Undergraduate Math/Stat Research Project Presentations
Exchange and MSU Student Research Teams
April 10, 2021
CHINA: 21:30 (CST)
USA: 9:30 AM (EDT)

https://msu.zoom.us/j/95470245088

Meeting ID: 954 7024 5088

Passcode: XJTU_MSU

Robust Machine Learning Denoising Algorithm for Single Cell RNAseq Data
Dongyuan Zhang, Reeta Bhanini and Jeremy Rebenstock
Supervisor(s): Yuying Xie

Risk Sharing with Range-Value-at-Risk
JiaXin Wei, Matelyn Mason
Supervisor(s): Haiyan Liu

Local Volatility Models in Mathematical Finance
Mengjie Shi, Zhan Zhan
Supervisor(s): Gabor Francsics

Variational Packing Problems
Wei Zhao, Samuel Sottile and Kenneth Jao
Supervisor(s): Keith Promislow and Yuan Chen

Computational Bayesian Analysis of Agriculture, Hydrology, and Ecosystem Services in the Lake Chad Basin
Zhihong Liu, Jennifer Abel
Supervisor(s): Frederi Viens

Quantum Control: Algorithms and Optimal Gate Design
Shunyao Wang, Charles Hultquist, Madeline Mitchell and Luke Perelli
Supervisor(s): Daniel Appelo, Fortino Garcia, Zhichao Peng

*** LUNCH BREAK ***

Federated Learning over Networks
Chijin Liu, Evan Bell and Wenyu Shang
Supervisor(s): Ming Yan

Machine Learning Approaches for Stochastic Modeling of Bio-chemical Reacting Processes
Guoqing Xie, Tom Ladouceur
Supervisor(s): Di Liu

Partial Differential Equations that Model Cancer Tumor Growth
Siming Yao, Riley Lawson
Supervisor(s): Olga Turanova and Anthony Sulak

Knots, Graphs, and Filling Surfaces
Ke Wang, James Schmidt, Lukas Brave and Pranjal Dangwal
Supervisor(s): Linhui Shen, Honghao Gao, Daping Weng

Semi-supervised and Supervised Methods for Machine Learning Tasks
YunZhang Hu, Nicholas Grabill and Alexander Sietsema
Supervisor(s): Ekaterina Rapinchuk

SS2020 Research Project Final Presentations
April 10, 2021
Project Descriptions
(in alphabetical order according to faculty supervisor)

Professor(s): Daniel Appelo
Additional Advisors/Mentors: Fortino Garcia and Zhichao Peng
Exchange Student: Shunyao Wang
MSU Students: Charles Hultquist, Madeline Mitchell and Luke Perelli
Title: *Quantum Control: Algorithms and Optimal Gate Design*
Subject Areas: Numerical Analysis, Linear Algebra, Quantum Control, Quantum Computing
Description: A quantum computer represents information in quantum bits (qubits) which can be manipulated by quantum gates just as classic bits in a digital circuit can be manipulated by classic gates like e.g. XOR or NOT-gates. However, unlike classical bits a qubit can exist in many states at once, so called superposition, and this is where the potential computing power of a quantum comes from. The description of a quantum system is governed by a Schrodinger equation which can be simulated by numerical methods. Since the sum of the probabilities of being in a quantum state must add up to one it is important to that the numerical methods preserve this property as well. The design of a quantum gate consists of determining a time dependent forcing (control) of the system (corresponding to a laser or a microwave field applied to the quantum computer) such that all possible input states evolves into the desired output states. In this project you will explore suitable numerical methods for different quantum computers (different Schrodinger equations) and use these to find optimal realizations of control signals that correspond to established quantum gates. Finding optimal realizations of quantum gates with short gate times is crucial for the practical implementation of quantum computers and is likely to be a active area of research for the foreseeable future.

Professor(s): Gabor Francsics
Exchange Student: Mengjie Shi
MSU Students: Zhan Zhan
Title: *Local Volatility Models in Mathematical Finance*
Subject Areas: Applied mathematics and financial mathematics
Description:
Description: Financial derivatives are highly important tools in financial risk management. Currently, more than several trillion dollars worth of financial derivative contract are traded and used by companies to manage exposure to risk. Calculating the price of financial derivatives is not only a very exciting, active research area in financial mathematics but also a very useful tool in the finance industry as well. In this project students will study analytical and numerical financial option pricing methods in the local volatility model framework. The students will learn the necessary background in financial mathematics, the mathematical foundation of the Black-Scholes-Merton model, constant elasticity variance models, and the local volatility models. We will study the recently developed Dyson-Taylor method. The goal is to compare the accuracy of recently developed closed form approximate solutions for the local volatility models and other known methods.

Professor(s): Di Liu
Exchange Student: Guoqing Xie
MSU Students: Tom Ladouceur
Title: *Machine Learning Approaches for Stochastic Modeling of Bio-chemical Reacting Processes*
Subject Areas: Applied stochastic analysis, numerical analysis, machine learning, network analysis
Description: We will study new machine learning methods for multiscale and stochastic models

arising from bio-chemical reacting networks and molecular dynamics. We will be focusing on recently developed network embedding techniques using techniques such as matrix factorization, random simulations and neural networks, that are scalable for large data. Emphasis will be on dimension reduction and efficient simulations of the stochastic systems. Specific applications include developing methods for generating low-dimensional node embeddings for directed graphs and identifying transition states of stochastic chemical systems. Through optimization via gradient ascent, we will embed graph vertices into a low-dimensional vector space while preserving the neighborhoods of each node.

