Classification on Vibroartrographic signals

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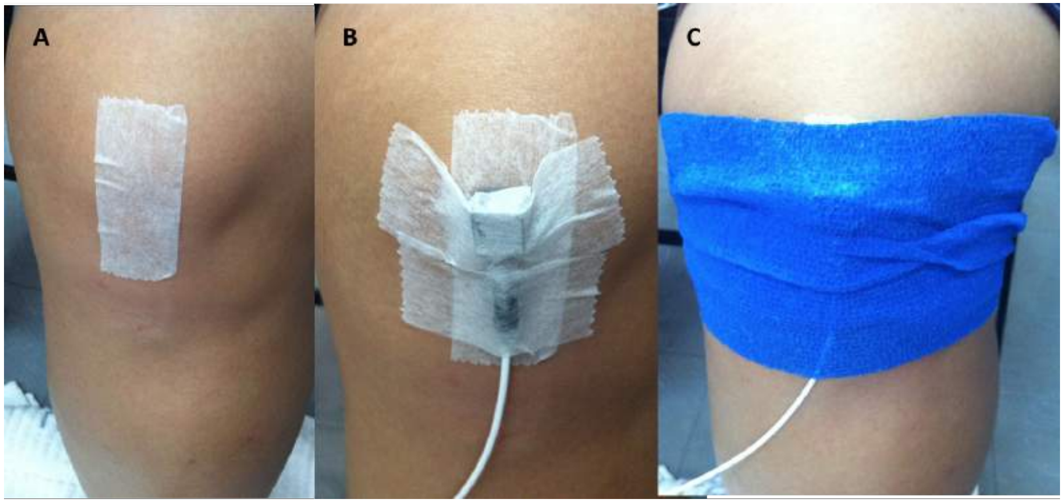
Outline

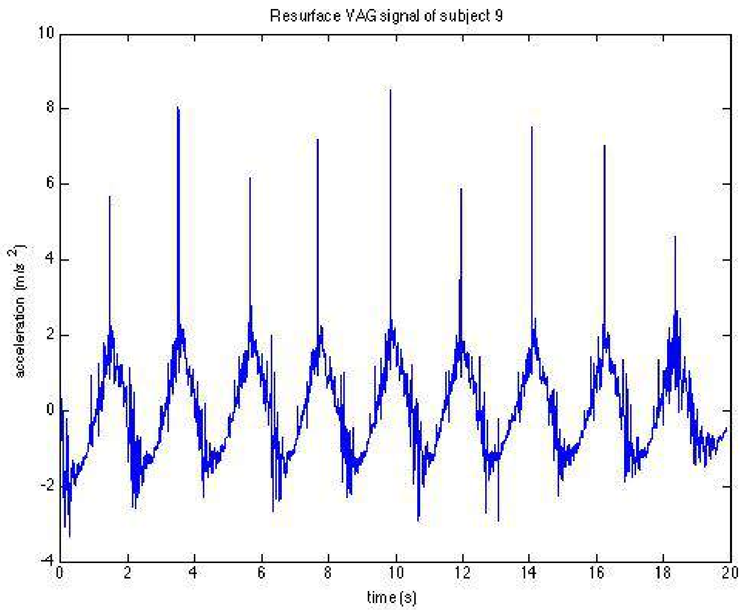
- Revisit VAG signals
- Noise removal with EEMD/DFA
- Overview on STFT results
- Challenge on classification problem

Recap on VAG Signal



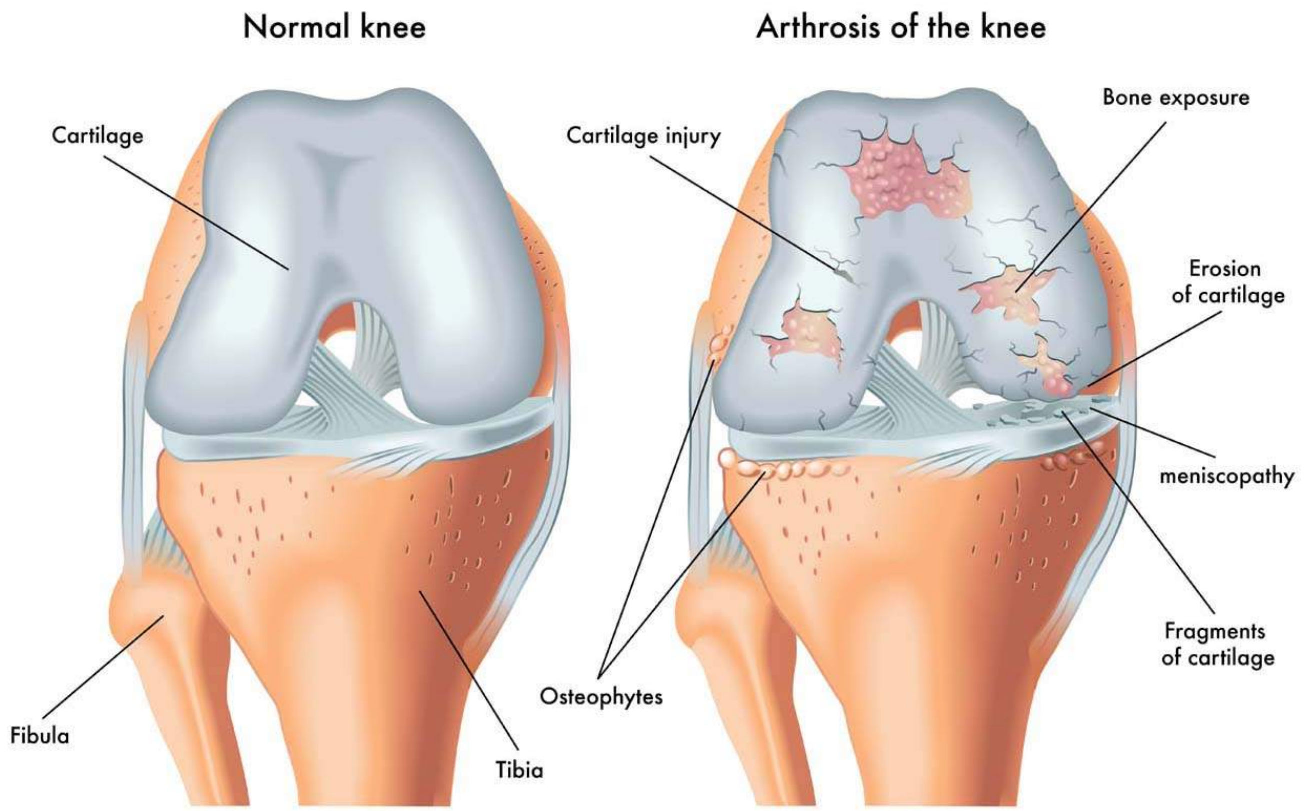
Demonstration of an attachment of an accelerometer.

