2nd MPI (Dresden + Leipzig) Day

June 6, 2025

CBG

Scientific Program

Long talks

Jane Ivy Coons (MPI CBG)
Title: Trek Rules and Identifiability for Discrete Lyapanov Models
Abstract: In this talk, we introduce discrete Lyapanov models from an algebraic perspective. These models are specified by a directed graph and arise as steady-state distributions of first-order vector autoregressive, or VAR(1), models. We are especially interested in identifying the parameters of the model from empirical moments. We first give a trek rule that parametrizes moments of any order using so-called “equitreks”, or treks whose directed paths all have the same length. We show that when the underlying graph is a DAG, the continuous model parameters are generically rationally identifiable from second-, third- and a small number of fourth-order moments. Finally we show that for any graph, the continuous parameters are locally identifiable from second- and third-order moments; that is, the map from parameter space to these moments is finite-to-one. Finally, we present preliminary findings on the polynomial relationships that hold among the second- and third-order moments. We show that when the graph is a directed tree whose only self-loop is a source, this ideal is toric. This is based on joint work in progress with Nataliia Kushnerchuk, Jiayi Li, Sarah Lumpp, Janike Oldekop, Cecilie Olesen Recke and Elina Robeva.

Benjamin Hollering (MPI MiS/TU Munich)
Title: Graphical Continuous Lyapunov Models
Abstract: Stationary distributions of multivariate diffusion processes have recently been proposed as probabilistic models of causal systems in statistics and machine learning. Taking up this theme, I will present a characterization of the conditional independence relations that hold in a stationary distribution of a diffusion process with a sparsely structured drift. The result draws on a graphical representation of the drift structure and clarifies that marginal independencies are the only source of independence relations. Central to the proof is an algebraic analysis of graphical continuous Lyapunov models which are obtained from multivariate Ornstein-Uhlenbeck processes. I will end with an exploration into the algebraic structure of these models with an emphasis on why it is particularly important for proving statistical results about them. This is based on joint work with Carlos Amendola, Tobias Boege, Mathias Drton, Sarah Lumpp, Pratik Misra, Daniela Schkoda

Carl Modes (MPI CBG)
Title: Morphogenesis in an Active Solid: Tissue Mechanics, In-Plane Collective Cell Behaviours, and Shape
Abstract: Understanding how epithelial sheets of cells robustly and reliably adopt complex shapes during animal development remains a key open problem of developmental biology and tissue mechanics. Classically, cortical contractility of the apical surface of these cells generating local bending moments in an effectively fluid tissue has been the go-to theoretical picture for such problems. However, many morphogenetic events are not well explained under this framework. We hypothesize that collective, in-plane active cell behaviours could instead generate effective spontaneous strains in a solid tissue and in so doing drive stable shape outcomes. We explore these ideas and their consequences in a series of lower dimensional and/or simplified arenas, from a quasi-1d spontaneous strain buckling instability model of the Drosophila cephalic furrow, to how actively driven neighbour rearrangements in vertex models can give rise both to entropic forces in the tissue and locally establish coarse-grained spontaneous strains at steady state. We then turn to a full-blown 3D problem where, together with experimental collaborators, we show that active, in-plane cellular behaviours create the spontaneous strains that ultimately shape the Drosophila wing disc pouch during the dramatic morphogenetic event known as eversion. Taken together, these findings establish active, in-plane, solid shape programming as a potentially general mechanism for animal tissue morphogenesis.

Eric Pichon-Pharabod (MPI MiS)
Title: Computing periods and volumes of semialgebraic sets
Abstract: I will present methods for computing integral of rational functions, called periods, using differential methods and an effective description of the topology of the underlying variety. The aim is to compute them to very high precision, with certified accuracy. This allows to recover algebraic invariants associated to the geometry. I will explain how these methods can be used to compute the volume of semialgebraic sets.

Short talks

Elke Neuhaus (MPI MiS)
Title: Algebraic Geometry meets Quantum Chemistry
Abstract: The question in quantum chemistry lies in understanding the electronic structure of a molecule via the solution of the electronic Schrödingers equation, a large eigenvalue problem. Coupled cluster theory offers solution methods by restricting the feasible set of quantum states to an algebraic variety. This so-called truncation variety arises by approximating the exponential parametrization of the quantum states. The number of solutions of this simplified problem is then called the coupled cluster degree and can be bounded above by algebraic variants of the truncation variety. We therefore study simple truncation varieties from an algebra-geometric point of view to gain insight into their meaning for the behavior of electrons.

Niharika Paul (MPI MiS)
Title: Computing phylogenetic invariants for time-reversible models: from TN93 to its submodels
Abstract: In this work, we study multiplicatively closed submodels of the phylogenetic model called Tamura-Nei; named Felsenstein 81 and Felsenstein 84. We study the phylogenetic invariants for a phylogenetic tree evolving under a submode of a given model. For quartets, we prove that the natural symmetric equations of the submodels together with rank conditions on the flattening matrix and equations coming from tripods provide equations that define the variety around the no-evolution point. This is joint work with Marta Casanellas, Jennifer Garbett, Roser Homs, and Annachiara Korchmaros.

Leon Renkin (MPI CBG)
Title: Chromatic Persistent Homology
Abstract: Chromatic persistent homology is a variant of persistent homology that incorporates additional categorical or combinatorial structure—such as labeling or coloring—into the filtration process. This construction gives rise to persistence modules over partially ordered sets and algebraic invariants that extend beyond the standard barcode. I will outline the basic framework of chromatic persistence, with particular emphasis on the algebraic and geometric interplay between differently colored features. Time permitting, I will highlight an application of chromatic persistent homology to a dataset of pancreas organoids.

Chinmayi Subramanya (MPI CBG)
Title: Ensnarled: Deciphering the architecture of complex interconnected systems
Abstract: In the vast realm of complex systems, the interplay between multiple networks is a recurring motif that permeates various domains, from crystal lattices and polymers to vascular systems and coiled DNA structures. While there has been significant work on complex networks in 2D models, the association between spatially embedded networks in 3D is still yet to be explored. Our model aims to quantify the topological coupling, or ‘ensnarlment,’ by utilizing the cyclic nature of each network and employing the Gauss linking integral to construct a linkage matrix based on Hopf-linked cycles. We then construct the so-called ‘ensnarlment operators’ on the networks’ respective edge spaces, whose elements denote the edges of the graphs which are most critical in the linkage. With this novel framework we model ensnarlment in different systems including the developing liver, with the ultimate goal of understanding the dynamics of organ network architectures and their impact on pathophysiology.