SOE 1: Tutorium: Physics of Behavior (joint session SOE/TUT/DY)

The emerging field of the physics of behavior seeks to quantitatively characterize complex behavior in biological agents under naturalistic conditions, using tools from dynamical systems theory and statistical physics. Even in simple organisms, behavioral richness demands new methods of measurement and analysis, as well as new theoretical frameworks. In the absence of a first-principles theory, data-driven approaches are essential, and the many interacting degrees of freedom call for descriptions capable of handling high-dimensional systems.

This tutorial introduces how concepts from dynamical systems theory and statistical physics can be applied to quantify behavior across biological scales and to develop simple yet predictive models. It is intended for physicists at all levels, beginning with graduate students, who are interested in computational approaches to modeling animal behavior. The tutorial is accompanied by an openly accessible code repository to support hands-on exploration of selected topics.

Time: Sunday 16:00–18:15 Location: HSZ/0004

Tutorial SOE 1.1 Sun 16:00 HSZ/0004

Physics of Behavior — •Greg Stephens — Vrije Universiteit Amsterdam, Amsterdam NL — OIST Graduate University, Tancha, JP

In these tutorials we view behavior as a complex dynamical system and we incorporate insights from dynamical systems theory and statistical physics to quantitatively capture what animals do. Of course, such theory was not historically developed to understand animal behavior, and there are particular challenges associated with the modeling of living systems. Of these, the most important is a lack of first-principles theory necessitating a data-driven approach.

In the first half of our session we will introduce two primary concepts. (1) Posture Space Analysis via Dimensionality Reduction. We explore posture space analysis by demonstrating how to decompose high-dimensional postural data into a few meaningful eigenpostures using Principal Component Analysis (PCA). The dataset used comes from C. elegans posture tracking. (2) Posture Space Dynamics via State Space Reconstruction. We review the concepts of state space and chaotic systems through a toy model. We then introduce a modern data-driven technique for state space reconstruction.

15 min. break

Tutorial SOE 1.2 Sun 17:15 HSZ/0004

Physics of Behavior — •Antonio Carlos Costa — Paris Brain Institute, Paris, France

Animal behavior is inherently nonlinear and multiscale, spanning millisecond movements to hour-long strategies. In the second half of our session, we will complement first-principles approaches with data-driven methods to identify multiscale dynamics in behavioral data.

We will present three key techniques: (1) state space reconstruction combined with transfer operators to extract long-timescale modes from partial observations, (2) coarse-grained modeling to infer slowly-varying behavioral dynamics and explain heavy-tailed statistics, and (3) a multiscale distance metric for reconstructing behavioral phenotypes from dynamic observations.

We will review the theoretical foundations of slow mode identification using transfer operators (illustrated with stochastic and chaotic toy models), and then demonstrate their applicability to real-world data, including posture dynamics in C. elegans and zebrafish.