EXERCISES – BIOLOGICAL SIGNALS

Exercise 11 - SS 2014 – Michel Kana

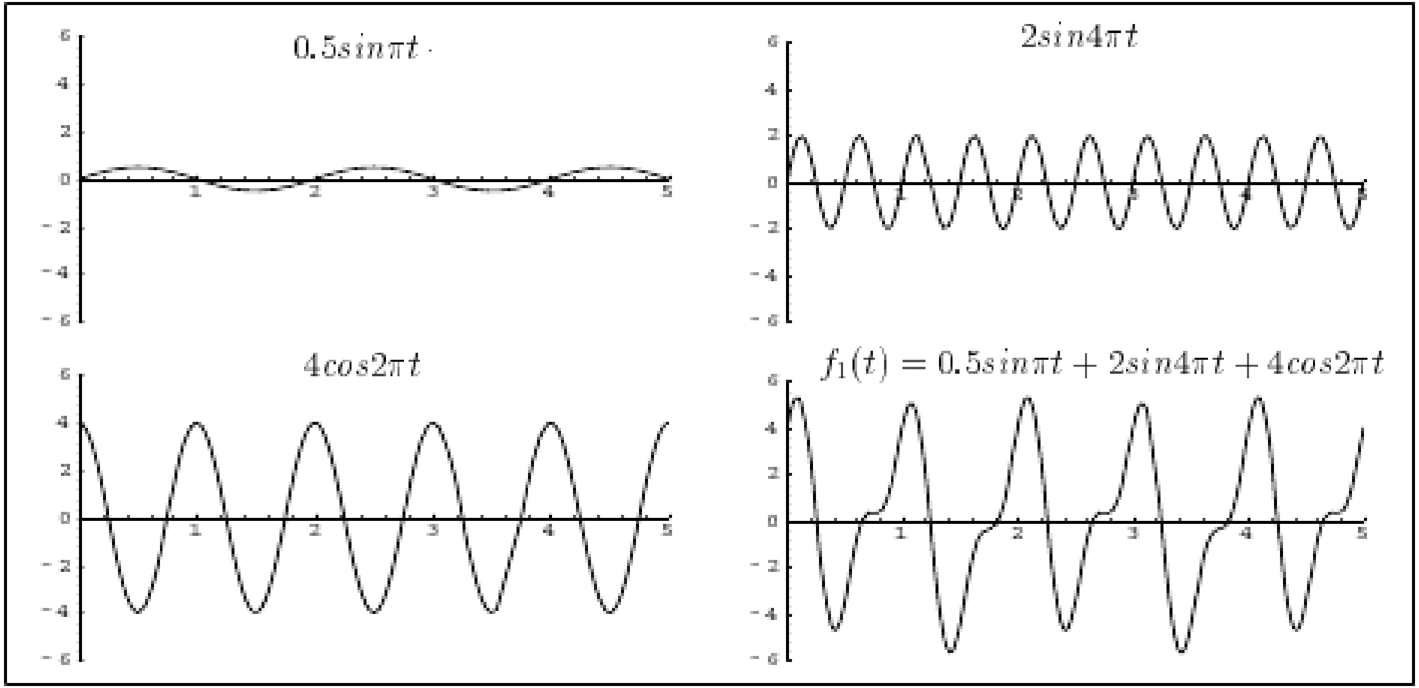
What will we do today?

1. **Introduction to Fourier Transform**
2. **Heart rate variability with Fast Fourier Transform**
3. **Introduction to Wavelet Transform**
4. **Heart rate variability with Wavelet Transform**
5. **Summary**

The Fourier Transform

- The Fourier transform is a mathematical transformation of a signal from a function of time into a function of frequency.
- Any continuous, periodic function can be represented as a linear combination of sines and cosines: $f(t) = \sum(A_k cos(2\pi\omega_k t) + B_k sin(2\pi\omega_k t)) \cdot$
- A_k, B_k are the Cosine and Sine amplitudes. ω_k are the frequencies.
- It is used to obtain the magnitude of frequency components.
- The Fast Fourier Transform is a quick algorithm for computing the Fourier transform directly from data.

