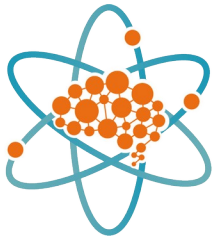

CORTEX

Core monitoring techniques and
experimental validation and demonstration

Extracting QOI out of experimental data : 2/2

2nd CORTEX Validation Workshop, 23-24 March 2021, Online

Klemen Ambrožič, Vincent Lamirand

Klemen.ambrozic@epfl.ch

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Outline

- Quantities of interest (**QOI**) recap
- Time series post-processing procedure: Best estimate + uncertainty (**BEPU**) recap
  - Synchronization
  - Detrending & normalization
  - Bootstrapping with replacement on per-oscillation basis
  - Spectral power estimates
  - Correlation and co-variance estimates
  - Distributions
- Conclusions (2/2)

Quantities of Interest

- Working in frequency domain: FFT

$$F(f)=\int_{-\infty}^{\infty} f(t)e^{-2\pi it}dt$$

- Periodogram

$$Per_{i,j}=conj\left(F_i(f)\right)\cdot F_j(f)$$

- Mean calculated by averaging (usually over N segments)

$$\overline{Per_{i.j}}=\frac{\sum^{N} Per_{i,j}}{N}$$

Quantities of Interest

- Power spectral density: Power of noise at specific frequency

$$PSD_{i,j}(f) = \left|\overline{Per_{i,j}(f)}\right|$$

- Phase shift:

$$\phi_{i,j}(f) = arg\left(PSD_{i,j}(f)\right)$$

- Coherence (linear connection between i&j)

$$COH_{i.j}(f) = \frac{\left|PSD_{i,j}(f)\right|^2}{\Re\left(PSD_{i,i}(f)\right) \cdot \Re\left(PSD_{j,j}(f)\right)}$$

Quantities of Interest

- Spectral power:

$$PS_{i,j}(F) = \int_{F_{min}}^{F_{max}} PSD_{i,j}(f)\,df$$

- Working in relative terms: ratios & differences to a selected reference detector, to obtain multiple estimates, check for biases and uncertainty propagation.

$$R_{\phi_{i,ref}}(F) = \phi_{i,j}(F) - \phi_{j,ref}(F)$$

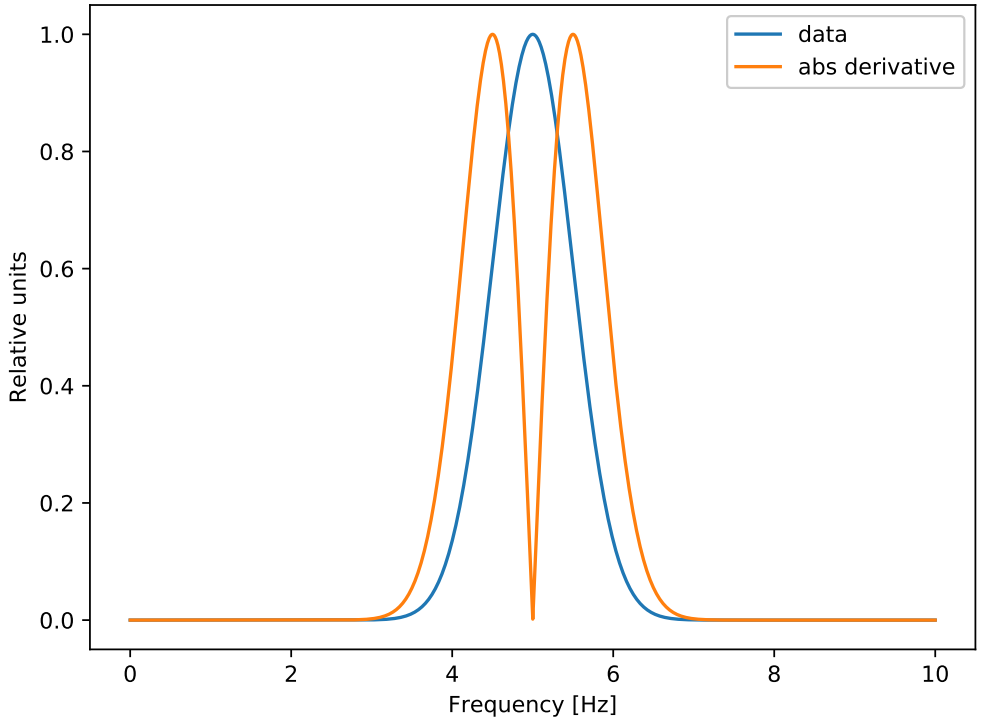
$$R_{PS_{i,ref}}(F) = \frac{PS_{i,j}(F)}{PS_{j,ref}(F)}$$