An example of VAG signals



Three important characteristics:

1. Spike
2. Motion trend
3. Mid range frequency



Difference between abnormal and normal knees.
Photo by Renee Silvester

Classification on resurface and non-resurface

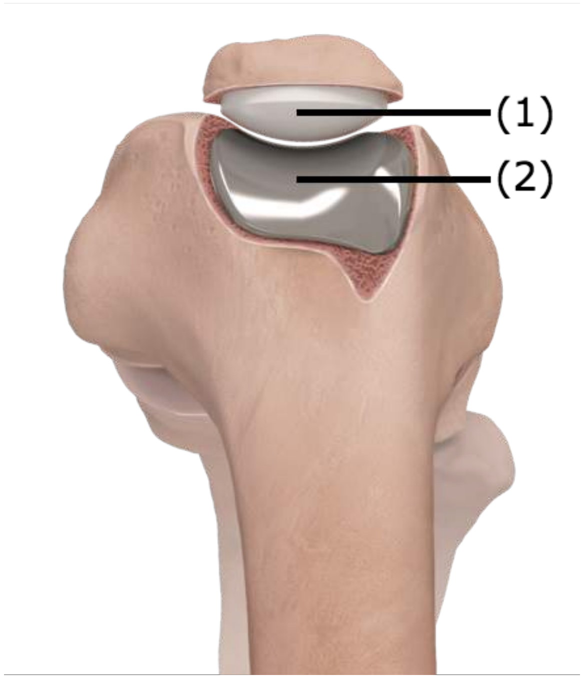
Goal classify normal and abnormal knee with VAG signal

Scope of work Since there are data from patients of two surgery methods available. We try to classify according to frequency and energy feature.

There are two class of data:

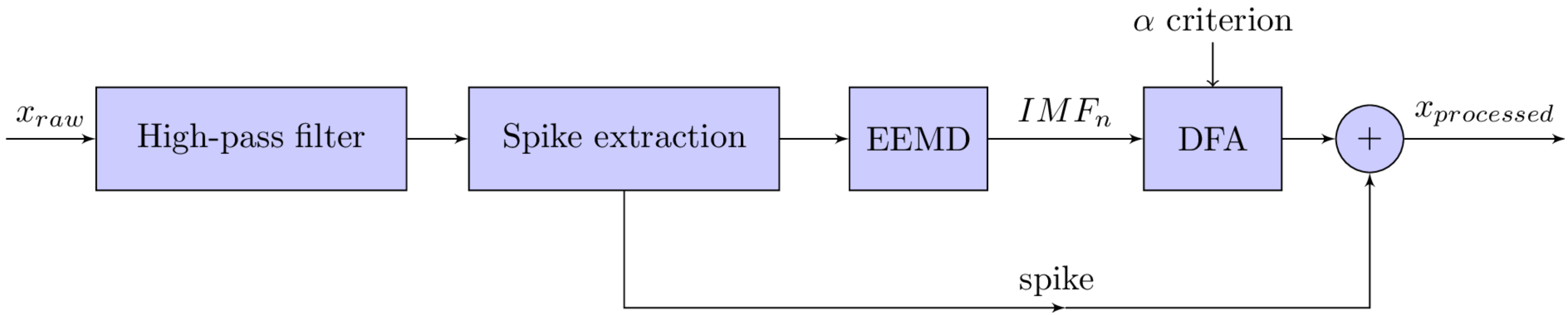
1. non-resurface: joint surface replacement (2)
2. resurface: joint surface (2) and patella replacement (1)

Assume: resurface ⇒ normal, non-resurface ⇒ abnormal



Label 1 shows an oval shape object used to replace a patella.

Processing overview



EEMD

(Ensemble Emperical Mode Decomposition)

It decomposes a signal into a set of signals called IMFs (Intrinsic Mode Functions)

