05_UnivariateAnalysis

July 2, 2024

1 Univariate Analysis of sEEG

1.1 Import and Functions

[2]:
```
from numpy import pi, linspace, sin, diff, arange, asarray, ndarray, zeros,␣
↪exp, array, linspace, median, gradient, around
from numpy import triu, triu_indices, triu_indices_from, var, mean, std, sqrt,␣
↪where, isnan, nan_to_num, delete, floor
from numpy import nan, flip, argwhere, ones, diag, correlate, corrcoef,␣
↪transpose, cov, flip, ceil, cos, sin, arctan
from numpy import angle, exp, amax, amin, absolute, meshgrid, fill_diagonal,␣
↪concatenate, c_, real, argsort, tile
from numpy import empty_like, zeros_like, log, logical_and, copy, greater,␣
↪invert, nonzero, count_nonzero, divide, repeat
from numpy import sign, append, hstack, savetxt, loadtxt, histogram

from numpy.random import normal, permutation
from numpy.linalg import norm

from matplotlib.pyplot import subplots, xlabel, ylabel, hist, bar, legend, axis
from matplotlib.pyplot import figure, xticks, yticks, rcParams, show

from scipy.optimize import curve_fit
from scipy.signal   import butter, sosfilt, find_peaks
from scipy.stats    import spearmanr, entropy
from scipy.spatial  import distance
from scipy.cluster  import hierarchy
from scipy.interpolate import interp1d
from scipy.fft import rfft, rfftfreq

from sklearn.preprocessing import MinMaxScaler

from pandas import read_csv, DataFrame

import pyedflib
```

```python
from string import ascii_uppercase

from itertools import product

from math import dist
```

[3]:
```python
def eeg_plot(data, offset, normalise=True):
    """
    Plot date columns in EEG style
    data:      two-dimensional array
    offset:    scaling factor
    normalise: normalisation of amplitudes to variance 1
    """
    from matplotlib.pyplot import subplots

    start = 0
    samples = data.shape[0]
    electrodes = data.shape[1]

    dataset = data[start:start+samples, :electrodes]
    means = data[start:start+samples, :electrodes].mean(axis=0)
    devs = data[start:start+samples, :electrodes].std(axis=0)

    fig, ax = subplots(figsize=(8, 6))

    if not normalise:
        ax.plot((dataset - means)      + offset*arange(electrodes-1,-1,-1),␣
↪linewidth=1);
    else:
        ax.plot((dataset - means)/devs + offset*arange(electrodes-1,-1,-1),␣
↪linewidth=1);

    ax.plot(zeros((samples, electrodes)) +␣
↪offset*arange(electrodes-1,-1,-1),'--',color='gray');
    ax.set(ylabel='Voltage')

    yticks([]);

    axis('tight');

    return fig, ax
```

1.2 Pick Patient, Seizure, Type, and read EEG

[4]:
```
# read prefiltered 60 sec segment

folder      = '../Data/'
patient     = '1'          # '1'
seizure     = '03'         # '01' or '02' or '03'
series_type = 'Onset'      # 'Background' or 'Onset'

sr_chars = folder + 'sampling_rate.txt'

df1 = read_csv(sr_chars, header=None)

sr = df1.iloc[0, 0]

series_chars = folder + 'Pat' + patient + '_Sz' + seizure + '_' + series_type +␣
↪'_1_100Hz.csv'

df2 = read_csv(series_chars)
df2.head()

data_np = df2.to_numpy()
data_prefiltered = data_np[:, 1:]

all_labels = df2.columns[1:]

print('')
print(series_chars)
print('')
```

```
../Data/Pat1_Sz03_Onset_1_100Hz.csv
```

[5]:
```
letter_list = list()

for new in all_labels:

    if new[0] not in letter_list:

        letter_list.append(new[0])


label_dict = dict()

for ind, letter in enumerate(all_labels):

    if letter[0] in label_dict.keys():
```

```
            pass

    else:
        label_dict[letter[0]] = [ind]

        dict_ind = len(label_dict.keys())

        if letter[0] != all_labels[0][0]:
            previous_letter = letter_list[dict_ind - 2]
            label_dict[previous_letter].append(ind)

    if ind == len(all_labels)-1:
        label_dict[letter[0]].append(ind+1)

label_letters = list(label_dict.keys())

label_dict
```

[5]:
```
{'A': [0, 11],
 'B': [11, 22],
 'C': [22, 31],
 'E': [31, 40],
 'F': [40, 49],
 'Z': [49, 56],
 'O': [56, 67],
 'T': [67, 74],
 'U': [74, 81],
 'V': [81, 92],
 'W': [92, 107],
 'X': [107, 122]}
```

