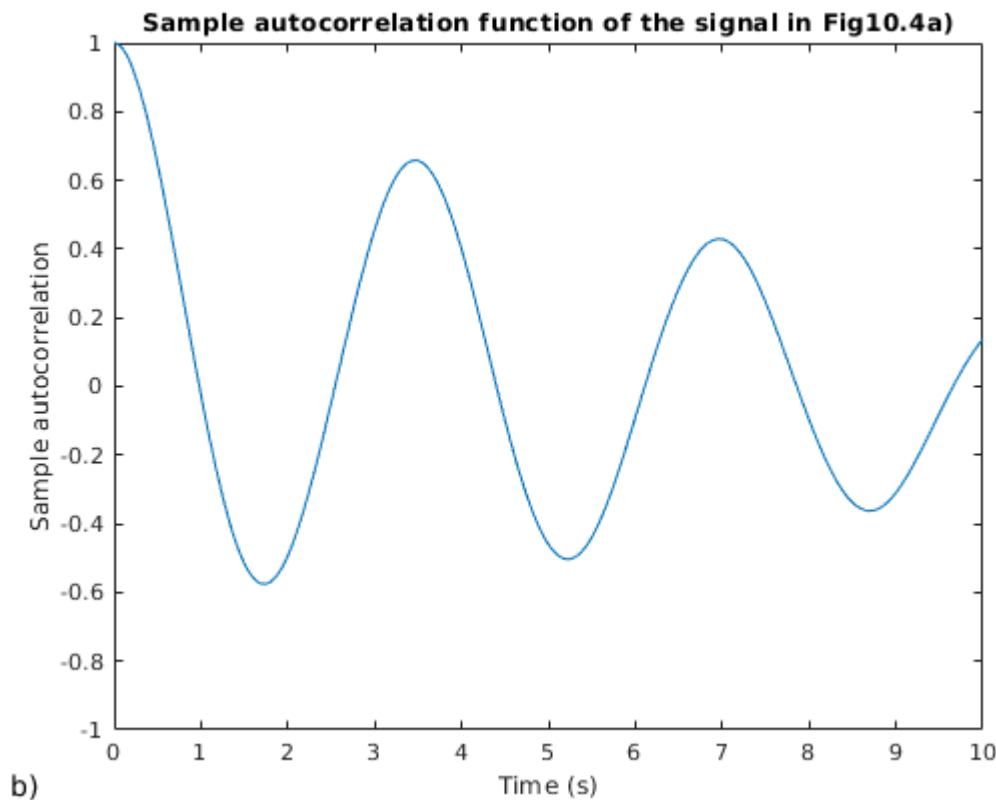
a)


```
figure
[normalizedACF, lags] = autocorr(resp, 'NumLags',1000,'NumSTD',2);
plot(lags/fs,normalizedACF)
```

```
xlabel('Time (s)')
ylabel('Sample autocorrelation')
title('Sample autocorrelation function of the signal in Fig9.4a)')
ylim([-1,1])
annonation_save('b)',"Fig9.4b.jpg", SAVE_FLAG);
```


b)

