The University of Chicago

Department of Statistics

Seminar

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"Neural Control at the Edge of Instability: Delays, Power Laws and Lévy Distributions"

Monday, April 14, 2003 at 4:00 PM
133 Eckhart Hall, 5734 S. University Avenue

ABSTRACT

The dynamics of neural feedback control mechanisms reflect the interplay between noise and retarded variables. Consequently appropriate mathematical models take the form of stochastic delay differential equations (SDDE). Here we discuss SDDEs in the context of a motor task that is likely familiar to all, namely stick balancing at the fingertip. Recent experiments demonstrate that for stick balancing the neural control mechanism is critically tuned near, or perhaps on, a stability boundary and state-dependent noise is an essential component. These observations can be reproduced by a SDDE that describes an inverted pendulum stabilized by time-delayed feedback with a noisy feedback gain (parametric noise). The importance of the combination of a critically tuned control mechanism together with state-dependent noise is that it provides a mechanism for maintaining control on time scales short compared to the neural latency. Furthermore it is observed that the changes in speed of the corrective movements applied to the balanced stick at the fingertip obey a power law and are Lévy distributed. With increased balancing skill the shape of the distribution for the changes in speed changes, but not the power law. Taken together these observations provide direct experimental evidence for self-organized criticality in the neural control and, in particular, support predictions that the nervous system learns from its mistakes to do better.
