From Fourier Series to Analysis of Non-stationary Signals – XI

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Transforms

- Fourier transform gives the spectrum of the whole time-series
- Which is OK if the time-series is stationary. But what if it is not?
- We need a technique that can march along a time-series and analyse spectral content in different time instants.
- (a) Short Time Fourier Transform, (b) Wavelet Transform

STFT and Non-Stationary Signal

1. Remove the mean of a signal
2. Perform moving average filtering
3. Do segmentation of a signal using window functions
4. Perform Fourier transform
5. Do not forget the interpolation

Moving Average Filtering

- Assume we have a signal corrupted with noise
- Find the mean
- Set the mean to zero (subtract)
- Apply moving average filter to the noisy signal
    - use filter order=3 and 5)
    - The higher filter order will remove more noise, but it will also distort the signal more (i.e. remove the signal parts also)
    - So, a compromise has to be found (normally by trial and error)

Examples and MATLAB project

Example 1: Digital filtering with classical filters

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1. Load the EEG signal
2. Remove the mean
3. Design LP (lowpass)digital filter which can remove higher frequencies
4. Use MATLAB commands for filtering the signal
5. Compare original signal with filtered
6. Perform spectrogram to the output of the filter

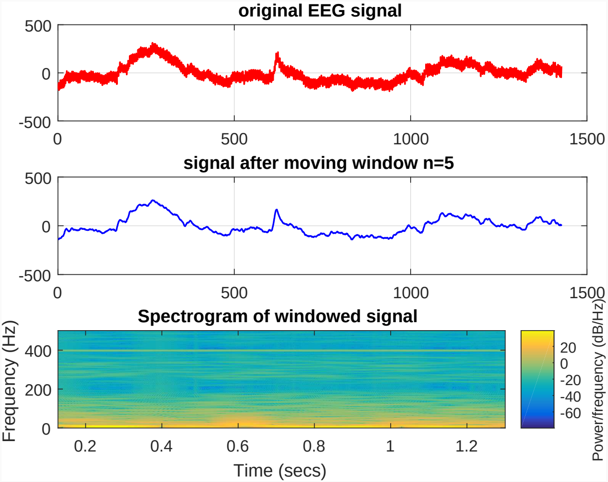
Example 1: Use digital LP filter

```
% Digital filtering
clear all
load('zdroj.mat');
signal=EEG(3).Data(:,1);
x=signal-mean(signal);
% cut of frequency
wn=30/50;
% degree
n=7;
% design elliptic filter
[b,a]=ellip(n,0.5,40,wn);
% find filter output
x2 = filter(b,a,x);
```

Average filtering

1. Load the EEG signal
2. Remove the mean of a signal
3. Make moving average filtering
4. Perform spectrogram to the averaged signal

EEG signal after averaging



Moving average filtering

- We can study the quality of averaging
- Apply moving average filter to the noisy signal (use filter order=3 and 5)
- The higher filter order will remove more noise, but it will also distort the signal more (i.e. remove the signal parts also)
- So, a compromise has to be found (normally by trial and error)

Example 2: Moving average filtering

```
% moving average filtering
clear all
load('zdroj.mat');
signal = EEG(3).Data(:,1);
N = length(x);
x = signal - mean(signal);
% length of average window is 3
for i=1:N-2,
y3(i)=(x(i)+x(i+1)+x(i+2))/3;
end
y3(N-1)=(x(N-1)+x(N))/3;
y3(N)=x(N)/3;
% length of average window is 5
for i=1:N-4,
y5(i)=(x(i)+x(i+1)+x(i+2)+x(i+3)+x(i+4))/5;
```

Example 2: Moving average filtering

```
y5(N-3)=(x(N-3)+x(N-2)+x(N-1)+x(N))/5;
y5(N-2)=(x(N-2)+x(N-1)+x(N))/5;
y5(N-1)=(x(N-1)+x(N))/5;
y5(N)=x(N)/5;
subplot(3,1,1), plot(x,'r');
title('original␣EEG')
subplot(3,1,2), plot(y3,'g');
title('EEG␣signal␣with␣averaging␣of␣length␣3')
subplot(3,1,3), plot(y5,'b');
title('EEG␣signal␣with␣averaging␣of␣length␣5')
print -depsc figureEEG
```