Loading irregular breathing signal

```
load('Irregular_T1.mat')
t=1/fs:1/fs:length(mp36_s(1,:))/fs;
```

```
resp=mp36_s(4,:);
% Define frequency ranges of interest fot the signal
Fmask_low_sig=br_rate_est(resp',fs)/60-0.1;
Fmask_high_sig=br_rate_est(resp',fs)/60+0.1;
Fmask_low_all=0.05;
Fmask_high_all=1;

% Compute periodogram
NyquistF = fs/2;
FResBPM = 0.5;
Nfft = (60*2*NyquistF)/FResBPM; %number of bins in power spectrum
[Pxx,F] = periodogram(resp,hamming(length(resp)),Nfft,fs);

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

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```
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
```
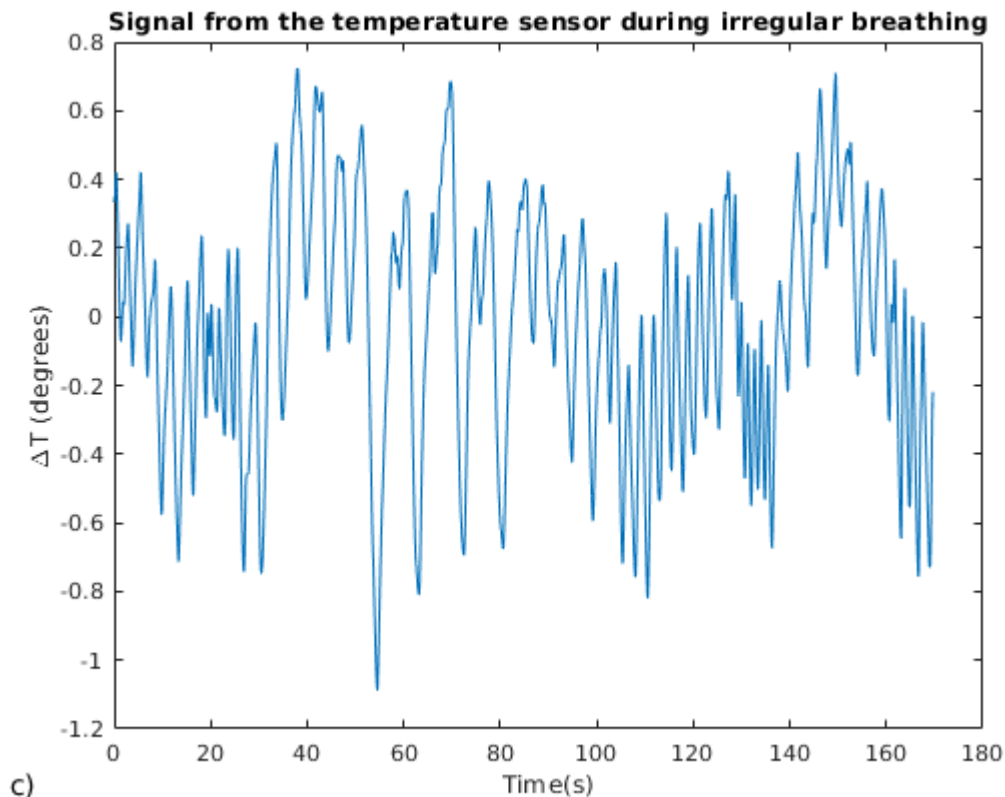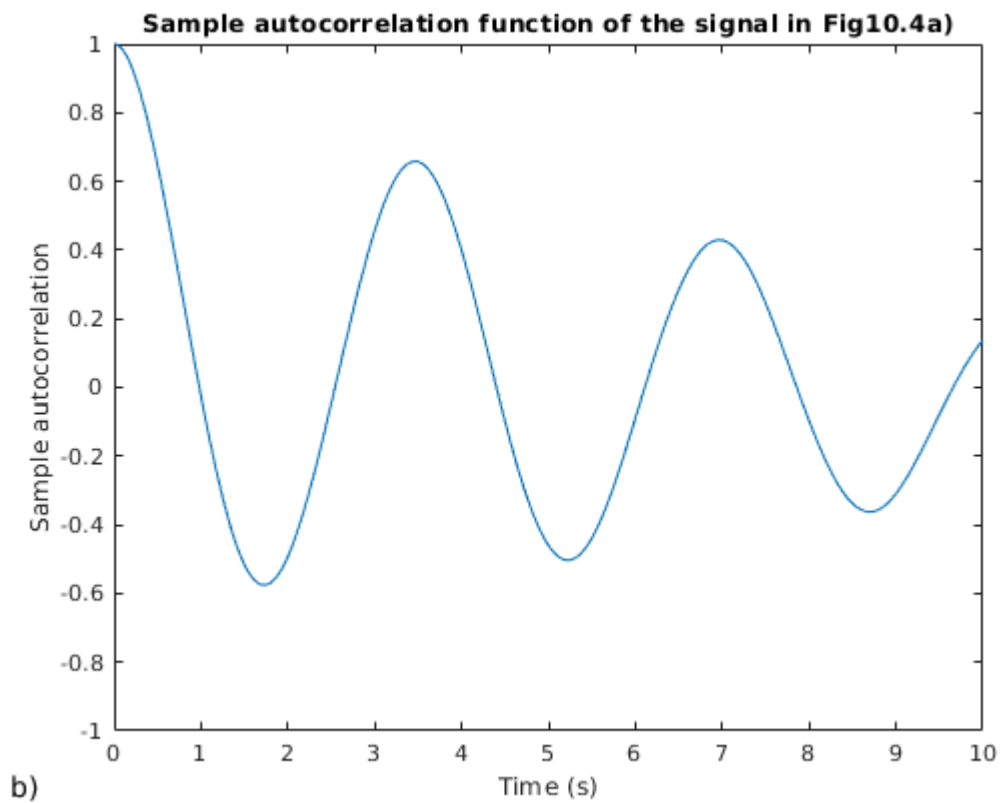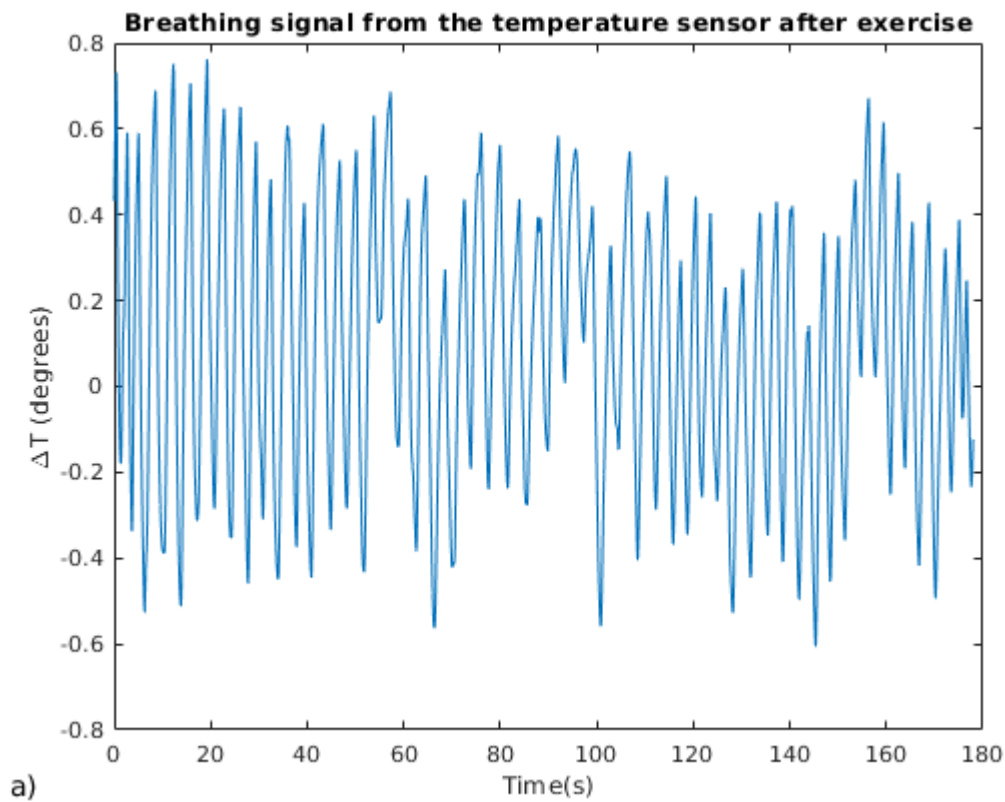
pSQI = 0

```
figure
% subplot(211)
% plot(t,mp36_s(2,:))
% xlabel('Time(s)')
% ylabel('Amplitude(mV)')
% title('Signal from respiratory belt')

plot(t,mp36_s(4,:))
xlabel('Time(s)')
ylabel('\DeltaT (degrees)')
title('Signal from the temperature sensor during irregular breathing')
annonation_save('c)',"Fig9.4c.jpg", SAVE_FLAG);
```


