Understanding natural vision using dimensionality reduction and compressive sensing techniques

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Research Question

We seamlessly recognize visual objects in the real world, but it remains a highly complex problem that even the best algorithms have failed to crack. To understand how our brain processes visual stimuli, we plan to record brain signals using microelectrode arrays containing hundreds of microelectrodes implanted in several visual areas in monkeys, while they view both natural images and parametric stimuli such as gratings. The resulting dataset is high-dimensional, since each stimulus evokes a time-varying pattern of activity recorded from the microelectrodes. To better understand natural vision, we need to find a mapping between these high-dimensional inputs and outputs. We aim to achieve this by employing state-of-the-art dimensionality reduction techniques analyzing the neural data.

Dimensionality reduction is a key step to reduce the volume of data. From the literature on compressed sensing, what we know is that if the data has a sparse representation in some dictionary, one can safely reduce dimension without losing information, in the sense that the features in the data get preserved despite the dimensionality reduction. Furthermore, one can reduce dimensionality by simply projecting the signal onto a randomly selected basis. However, in order to extract features from the dimensionality reduced data, a few key questions that need to be addressed are:

1. What is the inherent dimensionality of the data? This determines to what extent the dimensionality can be reduced without losing information. We need to develop robust, data-driven methods to determine the inherent dimensionality.
2. How can we extract the features of the data from the dimensionality-reduced measurements? This involves *dictionary learning*, where we learn both the dictionary in which the data admits a sparse representation as well as the sparse representation itself.
3. What kinds of processing can be done/questions can be answered in the compressed/dimensionality reduced domain itself, rather than having to reconstruct the high-dimensional data and then draw the inferences?
4. What are fast, efficient methods to do the above, so that these can be done in real-time.
5. Account for temporal and across-participant variations in the dimensionality.

Preferred background

Electrical Engineering, Signal Processing, Computer Science, Mathematics, Neuroscience.

For more information, see:
http://www.cns.iisc.ac.in/sray/
https://ece.iisc.ac.in/~cmurthy/doku.php?id=home