1.3 Settings and Filtering

[6]:
```
onset  = (146.7, 147.0, 146.7)
```

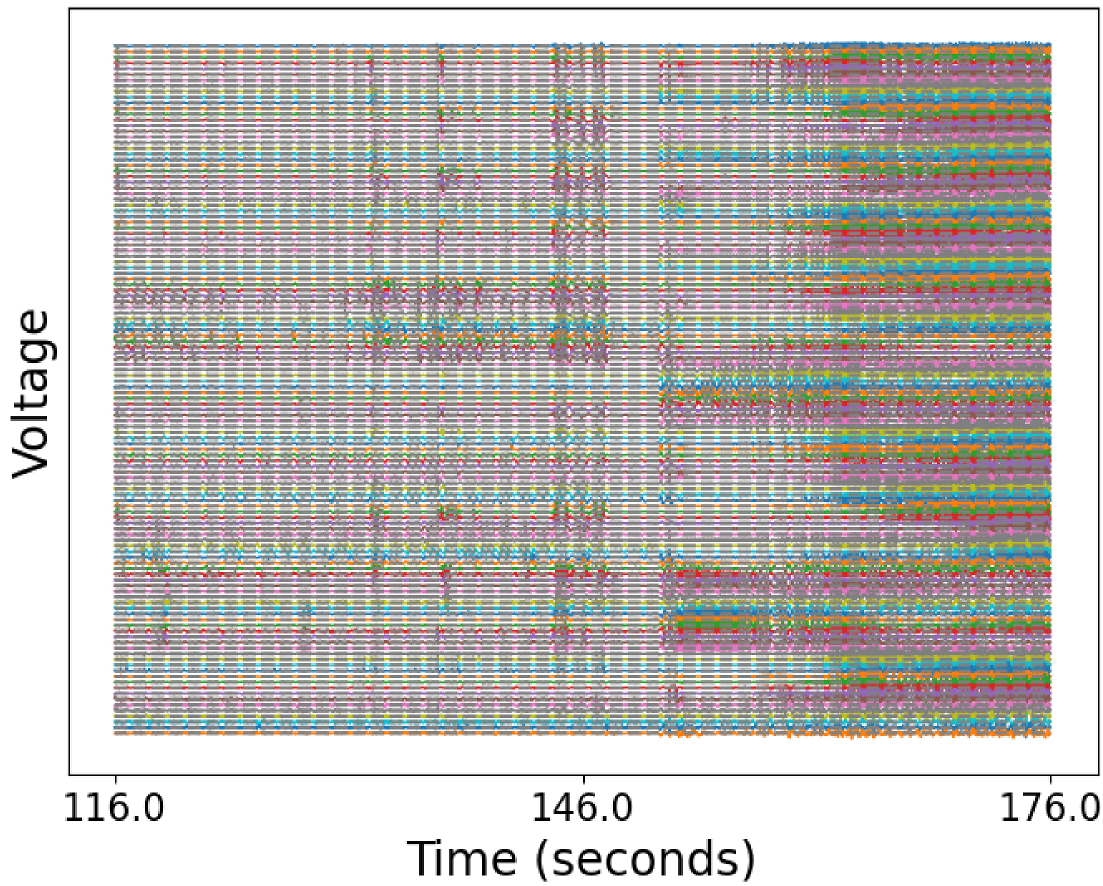
[7]:
```
time_max = 60

init_cut  = 25

band_low  = 1
band_high = 20

order = 5

rows_max = int(time_max * sr)

sample_start = int((onset[int(seizure)-1]-30)*sr)
```

```
# sample_start = 0

sample_end = sample_start + rows_max

channel_start, channel_stop = 0, data_prefiltered.shape[1]  # Bad channels 81,␣
↪82 for 2015lvxiaofu

number_channels = channel_stop - channel_start


data_unfiltered = data_prefiltered[:, channel_start:channel_stop]


sos = butter(order, (band_low, band_high), btype='bandpass', fs=sr,␣
↪output='sos')

data_filtered = zeros((rows_max, number_channels))

for index, column in enumerate(data_unfiltered.transpose()):
    forward = sosfilt(sos, column)
    backwards = sosfilt(sos, forward[-1::-1])
    data_filtered[:, index] = backwards[-1::-1]

data_filtered.shape
```

[7]: (60000, 122)