c)

Breathing signal from the temperature sensor after exercise

a)

Sample autocorrelation function of the signal in Fig10.4a)
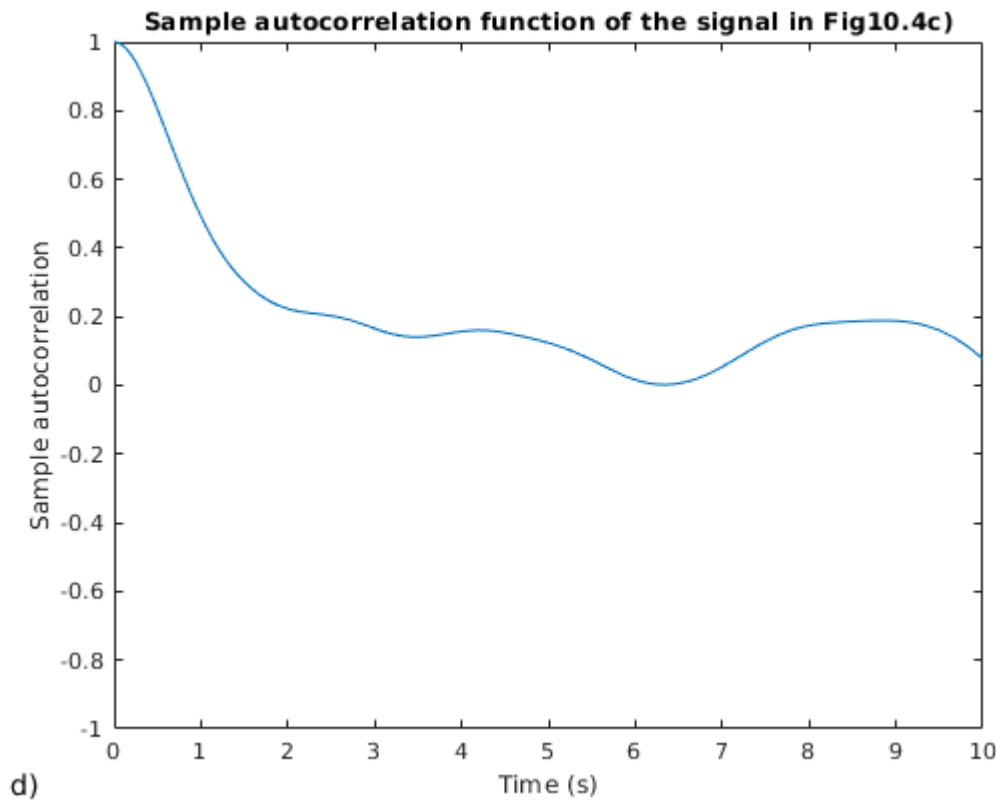
b)

```
figure
[normalizedACF, lags] = autocorr(resp, 'NumLags',1000,'NumSTD',2);
plot(lags/fs,normalizedACF)
xlabel('Time (s)')
```

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```
ylabel('Sample autocorrelation')
title('Sample autocorrelation function of the signal in Fig9.4c)')
ylim([-1,1])
annonation_save('d)',"Fig9.4d.jpg", SAVE_FLAG);
```


d)

Exersizes

Excersize 1: Show ACF for cases when respiratory belt waveform is selected instead of thermal sensor waveform.

Excersize 2: Instead of loading waveform obtained after exercise from the file 'PEX_T1.mat', load the waveform 'Free_T1.mat' that corresponds to the free breathing signal. Compute PowerRatio and show ACF. Why is the quality lower than in the case of the waveform after exercise?

Excersize 3: How does the length of the signal affects the PowerRatio and ACF. Reduce signals to 60 sec.