Inference in dynamical systems and the geometry of learning group actions

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We examine two data science questions motivated by two biological problems: (1) modeling time varying microbial communities and (2) modeling shapes and surfaces for evolutionary applications.

Question 1: Under what conditions are Bayesian methods for inference in deterministic dynamical systems with observation noise consistent. We will highlight the relation between Bayesian inference and a classical idea in dynamical systems called the thermodynamic formalism. We will provide a partial answer to Question 1 based on a variational characterization of a partition function.

Question 2: Given a set of shapes the synchronization problem is to consistently register or aligning the shapes. We develop a geometric framework that characterizes the synchronization problem. We use classic tools from the theory of fibre bundles in the geometric characterization. We then generalize the graph theoretic notion of a Laplacian to quantify obstructions to synchronization, specifically we develop a twisted Hodge theory. We then state an algorithm that learns group actions and demonstrate it's efficacy by clustering the molars of primates based on their shape. We will see the clusters correspond to eating habits.