

The Riemannian Potato: an Automatic and Adaptive Artifact Detection Method for Online Experiments using Riemannian Geometry

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January 23, 2013

- Context :
 - Online BCI experiments
- Problem :
 - Classification and/or adaptation very sensitive to artifacts.
 - Manual detection impossible.

Goal

- Online Artifacts detection
- Automatic : No parameters to set manually
- Adaptive : Adapt to non-stationarity
- Generic : Not specific to a particular kind of artifacts.

A new definition

- BCI \rightarrow detection of a reference activity
 - Motor Imagery
 - Evoked Potential

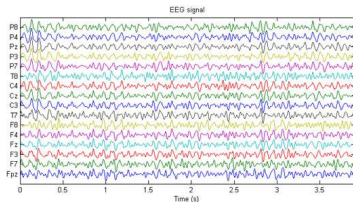
A New Definition

Artifact \implies Any kind of EEG signal different enough as compared to a reference activity.

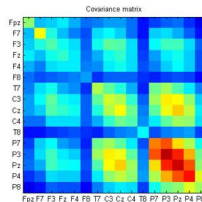
- 2 Steps :
 - 1 Characterization of the reference activity.
 - 2 Measuring the similarity.

Covariance Matrices

- Spatial covariance matrix of EEG signal \implies descriptor of brain activity.
- Manipulation through Riemannian geometry.



\mathbf{X}_i : Epoch of EEG signal

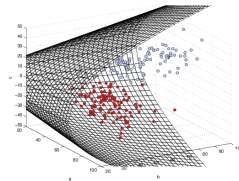


Spatial covariance matrix : $\hat{\Sigma}_i = \frac{1}{Ne-1} \mathbf{X}_i \mathbf{X}_i^T$

- Covariance matrices :
 - Symmetric and positive definite
 - Belong to a Riemannian Manifold.
 - Distance :

$$\delta_R(\Sigma_i, \Sigma_j) = \|\log(\Sigma_i^{-1/2} \Sigma_j \Sigma_i^{-1/2})\|_F$$

- Reference activity : specific region in the manifold.



Principle

- Define a Region Of Interest (ROI)
- Point outside the ROI \implies Artifact

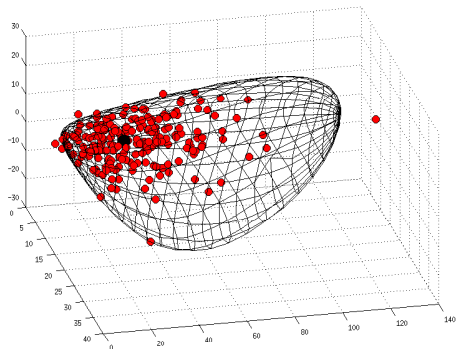
Riemannian Potato

- 1 Center of the ROI : Geometric mean of covariance matrices.

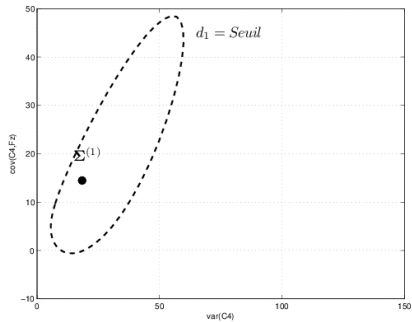
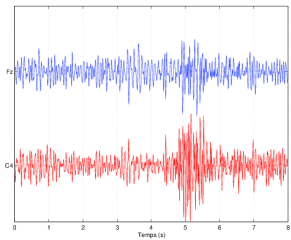
$$\bar{\Sigma} = \operatorname{argmin}_{\Sigma} \sum_i \delta_R(\Sigma, \Sigma_i)^2$$

- 2 Edge of the ROI : threshold on the distance to the center.

