UNC GREENSBORO

THE 15TH ANNUAL UNCG REGIONAL MATHEMATICS AND STATISTICS CONFERENCE

November 2, 2019

Conference History

The UNCG Regional Mathematics and Statistics Conference (RMSC) started under the name UNCG–RUMC (the University of North Carolina at Greensboro Regional Undergraduate Mathematics Conference). The first conference took place in 2005, and we have run the conference every year since. It started as an interdisciplinary conference that focused on student research in mathematical biology. However, the topics of student conference presentations were always open to all areas of research in the mathematical sciences. Recent conferences included presentations by both graduate and undergraduate students in a wide variety of research areas.

Conference in Numbers

Year	Student presentations	Student attendees	Non-student attendees
2005	12	23	12
2006	12	30	13
2007	15	36	14
2008	11	28	12
2009	20	44	21
2010	26	64	22
2011	48	132	30
2012	56	120	44
2013	57	115	42
2014	65	127	42
2015	49	125	39
2016	67	154	54
2017	57	154	32
2018	46	138	42

Recent Plenary Speakers

Year	Speaker	Affiliation
2014	Jerome Goddard II	Auburn University Montgomery
2015	Narayanaswamy Balakrishnan	McMaster University
2015	Laura Taalman	James Madison University
2016	Dominic Klyve	Central Washington University
2017	Talitha Washington	Howard University
2018	Suzanne Weekes	Worcester Polytechnic Institute

Funding and Support

- National Science Foundation (grant DMS–1632179)
- UNCG Department of Mathematics and Statistics
- Elon University's Chapter of Pi Mu Epsilon

Schedule

08:00–08:45	**Registration, posters setup, and refreshments**	
08:45–09:00	**Welcoming remarks:** Terry Shelton, Vice Chancellor for Research and Engagement (UNCG)	Sullivan 101
09:00–10:00	**Plenary lecture:** Brian Reich, Fine-scale spatiotemporal air pollution analysis using mobile monitors on Google Street View vehicles	Sullivan 101
10:00–10:15	**Coffee break**	
10:15–11:45	**Parallel morning sessions M1–M4**	
11:45–12:45	**Lunch**	
12:00–13:00	**Poster session:** coordinator Monica Goel (UNCG)	
13:00–14:00	**Parallel afternoon sessions A1–A4**	
14:00–14:15	**Coffee break**	
14:15–15:15	**Panel on math-stat careers:** Emily Griffith (NCSU), Thomas Parrish (Strix), Hristo Pavlov (Lincoln Financial), John Stufken (UNCG)	Sullivan 101
15:15–15:30	**Best presentation award ceremony**	Sullivan 101

Plenary Lecture

Fine-scale spatiotemporal air pollution analysis using mobile monitors on Google Street View vehicles

Brian Reich

North Carolina State University

People are increasingly concerned with understanding their personal environment, including possible exposure to harmful air pollutants. In order to make informed decisions on their day-to-day activities, they are interested in real-time information on a localized scale. Publicly available, fine-scale, high-quality air pollution measurements acquired using mobile monitors represent a paradigm shift in measurement technologies. A methodological framework utilizing these increasingly fine-scale measurements to provide real-time air pollution maps as well as short-term air quality forecasts on a fine-resolution spatial scale could prove to be instrumental in increasing public awareness and understanding. The Google Street View study provides a unique source of data with spatial and temporal complexities, with the potential to provide information about commuter exposure and hot spots within city streets with high traffic. We develop a computationally-efficient spatiotemporal model for these data and use the model to make short-term forecasts and high-resolution maps of current air pollution levels. We also show via an experiment that mobile networks can provide more nuanced information than an equally-sized fixed-location network. This modeling framework has important real-world implications in understanding citizens' personal environments, as data production and real-time availability continue to be driven by the ongoing development and improvement of mobile measurement technologies.

Morning Sessions M1–M4

Morning Session M1 — Chair: Yishi Wang — Sullivan 101

10:15–10:30 Lloyd Goldstein, Analysis of chemical exposure data in the LIFECODES data set using latent transition analysis.

