EEG signal analysis for epileptic seizure genesis study

Pierre Guetschel, Théodore Papadopoulo, Fabrice Duprat

EEG signal analysis for epileptic seizure genesis study

Pierre Guetschel, Théodore Papadopoulo, Fabrice Duprat

Université Côte d'Azur, Inria Sophia Antipolis-Méditerranée, Athena Project-Team, France

Contact: Theodore.Papadopoulo@inria.fr

https://team.inria.fr/athena/

Abstract: Epilepsy is a neurological disorder that manifests itself as episodes of epileptic seizure characterized by an unusually sporadic neural activity observable by EEG. A model of transgenic mouse affected by epilepsy has been developed in order to better understand, predict and preventively treat these seizures. Between the seizures, we observe some interictal spikes that are expected to be used as predictive tools for the seizures. We were interested in developing algorithms to automate their detection, counting and characterisation. A major obstacle was the contamination of the studied signals by artefacts. The first approach was to decompose the signal with a Convolutional Dictionary Learning framework, but it was inconclusive. The successful approach was to, first, detect and cut the artefactual zones using a threshold on the signal norm, then a rough spike detection and finaly, a classification of the spikes between desirable and unwanted events using a classifier trained on a small dataset of hand-picked events.

1 Dictionary Learning

- **Signal** $X \in \mathbb{R}^{N\times T\times P}$ *Input*
- **Dictionary/Atoms** $D \in \mathbb{R}^{K\times T_{atoms}\times P}$ *Output*
- **Activations/Code** $z \in \mathbb{R}^{N\times K\times (T-T_{atoms}+1)}$ *Output*

$$\min_{D,z}\sum_n\left(\left\|X^n-\sum_k D_k * z_k^n\right\|_2^2+\lambda\sum_k |z_k^n|\right)$$

under the *atom norm* constraint: $\forall k, \|D_k\|_2 \le 1$ *mandatory*

the *rank-1* constraint: *optional*

$$\forall k, \exists u_k \in \mathbb{R}^P, \exists v_k \in \mathbb{R}^{T_{atoms}}, D_k = v_k u_k^\top$$

the *delta* constraint: *optional*

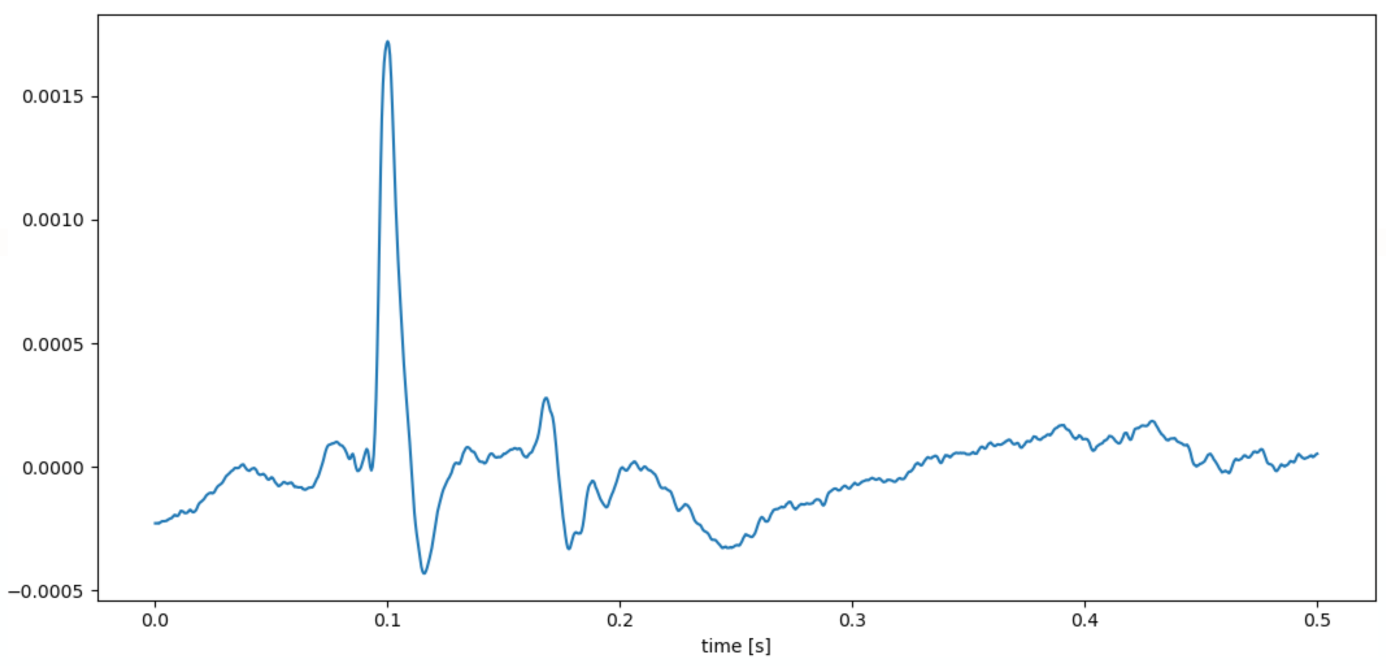
$\forall i_1 i_2 k_1 k_2 n, i_1 \neq i_2 \wedge |i_1 - i_2| \le \Delta \wedge z_{k_1}^n[i_1] \neq 0 \implies z_{k_2}^n[i_2] = 0$