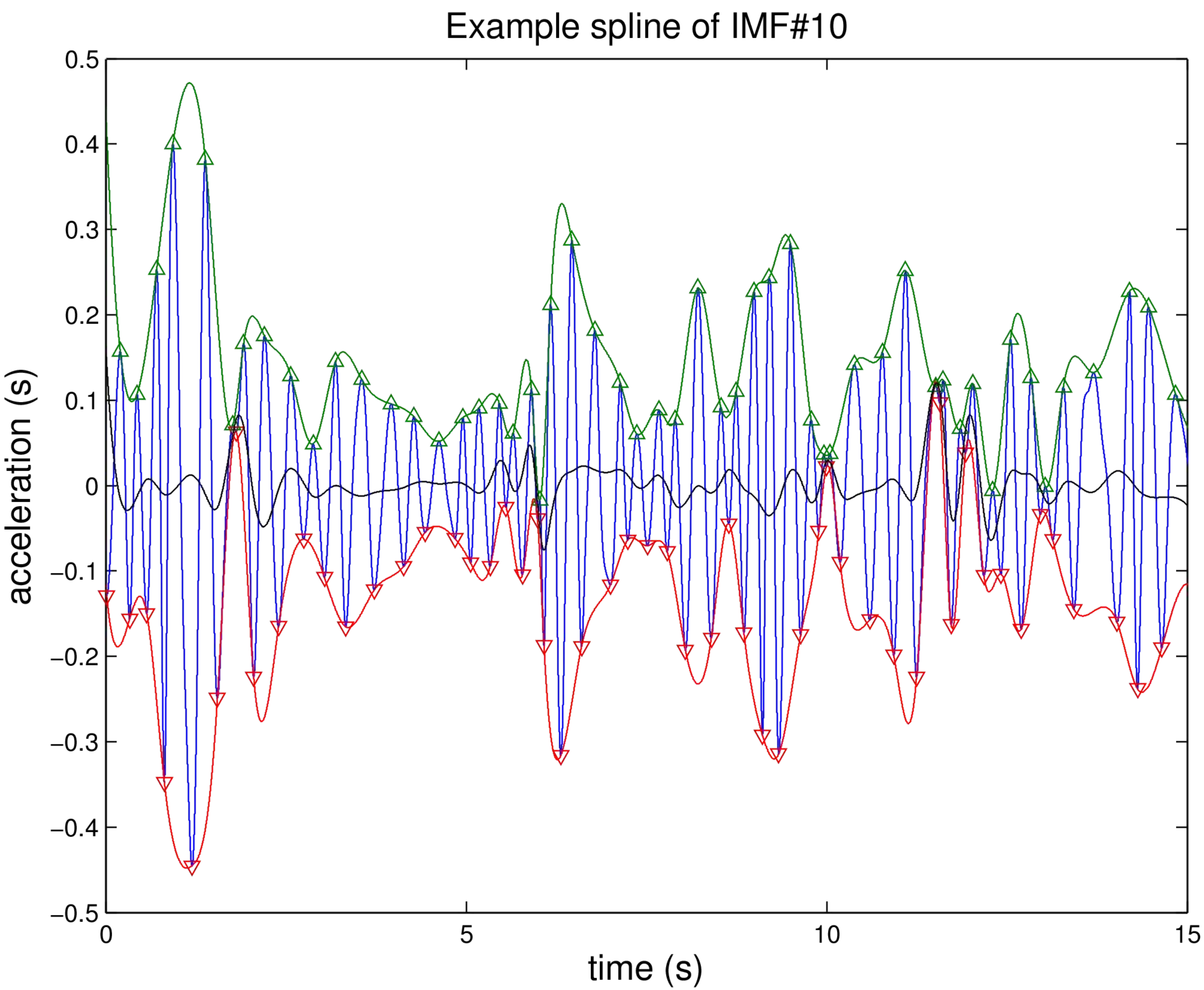
Why EEMD?

EEMD is common in physiological signals procesing. Since VAG signals is non-stationary and noise are spread over the frequency band, EEMD is considered to be an appropriate choice.

How to obtain IMF

Sifting process: Interpolated upper and lower envelope and evaluate its mean. Then subtract this signal by this mean.

Repeat until reach (i) given iteration or (ii) signal has specific number of zero crossing.



Example spline of IMF#10
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
acceleration (s)
0
5
10
15
time (s)

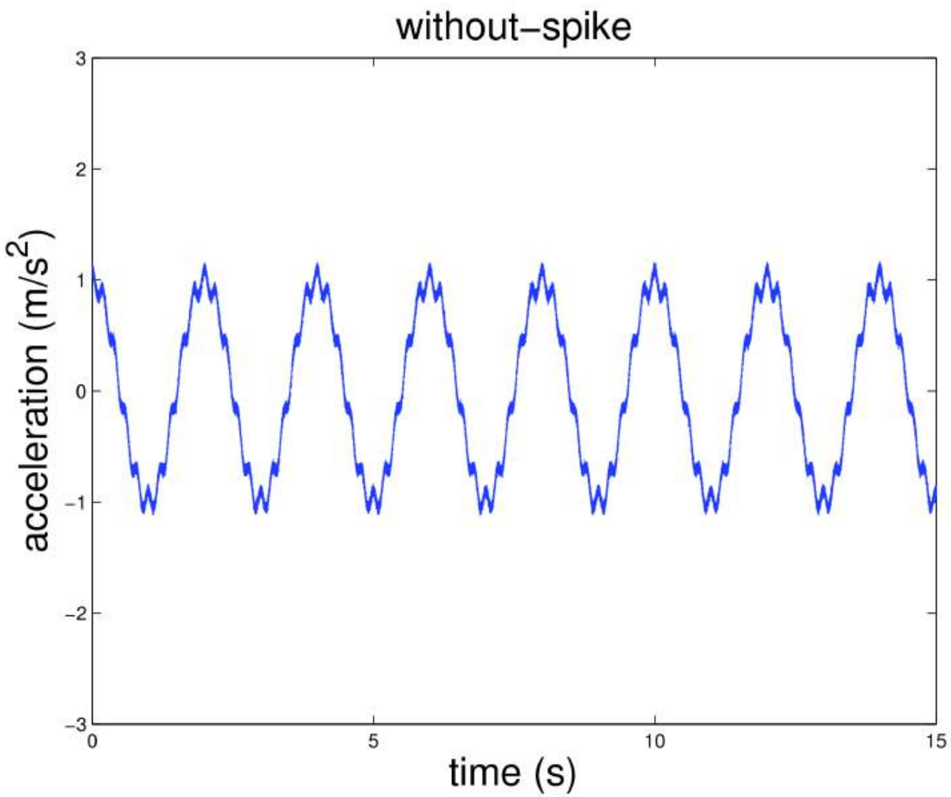
For iteration i of determining IMF c_i, we also obtain a residual r_i, the first iteration expression is given by

