2025 Texas A&M REU Miniconference

Blocker 117

SCHEDULE

MONDAY, July 14

10:00: Parameter Sensitivity and Bistability in a Caspase Activation Model of Apoptosis,
by Megan Dowdell (University of Tampa)

10:30: Applications of Liouville Discrepancy to Quantum Dynamics
by Matthew Bradshaw (University of Connecticut), Titus de Jong (University of California, Irvine), Audrey Wang (Rice University)

TUESDAY, July 15

10:00: On the Identifiability of Directed-Cycle Linear Compartmental Models,
by Tyler Huneke (University of Maryland)

10:30: Identifiability of Leak Parameters in Linear Compartmental Models,
by Tegan Keen (Colorado State University)

11:00: Connections between common slice obstructions and the Eisermann ribbon obstruction
by Megan du Preez (University of Texas at Tyler), Bryan Silva (University of California, Irvine), Eric Yu (University of Pennsylvania)

TITLES AND ABSTRACTS

Megan Dowdell

Title: Parameter Sensitivity and Bistability in a Caspase Activation Model of Apoptosis

Abstract:

How do cells decide between survival and self-destruction? This project explores that question using a mathematical model of apoptosis, the programmed cell death pathway. We use the

8-dimensional caspase network introduced by Eissing et al. and symbolically reduce it to a 2D model centered on Caspase-3 and Caspase-8 dynamics. This reduced system preserves key bistable features and enables efficient and accurate simulation, nullcline analysis, and steady-state classification. We also explore a further simplification to a 1D model, but find that it produces biologically implausible results, such as negative concentrations, and ultimately fails to capture the system's switching behavior. By performing parameter sweeps using our 2D model, we rank reactions based on their bistability windows, revealing which rates are most sensitive to disruption. We identify distinct dynamic behaviors resulting from individual parameter eliminations and find that only the inhibitory feedback associated with parameter I11 can be removed without destroying bistability. These results demonstrate how mathematical models can uncover the key mechanisms that govern biological decision-making, and they lay the groundwork for future experimental validation.

Matthew Bradshaw, Titus de Jong, Audrey Wang

Title: Applications of Liouville Discrepancy to Quantum Dynamics

Abstract:

We establish quantum dynamical upper bounds for quasi-periodic Schr\"odinger operators with Liouville frequencies. Our approach combines semi-algebraic discrepancy estimates for the sequence $\{\theta + n\alpha\}_{n=1}^N$ with quantitative Green's function estimates adapted to the Liouville setting.

Tyler Huneke

Title: On the Identifiability of Directed-Cycle Linear Compartmental Models

Abstract:

In computational biology, linear compartmental models represent dynamic ecological and pharmacokinetic systems using directed graphs. These models split the environment into finitely many subsystems (our graph vertices), and use experimental data to determine the transfer rates of subsystem populations through a system of nonlinear equations found using differential algebra. With this, questions of interest are the number of distinct transfer rate combinations admitted by a system (identifiability degree) and the number of solutions for transfer rates between particular subsystems.

In the past, algebraic methods have been used in some model classes to find an upper bound for their identifiability degree. We focus on an alternative method using linear algebra and combinatorics to expand on this work, which allows us to bound, or even determine, the

identifiability degree of broader classes of models. Similarly, we bound the number of possible solutions for any transfer rate in those models. Using this new method, we develop a complete understanding of the identifiability of directed-cycle models.

Tegan Keen

Title: Identifiability of Leak Parameters in Linear Compartmental Models

Abstract:

In many applications, including in ecology and pharmacokinetics, linear compartmental models are used to model transfer between "compartments" which may represent populations, drug concentration, etc. Such models are represented by directed graphs in which the edges represent the transfers between compartments. An important feature of such models is the identifiability degree, which summarizes the extent to which it is possible to recover the transfer rates from noiseless experimental data. More precisely, the identifiability degree of a parameter is 1 if the transfer rate can be recovered uniquely, and is greater than 1 if the transfer rate can be recovered only up to a finite set (this size is equal to the degree).

In this presentation, we investigate the effects of adding leaks (edges directed out of the model) on the identifiability degree. We show that in a model represented by a strongly connected graph, if exactly one leak is in the same compartment as an output, then that leak parameter is uniquely identifiable. We investigate improvements to this result, looking at the preservation of the identifiability degree of the non-leak parameters and the applicability to non-strongly connected graphs, like in the case of directed path models.

Megan du Preez, Bryan Silva, Eric Yu

Title: Connections between common slice obstructions and the Eisermann ribbon obstruction

Abstract:

An n-component slice link is a smooth embedding of n disjoint circles into S^3 that bounds n disjoint, smoothly embedded disks in B^4. A ribbon link is a slice link that bounds n disjoint disks in S^3 with only ribbon singularities.

In 2008, Eisermann showed that all ribbon links with n-components have Jones polynomials that are divisible by the Jones polynomial of the n-component unlink. This has not been

proven to apply to slice links, but we conjecture that it follows from several well-known slice obstructions. In particular, we conjecture that Alexander nullity being equal to $n-1$ implies Eisermann's divisibility condition. We prove that it holds for every 2-component slice link and for all links whose prime decomposition consists of links with fewer than 15 crossings. In this talk, we also continue to explore the conjecture by looking at special families of links, including untwisted cables of knots.