Spectral power estimates

- Spectral power:

$$PS_{i,j}(F) = \int_{F_{min}}^{F_{max}} PSD_{i,j}(f)\,df$$

- How to select integration limits?
  1) Finding PSD maxima
  2) Finding local minima
  3) Estimating Full Width Half Maximum (FWHM) from PSD derivative extrema: 3x distance



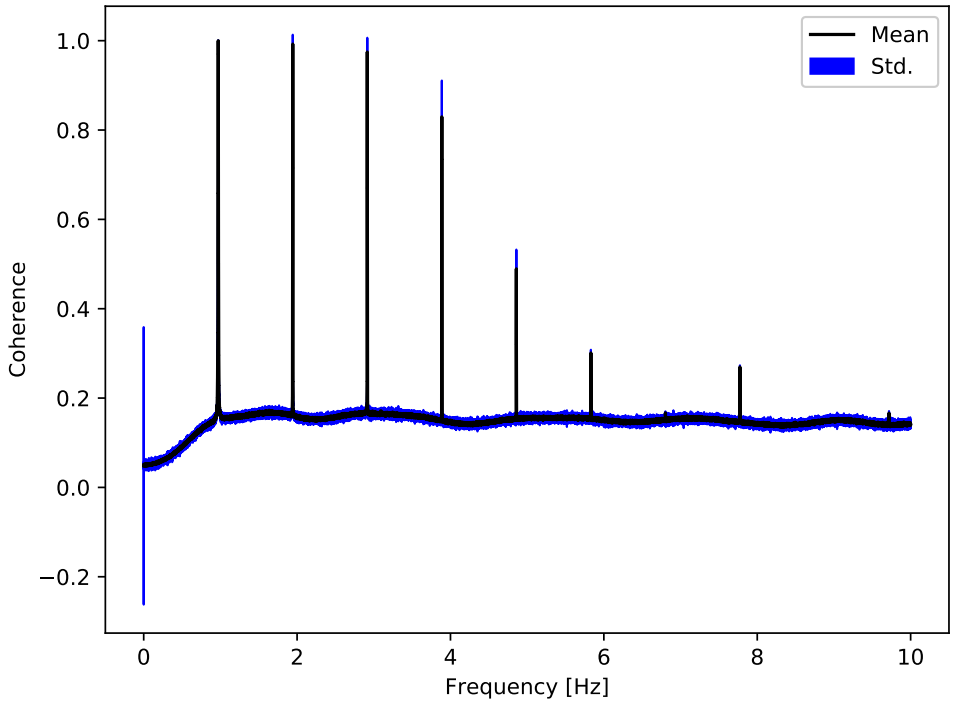
BEPU

- Working with relative quantities and ratios.
- Synchronization of data from all measurement systems
- Removal of unwanted correlations between consecutive oscillations & windowing
- Various contributions
- Inclusions of correlations
- Distributions

Inclusion of correlations

$$PSD_{i,j}(f) = \left|\overline{Per_{i,j}(f)}\right| \qquad COH_{i.j}(f) = \frac{\left|PSD_{i,j}(f)\right|^2}{\Re\left(PSD_{i,i}(f)\right) \cdot \Re\left(PSD_{j,j}(f)\right)}$$

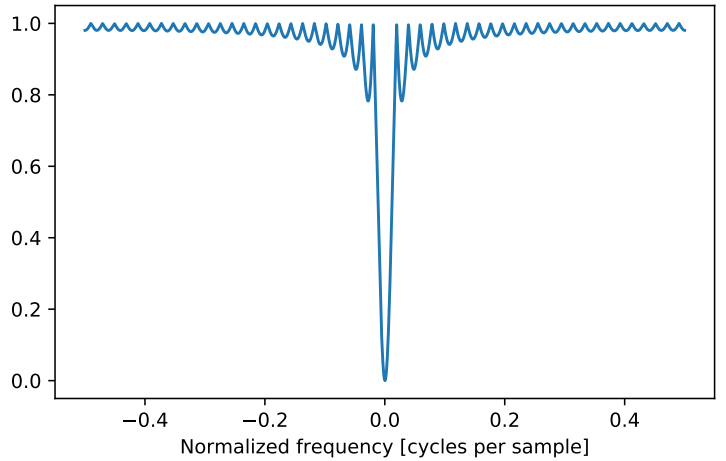
- Coherence is a measure of correlation in frequency domain to calculate PS