$$r_1 = x_{input} - c_1$$

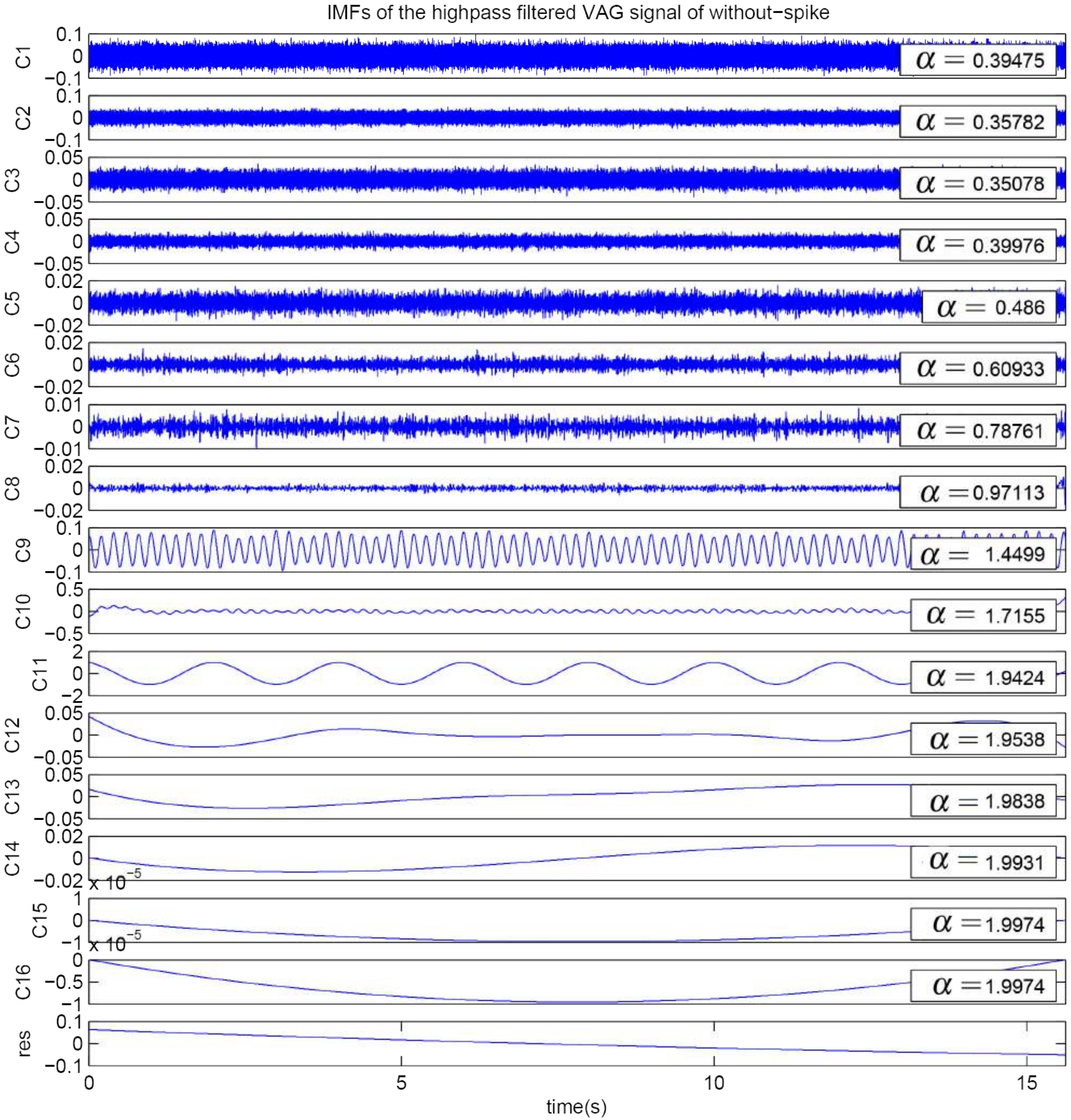
Then the residual r_i will be the input of the next iteration.

$$r_{i+1} = r_i - c_{i+1}$$

Example



$$y(t) = \cos(\omega t) + \cos(10\omega t) + n(t), n \sim \mathcal{N}(0, 0.1)$$


IMFs of the highpass filtered VAG signal of without−spike
C1
α = 0.39475
C2
α = 0.35782
C3
α = 0.35078
C4
α = 0.39976
C5
α = 0.486
C6
α = 0.60933
C7
α = 0.78761
C8
α = 0.97113
C9
α = 1.4499
C10
α = 1.7155
C11
α = 1.9424
C12
α = 1.9538
C13
α = 1.9838
C14
α = 1.9931
x 10^−5
C15
α = 1.9974
x 10^−5
C16
α = 1.9974
res
time(s)

DFA

(Detrended Fluctuation Analysis)

DFA is used to label whether an IMF is *correlated*.

$$C(s) = \mathbf{E}[x(t)x(t+s)] \approx \frac{1}{N-s} \sum_{t=1}^{N-s} x(t)x(t+s)$$