Professor(s): Haiyan Liu
Exchange Student: JiaXin Wei
MSU Students: Matelyn Mason
Title: *Risk Sharing with Range-Value-at-Risk*
Subject Areas: Actuarial Science
Description: The problem of risk sharing concerns the redistribution of a total risk among multiple participants. In this project, we will study the problem of risk sharing among participants using risk measure range-value-at-risk (RVaR) when individual risks follow a multivariate normal distribution. The students will learn properties of risk measures RVaR and value-at-risk, and attempt to establish a quantile inequality of RVaR.

Professor(s): Keith Promislow
Additional Advisors/Mentors: Yuan Chen
Exchange Student: Wei Zhao
MSU Students: Samuel Sottile and Kenneth Jao
Title: *Variational Packing Problems*
Subject Areas: Applied Math and PDE
Description: Packing problems play a fundamental role in mathematics, presenting fundamental questions about geometry and space. Typically, these are presented in terms of incompressible objects, while many applications the objects to be packed are compressible and partially conform to the spatial constraints. While compressibility may at first seem to be a complication, in many ways it regularizes the problem. We will examine the problem of packing compressible spheres in a geometry, with the primary goal of understanding situations in which symmetry breaking drives identical spheres to separate into two classes of compression to obtain an optimal packed state.

Professor(s): Ekaterina Rapinchuk
Exchange Student: YunZhang Hu
MSU Students: Nicholas Grabill and Alexander Sietsema
Title: *Semi-supervised and Supervised Methods for Machine Learning Tasks*
Subject Areas: machine learning, data classification
Description: Many machine learning models are supervised: to predict an output from a given input, the model trains on many samples of input data labeled with the correct output. In practice, such labeled data may be difficult or expensive to produce. For this reason, one can use semi-supervised models, which instead train on a small amount of labeled data in tandem with a large amount of unlabeled data. We present comparisons of the performance of supervised and semi-supervised models with respect to the availability of labeled training samples.

Professor(s): Linhui Shen
Additional Advisors/Mentors: Honghao Gao, Daping Weng
Exchange Student: Ke Wang
MSU Students: James Schmidt, Lukas Brave and Pranjal Dangwal
Title: *Knots, Graphs, and Filling Surfaces*
Subject Areas: Algebra and Symplectic Geometry

Description: Knots are tangled strings in Euclidean space. They are the most fundamental geometric objects to work with, and knot theory is closely related to many branches of mathematics. This project aims at understanding the filling problem for knots using interdisciplinary mathematics from combinatorics and abstract algebra. In particular, we shall use tools from graph theory and the theory of cluster algebras. In this project, we will learn basics theories of knot invariants, graph theory and cluster algebras. We will also attempt to classify filling surfaces via graphs for a finite type knot, under the supervision of a faculty team.

Professor(s): Olga Turanova
Additional Advisors/Mentors: Anthony Sulak
Exchange Student: Siming Yao
MSU Students: Riley Lawsonss
Title: *Partial Differential Equations that Model Cancer Tumor Growth*
Subject Areas: Partial differential equations, numerical analysis
Description: The project concerns partial differential equations that model cancer tumor growth. The aim is to study and find connections between models that describe the tumor at a cellular level, and those that characterize the tumor as a set and prescribe a law for the evolution of its boundary. These two types of models correspond to two classes of PDEs -- diffusion equations and free boundary problems.

Professor(s): Frederi Viens
Exchange Student: Zhihong Liu
MSU Students: Jennifer Abel
Title: *Computational Bayesian Analysis of Agriculture, Hydrology, and Ecosystem Services in the Lake Chad Basin*
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 engage in the following applied statistics topic: Understanding the factors which drive the hydrology of the Lake Chad Basin in the Eastern Sahel, one of the world's least developed regions, including the effect of global climate change, the effect of local rainfall, and water usage from agricultural production in the region; plus a study towards optimizing Lake Chad's ecosystem services, particularly through livestock production in northeast Nigeria; and an attempt at integrating both studies.

Professor(s): Yuying Xie
Exchange Student: Dongyuan Zhang
MSU Students: Reeta Bhanini and Jeremy Rebenstock
Title: *Robust Machine Learning Denoising Algorithm for Single Cell RNAseq Data*
Subject Areas: Applied Statistics
Description: One of the most promising cancer treatments is the Immunotherapy, which invokes a patient's immune system to eliminate cancer cells. A major Compelling evidence suggests that a favorable clinical response to immunotherapy relies on the tumor immune microenvironment in terms of immune cells landscape, which can be measured via Single Cell RNAseq (scRNAseq) technology. However, scRNAseq data is nonlinear and often contaminated with outliers, which makes the estimation of the immune landscape non-trivial. Thus, it is imperative to develop a robust machine-learning algorithm to denoise the data in a manifold. We develop a nonlinear manifold denoising algorithm and show it outperform existing methods in both synthetic and real datasets.

Professor(s): Ming Yan
Exchange Student: Chijin Liu
MSU Students: Evan Bell and Wenyu Shang
Title: *Federated Learning over Networks*
Subject Areas: Computational Mathematics, Optimization

Description: Seamless operation of distributed wireless sensor networks relies heavily on optimization frameworks that are under the hood. In addition to the difficult network topology, the data at one sensor can be also big that prohibits the access of the whole data in an efficient way. Distributed algorithms can preserve privacy at difference agents as well. In this project, we will develop distributed optimization methods over networks with stochastic approaches. If this is successful, these algorithms can be used in many applications beyond wireless sensor networks. Some other examples are internet of thing, power grid, autonomous vehicles, and smart cities.