An ecological approach to neural computation

Romain Brette

Institut Universitaire de France

In traditional theories of perception, primitives are extracted from sensory signals, and ecologically relevant stimuli are described in terms of complex combinations of these primitives. The ecological psychologist James Gibson criticized this view, for the concept of primitive is a mathematical abstraction that may have no ecological meaning. What is elementary for a sensory system may not be simple in terms of mathematical primitives, and conversely. Instead, Gibson argued that objects in an animal's environment produce sensory signals that are highly structured, and the invariant structure is what is meaningful about the environment. He proposed that sensory systems directly extract this invariant structure.

With this point of view, I will address two questions, focusing on the auditory system:

1) what invariant structure can be considered elementary for a sensory system?

2) how can neurons extract this structure?

I will show that in a monaural context, sounds that produce such an elementary structure are periodic sounds, that is, sounds that elicit a pitch percept. In a binaural context, stimuli that produce an elementary structure across the two cochleae are binaural sounds produced by a single source in the environment.

I will show electrophysiological evidence that binaural neurons of the cat's inferior colliculus encode this structure. From the observation that similarity in sensory signals translates to synchrony in neuron responses, I will demonstrate that simple spiking models based on these ideas can indeed decode the elementary structure of auditory signals corresponding to pitch and sound location.