and the L_0 *norm* constraint: $\forall n, \|z^n\|_0 \le M$ *optional*

2 Interictal spikes

Interictal spikes are:

- appearing between epileptic seizures
- expected to be used as predictive tools for the seizures
- the events we try to detect and characterize



3 Datasets

Pre-study:

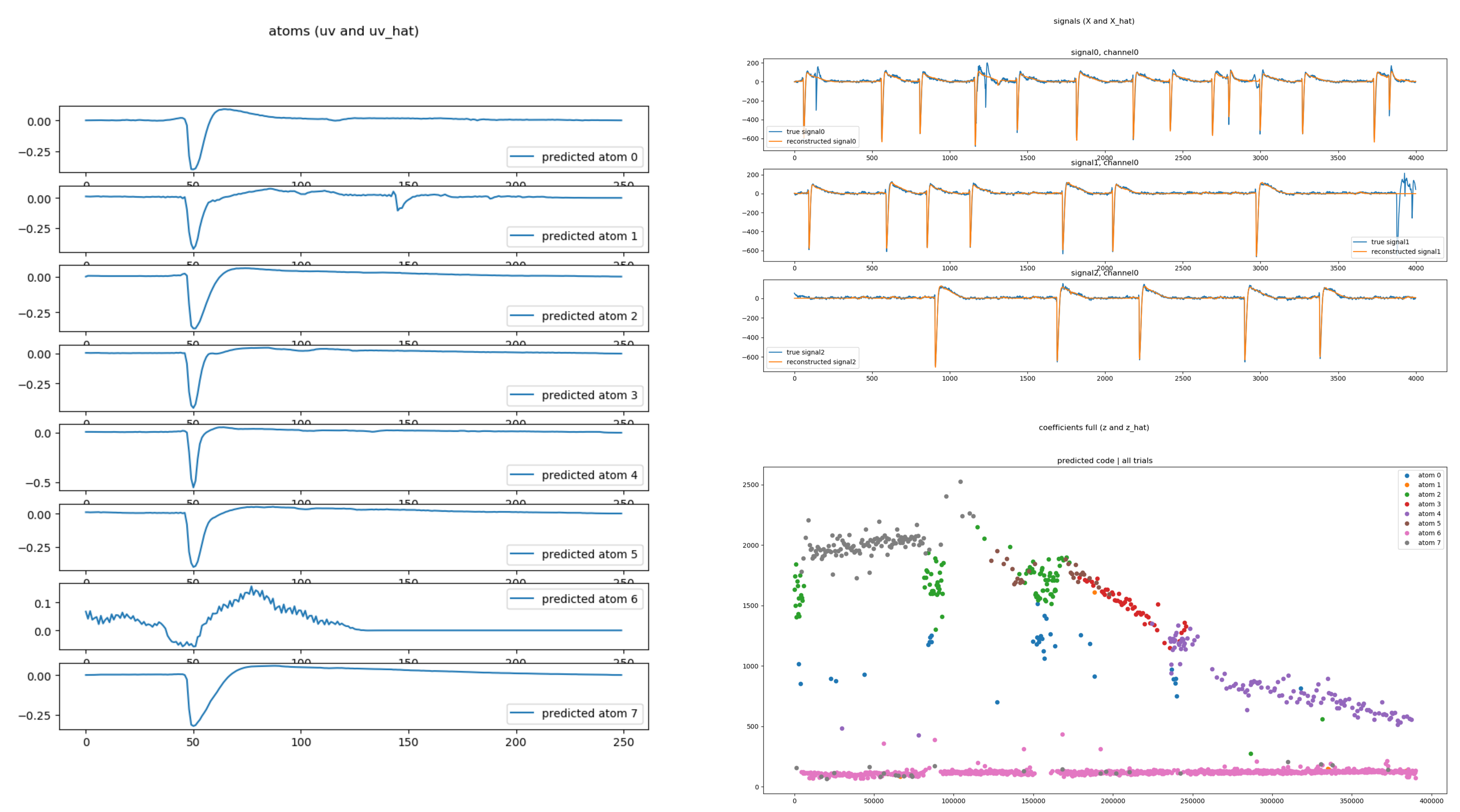
- asleep rats
- with bicuculline injected to simulate interictal spiking activity
- 1h long recording