The Fourier Transform



k	Frequency (ω_k)	Cosine Amplitude (A_k)	Sine Amplitude (B_k)
1	1/2	0	1/2
2	2	0	2
3	1	4	0

The Fourier Transform in Matlab

Consider the following data x with two component frequencies components and noise

Sample frequency (Hz)

10 sec sample

```
fs = 100;
t = 0:1/fs:10-1/fs;
x = (1.3)*sin(2*pi*15*t) +  (1.7)*sin(2*pi*40*(t-2)) + 2.5*gallery('normaldata',size(t),4);
```

15 Hz component

40 Hz component

Gaussian noise

The Fourier Transform in Matlab

Use **fft** to compute the discrete Fourier Transform and its power.

Window length

Transform length

```
m = length(x);
n = pow2(nextpow2(m));
y = fft(x,n);
f = (0:n-1)*(fs/n);
power = y.*conj(y)/n;
```

Discrete Fourier Transform

Frequency range

Power of the DFT

nextpow2 finds the exponent of the next power of two greater than or equal to the window length (ceil(log2(m)))
pow2 computes the power. Using a power of two for the transform length optimizes the FFT algorithm

The Fourier Transform in Matlab

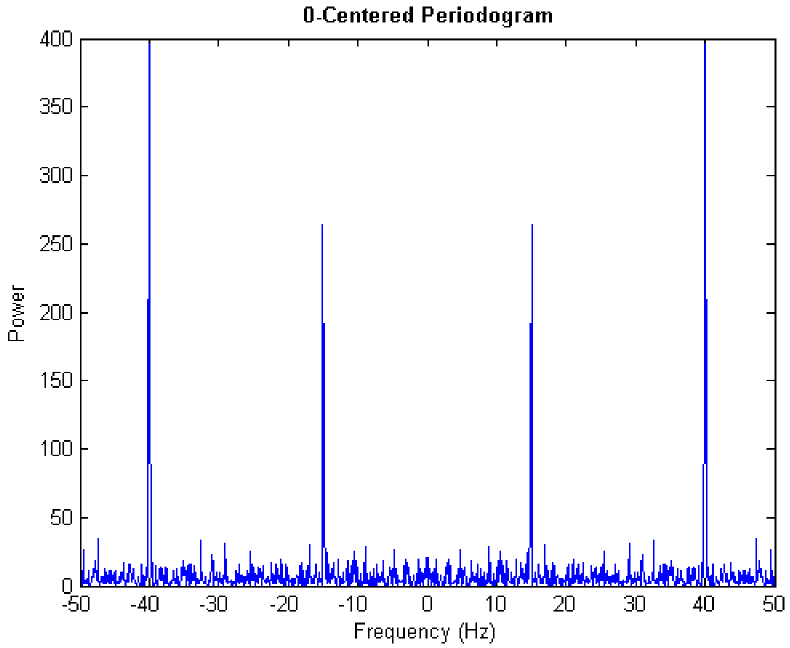
A plot of power versus frequency is called a *periodogram*

Rearrange y values

0-centered frequency range

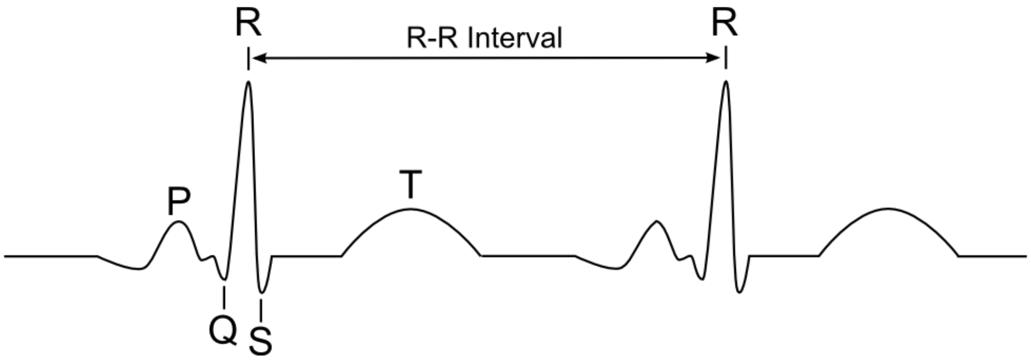
```
y0 = fftshift(y);
f0 = (-n/2:n/2-1)*(fs/n);
power0 = y0.*conj(y0)/n;
plot(f0,power0)
xlabel('Frequency (Hz)')
ylabel('Power')
title('{\bf Periodogram}')
```

0-centered frequency range



Heart Rate Variability

- There are physiological rhythms in the beat-to-beat heart rate signal (series of intervals between adjacent QRS complexes).



