# Department of Mathematics Colloquium Series Academic Year 2019-20

## Spring 2020

**Title:** Modelling the potential role of engineered symbiotic bacteria in malaria control
**Speaker:** Xiunan Wang
University of Alberta
**Date:** Thursday, February 6
**Location:** EMCS 422
**Time:** ***3:00pm***
*Abstract.* The engineered symbiotic bacteria Serratia AS1 may provide a novel, effective and sustainable biocontrol of malaria. These recombinant bacteria have been shown to be able to rapidly disseminate throughout mosquito population and to efficiently inhibit development of malaria parasites in mosquitoes in controlled laboratory experiments. In this talk, I will present a climate-based malaria model which involves both vertical and horizontal transmission of the engineered Serratia AS1 bacteria in mosquito population. We show that the global dynamics of the model system is totally determined by the vector reproduction ratio and the basic reproduction ratio. Numerically, we verify the obtained analytic result and evaluate the effects of releasing the engineered Serratia AS1 bacteria in field by conducting a case study for Douala, Cameroon. We find that ideally, by using Serratia AS1 alone, it takes at least 25 years to eliminate malaria from Douala, which implies that continued long-term investment is needed in the fight against malaria and confirms the necessity of integrating multiple control measures.
*This talk may be appropriate for all students with a strong interest in research.*

**Title:** Wave propagation and inverse problems
**Speaker:** Shixu Meng
University of Michigan
**Date:** Tuesday, February 4
**Location:** EMCS 422
**Time:** 3:00pm.
*Abstract.* Wave propagation describes the interaction of waves with natural or manufactured perturbations of the medium through which they propagate. The

corresponding inverse problem (or imaging) is to estimate the medium from observations of the wave field. It has applications in a broad spectrum of scientific and engineering disciplines, such as medical diagnosis, health and wellness, tunnel imaging, seismic imaging, non-destructive material testing, sub-wavelength imaging, and material design. I will address three topics: imaging in tunnels, electromagnetic transmission eigenvalue, and dynamic homogenization in periodic media.
*This talk may be appropriate for all students with a strong interest in research.*

**Title:** Linear, half linear and fractional Lyapunov-type inequalities and applications
**Speaker:** Sougata Dhar
University of Connecticut
**Date:** Wednesday, January 29
**Location:** EMCS 238
**Time:** 3:00pm.

*Abstract.* The famous Lyapunov inequality plays an important role in the study of oscillation, eigenvalue problems, and many other areas of differential equations. Due to its importance, the inequality has been improved and generalized in many forms. In this presentation, we will discuss several Lyapunov-type inequalities for second and third order linear, half-linear and fractional differential equations. We obtain sharper inequalities than many existing results in the literature. Furthermore, by combining these inequalities with the ``uniqueness implies existence'' theorems by several authors, we establish the uniqueness and hence existence-uniqueness results for several classes of boundary value problems. This is the first time for the Lyapunov-type inequalities to be used to deal with boundary value problems and we expect that this approach can be further applied to study general higher-order boundary value problems.

**Title:** Relaxation Oscillations in Slow-Fast Systems and Regime Shifts in Ecology
**Speaker:** Dr. Ting-Hao Hsu
University of Miami
**Date:** Monday, January 27
**Location:** EMCS 238
**Time:** 3:00pm.

*Abstract.* Relaxation oscillations in dynamical systems are periodic orbits with slow and fast segments. Regime shifts in ecology are continual abrupt changes between different long-lasting dynamics. I will demonstrate a new criterion for the existence of relaxation oscillations and then use the theorems to track regime shifts in some ecological models that exhibit disease outbreaks and rapid evolution. The approach is based on extending the so-called entry-exit function to multi-dimensional slow-fast systems using geometric singular perturbation theory. This talk may be appropriate for all students with a strong interest in research.

**Title:** Inference on Shape and Location Parameters in Multivariate Skew-Normal Family
**Speaker:** Dr. Ziwei Ma
New Mexico State Univeristy
**Date:** January 23, 2020
**Location:** EMCS 422
**Time:** 1:50pm

*Abstract:* The notion of sparsity is essential in signal processing and data science where one explores the underlying low-dimensional structure of signals for data compression, economical sensing, algorithm efficiency, etc. In addition to the applications, its theory is deeply connected to fields like harmonic analysis, functional analysis, convex geometry, random matrix and probability theory. We will start the talk by introducing some classical results on sparse data recovery when the linear measurements are drastically undersampled. Some new results related to signals sparse in a frame will follow. An application in image inpainting will be briefly discussed in the end.