Correlation can be written in term of power law as

$$C(s) \propto s^{-\gamma}$$

Parameter γ can be indirectly estimated by Fluctuation function

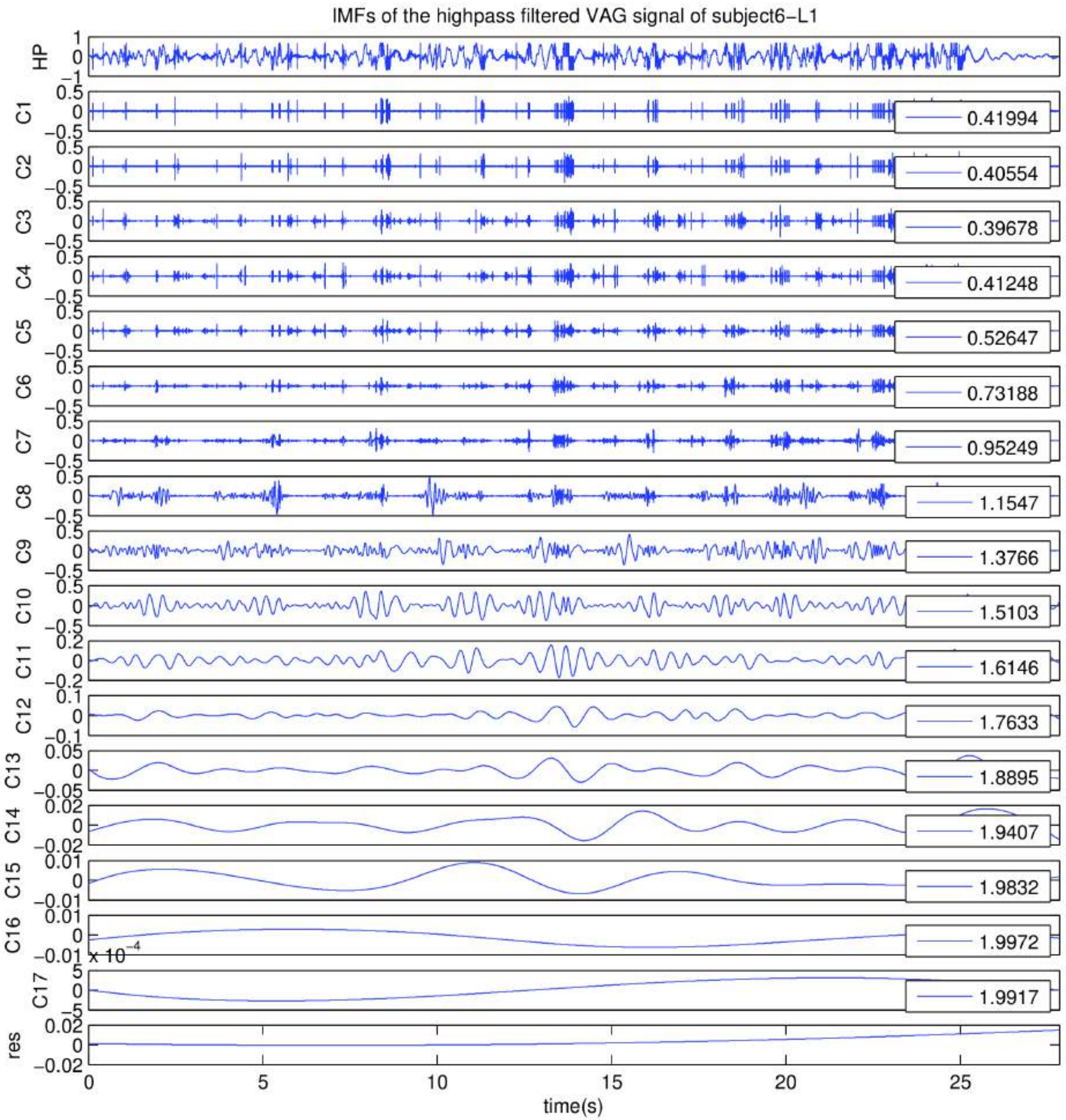
$$F(s) = s^{1-\frac{\gamma}{2}} = s^{\alpha},$$

where s is a segmentation length of the signal.

Some important range of α are as followed:

- $\alpha < 0.5$ short-range correlated
- $\alpha = 0.5$ uncorrelated, white noise
- $\alpha > 0.5$ correlated

Normally, signal which $\alpha \leq 0.5$ is discard.


IMFs of the highpass filtered VAG signal of subject6−L1
HP
C1
0.41994
C2
0.40554
C3
0.39678
C4
0.41248
C5
0.52647
C6
0.73188
C7
0.95249
C8
1.1547
C9
1.3766
C10
1.5103
C11
1.6146
C12
1.7633
C13
1.8895
C14
1.9407
C15
1.9832
C16
1.9972
x 10^−4
C17
1.9917
res
time(s)

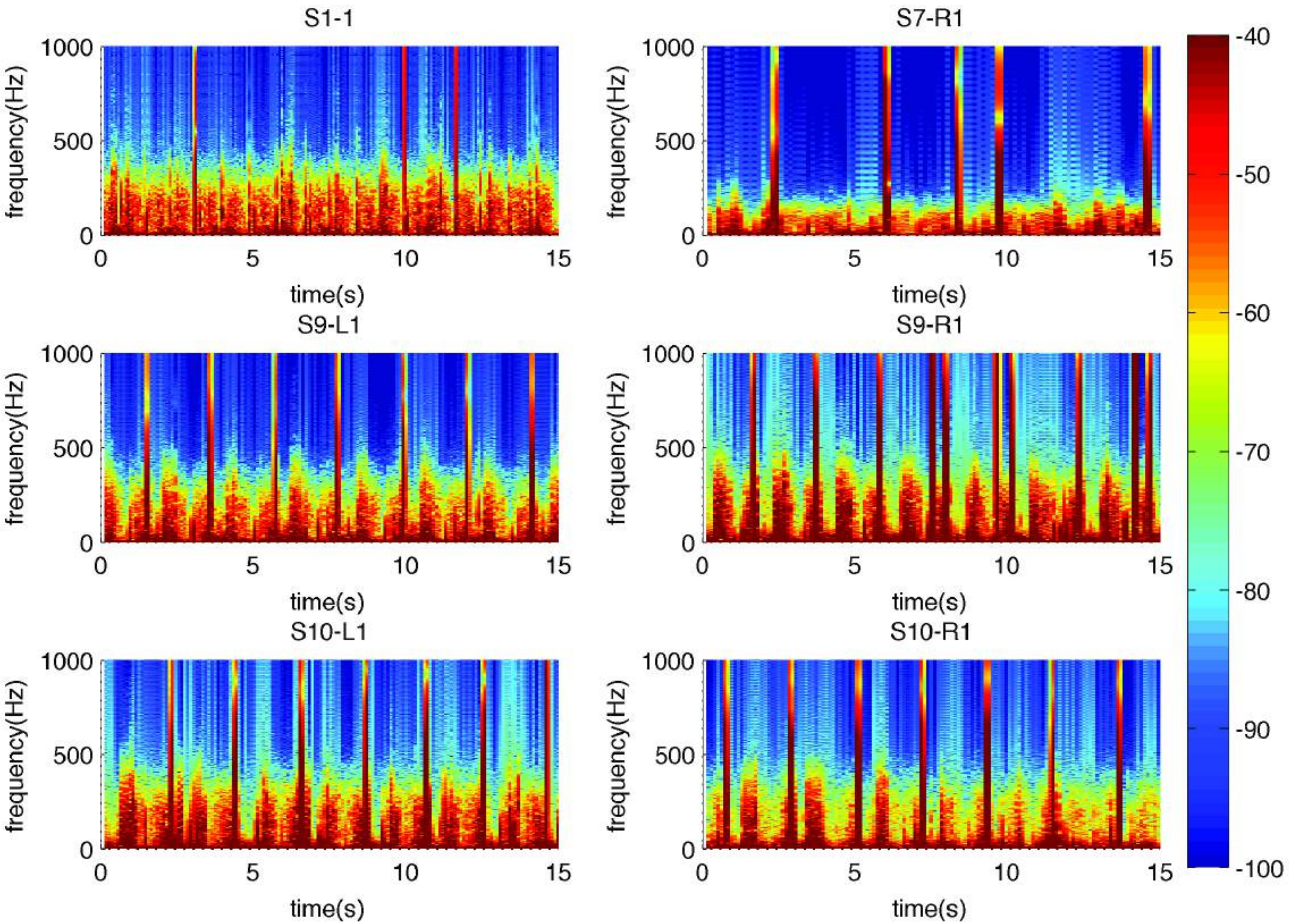
Short time Fourier transfrom (STFT)