845	745	812	732

Exercice 1: RR Interval measurement with BIOPAC

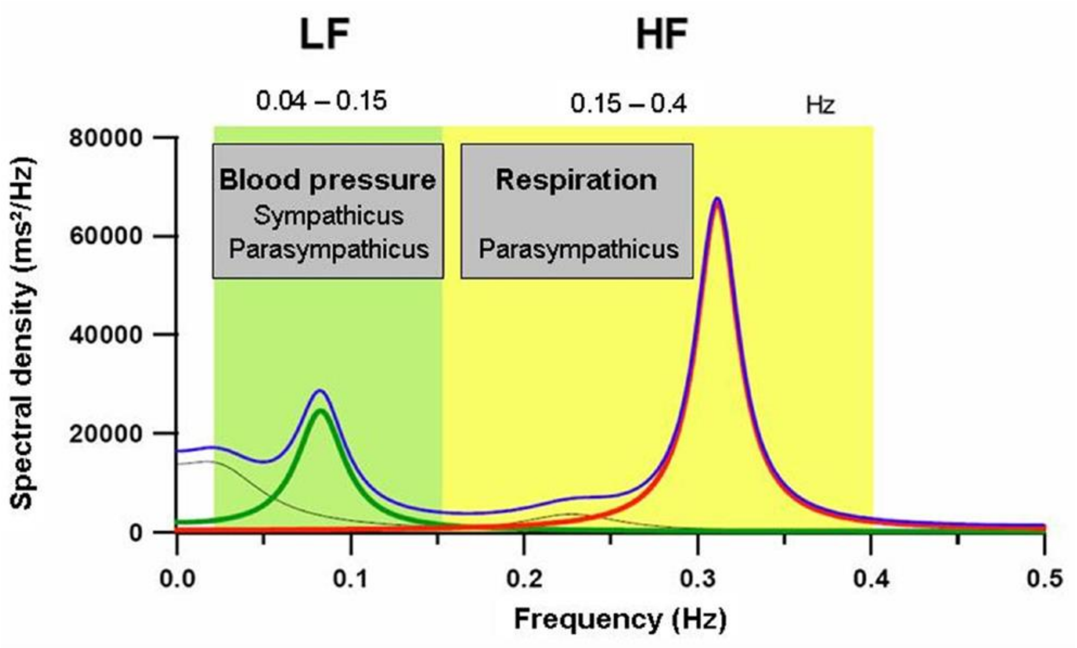
- **Biopac MP35 measurement system**
  - ECG is recorded using Biopac SS2L wires plugged in the first channel.
- **Biopac Student Lab PRO software**
  - The acquisition is set up at a sampling rate of *200 Hz*.
  - Analog Channel CH1 should have the preset ECG (.5 - 35 Hz).
  - Calculation Channel C1 should have the preset ECG – RR Interval

Heart Rate Variability

- Analysis of HRV is usually studied in frequency domain by converting RR intervals signal to frequency components using Fast Fourier Transform.

The spectral values for HRV can be calculated for frequency bands:

- **very low** (VLF: 0-0.04 Hz)
- **low** (LF: 0.04–0.15 Hz)
- **high** (HF: 0.15–0.4 Hz).



Heart Rate Variability

- Low frequency oscillations are considered to be mediated by **combined sympathetic and parasympathetic** activity at rest while there is a predominance of sympathetic activity during stressful conditions
- High frequency heart rate oscillations are associated with respiratory sinus arrhythmia and reflect **parasympathetic activity**
- Very low frequencies are considered to be linked to the renin-angiotensin system, endothelial factors and thermoregulation.

Heart Rate Variability with Matlab

- Importing RR intervals from Biopac into Matlab
  - File -> Save as text

Window length

Transform length

```
fs = 4;
x = resample (RR, 4, 200)
m = length(x);
n = pow2(nextpow2(m));
y = fft(x,n);
f = (0:n-1)*(fs/n);
power = y.*conj(y)/n;
```