Various contributions

- Bootstrapping statistics
- Frequency resolution : Phase angle uncertainty increasing with frequency
- Data detrending and normalization

  by moving average
- Detector signal :
  - Pulse mode : statistics
  - Current mode : signal to noise



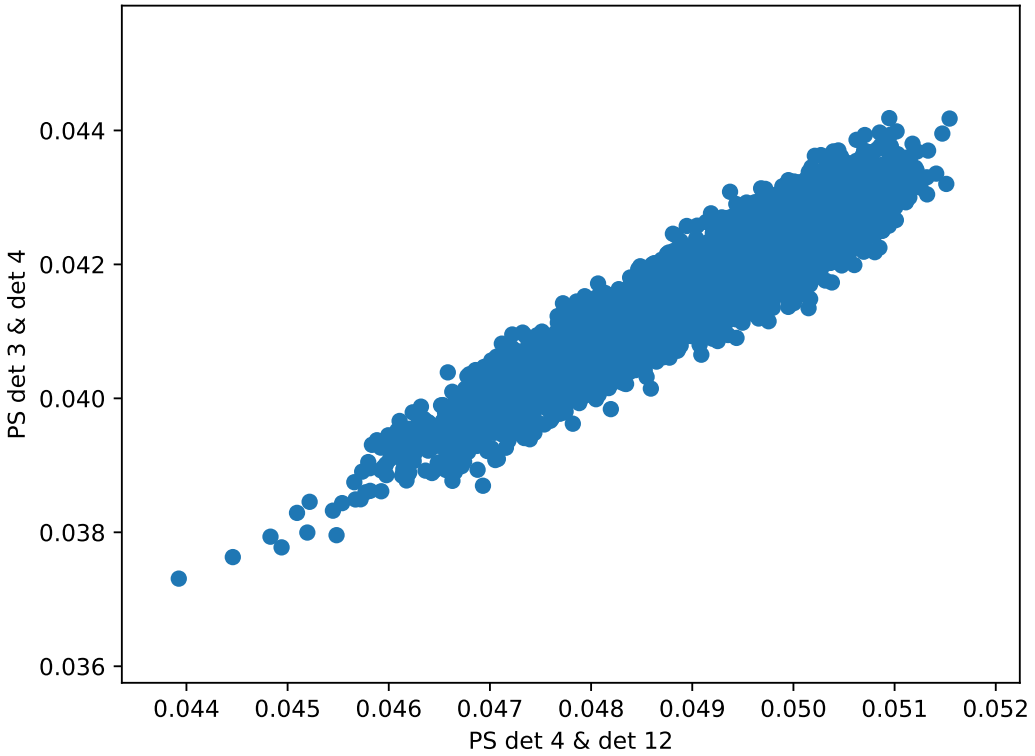
Inclusion of correlations

- Tally of individual bootstrap samples in order to obtain correlations :

  same noise source

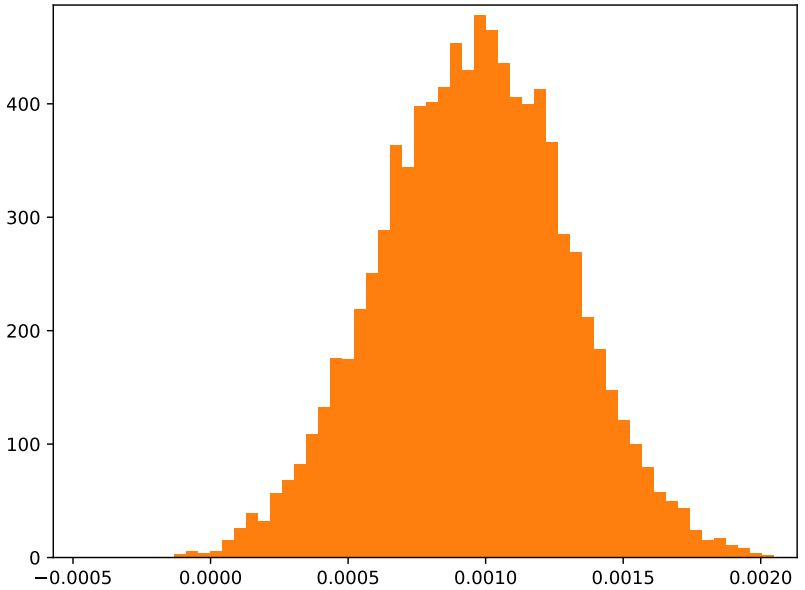
$$R_{PS_{i,\,ref}}(F) = \frac{PS_{i,j}(F)}{PS_{j,ref}(F)}$$

