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Data rules; but theory understands

An introduction to a Special Issue on “Mathematical Models of Visual Coding”

Arguably, no collection of biological facts about the brain, nor our ability to simulate ever more complex networks of realistic neurons, will ever answer how this magnificent piece of machinery works.

At least, not without a theory.

Today’s technology is advancing in amazing strides. For example, we have developed an unprecedented ability to measure simultaneously from multiple neurons and brain locations using electrode arrays and optical imaging techniques; we can use high-throughput electron microscopy to reconstruct local circuits down to cells and synapses; and so on. Simultaneous with these advances there is one question that permeates the halls of all neuroscience meetings: “What are we going to do with all these data?”

One answer consists in developing sophisticated data analysis methods to process high dimensional data sets like the ones associated with large multi-electrode arrays. Most computational neuroscientists are currently focused on developing such methods, and have achieved impressive and much needed progress. However, this it not sufficient. We also need to develop theoretical ideas that address the fundamental questions of neuroscience: what does neural activity represent and how do neural circuits implement computations? Unfortunately, theories of neural computation remain surprisingly sparse (compared for instance to the enormous body of literature devoted to data), a clear sign that theoretical neuroscience is still very much in its infancy.

While all of neuroscience could benefit from better theories, visual neuroscience provides an excellent starting point because it is one of best areas where enough data and knowledge has been amassed to allow for precise theoretical ideas about brain function to emerge at the systems level and their consequences tested experimentally.

The present volume provides a broad collection of samples of such line of work. From insights about the statistics of natural signals that are encoded by the brain (Barth et al., Lazar et al., Hosseini et al.), to the influence of neural variability (Ma) and normalization (Ringach) in the coding of information by neuronal populations, to normative theories of attention (Chikkerur et al., Dayan and Solomon), to the mathematical modeling of large neuronal networks of visual cortex (Zhu et al.) and of psychophysical data (Webb et al. and Tsofe et al.), to the application of biological concepts in the design of computer vision systems (Han and Vasconcelos).

All these studies aim to develop a theoretical framework for visual computation or more generally for the encoding and processing of information by the brain. Mathematicians often say that “a well-posed question is one that is already half-answered”. We think the same applies in systems neuroscience. Once we are able to develop the appropriate theoretical concepts, half of the problem of understanding brain function will be solved.

Data rules, but theory understands.

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