2 Complete EEG

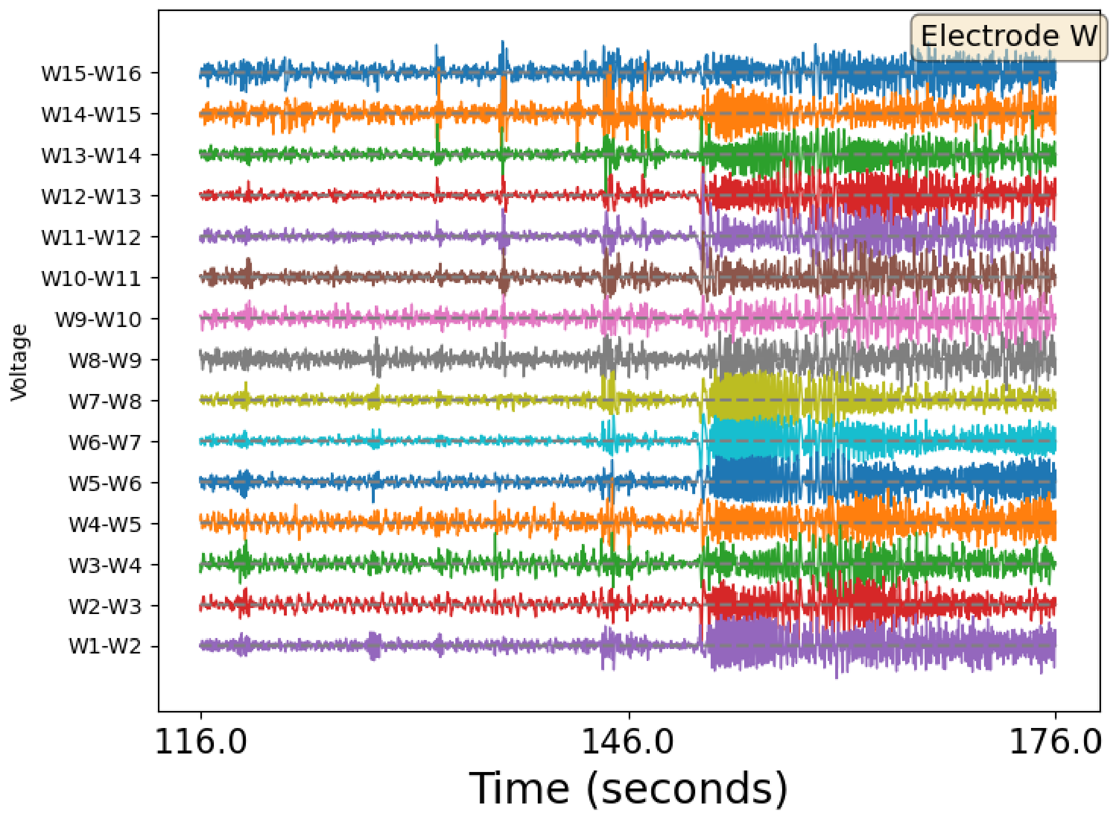
[8]:
```
fig, ax = eeg_plot(data_filtered, 5)

ax.set_xticks(linspace(0, rows_max, 3))
labl = linspace(sample_start//sr, sample_start//sr + time_max, 3)
ax.set_xticklabels(labl, fontsize=16)
ax.set_xlabel('Time (seconds)', fontsize=20)

ax.set_ylabel('Voltage', fontsize=20);

show()
```



3 A Single Electrode

[41]:
```
elec_name = 'W'

all_labels_np = asarray(all_labels)

elec_label_names = all_labels_np[label_dict[elec_name][0]:
 ↪label_dict[elec_name][1]]

data_chan      = data_filtered[:, label_dict[elec_name][0]:
 ↪label_dict[elec_name][1]]

chans = data_chan.shape[1]

factor = 5

fig, ax = eeg_plot(data_chan, factor, normalise=True)
ax.set_yticks(factor*arange(chans))
```

```
ax.set_yticklabels(elec_label_names)

ax.set_xticks(linspace(0, rows_max, 3))
labl = linspace(sample_start//sr, sample_start//sr + time_max, 3)
ax.set_xticklabels(labl, fontsize=16)
ax.set_xlabel('Time (seconds)', fontsize=20)

# these are matplotlib.patch.Patch properties
props = dict(boxstyle='round', facecolor='wheat', alpha=0.5)

# place a text box in upper left in axes coords
textstr = 'Electrode ' + elec_name
ax.text(0.81, 0.98, textstr, transform=ax.transAxes, fontsize=14,
    verticalalignment='top', bbox=props);

show()
```




```
[ ]:
```

3.1 Pick a Segment and Normalise

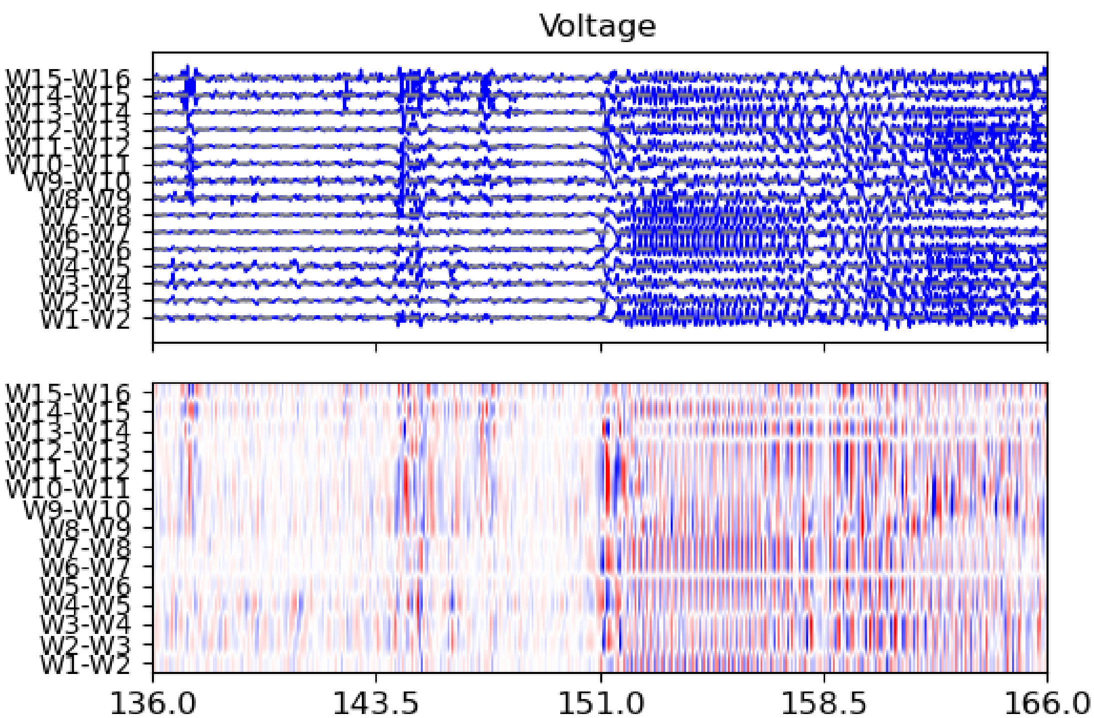
[44]:
```
seg_start = 20000
seg_stop  = 50000

rows_seg = seg_stop - seg_start

data_chan_seg      = data_chan[seg_start:seg_stop, :]

means              = data_chan_seg.mean(axis=0)
devs               = data_chan_seg.std(axis=0)
data_chan_seg_norm = (data_chan_seg - means)/devs
```