10:30–10:45 Drew Johnston, Detecting atrial fibrillation with R-R intervals.

10:45–11:00 Jericho Lawson, Real-time classification of atrial fibrillation using RR intervals and transition states.

11:00–11:15 Simon-Peter Nyamoko-Agata, Modeling NCAA tournament picks.

11:15–11:30 Matthew Miller, Accounting for location measurement error in atomic resolution images of crystalline materials.

11:30–11:45 Wanqiao Xu, Eigenvalue distributions of random iterated block matrices.

Morning Session M2 — Chair: Maya Chhetri — Sullivan 200

10:15–10:30 Ananta Acharya, Existence results for a class of steady state reaction diffusion systems.

10:30–10:45 Nalin Fonseka, On the effects of the exterior matrix hostility and a U-shaped density dependent dispersal on a diffusive logistic growth model.

10:45–11:00 Amila Muthunayake, Singular reaction diffusion equations where a parameter influences the reaction term and the boundary condition.

11:00–11:15 Juan Quiroa, Analysis of positive solutions for a reaction-diffusion model where the reaction term grows linearly at infinity.

11:15–11:30 Can Phan, A reversed S-shaped bifurcation curve.

11:30–11:45 Elliott Hollifield, Positive solutions to a fractional Laplacian problem.

Morning Session M3 — Chair: Cuixian Chen — Sullivan 201

10:15–10:30 Badr Aloraini, Variance estimation using randomized response technique.

10:30–10:45 Qi Zhang, Mean estimation of sensitive variables under non-response and measurement errors using optional RRT models.

10:45–11:00 Romesh Ruwan Thanuja Liyana Arachchige, Data generation for longitudinally reversible process.

11:00–11:15 Bin Luo, Robust high-dimensional M-estimator framework for bi-level variable selection.

11:15–11:30 Mityl Biswas, Hypothesis testing in nonlinear function on scalar regression with application to child growth study.

11:30–11:45 Wonkyung Jang, When early childhood education meets machine learning: Issues with replication and reproducibility.

Morning Session M4 — Chair: Arran Hamm — Sullivan 203

10:15–10:30 Josiah Bauer and Sarah Fleetwood, Modeling the latent reservoir in the dynamics of HIV infection with CTL memory.

10:30–10:45 Claire Berchtold and Hannah Mitchum, Global dynamics of the HIV latent reservoir with latency reversing agents and immune response.

10:45–11:00 Kevin Buck, Modeling the spread of disease with vaccination and opinion dynamics.

11:00–11:15 Elizabeth Dicus, Mathematical modeling of sex trafficking.

11:15–11:30 Addie Harrison, Pattern and stripe formation in zebrafish.

11:30–11:45 Nick Corak, The formation and stability of tropical cyclones.

Afternoon Sessions A1–A4

Afternoon Session A1 — Chair: Loc Nguyen — Sullivan 101

13:00–13:15 Phuong Nguyen, A numerical method for an inverse source problem for parabolic equations and its application to a coefficient inverse problem.

13:15–13:30 Thuy Le, A convergent numerical method to recover the initial condition of nonlinear parabolic equations from lateral boundary data.

13:30–13:45 Katelyn Settlemyre, How big is that number? A brief introduction to p-adic numbers.

13:45–14:00 Sandi Rudzinski, Examples of class fields over local fields.

Afternoon Session A2 — Chair: Duha Hamed — Sullivan 200

13:00–13:15 Harrison Ingram, Low sensitivity to group members inhibits cooperation on evolving multiplayer networks.

13:15–13:30 Olivia Greathouse, Let's talk about it! Human vs. avatar interviewers.

13:30–13:45 Tianen Liu, Data privacy in the digital world.

13:45–14:00 Andrew Mosteller, Abracadabra: math, magic, and more!

Afternoon Session A3 — Chair: Teralea Moore — Sullivan 201

13:00–13:15 Dylan O'Connor, Lexell's theorem on the hyperboloid model of the hyperbolic plane.

13:15–13:30 Kristen Scheckelhoff, Tessellations of hyperbolic 3-Space.

