Wissenschaftskolleg zu Berlin

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FOCUS

PROJECT

The Computational Principles of Natural Perception

My work at the Wissenschaftskolleg will focus on writing a book on natural perception. The book will approach perception from a theoretical viewpoint and describe the computational principles that allow biological perceptual systems to function in complex, natural environments at levels far beyond what is currently possible with artificial systems. The goals of this approach are to understand the set of problems that biological perceptual systems solve, develop algorithms for solving those problems, and understand their implementation in biology. Biological perceptual systems are stunning in their complexity, and although a great deal has been learned about their anatomical structure and physiological organization, insights into their underlying information-processing algorithms have been difficult to obtain. Recent developments, however, have begun to elucidate some of the computational principles underlying biological perception, making it possible to explain the properties of biological sensory codes, their relationship to the natural perceptual environment, and the tasks animals need to perform. The book will present a comprehensive exposition of the latest developments in the field from a theoretical, computational, and experimental viewpoint. An important aim is to develop and summarize testable computational theories of perceptual function. This will lead to deeper insight into higher-level neural representations and information-processing strategies used by biological perception.

Recommended Reading

Karklin, Y. and M. S. Lewicki. "Learning higher-order structures in natural images." Netw. Comput. Neural Syst. 14, 3 (2003): 483-499.
Smith, E. C. and M. S. Lewicki. "Efficient auditory coding." Nature 439 (2006): 978-982.
Doi, E. and M. S. Lewicki. "A Theory of retinal population coding." Advances in Neural Information Processing Systems 19 (2007).

TUESDAY COLLOQUIUM, 10.02.2009

Deducing the Principles of Natural Perception

Our senses and perception of the world form the foundation of our conscious experience, yet we have little insight into their workings. Perception is mysterious to us, because most of it happens without effort and without thought, so we little appreciate the sheer complexity of the problems our brain solves. How can we study perception and the brain processes that subserve it? How will we come to understand it? There are many approaches. We can also look at the anatomy of neurons and how they are connected. From this we learn there although are also intriguing similarities and patterns across individuals and species, there are also a bewildering variety of neurons and the neural circuits seems so complex as to be random. We can look at the physiology -- how neurons respond to different visual features or sound patterns. Here we also see that nature has some order and the perceptual systems of different species respond to the similar types of features, but the responses of a large number of neurons remains difficult to characterize, and we have very little insight into how a population of neurons functions as a whole. We can study perception itself to understand the cues that underlie things like the perception of surfaces or the phonemes in speech, but although we might be able to describe what we perceive, it is frustratingly difficult to say how we do it. Finally, we could take a computational approach and try to develop computer algorithms that recognize objects or speech, but, in spite of decades of effort, these algorithms still fall far short of our own perception and provide essentially no insight into brain function.

We have all these approaches, and yet we still have only the vaguest notion of how perception works. Is a functional understanding possible? In this talk, I will describe how perception and neural function can be investigated from a theoretical viewpoint. The aim of this approach is to understand natural perception in terms of fundamental information processing principles. The hypothesis I will explore is that, through the continual process of natural selection, biological perceptual systems have evolved to points of optimality, balancing underlying computational goals with the limitations of neural resources and the requirements of the animal's behavior. I will show how a simple set of theoretical principles can be used to learn optimal representations for either images or sounds and can predict the neural data. This approach can be extended to learn abstract sensory properties and invariant features that can subserve higher-level tasks such as perceptual organization and analysis of complex, natural scenes. To the extent this hypothesis is true, these computational principles should not only define and achieve ideal performance, but also predict perceptual behavior, neural data, and the range of solutions that exist in nature.

PUBLICATIONS FROM THE FELLOWS' LIBRARY

Lewicki, Michael S. (Lausanne,2014)

Scene analysis in the natural environment

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1685498272

Lewicki, Michael S. (2005)

Learning efficient auditory codes using spikes predicts cochlear filters

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=877701628