

Undergraduate Math/Stat Research Project Introductions

Exchange and MSU Student Research Teams

Friday, February 1, 2019

4:30 – 6:30, C-304 WH

Professor: Yuehua Cui

Exchange Student: Yang Liu

MSU Students: Gaeun Lee, Deontae Hardnett, Glenna Wang

Title: *Longitudinal Data Analysis*

Subject Areas: Biostatistics

Description: This is a project to identify genetic risk factors associated with woman's binge eating disorder during puberty in a twin study. Longitudinal data analysis methods such as generalized estimating equation approach will be applied to assess the longitudinal genetic effect moderated by hormone changes over the menstrual cycle. The data also contain genetic information. Thus, a longitudinal genetic association analysis will also be involved. Student(s) will learn necessary statistical skills on longitudinal and genetic data analysis.

Professors: Teena Gerhardt and Gabe Angelini-Knoll

Exchange Student: Minhua Cheng

MSU Students: Noah Ankney

Title: *Coalgebras and their Invariants*

Subject Areas: Algebra and Topology

Description: Coalgebras are algebraic objects equipped with an operation, called a comultiplication, which arise naturally in topology. In this project, students will study coalgebras and their properties. Students will learn background in homological algebra and algebraic topology, and use tools from these areas to compute an invariant of coalgebras called coHochschild homology. Understanding this invariant is an essential step towards computing topological coHochschild homology, an exciting new object of study in algebraic topology.

Professors: Ilya Kachkovskiy and Shiwen Zhang

Exchange Student: Xingyan Liu

MSU Students: John Buhl, Isaac Cinzori, Isabella Ginnett, Mark Landry, Yikang Li

Title: *Landscape Theory for Tight-Binding Hamiltonians*

Subject Areas: Analysis, Spectral Theory, Mathematical Physics

Description: Anderson localization is one of the central phenomena studied in modern mathematical physics, especially in dimensions 2 and 3, starting from Nobel-prize winning discovery by P. W. Anderson. Recently, a new approach for the 1D discrete model was proposed by Lyra, Mayboroda, and Filoche, which shows interesting relations with the Dirichlet problem on the lattice and also allows to significantly reduce complexity of some numerics related to the problem. The main goal of the project is to extend this approach to higher (and most interesting physically) dimensions. The project will involve advanced reading, possible new results in finite and infinite-dimensional spectral theory, understanding physics behind some problems in

linear algebra, and novel numerical experiments. Original research results are expected as an outcome for successful students.

Professor: Rajesh Kulkarni

Exchange Student: Gengzhuo Llu

MSU Students: Jon Miles

Title: *Polynomial Equations over and maximal subfields of Division Algebras of degree 3*

Subject Areas: Algebra, specifically Galois theory

Description: A description to solutions of polynomial equations over a field is an important part of abstract algebra and forms important part of algebraic geometry. A similarly fascinating question with increasing importance is solutions of polynomial equations over division algebras. A division algebra must have dimension that is square of an integer over its center when the dimension is 9, solutions to polynomial equations over these division algebras can be described beautifully by using conjugate splittings. This project will explore further questions when the coefficients are in a division algebra of dimension 9 and also of dimension 16. The project is also explore the relationship of these questions with zeta functions of division algebras of degree 3.

Professor: Gee Y. Lee

Exchange Student: Zihao Gu

MSU Students: Charlie Crampton, Ahmad Zaini

Title: *Frequency-severity Insurance Ratemaking Using Modern Techniques*

Subject Areas: Actuarial Science

Description: Accurate insurance rates are required for the solvency of an insurance provider, as well as the affordability of insurance coverage for the policyholder. In this project, the student will obtain hands on ratemaking experience under the supervision of an actuarial science faculty member. We will analyze a problem, and learn how to build and utilize models to provide a solution to an actuarial problem. We will develop models for a hypothetical ratemaking problem, and utilize historic frequencies and severities to build and test our models. Data from the Medical Expenditure Panel Survey (MEPS) will be utilized to implement the frequency-severity approach to ratemaking. Throughout the course of the project, we will attempt to improve existing models, and in particular we will explore the possibility of using penalized likelihoods in combination with long-tail loss distributions and generalized additive models, as time permits.

Professor: Aaron Levin

Exchange Student: Shengkuan Yan

MSU Students: Luke Wiljanen

Title: Constructing Large Ideal Class Groups

Subject Areas: Number Theory, Algebraic Geometry

Description: The ideal class group of a number field is a fundamental and well-studied object in number theory which gives a measure of the extent to which unique factorization in a ring of integers fails. Recently, a geometric approach to constructing number fields with a large ideal class group has been developed. This approach relies on finding curves with certain properties, and the project will explore theoretical aspects of this problem, as well as the possibility of constructing algorithms to search for suitable curves.