Example 2: Moving average filtering

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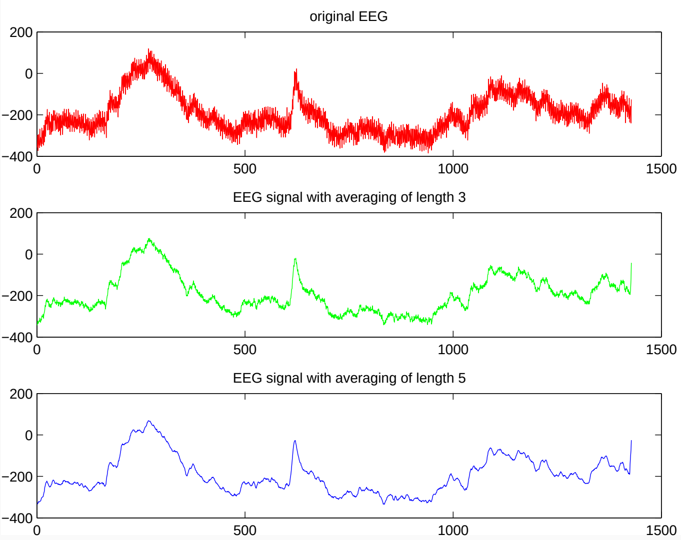

Example 3: Denoising the EEG with wavelets

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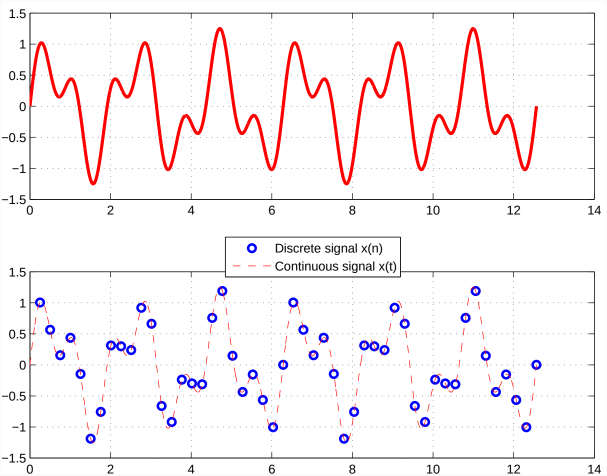
1. Load the EEG signal
2. Remove the mean
3. Perform the approximation of the signal by wavelet transform
4. Use MATLAB commands to find approximation of a noisy EEG signal
5. Compare original signal with approximation
6. Perform spectrogram to the approximated of the filter

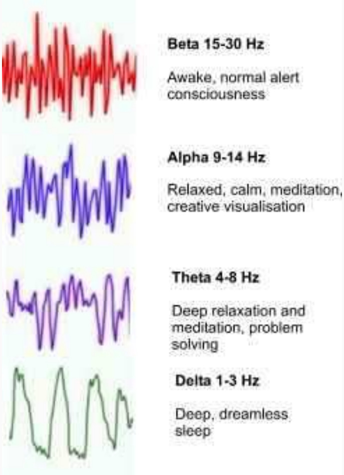
Example 3: Denoising the EEG

```
clear all
load('zdroj.mat');
signal=EEG(3).Data(:,1);
x=signal-mean(signal);
namea='dmey' ;
% Perform decomposition at level 2 of x using
dmey
[c,m] = wavedec(x,2,namea);
% Extract approximation coefficients from
wavelet decomposition structure [c,m].
ca3 = appcoef(c,m,namea,2);
% Reconstruct approximation from wavelet
decomposition structure [c,m].
a2 = wrcoef('a',c,m,namea,2) ;
% Perform the spectrogram of approximated
```

Approximated EEG signal using wavelet transform



Some preliminary info about EEG



Brain waves within 0-30 Hz

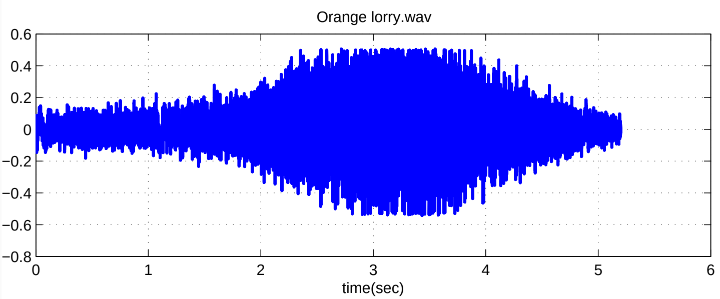
Homework

Homework 6 – DTMF

1. Load the audio signal `dtmf3.vaw` containing noisy DTMF audio signal with additional signals that corrupt the DTMF information.
2. Filter out as much of the noise as you are able to.
3. Demonstrate the original and "cleaned" version of the signal on their respective spectrograms.
4. Decode the DTMF information and write down the numbers (and possibly other symbols) that are being transmitted.

Final MATLAB project

A lorry passing in front of a microphone



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- In order to consult your noise measurement and compiling the final project, we will meet after 20SK lecture every Monday until the end of the winter term. Do not hesitate to contact me any time later.
- I suggest to deliver your project on transportation-related signal analysis by February 17, 2020.
- Expect up to 6 weeks for evaluation (11MAT block, my off-house duties)
- Merry Christmas!