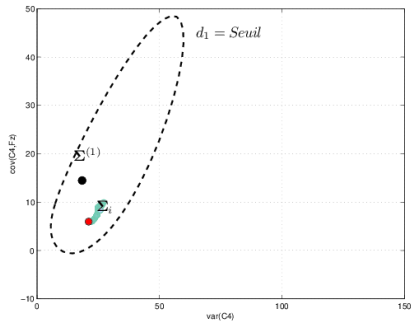
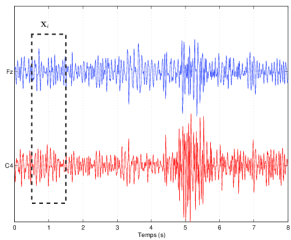
$$\delta_R(\bar{\Sigma}, \Sigma_i) = th = \mu + 2.5\sigma$$



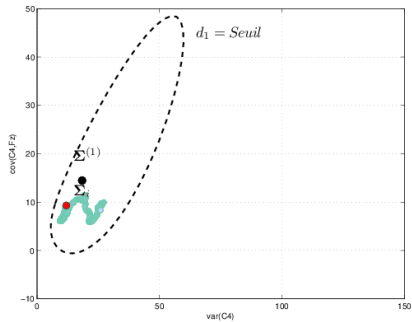
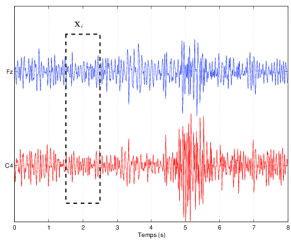
Illustration



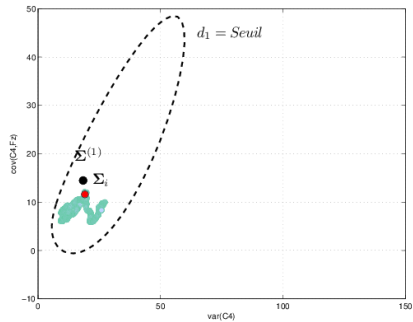
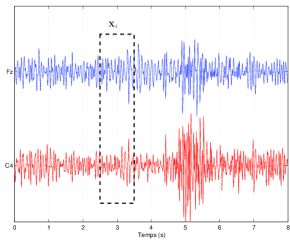
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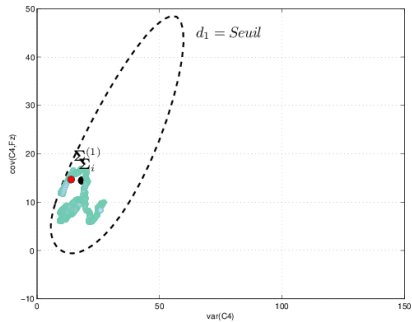
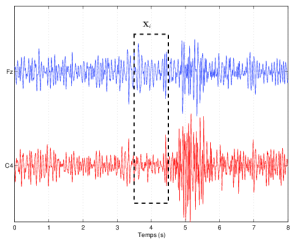
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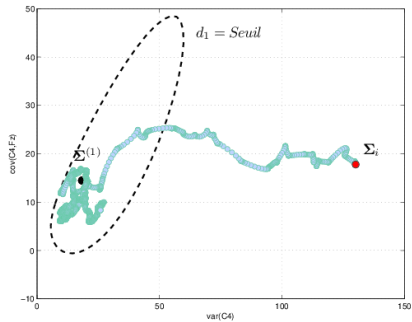
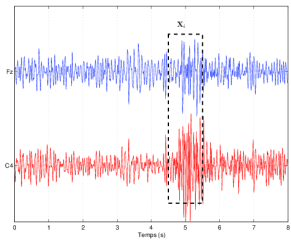
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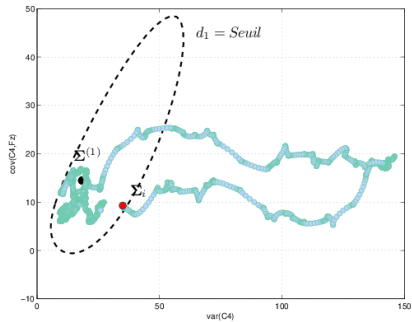
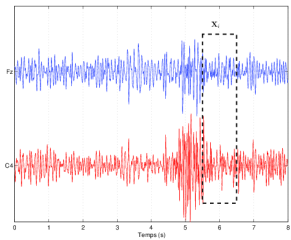
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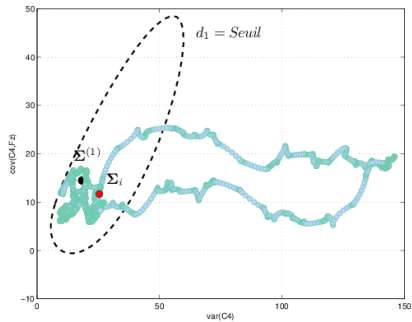
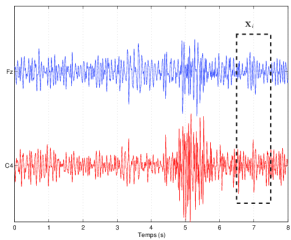
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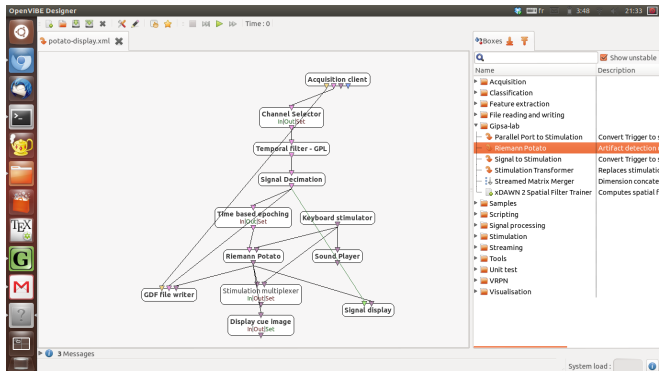
- Use baseline EEG as reference activity.
- Adaptive geometric mean