13:30–13:45 William Cruse, A topological data analysis approach to time series classification.

13:45–14:00 Christopher Pritchard, The space of persistence diagrams has infinite asymptotic dimension.

Afternoon Session A4 — Chair: Wei-Kai Lai — Sullivan 203

13:00–13:15 Adrian Avalos, Integers partitions, Gaussian binomial coefficients, and Galois numbers.

13:15–13:30 Paul Hazelton and Suzanna Thompson, Ramsey and star-critical Ramsey numbers involving generalized fans.

13:30–13:45 Talon LaClair, Tournament scheduling: Let's play (soft)ball!

Oral Presentations

Existence results for a class of steady state reaction diffusion systems

Ananta Acharya[1], N. Fonseka

[1]*UNC Greensboro*

We study positive solutions for a system of steady state reaction diffusion equations where a parameter influences the reaction terms as well as the boundary conditions. We discuss a bifurcation result at a certain value A of this parameter, and existence of a solution beyond A. We prove our results using the method of sub-super solutions.

Faculty mentor: Ratnasingham Shivaji

Variance estimation using randomized response technique

Badr Aloraini[1], Muhammad Nouman Qureshi, Sadia Khalil

[1]*UNC Greensboro*

When conducting surveys, it is sometimes difficult to make a direct observation on the variable of interest. This is more so in the case where the research involves a topic that is a taboo in nature. In surveys on such topics, some of the respondents might give false responses. To offer a solution to this, a randomized response technique (RRT) was developed by Warner (1965). The technique allows respondents to provide a response while maintaining their privacy. The problem of mean and variance estimation is a topic that has been explored very well by researchers, although less so the problem of variance estimation. This is particularly the case in the context of RRT models. We propose some variance estimators for sensitive variables using auxiliary information. We examine the performance of the proposed estimators through a simulation study and through a numerical example.

Faculty mentor: Sat Gupta

Integers partitions, Gaussian binomial coefficients, and Galois numbers

Adrian Avalos

Coastal Carolina University

We'll begin by introducing integer partitions and Gaussian binomial coefficients using the inversion statistic on sequences. We'll then discuss Galois numbers and introduce the notion of fundamental sets of sequences. When inspecting the coefficients of Galois numbers associated with sequences of sufficient length, an interesting pattern emerges between finite differences of those coefficients and integer partitions. We will establish this pattern intuitively. Then, we will discuss Gaussian multinomial coefficients, generalized Galois numbers, and integer partitions with kinds. To close, we will allude to an extension of the previously inspected pattern as it relates to generalized Galois numbers and integers partitions with kinds.

Faculty mentor: Mark Bly

Modeling the latent reservoir in the dynamics of HIV infection with CTL memory

Josiah Bauer, Sarah Fleetwood

Winthrop University

In this project, we model the dynamics of HIV-1 latently infected cells under the effects of a natural immune response. Our purpose in this model is to study the long-term effects of CTL memory on viral load. We establish the existence of equilibria and the global asymptotic stability of the disease-free equilibrium based on the rate that cells are latently infected vs. actively infected. We then perform numerical simulations to illustrate the stability behavior of immune-free and internal equilibria. Furthermore, we demonstrate antiretroviral therapy can stimulate a memory response and reduce the viral load in the case when all equilibria exist.

Faculty mentors: Kristen and Zach Abernathy

Global dynamics of the HIV latent reservoir with latency reversing agents and immune response

Claire Berchtold, Hannah Mitchum

Winthrop University

In this project, we model the dynamics of HIV-1 latently infected cells under the effects of latency reversing agents (LRAs) to promote a natural immune response. We establish the existence of immune-free and positive equilibria and then utilize Lyapunov functions to prove the global asymptotic stability of each. Numerical simulations are performed to support and illustrate these results. We conclude with a discussion on the model's predicted threshold for LRA effectiveness to stimulate a natural immune response and decrease the size of the latent reservoir.