Professor: Vladimir Peller

Exchange Student: Dingjia Mao

MSU Students: Yuan Luo

Title: *Functions of Perturbed Matrices*

Subject Areas: Analysis, Linear Algebra

Description: The project will deal with comparing functions $f(A)$ and $f(B)$ for square matrices A and B . In particular, the problem is to estimate the norm of $f(A)-f(B)$ in terms of the norm of $A-B$. Such estimates depend on properties of the functions f . Such problems are problems in perturbation theory in the case when we deal with linear operators on finite-dimensional spaces.

Professor: Frederi Viens

Exchange Student: Zeyuanm Li

MSU Students: Aaron Bawol, Zoe Zhang

Title: *Financial Mathematics and Actuarial Science*

Subject Areas: Applied Probability

Description: The question of how to allocate funds for risky and risk-free investments is notoriously plagued by the inability to estimate the rates of returns of risky stocks. Beyond the industrial question of "discovering alpha", the student will have the option to investigate mathematical methods based on the concept of robust optimization, where an investor takes into account aversion to financial and insurance risks as well as aversion to modeling ambiguity. The latter ambiguity is the inability to be sure that a model is better than all other models. It is strongly related, in principle, with challenges in statistical estimation. This project will use tools from stochastic control, and may involve working with financial data, either historically for backtesting, or live data for testing algorithms in real time. Part of this project may delve into the structure of limit-order books for high-frequency financial algorithms on US stock markets. Part of it may investigate statistical arbitrage opportunities, as those currently found in Chinese and Hong Kong stock markets.

Professor: Frederi Viens

Exchange Student: Liu Meiqi

MSU Students: Yifei Li, Anna Weixel, Xinjoo Yu

Title: *Bayes in Environmental, Agricultural, and Earth Sciences*

Subject Areas: Computational Bayesian Statistics

Description: The use of Bayesian statistics is becoming more widespread because of the possibility of implementing complex Bayesian posterior calculations and their associated samples, thanks to modern computational platforms. Prof Viens and his team are involved in various applied projects, some of which have substantial associated theoretical questions, all of which involve a need for implementing approximate Bayesian computation. The exchange student will learn about classical linear Bayesian hierarchical modeling, about its numerical implementation using the so-called Gibbs sampler, and will have opportunities to engage in one or more of the following applied statistics topics:

(a) understanding the factors which drive the hydrology of the Lake Chad Basin in the Eastern Sahel: a study towards optimizing ecosystem services and preserving the environment in one of

the world's least developed regions.

(b) developing a model for paleoclimatology in the late Holocene, which includes accounting for the role of the oceans: a study towards accurate assessment of uncertainty for climate projection over the next two centuries.

(c) agricultural productivity and applied economics: estimating structural equations for hierarchical models at the farmer to region level in least developed countries in Africa and Asia, including estimating environmental, social, and soil-science factors in maize yield.

Professor: Rongrong Wang

Exchange Student: Shuai Yuan

MSU Students: Jonathan Fleck, Brian Rago

Title: *Improving Image Quality via Compressed Sensing*

Subject Areas: Applied Mathematics

Description: In natural and seismic image processing, blind deconvolution includes a wide class of problems whose solution leads to image denoising or image super-resolution. In this project, student will help to 1. develop and analysis a new optimization framework to model the blind deconvolution problem; 2. design efficient algorithms to solve the proposed optimization framework; 3. Apply the method to real image processing tasks. Through working on this real-world problem, student will get familiar with basic convex analysis and Compressed Sensing techniques useful to tackle many emerging challenges in Science and Engineering.

Professor: Guowei Wei

Exchange Student: Che Yang

MSU Students: Neel Modi, Chenzhi Pan

Title: *Machine Learning and Applications*

Subject Areas: Computational Mathematics

Description: We are interested in designing advance machine learning and deep learning architectures for realistic applications to finance, insurance, actuarial science and other industries. Our goal is to carry out mathematical analysis and improvement of existing ensemble methods (i.e., random forest, gradient boosted decision trees, extra trees, etc.), multitask learning and deep neural networks (convolutional neural network, recurrent neural network, Boltzmann machine, etc). The student will work with my PhD students or postdocs to learn related machine learning theory and algorithm, and applications.