3.2 Time Series & Heatmap

[45]:
```
offset = 5

################################### Time Series
fig, (ax1, ax2) = subplots(nrows=2, figsize=(6,4))

### Voltage Series
ax1.plot(data_chan_seg_norm + offset*arange(chans-1,-1,-1), linewidth=1,␣
 ↪color='b');
ax1.plot(zeros((rows_seg, chans)) +␣
 ↪offset*arange(chans-1,-1,-1),'--',color='gray');
ax1.set_yticks(offset*arange(chans))
ax1.set_yticklabels(elec_label_names)
ax1.margins(x=0)
ax1.set_xticks(linspace(0, rows_seg, 5))
labl =        linspace((sample_start+seg_start)//sr, (sample_start+seg_stop)//
 ↪sr, 5)
ax1.set_xticklabels([], fontsize=12)
ax1.set_title('Voltage', fontsize=12)


### Voltage Heatmap
ax2.imshow(data_chan_seg_norm.T, aspect='auto', cmap='bwr', vmin=-3, vmax=3);
ax2.set_yticks(arange(chans))
ax2.set_yticklabels(flip(elec_label_names));

ax2.set_xticks(linspace(0, rows_seg, 5))
labl =        linspace((sample_start+seg_start)//sr, (sample_start+seg_stop)//
 ↪sr, 5)
ax2.set_xticklabels(labl, fontsize=12)


fig.tight_layout()
```

```
title_chars = 'figs/Sz' + seizure + '_' + elec_name + '_timeseries_' + 'L' +␣
↪str(band_low) + '_H' + str(band_high) + '_Start' + str(seg_start) + '.png'
# fig.savefig(title_chars, format='png')
print(title_chars)

show()
```

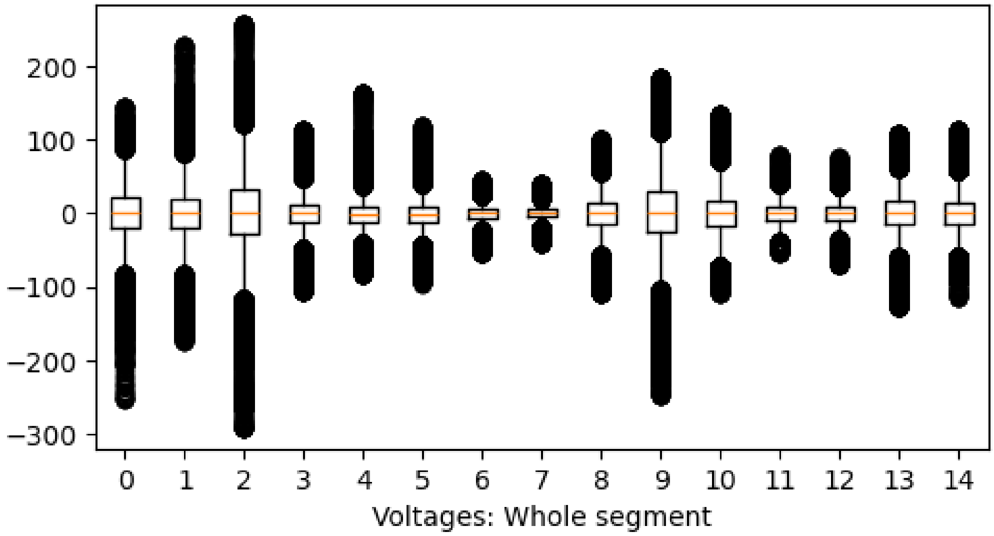
```
figs/Sz03_W_timeseries_L1_H20_Start20000.png
```



Electrode A: during the seizure too regular, too big, too synchronised.