Faculty mentors: Kristen and Zach Abernathy

Hypothesis testing in nonlinear function on scalar regression with application to child growth study

Mityl Biswas

NC State University

We propose a kernel machine based hypothesis testing procedure in nonlinear function-on-scalar regression model. Our research is motivated by the New-

born Epi-genetic Study (NEST), a federally-funded research project on how environmental exposures and nutrition affect how genes work, where the question of interest is whether a pre-specified group of toxic metals or methylation at any of 9 differentially methylated regions (DMRs) is associated with child growth. We take the child growth trajectory as the functional response, and model the toxic metal measurements and methylation percentages jointly using a nonlinear function. We use a kernel machine approach to model the unknown function and transform the hypothesis of no effect to an appropriate variance component test. We demonstrate our proposed methodology using a simulation study and by applying it to analyze the NEST data.

Faculty mentor: Arnab Maity

Modeling the spread of disease with vaccination and opinion dynamics

Kevin Buck

Wake Forest University

One standard model for the spread of infectious disease is the SIS model; a compartmental model with reversible flow between infected and susceptible populations. In the SIS model it is well known that the disease becomes endemic or extinct depending on whether the basic reproduction number is above a threshold. However, in recent years there have been several outbreaks of measles, which was declared to be eliminated in 2000. These outbreaks are localized in communities that no longer believe vaccination is an appropriate response to the threat of disease. In this talk, we present an adapted SIS model which accounts for vaccination and the changing opinions concerning vaccinations. In particular, we consider a spatiotemporal model that couples the standard SIS dynamics to a nonlocal opinion dynamics model. Currently, we are analyzing bifurcations with respect to parameters such as force of infection, population fickleness, and relative birth rate. Preliminary results yield a transcritical bifurcation similar to the SIS model, however, we are exploring the existence of a Turing bifurcation which would lead to pockets of infected individuals.

Faculty mentor: John Gemmer

The formation and stability of tropical cyclones

Nick Corak

Wake Forest University

A presumed impact of global climate change is the increase in frequency and intensity of tropical cyclones. As early as 1988, Kerry Emanuel posed that the dynamics of a tropical cyclone can be modeled as a Carnot engine that transfers thermal energy from the ocean into mechanical energy in the form of cyclonic winds. In 2017, Emanuel and Zhang modeled tropical cyclones with a low-dimensional dynamical system coupling inner-core tangential wind speed with moisture. In this talk we study the existence and stability of fixed points for this dynamical system and analyze their sensitivity to white noise. The fixed points in this system correspond to the dissipation or presence of a cyclone. The model admits a saddle-node bifurcation dependent upon wind shear and thermodynamic parameters. The addition of white noise to the system allows us to explore the susceptibility of the model to tipping from a non-cyclone state to a cyclone state. Further understanding of the formation and stability might provide insight into the underlying mechanisms that govern the formation of cyclones.

Faculty mentor: John Gemmer

A topological data analysis approach to time series classification

William Cruse

UNC Greensboro

Time series classification is a challenging task due to the inaccuracies of machine learning. One of main fundamental tasks is to define distances among time series. Two of the widely used distances are Euclidean and Dynamic Time Warping. When classifying time series, one popular method is the K Nearest Neighbor algorithm. This algorithm can be used with both Euclidean and Dynamic Time Warping distances. For most cases, this algorithm is not a perfect method of classification and there will be some error rate. In this work, we propose new distances based on persistent homology, a recent developed tool in the field of topological data analysis. We consider the UCR Time Series Database, which provide a vast amount of time series for classification benchmark. We also compare the performances between the proposed distances and existing ones and explore their differences.

Faculty mentor: Yu-Min Chung

Mathematical modeling of sex trafficking

Elizabeth Dicus

Wake Forest University

In this work we adapt a compartmental model of sex trafficking developed by Davidoff et. al. Their system models the women and men's populations as a system of differential equations, in which the women's population flows between Susceptible, Prostitute, Rehabilitated, and Incarcerated compartments and the men's population flows between Potential Customers, Abstainers, Active Customers, and Incarcerated. However, this model does not account for the interaction between the women and men in the sex industry. To ameliorate this problem, we developed a model that couples the women and

men's systems, specifically accounting for supply and demand. Currently we are exploring bifurcations in this system, with respect to parameters such as rehabilitation rate, incarceration rate, and poverty. Once this analysis has been completed, the next step is to apply the model using parameters drawn from real world data. We are especially interested in using data from countries with varying poverty levels, incarceration rates, cultural differences, and immigration control, such as the United States, India, Greece, the Netherlands and the Philippines.