Main dataset:

- awakened mice (muscular artefacts in recordings)
- made epileptic by genetic modification plus fiver simulation [3]
- 24/7 iEEG recordings

4 Experiments and results

Pre-study: Good results with Dictionary Learning (L_0 norm, rank-1 and delta constraints): good signal reconstruction and interpretable atoms and encoding.



Main study: Inconclusive results with Dictionary Learning because : too few interictal spikes (only 57 in the 24h long studied recording) and artefacts amplitude (10x the signal of interest) and heterogeneity.

Successful 3-step solution :

1. threshold on signal norm to detect and cut off artefacts
2. rough peak detection (scipy's `find_peaks`)
3. **feature extraction** on the detected spikes + **classification**

Features are spectrograms.

Classification with Random Forests (various classical models tested (LDA, SVM, decision trees), all giving good results), 97% accuracy.

5 Contributions and Conclusion

Throughout this work, we extended the alphacsc library [1] to deal with more cases, we produced muscular artefact detectors by threshold or BSS (not addressed here) and we implemented an event detection pipeline with an user-friendly interface already used by biologists and suitable for various types of events.

Acknowledgements: This work has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and. innovation program (ERC Advanced Grant agreement No 694665: CoBCoM - Computational Brain Connectivity Mapping)

References:
[1] T. D. La Tour, T. Moreau, M. Jas, and A. Gramfort. Multivariate convolutional sparse coding for electromagnetic brain signals. In *Advances in Neural Information Processing Systems*, pages 3292–3302, 2018.
[2] S. Hitziger. *Modeling the variability of electrical activity in the brain.* PhD thesis, 2015.
[3] A. R. Salgueiro-Pereira, F. Duprat, P. A. Pousinha, A. Loucif, V. Douchamps, C. Regondi, M. Ayrault, M. Eugie, M. I. Stunault, A. Escayg, et al. A two-hit story: Seizures and genetic mutation interaction sets phenotype severity in scn1a epilepsies. *Neurobiology of disease*, 125:31–44, 2019.

Source codes available at `https://gitlab.com/PierreGtch/{artefacts,interictal_spike,alphacsc_dilation}`