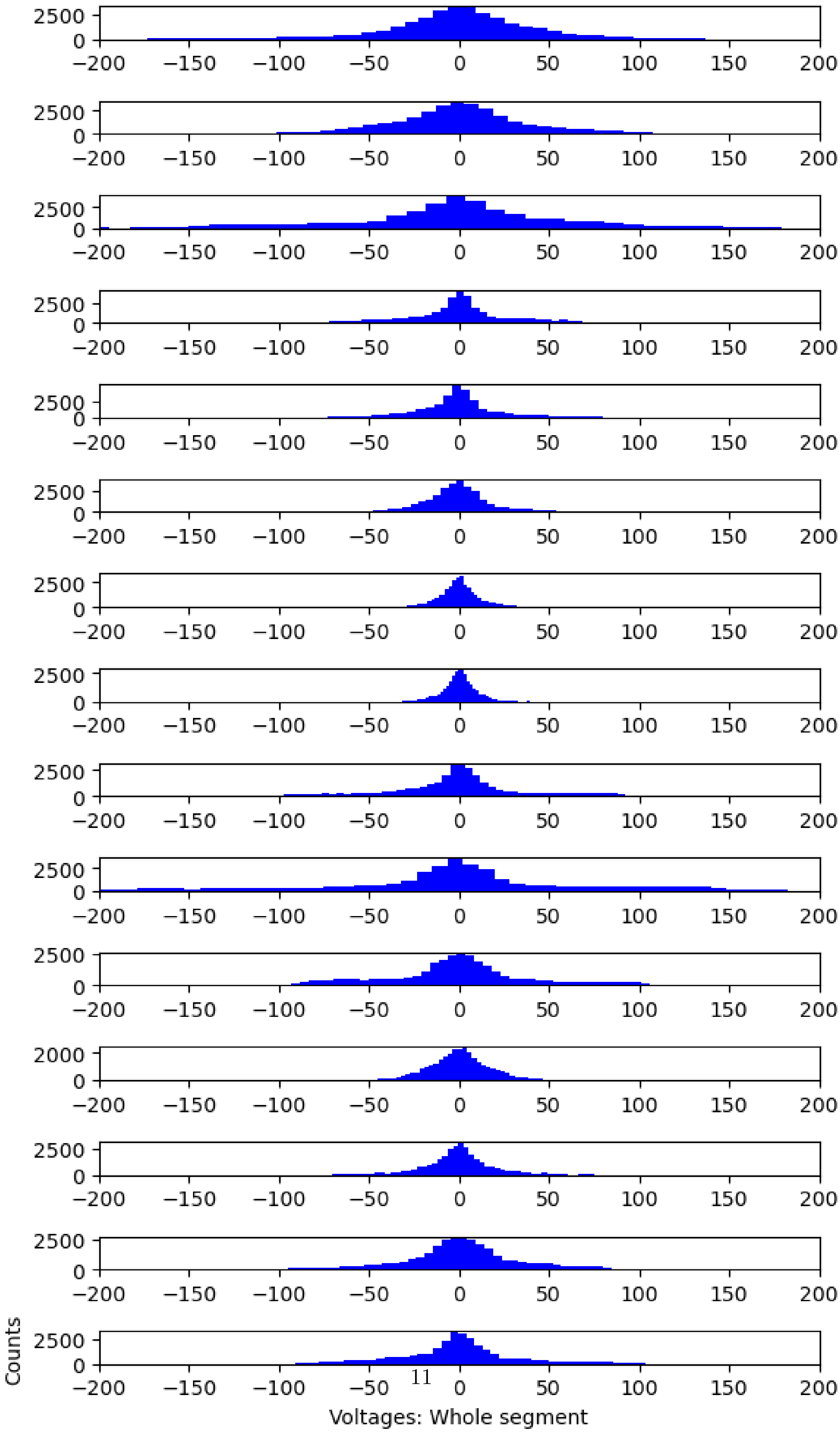
3.3 Boxplots of Each Channel

[46]:
```
fig, ax = subplots(figsize=(6,3))

ax.boxplot(data_chan_seg);
ax.set_xlabel('Voltages: Whole segment')
ax.set_xticklabels(arange(chans));

show()
```



