Introduction

Matching pursuit is an effective method of signal representation and feature extraction widely used in neural signal analysis. However, its traditional implementation is slow and computationally demanding, restricting its use in real-time practical applications, especially when the analyzed data has numerous channels such as in electroencephalography (EEG). We propose a new faster matching pursuit algorithm, predictive matching pursuit, and verify its speed improvement in neural signal applications.

Matching Pursuit

Matching pursuit (MP) is an algorithm that decomposes a signal into a linear expansion of waveforms that are selected from a redundant dictionary of functions. From this large dictionary of possible functions, a sub-family of time-frequency atoms is chosen in such a way as to best match the local signal structures. The family of time-frequency atoms is created by scaling, translating, and modulating a window function \( g(t) \):

\[
g_s(t) = \frac{1}{\sqrt{s}} g\left(\frac{t - \mu}{s}\right) e^{j\xi t}
\]

where \( s > 0 \) is scale, \( \xi \) is frequency modulation, and \( \mu \) is translation [1]. The minimum of time-bandwidth product is obtained when \( g(t) \) is Gaussian. In this case, \( g_s \) are called Gabor functions (Gauss modulated by sinus).

Methods

Traditional Matching Pursuit

The traditional matching pursuit algorithms are restricted within every epoch, and never utilize information collected from the previous epochs. The figures above illustrate the decomposition process of three successive epochs within an electrocorticographic (ECoG) signal using traditional matching pursuit. In each frame, the figure below shows the reconstructed signal, and the figure above shows the atoms already selected by matching pursuit. (Every black pixel represents an atom in the dictionary. When it is selected, it turns white.) As can be seen, traditional matching pursuit searches among the entire dictionary regardless of how many epochs it has processed. This is inefficient and what we will improve.

Predictive Matching Pursuit

Since the signal feature variability over epochs is limited, a majority of Gabor dictionary atoms have a very low probability of appearing in the representation. Therefore, as we get more and more information about the signal structure during matching pursuit, we can reduce the size of the Gabor dictionary according to some criterion.

The figures above illustrate the decomposition process of the same three epochs using predictive matching pursuit. Even though search among the whole dictionary is still required for the first epoch, the dictionary sizes for the second and third epochs are greatly reduced based on the prediction of their signal structures. As a result, the decomposition of the same signal can be done with a much higher speed and nearly no precision loss.

Performance

Figure (a) compares the performance of predictive matching pursuit with traditional matching pursuit. For the two epochs examined, the error curves of both methods share the same trend before reaching a reconstruction accuracy of 99.99%. However, predictive matching pursuit uses only 20% of the original dictionary for the same error rate. Figure (b) shows the time course of an ECoG signal with a seizure (top) and the estimated time complexity (a measure of the computational load to perform the signal decomposition) corresponding to each 5-second epoch of it using different implementation algorithms (bottom).

Future Work

- Evaluate the algorithmic performance more precisely using the Performance Application Programming Interface (PAPI)
- Explore the effect of the correlations among epochs on the performance of predictive matching pursuit
- Implement real-time detection of epileptic seizures in ECoG signals using predictive matching pursuit

References