$$R_{\phi_{i,ref}}(F) = \phi_{i,j}(F) - \phi_{j,ref}(F)$$

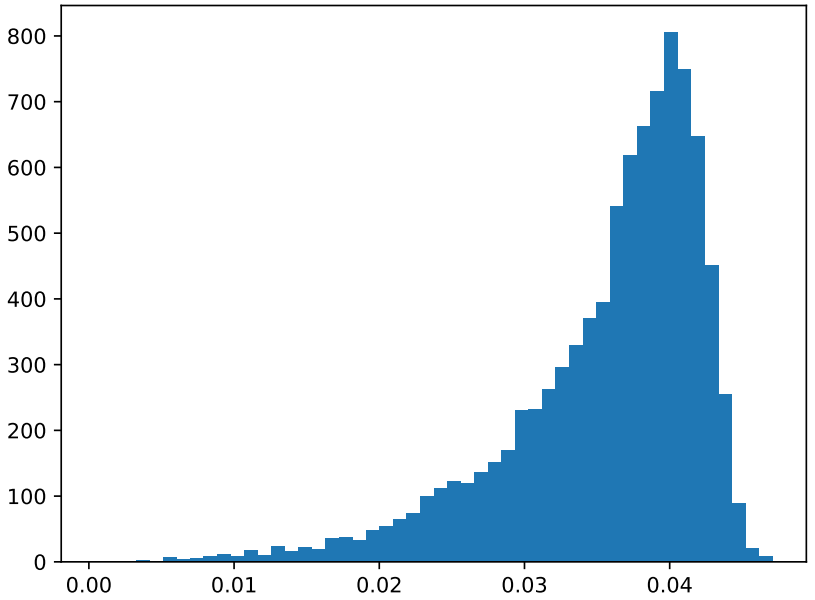


Distributions

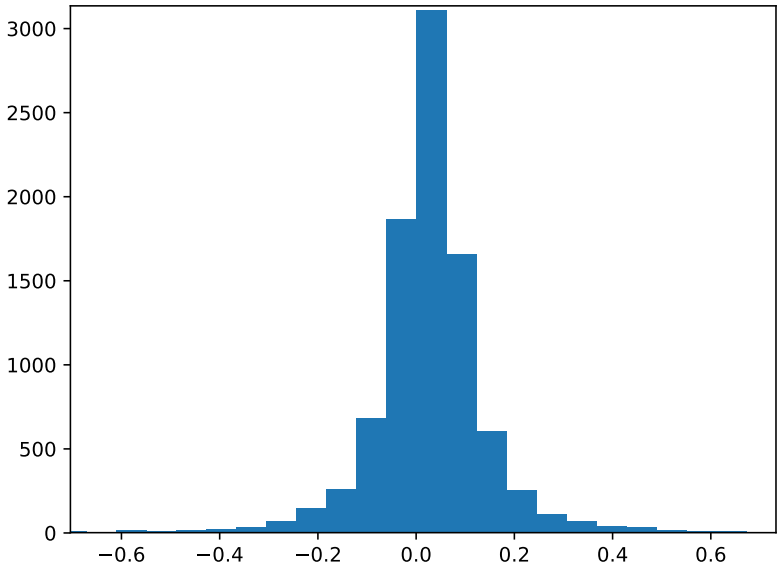
- Periodogram components



- PSD



- Phase angle



Conclusions

- Uncertainty from various contributions + statistics
- Inclusion of correlations both for PS and PS ratio calculations :
  - Coherence
  - Correlation by tallying individual boostrapping steps
  - Comparison with uncertainty of PS ratio evaluations.

Thank you