**Title:** Recovering Sparse Data: Theory and Applications
**Speaker:** Dr. Xuemei Chen
New Mexico State Univeristy
**Date:** January 21, 2020
**Location:** EMCS 422
**Time:** 3:00pm

*Abstract:* The notion of sparsity is essential in signal processing and data science where one explores the underlying low-dimensional structure of signals for data compression, economical sensing, algorithm efficiency, etc. In addition to the applications, its theory is deeply connected to fields like harmonic analysis, functional analysis, convex geometry, random matrix and probability theory. We will start the talk by introducing some classical results on sparse data recovery when the linear measurements are drastically undersampled. Some new results related to signals sparse in a frame will follow. An application in image inpainting will be briefly discussed in the end.

**Title: Opportunities and Challenges for AI and Math in Drug Discover**y
**Speaker:** Dr. Duc Nguyen
Michigan State University
**Date:** Thursday, January 5, 2020
**Time:** 3:00pm
**Location:** EMCS 422

*Abstract.* Drug discovery is one of the most challenging tasks in the biological sciences since it requires over 10 years and costs more than $2.6$ billion to put an average novel medicine on the marketplace. The abundant availability of biological data along with the flourishing advanced AI algorithms opens a future with great hope for discovering new drugs faster and cheaper. Unfortunately, AI faces an enormous obstacle in drug discovery due to the intricate complexity of biomolecular structures and the high dimensionality of biological datasets. In our lab, these challenges have been tackled mathematically. We have introduced multiscale modeling, differential geometry, algebraic topology, and graph theory-based models to systematically represent the diverse biological datasets in the low-dimensional spaces. Combining these mathematical representations with cutting edge deep neural networks, we arrived at novel models not only perform well on virtual-screening targeting important drug properties but also have the ability to design new drugs at an unprecedented speed. Our team has emerged as a top winner in D3R Grand Challenges, a worldwide annual competition series in computer-aided drug design, in the past few years.

*This talk may be appropriate for all students with a strong interest in research.*

**Fall 2019**

**Title: Field Theoretic Methods for Polymers**
**Speaker:** Dr. Rajeev Kumar
Oak Ridge National Laboratory
**Date:** Tuesday, November 5, 2019
**Time:** 3:00pm
**Location:** EMCS 422
*Abstract.* Understanding structure and dynamics of polymers is of great fundamental and technological interest. In contrast to small-molecular systems, structure and dynamics of polymers depend on conformational degrees of freedom. The conformational degrees of freedom can be tailored either using novel synthesis schemes focused on altering architecture of the polymer chains or by geometrical confinements such as in polymer nanocomposites and thin films. In all these cases, accounting for chain conformations is vital for correct simulations of polymers. In this regard, path integral representation of a polymer chain allows field theoretical methods to be useful in simulating polymers. In this presentation, I will present our research in simulating neutral and charged polymers using field theoretic methods. Comparisons with experimental results obtained from neutron reflectivity experiments, broadband dielectric spectroscopy and scattering will be presented. Examples will include thin films of polydisperse di-block copolymers, thin film blends of homopolymers and bottlebrush copolymers, and pH responsive polyelectrolyte brushes (grafted chains). It will be shown that field theoretic methods coupled with precision synthesis and appropriate experiments provide unparalleled insights into physics of polymers.
*This talk may be appropriate for all students with a strong interest in research.*

**Title:** Understanding Electrostatic Correlations in Polymers
**Speaker:** Dr. Rajeev Kumar
Oak Ridge National Laboratory
**Date:** Wednesday, November 6, 2019
**Time:** 3:30pm
**Location:** UTC SimCenter Auditorium

*Abstract.* Fundamental and applied research on neutral non-polar homopolymers as well as block copolymers over the last four decades have played major roles in advancing various areas such as organic electronics, photonics, cosmetics and chemical separation/filtration. Nonetheless, increasing energy demands and novel technologies require significantly improved materials for modern applications such as in the area of energy storage, polymer batteries and water purification membranes, to name a few. Ionic and zwitterionic polymers synthesized by introducing charges on the monomers have been shown to be promising materials with desirable responses to various stimuli in applications such as actuators, capacitors, membranes and polymer batteries. However, the simple introduction of charges leads to dramatic changes in structure and dynamics of the polymers. These changes get reflected in the responses of the polymers to temperature, applied electric fields and solvents used in the processing. Presence of a large parameter space and lack of our understanding about the fundamental electrostatic correlations greatly hinder any hope for systematic designs of the ionic and zwitterionic polymers for various energy applications. In this talk, I will present our recent theory and simulation work in developing fundamental understanding of electrostatic correlations in ionic and zwitterionic polymers. In particular, importance of often-neglected gradients/non-local effects of electric polarization in affecting electrostatic correlations in polar polymers will be discussed. Furthermore, effects of electrostatic correlations and their close connections to polarization will be discussed in light of experimental results obtained using scattering and reflectivity measurements, broadband dielectric spectroscopy, and atomic force microscopy-based measurements.

