Compressed sensing, sparsity, and dimensionality in neuronal information processing and data analysis

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Abstract:

For most of its history, neuroscience has made wonderful progress by considering problems whose descriptions require only a small number of variables. For example, Hodgkin & Huxley (1952) discovered the mechanism of the nerve impulse by studying the relationship between two variables: the voltage and the current across the cell membrane. But as we have started to explore more complex problems, such as the brain’s ability to process images and sounds, neuroscientists have had to analyze many variables at once. For example, any given gray-scale image requires N analog variables, or pixel intensities, for its description, where N could be on the order of 1 million. Similarly, such images could be represented in the firing-rate patterns of many neurons, with each neuron’s firing rate being a single analog variable. The number of variables required to describe a space of objects is known as the dimensionality of that space; i.e., the dimensionality of the space of all possible images of a given size equals the number of pixels, whereas the dimensionality of the space of all possible neuronal firing-rate patterns in a given brain area equals the number of neurons in that area. Thus our quest to understand how networks of neurons store and process information depends crucially on our ability to measure and understand the relationships between high-dimensional spaces of stimuli and neuronal activity patterns.

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