Jitter-Adaptive Dictionary Learning - Application to Multi-Trial Neuroelectric Signals
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Multi-trial analysis in neuroscience

- **Trials:** recordings of neuronal electromagnetic activity under similar conditions.
- **Goal:** detect similar waveforms and describe how they change across trials.

![Graph showing time vs. trials with a scatter plot and a linear regression line]

Existing approaches:
- **Averaging:** loses the information present in individual trials.
- **Matrix factorization (PCA, ICA, dictionary learning)** (11):
- **Linear approach:** does not account for temporal shifts [2].
- **Variants of matching pursuit** (3):
- Do not learn waveforms but require predefined dictionary.

**Atom:**

\[ \Delta \]

\[ \Delta = \{ \Delta \} \]

**Epochs:**

- **Epoch 41**
- **Epoch 111**
- **Epoch 161**

Jitter-Adaptive Dictionary Learning (JADL)

- **1-regularized optimization**

\[ \begin{align*}
(\delta_{k}, s_{k}, b_{k}) = & \min_{\delta_{k}, s_{k}, b_{k}} \sum_{n} \sum_{k} a_{n} b_{k} \delta_{k} + \lambda \| s_{k} \|_{1} \\
\text{s.t.} & \quad |\delta_{k}| = 1, \quad b_{k} \in \Delta
\end{align*} \]

**Dictionary:**

- **Update:**

\[ \begin{align*}
\text{Sparse coding: update } (a_{n}, b_{k}) & \quad \text{idea as } \Delta \text{ is finite, we can first apply all possible shifts to } D, \text{ yielding the "unrolled" dictionary } D^{\delta} \\
& \quad \text{sparse coding can now be performed over } D^{\delta}, \text{ the non-zero coefficients show which shifts are used.}
\end{align*} \]

**Algorithm 1**

**Sparse coding update**

**Dictionary update**

**Learned coefficients and shifts provide insight into data**

**Real data**

In an animal model of epilepsy, local field potentials were recorded during one hour with an intra-cranial electrode in a Winster-Han rat. Bipolarization (a block of inhibition) was injected in the cortex to elicit epileptic-like discharges. 169 of these spikes were then selected visually and segmented into epochs of 10 seconds.

**Jitter-Adaptive Dictionary Learning (JADL)**

- **Learned coefficients and shifts provide insight into data**

**Conclusion**

We presented a new method (JADL) which is an extension to dictionary learning and designed to analyze multi-trial neuroelectric datasets. We evaluated JADL on synthetic and real data and showed its superiority to common dictionary learning. In particular, JADL showed the following qualities:

- **Ability to learn main waveforms and to separate them.**
- **Learned shifts and coefficients give insights into the changes of waveforms (phase, latency, amplitude).**
- **Computational efficiency, even for high shift-tolerance.**
- **Robustness and denoising qualities.**