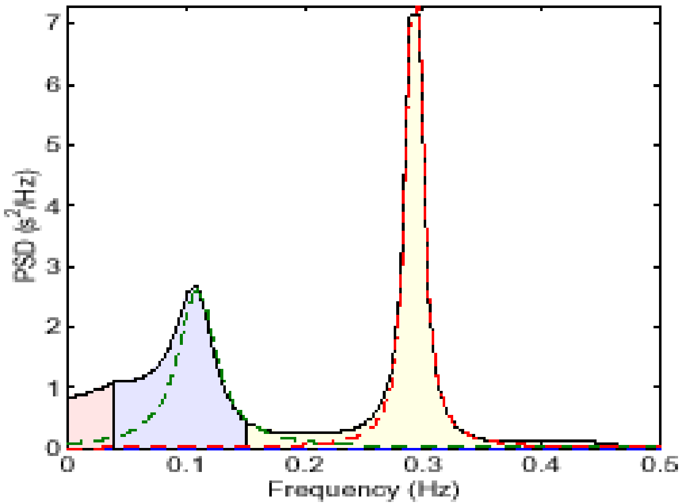
Discrete Fourier Transform

Frequency range

Power of the DFT

Heart Rate Variability with Matlab

```
y0 = fftshift(y);
f0 = (-n/2:n/2-1)*(fs/n);
power0 = y0.*conj(y0)/n;
start = round((0.04*length(y0))/fs);
end = round((0.5*length(y0))/fs);
plot(f0(start:end),power0(start:end))
xlabel('Frequency (Hz)')
ylabel('Power')
title('{\bf Periodogram}')
```



Exercice 2: HRV during deep breathe test

- **Procedure**
  - Subject is instrumented for ECG measurement with Biopac.
  - Perform a 1 min recording under resting conditions.
  - Perform another 1 min recording while the subject breathes at a rate of 6 respiration cycles per minute: 5 seconds for each inhalation and 5 seconds for each exhalation.
- **Evaluation**
  - Estimate the total power of each frequency band (VLF, LF and HF) using the Integral measurement tool.
    - Calculate the percentage change in the power of HF component before and during the test
    - Find the subject with the greatest change in parasympathetic activity

Exercice 3: HRV during physical exercise

- **Procedure**
  - Subject is instrumented for ECG measurement with Biopac.
  - Perform a 1 min recording in a lying position.
  - Perform another 3 min recording while the subject is performing a pedaling exercise. Both legs are suspended in the air and pedaling movements are executed.

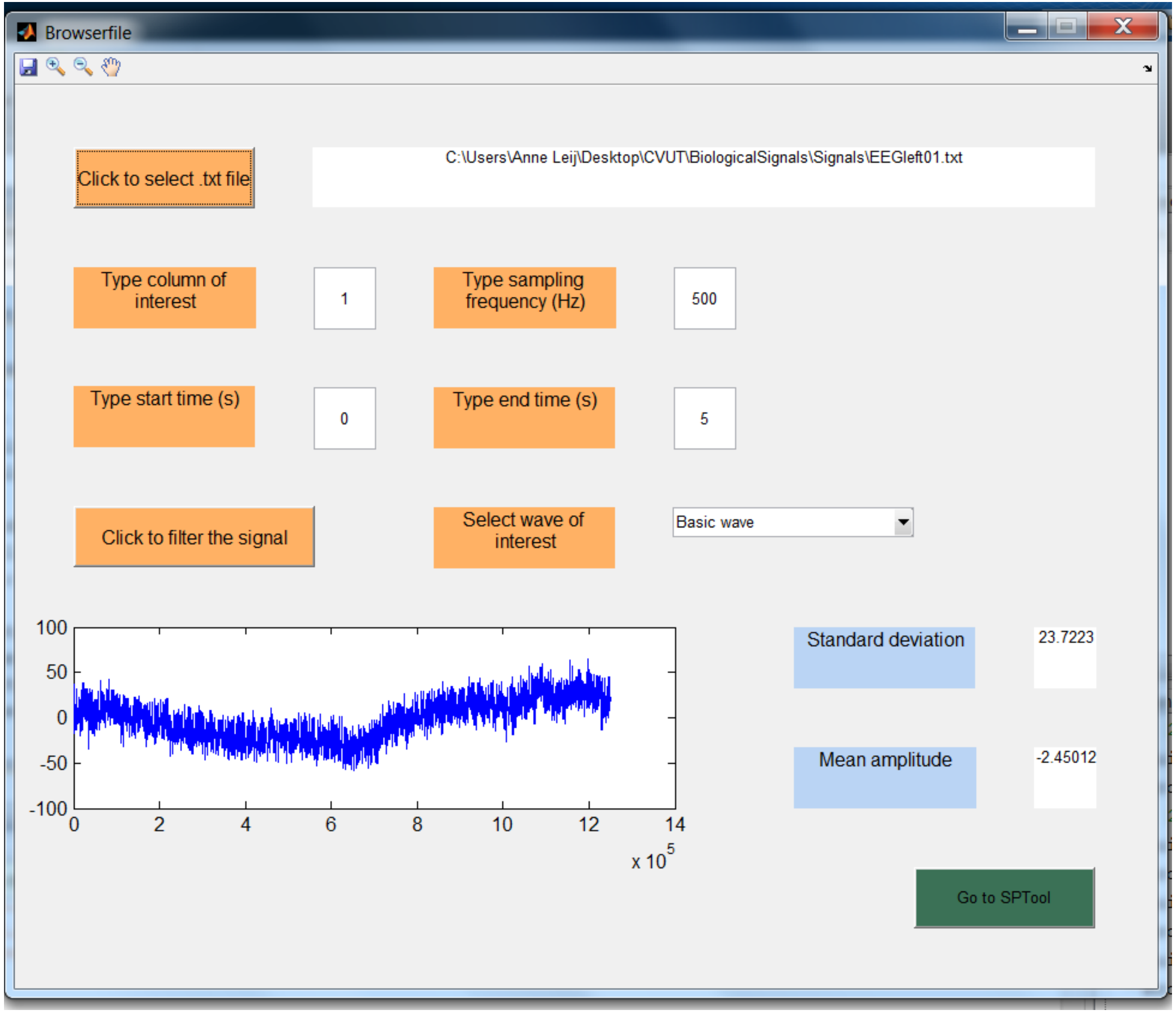
- **Evaluation**
  - Estimate the total power of each frequency band (VLF, LF and HF) using the Integral measurement tool.
    - Calculate the percentage change in the power of LF component before and during the test
    - Find the subject with the greatest change in sympathetic activity

