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Capturing the nonlinear dynamics of animal behavior with Applications to the Nematode *C. elegans*

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From microorganisms to humans, animals behave by making complex changes in their shape and posture over time with remarkable flexibility. To deal with the complexity of animal behavior existing analysis methods view it as a discrete time process, which is composed of transitions between a finite number of stereotyped motifs, such as walking or reaching. This viewpoint, however, ignores the fact that most behavior is not stereotyped. There is, therefore, a need for a perspective that captures the continuous complexity of animal behavior and offers detailed insights into general principles underlying its generation and control.

In my Ph.D. thesis, I propose a new approach of analyzing animal behavior, based on the idea that it is fundamentally a continuous time spatiotemporal dynamical system. I develop methods to transform behavioral recordings into a geometrical object called the "behavioral state space". As an organism moves, the corresponding behavioral state traces out a continuous trajectory in the state space, such that the geometry and topology of the trajectories encode quantitative and qualitative properties of behavior. Finally, I characterize an organism's behavioral dynamics in terms of the topological invariants estimated from the local Jacobians of the state space trajectories. The invariants capture essential aspects of a dynamical system, such as the number of degrees of freedom, symmetries in the governing equations of motion, and measures of predictability and variability.

I use the tools and concepts developed the above to perform a detailed characterization of continuous dynamics of freely behaving *C. elegans* worms.