Functionnal data analysis applied to neurology

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Outline

1. Familiar with the problem
   - Experiment
   - Data display
2. Windowed approach
3. CUSUM algorithm

Patient path :

- about 6 secondes idle
- 10-metre walk
- about-turn
- 10-metre walk

Data acquisition by two inertial measurement units :

- set on the back and the right foot
- accelerations and angular velocities
- recorded at 20 Hz
- deliver in the frame of reference (anteroposterior, mediolateral, vertical)

Filename extension is .txt or .csv

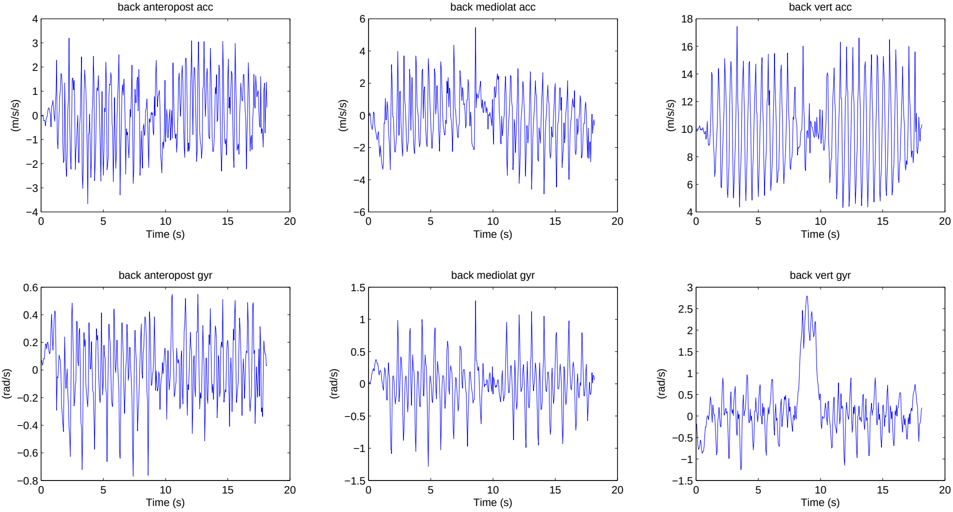
- Need procedures to import to MATLAB .mat format

Display function

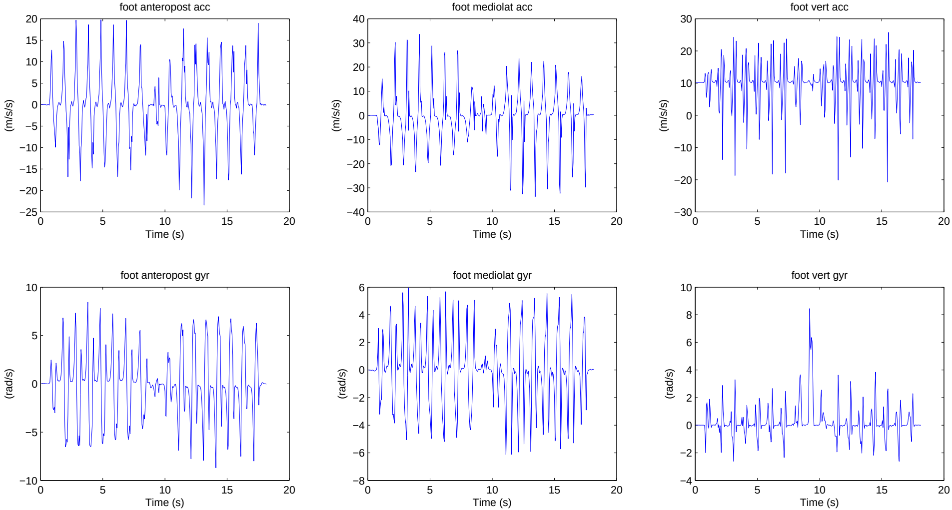
- Different phasis are apparent without modification need

$\Longrightarrow$ Automatic segmentation must be fast and accurate, as much as the eye

Example of back IMU record



Example of foot IMU record



1. Familiar with the problem

2. Windowed approach
   - With Fourier
   - With statistics

3. CUSUM algorithm

Ref. *Classification of periodic activities using the Wasserstein distance*, L. Oudre, J. Jakubowicz, P. Bianchi, C. Simon

Frequency spectrum bandwidthed from 0.5 to 5 Hz on a window

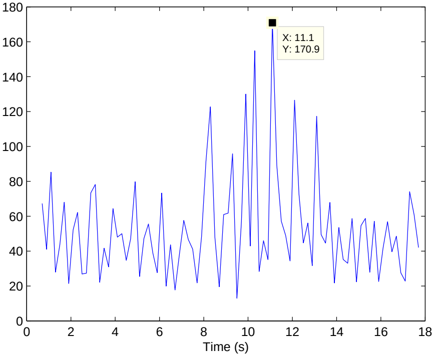
Wasserstein distance is less shift-sensitive, used in image and music signal processing

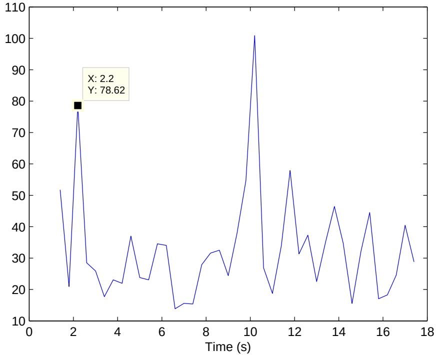
$$d_W(g,h) = \int_0^{\pi} \left| \int_0^{x} g(t) - h(t)dt \right| dx$$