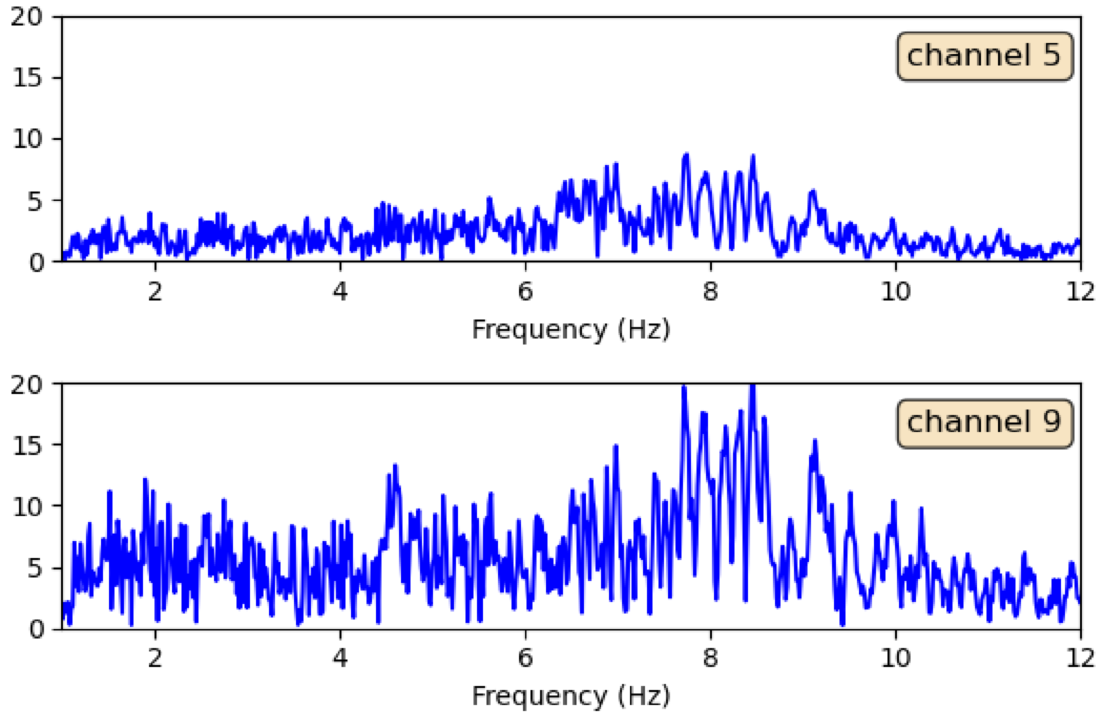
3.4 Histograms

[47]:
```
fig, ax = subplots(nrows=chans, figsize=(6,10))

bins = 50

for index in arange(chans):

    ax[index].hist(data_chan_seg[:,index], bins=bins, color='b');
    ax[index].set_xlim(-200, 200)

ax[-1].set_xlabel('Voltages: Whole segment')
ax[-1].set_ylabel('Counts');

fig.tight_layout()

show()
```


2500
2000
0
−200 −150 −100 −50 0 50 100 150 200
Counts
Voltages: Whole segment

3.5 The Fourier Spectrum

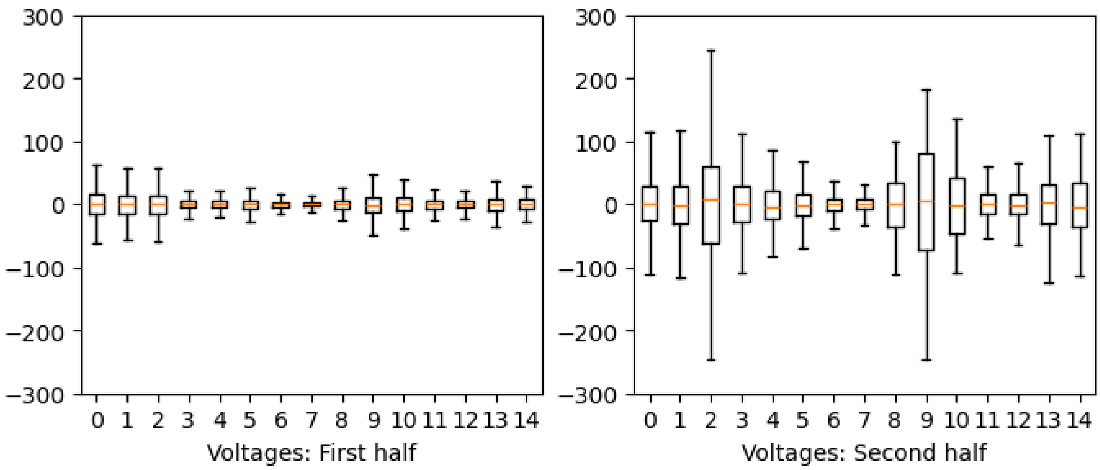
[59]:
```
chan1, chan2 = 5, 9

ylim = 20

# frequencies
freqs = rfftfreq(rows_max, 1 / sr)

# amplitude
amplitudes = (2.0 / rows_max)*abs(rfft(data_filtered, axis=0))


fig, ax = subplots(nrows=2, figsize=(6, 4))

ax[0].plot(freqs, amplitudes[:, chan1], c='b');
ax[0].set_xlim(1, 12);
ax[0].set_ylim(0, ylim);
ax[0].set_xlabel('Frequency (Hz)');

ax[1].plot(freqs, amplitudes[:, chan2], c='b');
ax[1].set_xlim(1, 12);
ax[1].set_ylim(0, ylim);
ax[1].set_xlabel('Frequency (Hz)');

# these are matplotlib.patch.Patch properties
props = dict(boxstyle='round', facecolor='wheat', alpha=0.8)

# place a text box in upper left in axes coords
textstr = 'channel ' + str(chan1)

ax[0].text(0.83, 0.89, textstr, transform=ax[0].transAxes, fontsize=12,
    verticalalignment='top', bbox=props)

textstr = 'channel ' + str(chan2)

ax[1].text(0.83, 0.89, textstr, transform=ax[1].transAxes, fontsize=12,
    verticalalignment='top', bbox=props)

fig.tight_layout()

show()
```