STFT analyzes the signals into parts called window $w[n]$.
The STFT of a VAG signal $y[n]$ is given by

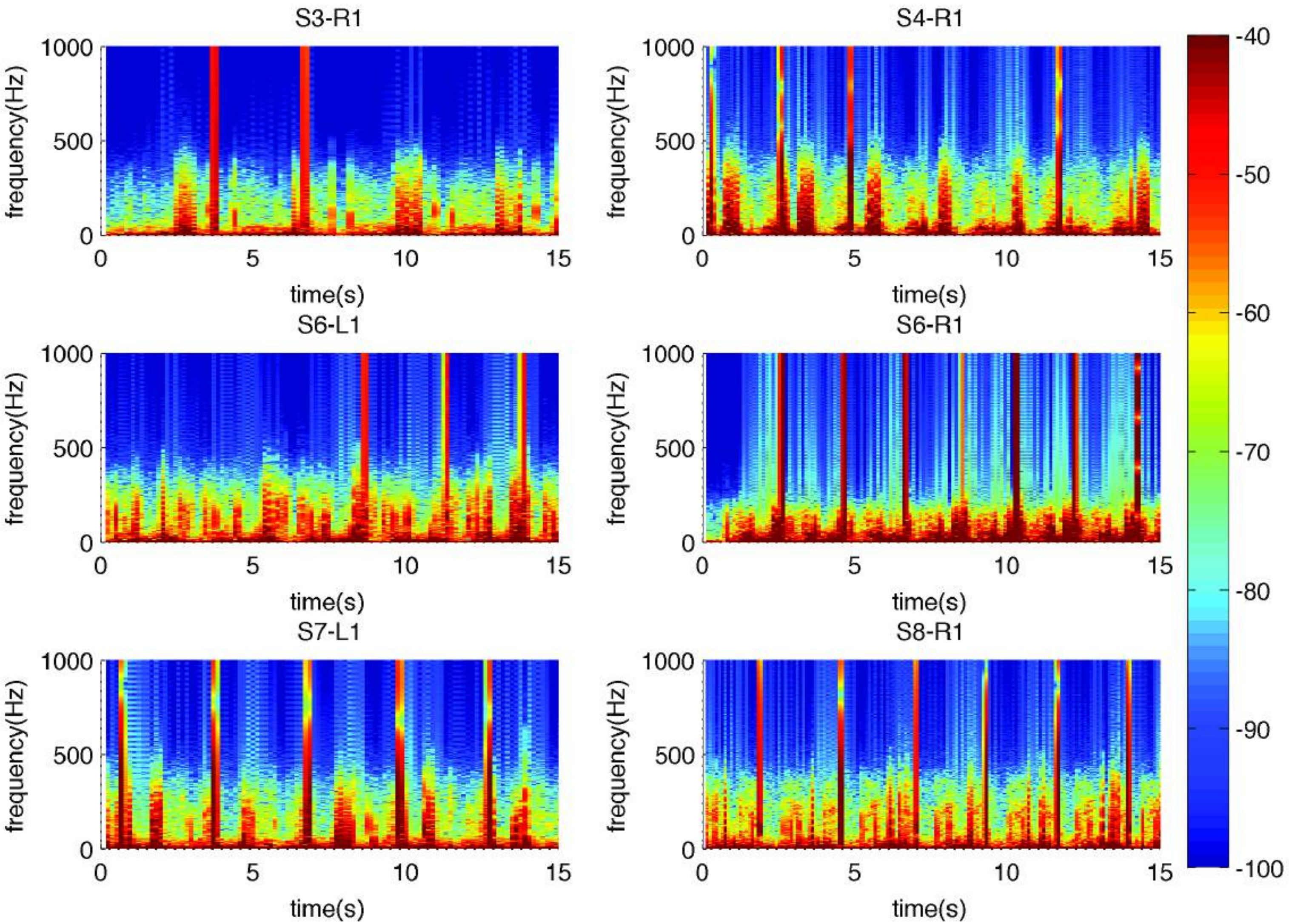
$$Y(m,\omega) = \sum_{n=m}^{L-m-1} y[n]w[n-m]e^{-j\omega n},$$