Point to point distance

$$d(x,y) = d_W\left(\frac{x}{||x||_1}, \frac{y}{||y||_1}\right) + \mu \cdot \Big| \, ||x||_1 - ||y||_1 \Big|$$

Application back angular velocities : 16 and 32-sampled windows, 75% overlap



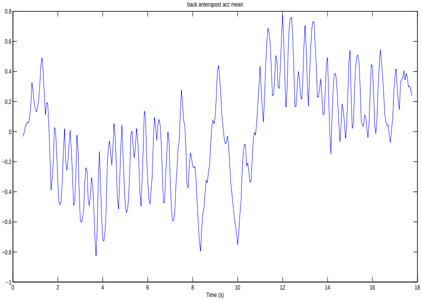


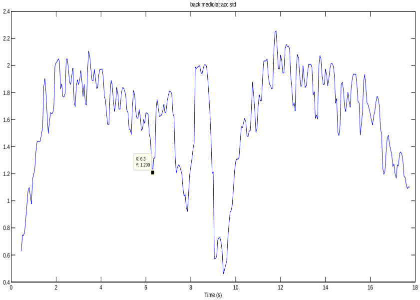
Many proposed features in literature :

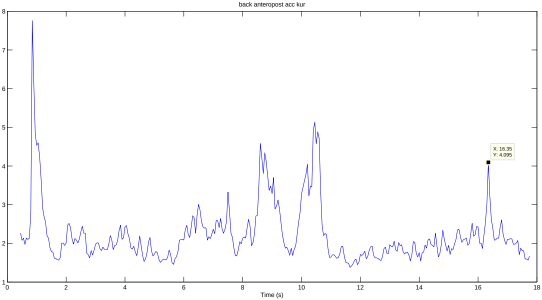
- $a_{ML} + a_V$, a_{AP} and a_V means ;
- $a_{AP} + a_V$ and a_{ML} standard-deviations ;
- a_V median;
- a_{ML} 95-percentile; *etc*

Good results with kurtosis

Issue on window length : accuracy/smooth trade-off, hard under 100 Hz


back anteropost acc mean
Time (s)


back mediolat acc std
X: 6.3
Y: 1.209
Time (s)


back anteropost acc kur
X: 16.35
Y: 4.095
Time (s)

1. Familiar with the problem

2. Windowed approach

3. CUSUM algorithm
   - Working
   - First results

Ref. *Detection of Abrupt Changes : Theory and Application*, M. Basseville, I. V. Nikiforov (1993)

Proposed by E. S. Page in 1954

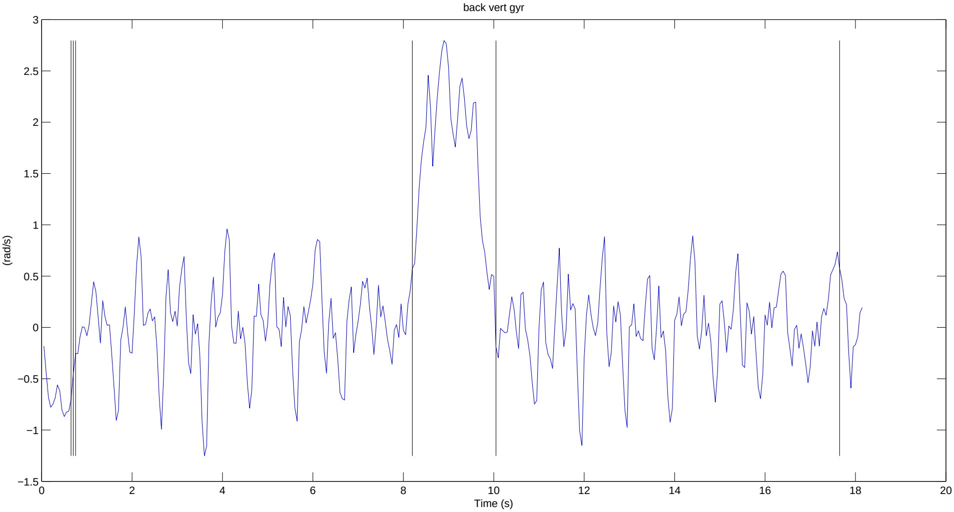
Based on maxima of likelihood estimated

$$\tilde{\Lambda}_1^N(k) = \inf_{\tilde{\theta}_0} \sup_{\theta_0} \sup_{\theta_1} \ln \left[\frac{\prod_{i=1}^{k-1} p_{\theta_0}(y_i) \cdot \prod_{i=k}^{N} p_{\theta_0}(y_i)}{\prod_{i=1}^{N} p_{\tilde{\theta}_0}(y_i)} \right]$$

$$\hat{t}_0 = \arg \max_{1 \leq k \leq N} \tilde{\Lambda}_1^N(k)$$

Assume independent signals under normal distribution

Applied on norme acceleration norms and yaw by dichotomy


back vert gyr
(rad/s)
Time (s)
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
0
2
4
6
8
10
12
14
16
18
20