Team Projects

- **Project 1: Cardiovascular Signal Analyzer**
  - Digital filtering of a raw PPG signal
  - Extraction of PH (pulse height) and PP (peak-to-peak) values from a filtered PPG signal
  - MAP estimation using PH
  - Fourier transform of PP intervals and estimation of HF and LF
  - Implementation in Matlab, if possible with an interactive GUI
    - User should be able to import the raw signal import from a Biopac text export
    - User should be able to enter the sampling frequency, signal type (ECG or PPG or both) and channel numbers
    - User should be able to filter the raw signal
    - User should be able to execute PP, PH, MAP, LF, HF computation
    - User should be able to display plots of the raw signal for a given start and end timestamp
    - User should be able to display plots of PP, PH, MAP over the time for a given start and end timestamp and display the value of LF and HF

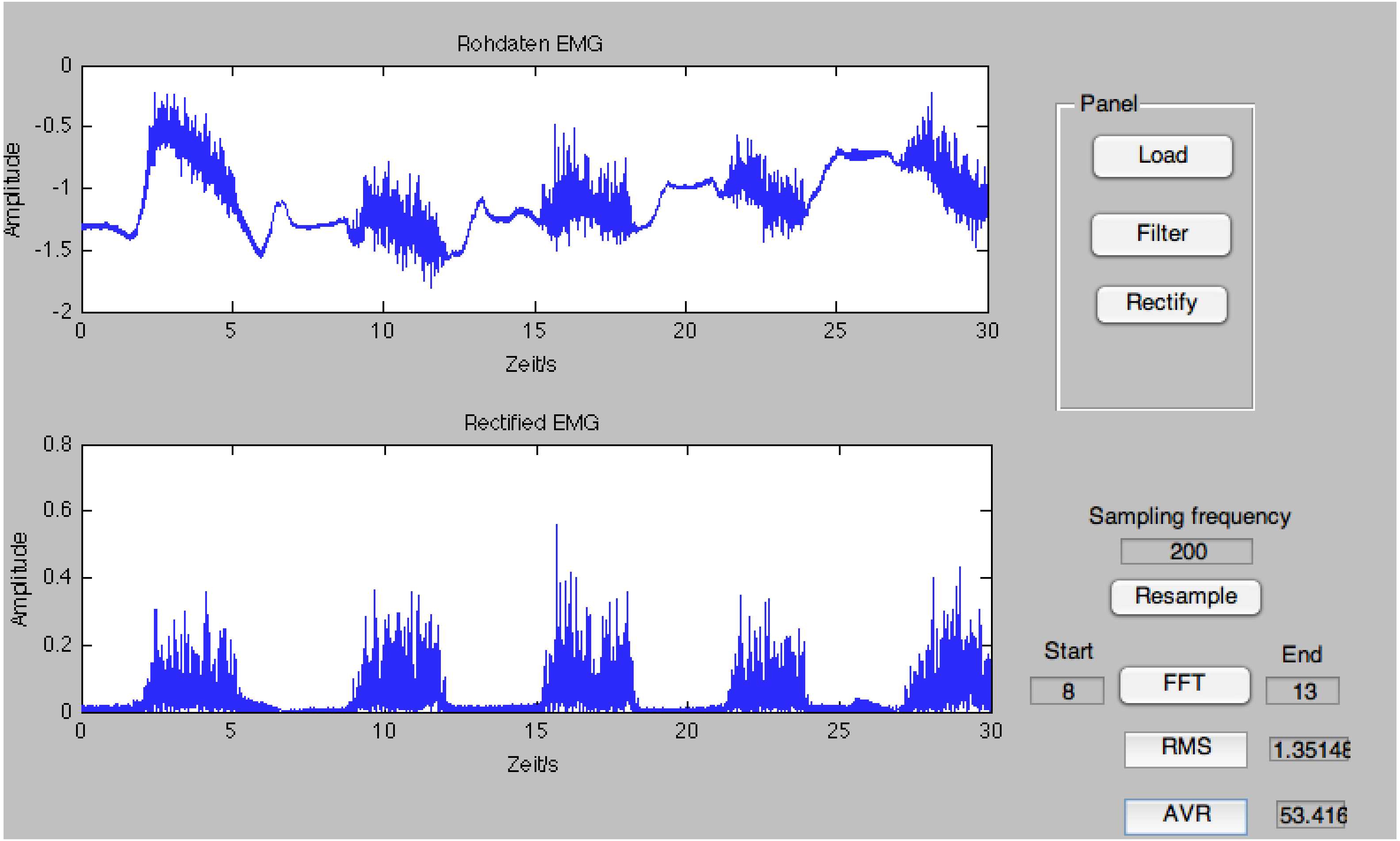
Team Projects

- **Project 2: Nervous Activity Analyzer**
  - Digital filtering of a raw EEG signal
  - Extraction of alpha, beta, theta, delta waves from a filtered EEG signal
  - Computation of STD, AVG and CC
  - Implementation in Matlab, if possible with an interactive GUI
    - User should be able to import the raw signal import from a Biopac text export
    - User should be able to enter the sampling frequency
    - User should be able to filter the raw signal
    - User should be able to execute alpha, beta wave, theta, delta wave computation using Fourier or Wavelet transform or digital filtering
    - User should be able to execute STD, AVG, CC computation
    - User should be able to display plots of the raw signal for a given start and end timestamp