where $w[n]$ is a window function of length L

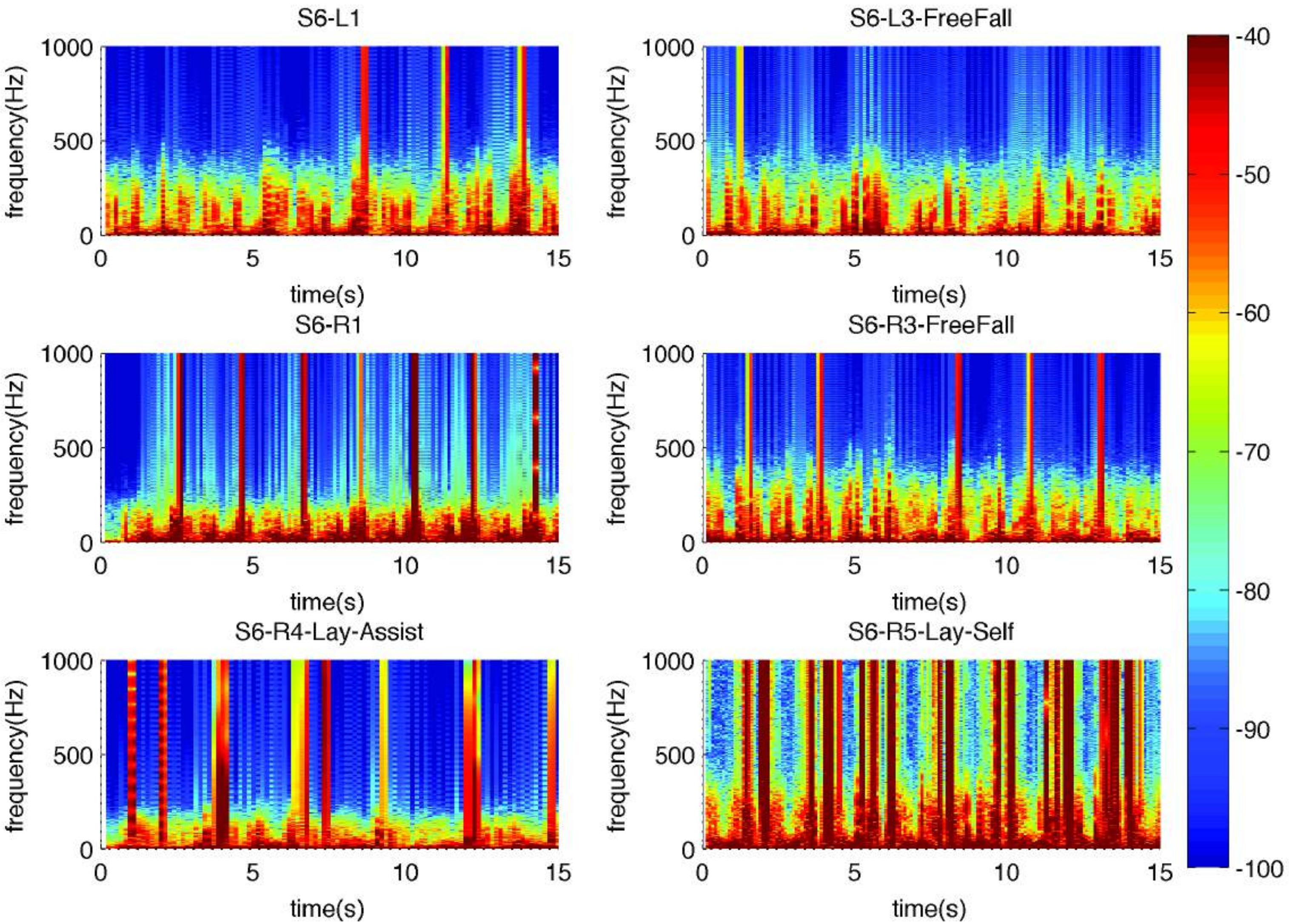
STFT results of resurface class



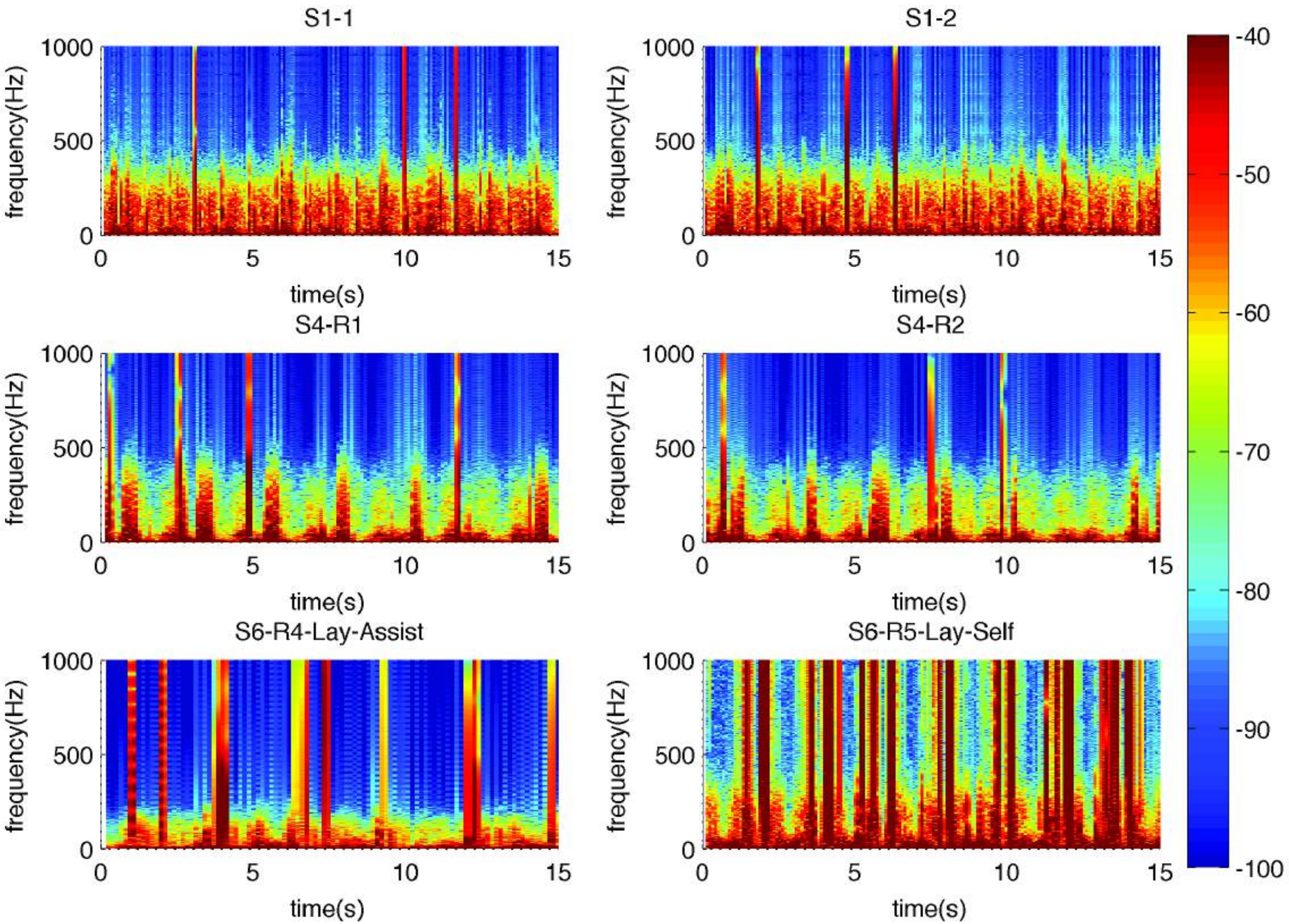
STFT results of non-resurface class

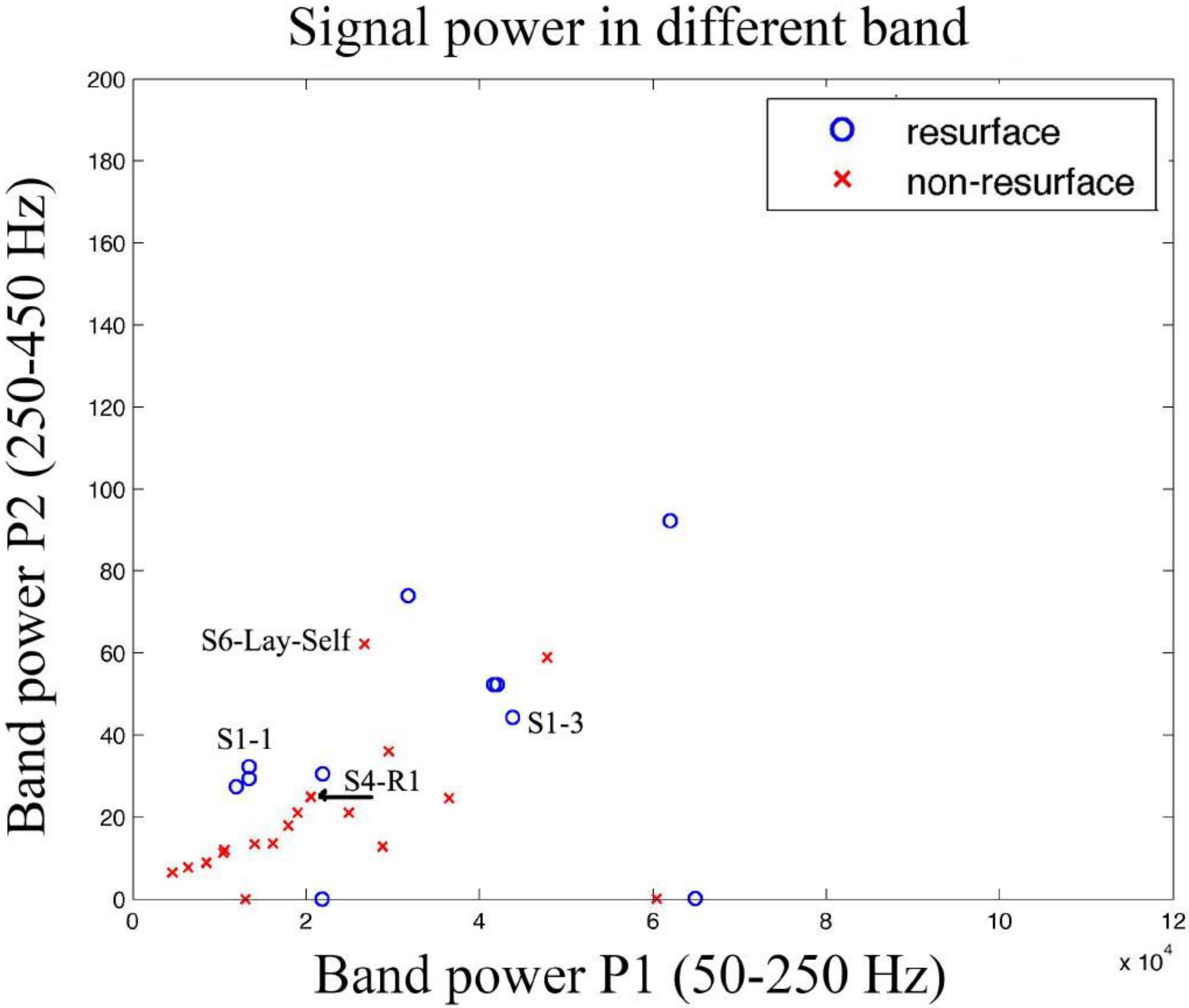


STFT results under different condition



STFT results of subject with sound





Signal power in different band
resurface
non-resurface
Band power P2 (250-450 Hz)
Band power P1 (50-250 Hz)
x 10^4
S6-Lay-Self
S1-1
S1-3
S4-R1
0
2
4
6
8
10
12
20
40
60
80
100
120
140
160
180
200

Conclusion

- Despite processing with EEMD/DFA, the resurface/non-resurface data set are not different.
- There are differences when measurement is carried out under differenct condition.
- Subjects with cracking sound has magnitude according to their severity.

Thank you
for your attention.

contact me via GitHub : fangyibkk