Dictionary learning for M/EEG multidimensional data
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1. Jitter-adaptive dictionary learning model (JADL)

JADL is a dictionary learning framework that allows for online learning of the dictionary and the sparse coefficients of the input signal. It is an extension of the sparse coding problem (i) by low-rank approximation (ii).

\[ x_j = \sum_{i=1}^{K} a_{ij} d_i + r \]

where \( x_j \) is the signal in channel \( j \), \( a_{ij} \) are the coefficients, \( d_i \) are the atoms of the dictionary, and \( r \) is the noise. The dictionary \( D \) and the coefficients \( A \) are learned in an iterative process.

2. Our modified JADL model

We propose an extension to the JADL model that allows for online learning of the dictionary and the sparse coefficients of the input signal. It is an extension of the sparse coding problem (i) by low-rank approximation (ii).

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3. Synthetic data generation

Create a dictionary of 3 signals. Generate an extended dictionary of 9 signals:

- Introducing random jitters (from the set \( \Delta \) of \( N \) contiguous allowed shifts) to the dictionary's atoms.
- Select 3 source groups, each of them containing 3 neighboring sources.
- Combine the generated signals with a lead field matrix \( C \) computed from real EEG samples.
- Shifted versions of the dictionary \( D \) are used to generate the corrupted signal.
- Generated clean M/EEG measurements of 6 channels, \( M = 200 \) trials, and \( N = 515 \) time samples.

4. Results on lead field synthetic data

A comparison between the original and our multi-dimensional JADL model shows:

- Similar results when the best channel is used by the single-channel algorithm.
- Worse results for the single-channel algorithm when a medium or the worst channel is used.
- Complete results for the multi-channel algorithm are unacceptable for recovery at all channels of the dictionary used to generate the signals.
- A small but superior performance for the multi-channel approach based on the coefficients vectors obtained by the goodness of fit metric: 0.999, 0.998 and 0.993 instead of 0.992, 0.977 and 0.946 for the single-channel approach using the best channel and 0.939, 0.512, 0.512 using the worst channel.

5. Results on real data

The multi-dimensional approach is tested using real MEG and EEG data:

- \( C = 200 \) channels.
- \( M = 63 \) trials.
- \( N = 541 \) time samples, contaminated by ambient noise.

6. Conclusions

The method shows superior performance and less noisy estimated waveforms compared to the original single-channel JADL framework, both on synthetic and real data.

- It is more robust to various levels of noise.
- Using the JADL framework allows one to deal with signal variabilities such as jitters which is difficult to do with standard methods such as PCA or ICA.
- Not having to select a "best" channel (as with the JADL method) is both a user simplification and allows the exploitation of all the available information from M/EEG trial by trial signal decomposition. Thus, it provides better estimations of waveforms in the dictionary.