    - User should be able to display plots of alpha, beta wave, theta, delta waves over the time for a given start and end timestamp and display the values for STD, AVG and CC


Browserfile
Click to select .txt file
C:\Users\Anne Leij\Desktop\CVUT\BiologicalSignals\Signals\EEGleft01.txt
Type column of interest
1
Type sampling frequency (Hz)
500
Type start time (s)
0
Type end time (s)
5
Click to filter the signal
Select wave of interest
Basic wave
100
50
0
-50
-100
0
2
4
6
8
10
12
14
x 10^5
Standard deviation
23.7223
Mean amplitude
-2.45012
Go to SPTool

Team Projects

- **Project 3: Muscle Activity Analyzer**
  - Digital filtering of a raw EMG signal
  - Computation of rectified EMG from a filtered EMG signal
  - Computation of the spectrum of the filtered EMG signal using Fourier transform
  - Computation of RMS, ARV
  - Implementation in Matlab, if possible with an interactive GUI
    - User should be able to import the raw signal import from a Biopac text export
    - User should be able to enter the sampling frequency
    - User should be able to filter the raw signal
    - User should be able to execute rectified EMG computation
    - User should be able to execute Fourier transform of the rectified EMG for a given start and end timestamp
    - User should be able to execute RMS, ARV computation for a given start and end timestamp
    - User should be able to display plots of the raw EMG, rectified EMG, EMG Fourier transform for a given start and end timestamp
    - User should be able to display the values for RMS, ARV for a given start and end timestamp


Rohdaten EMG
Amplitude
Zeit/s
Rectified EMG
Amplitude
Zeit/s
Panel
Load
Filter
Rectify
Sampling frequency
200
Resample
Start
8
FFT
End
13
RMS
1.35146
AVR
53.416