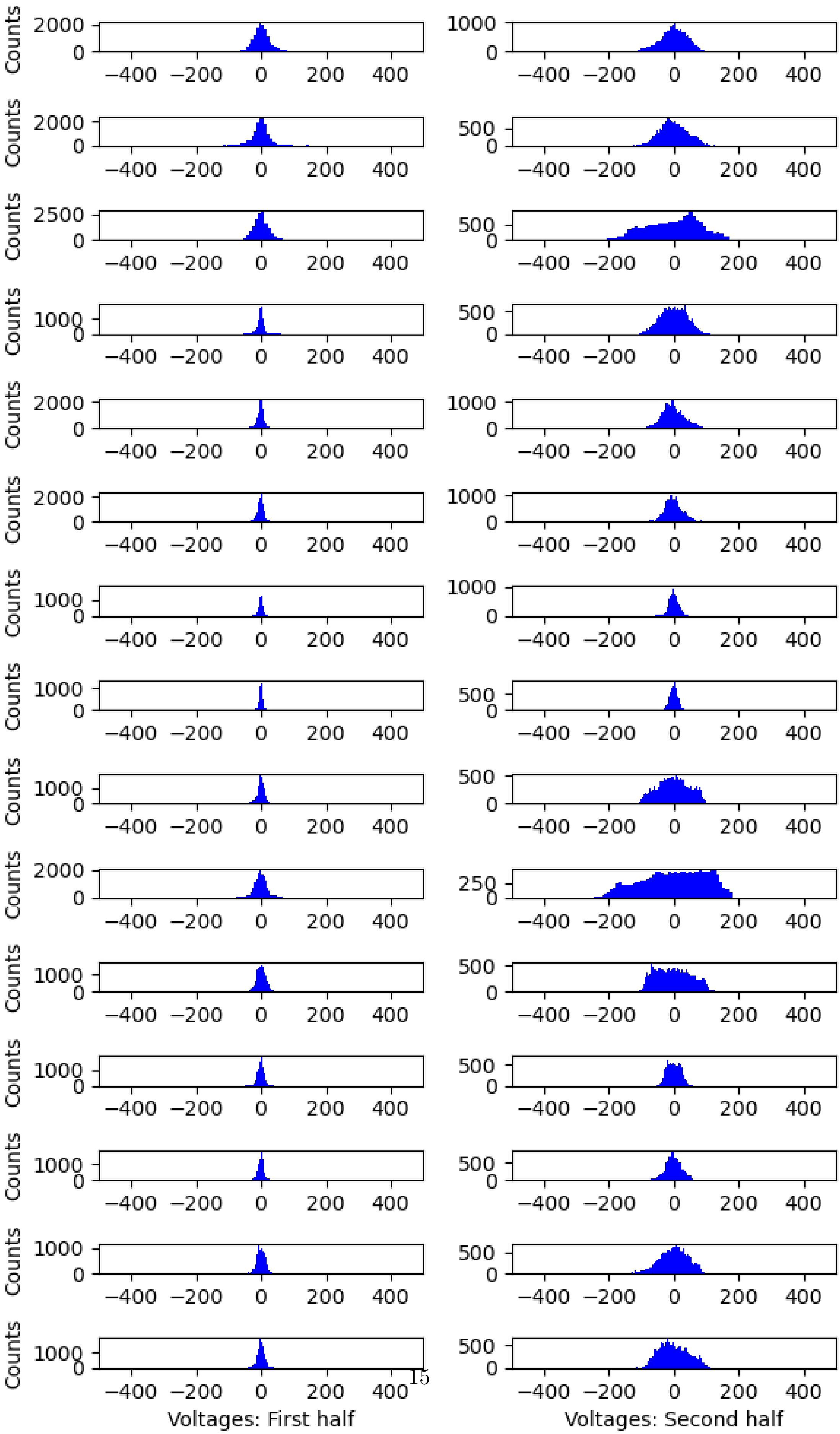
[ ]:

3.6 Boxplots & Histograms of Half Segments

[53]:
```
limit = 300

fig, ax = subplots(ncols=2, figsize=(8,3))

ax[0].boxplot(data_chan_seg[:rows_seg//2,:], showfliers=False);
ax[0].set_xticklabels(arange(chans))
ax[0].set_ylim(-limit, limit)

ax[0].set_xlabel('Voltages: First half')

ax[1].boxplot(data_chan_seg[rows_seg//2:,:], showfliers=False);
ax[1].set_xticklabels(arange(chans))
ax[1].set_ylim(-limit, limit)

ax[1].set_xlabel('Voltages: Second half');

show()
```