**Title:** The Density of Complex Zeros of Random Sums
**Speaker:** Mr. Christopher Corley
University of Tennessee at Chattanooga
**Date:** Friday, November 1, 2019
**Time:** 3:00pm
**Location:** EMCS 422
*Abstract.* The algebraic properties and utility of deterministic polynomials are well understood. In many real-world applications, the coefficients of algebraic polynomials are random variables, especially when they are determined by an experiment or rounded off to some specified number of decimal places before starting a numerical solution. As a result, the coefficients carry an element of

random error. Random polynomials have applications in many fields of mathematics, physics, engineering, computer science, and economics. In 1943, Kac studied the distribution of real zeros of random polynomials whose coefficients are i.i.d. random real Gaussian variables, and obtained an exact formula for the expected value of the number of zeros in measurable subsets of the reals. In subsequent investigations, the expected number of real zeros was considered for several distributions besides the normal law for the coefficients. In 1995, Shepp and Vanderbei devised a method based on Cauchy's argument principle and the Cholesky decomposition to extend Kac's result to the complex plane. Most authors establish certain properties of the zeros under very general distributional assumptions. The cost of this generality is that these results only hold asymptotically. In later work, Vanderbei introduced a modest generalization to the core assumptions underlying these results, and showed that comparable exact formulas can be obtained for a wide class of random sums. In this talk I will present exact formulas for its K-level crossings, including those for the classes OPRL and OPUC of random orthogonal polynomials. The method employs the Kac–Rice formula for the expected value of quadratic forms of Gaussian random variables.
*This talk may be appropriate for all students with a strong interest in mathematical and statistical research.*

**Title:** Immersed Finiate Element Methods and Some Applications
**Speaker:** Dr. Tao Lin
Virginia Tech University
**Date:** Friday, October 25, 2019
**Time:** 2:25pm
**Location:** EMCS 422
*Abstract.* Interface problems appear in numerical simulations in domains consisting of multiple materials that result in discontinuous coefficients in the involved partial differential equations whose solutions are often lack of regularity across the material interfaces. This deficiency of the global regularity requires traditional finite element (FE) methods to use fitted meshes in which each element essentially contains one of the materials; otherwise, their performance cannot be guaranteed. Fitted meshes are unstructured unless material interfaces have trivial geometries. Having to use unstructured meshes can make traditional FE methods inefficient or even troublesome in some applications. In this

presentation, we will have an introductory discussion about the recently developed immersed finite element (IFE) methods that can utilize interface-independent meshes; hence, they can use structured/Cartesian meshes even for interfaces with non-trivial geometries. We will then present two applications to demonstration the benefits of IFE methods for moving interface problems. The first application is for incompressible interfacial flows governed by the Stokes equation whose interface is driven by the local fluid velocity. The second application is for some interface inverse problems of partial differential equations in which the approximate interface is driven by the shape optimization algorithm.

**Title:** Sparsity Regularization Using Wavelets in Electrical Impedance Tomography
**Speaker:** Dr. Taufiquar R Khan
Clemson University
**Date:** Friday, September 20, 2019
**Time:** 2:15pm
**Location:** EMCS 422
*Abstract.*
In this talk, we provide an introduction to regularization approaches for solving ill-posed inverse problems such as Electrical Impedance Tomography (EIT). We will also discuss the role of sparsity in EIT as well as the importance of wavelets. We will provide overview of the inverse problem in EIT and discuss the application and instability of the inversion in EIT. We will present the sparsity approach to solve the inverse problem and compare the sparsity approach to other approaches such as Gauss Newton method, statistical inversion.
If time permits, we will also present a graduate student professional development project "Math in Medicine" in the School of Mathematical and Statistical Sciences at Clemson University funded through the Burroughs Wellcome Fund.