$$\bar{\Sigma}_t = \bar{\Sigma}_{t-1}^{\frac{1}{2}} \left[\bar{\Sigma}_{t-1}^{-\frac{1}{2}} \Sigma_i \bar{\Sigma}_{t-1}^{-\frac{1}{2}} \right]^{\frac{1}{\alpha}} \bar{\Sigma}_{t-1}^{\frac{1}{2}}$$

- Adaptive threshold (adaptive mean and std)
- Adapt when $\delta_R(\bar{\Sigma}_t, \Sigma_i) < th_t$ (if $t > 10$ s)

Openvibe implementation.

- 7 electrodes
- Frequency filtering : 1-20 Hz
- Window for covariance matrix estimation : 1.5 s
- Initialization : 10 s of baseline signal.



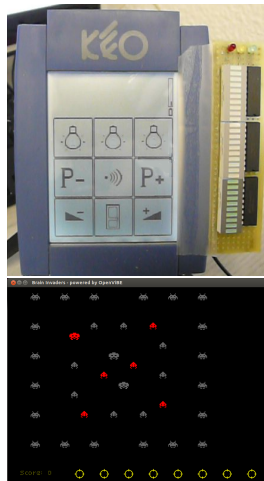
How to use the potato ?

1 Signal processing

- Ignore corrupted trials
 - ex : Brain switch.
- ⇒ Improve performance.

2 Paradigm

- Pause until clean signal.
 - ex : Brain invaders.
- ⇒ The user learn how to avoid artifacts.



- Simple method (distance, geometric mean).
- No parameters to tune manually.
- Not specific to a particular kind of artifact.
- Fast training.
- Adaptive.

Integrated in the next official release of OpenViBE.

Thank you for your attention.

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Code :

- Riemannian Potato in OpenViBE :
<http://code.google.com/p/opencvibe-gipsa-extensions>
- Riemannian Geometry toolbox for Matlab :
<http://github.com/alexandrebarachant/covariancetoolbox>