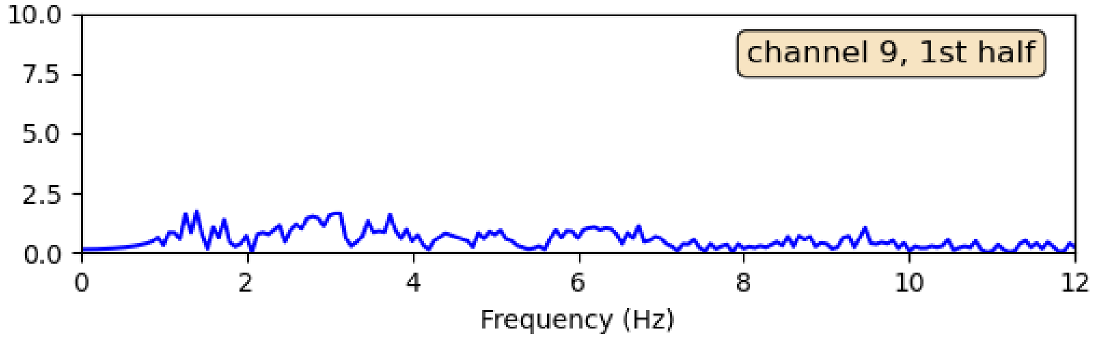
[54]:
```
fig, ax = subplots(nrows=chans, ncols=2, figsize=(6,10))

for index in arange(chans):

    ax[index, 0].hist(data_chan_seg[:rows_seg//2,index], bins=bins, color='b');
    ax[index, 0].set_ylabel('Counts');
    ax[index, 1].hist(data_chan_seg[rows_seg//2:,index], bins=bins, color='b');
    ax[index, 0].set_xlim(-500, 500)
    ax[index, 1].set_xlim(-500, 500)

ax[-1, 0].set_xlabel('Voltages: First half')
ax[-1, 1].set_xlabel('Voltages: Second half')

fig.tight_layout()

show()
```

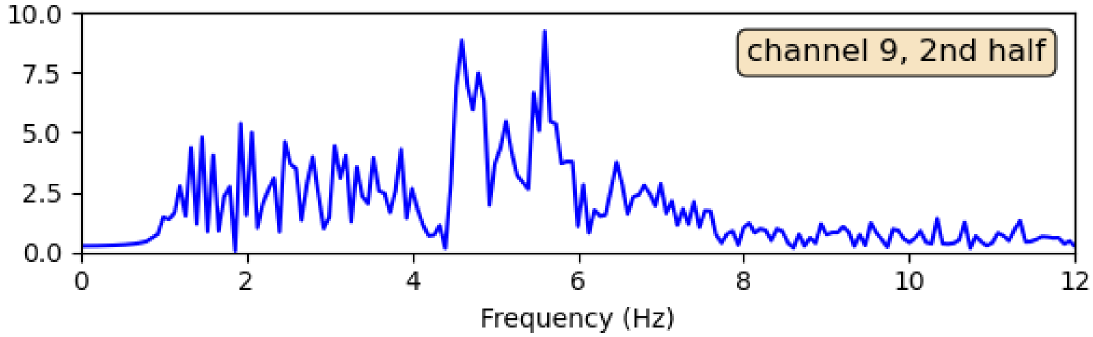

Counts
Voltages: First half
Voltages: Second half

3.7 Fourier spectra of half segments

[62]:
```
chan = 9

ylim = 10

# frequencies
freqs = rfftfreq(rows_seg//2, 1 / sr)

# amplitude
amplitudes_1 = (2.0 / rows_max)*abs(rfft(data_chan_seg[:rows_seg//2, :],␣
↪axis=0))
amplitudes_2 = (2.0 / rows_max)*abs(rfft(data_chan_seg[rows_seg//2:, :],␣
↪axis=0))


fig, ax = subplots(nrows=2, figsize=(6, 4))

ax[0].plot(freqs, amplitudes_1[:, chan], color='b');
ax[0].set_xlim(0, 12);
ax[0].set_ylim(0, ylim);
ax[0].set_xlabel('Frequency (Hz)');

ax[1].plot(freqs, amplitudes_2[:, chan], color='b');
ax[1].set_xlim(0, 12);
ax[1].set_ylim(0, ylim);
ax[1].set_xlabel('Frequency (Hz)');

# these are matplotlib.patch.Patch properties
props = dict(boxstyle='round', facecolor='wheat', alpha=0.8)

# place a text box in upper left in axes coords
textstr = 'channel ' + str(chan) + ', 1st half'

ax[0].text(0.67, 0.89, textstr, transform=ax[0].transAxes, fontsize=12,
    verticalalignment='top', bbox=props)

textstr = 'channel ' + str(chan) + ', 2nd half'

ax[1].text(0.67, 0.89, textstr, transform=ax[1].transAxes, fontsize=12,
    verticalalignment='top', bbox=props)

fig.tight_layout()
```

```
show()
```





4 Summary

- EEG is integral over extracellular currents in complex brain tissue (neurons, glia, blood vessels)
- EEG is organised in spatio-temporal patterns
- Normal Dynamics: irregular in frequency; small in amplitude; non-specific waveform
- Epileptic Dynamics: more regular frequency; often large amplitude; charactersitic waveforms.

5 Try It Yourself

Display data from different electrodes and pick different segments to re-run the code. You will be able to find segments with strongly contrasting types of dynamics. If you achieve to adjust the half segments, you will be able to maimise the contrast in univariate measures.