Faculty mentor: John Gemmer

On the effects of the exterior matrix hostility and a U-shaped density dependent dispersal on a diffusive logistic growth model

Nalin Fonseka[1], J. Goddard, Q. Morris, B. Son

[1] *UNC Greensboro*

We study positive solutions for a steady state reaction diffusion model arising in population dynamics where the population exhibits a logistic growth in the interior and a U-shaped density dependent dispersal on the boundary. We establish non existence, existence and multiplicity results. We also discuss the evolution of the bifurcation curve for positive solutions when the exterior matrix hostility varies.

Faculty mentor: Ratnasingham Shivaji

Analysis of chemical exposure data in the LIFECODES data set using latent transition analysis

Lloyd Goldstein

Drew University

Latent transition analysis is used to analyze the LIFECODES birth cohort data set in order to characterize patterns in chemical exposures data. This characterization is important for potential public health prevention strategies. Three latent classes is found to be the optimal number to use, and three distinct, consistent latent classes are produced at each of three time points using the PROC LTA package in SAS (Lanza 2015). Examining the chemical exposure makeups of each latent class, they are termed "low exposure", "medium exposure", and "high exposure". Assessing transition probabilities shows that latent classes remain very consistent over time. Agreement statistics are also fairly high, indicating that latent classes measure consistent constructs over time. This was most notable from the first to last time point considered, indicating that these constructs are consistent through the full period of time we analyze (percent agreement: 77.7%, Cohen's Kappa: .665). Latent classes are found to be significantly helpful in some cases for predicting levels of oxidative stress, particularly for the oxidative stress biomarker OHdG (mean p-value for likelihood ratio test examining OHdG: .042). Overall, latent transition analysis shows promise for applications in chemical mixtures analysis settings.

Faculty mentor: Rachel Carroll

Let's talk about it! Human vs. avatar interviewers

Olivia Greathouse[1], Anthony Illescas

[1] *Winthrop University*

Virtual avatars do not yet resemble people, yet previous research suggests that spoken interactions with avatar vs. human interviewers may not differ greatly. For example, prior work found little to no difference in job anxiety when conducting interviews with virtual avatars. Using a modified Wizard of Oz methodology, we seek to compare potential behavioral differences in spoken interactions for a mock interview scenario when the human interviewer is viewed as a human in the real world versus as a virtual avatar using Magic Leap augmented reality goggles. Specifically, building on relevant research on measuring engagement through speech characteristics, we quantify and compare interaction engagement for the avatar vs. human visual conditions using analysis of automatic speech-to-text content and speech prosody characteristics.

Faculty mentors: Joe Geigel, Nalin Ranjan, Reynold Bailey, Cecilia Alm

Pattern and stripe formation in zebrafish

Addie Harrison[1], Berke Türkay, Gisela Hoxha, Madison Russell, and Gil Parnon

[1] *Wake Forest University*

Zebrafish (*Danio rerio*) are a freshwater fish that are characterized by their black stripe and yellow interstripe pattern, against their counterpart Danios who display an array of different patterns. Zebrafish are a common species to study in biology due to their fully sequenced genome, mutant availability, and transparent embryo development. Zebrafish also make an interesting computational biology study subject because of their pigmented skin patterns. Their skin patterns develop from self-organizing cells which involves different mechanisms and variables that can be modeled from a mathematical perspective. Many of the mechanisms involved are still not well understood. However, continuing progress on empirical research has helped to provide more accuracy in developing the skin pattern mechanisms on zebrafish. Past research on the zebrafish, focused on developing a working five cell model for the fish body and a two cell model for the fin. Our team (Berke Türkay, Gisela Hoxha, Madison Russell, and Gil Parnon) focused on implementing and modifying the five cell model on the tail fin and anal fin. Analyzing the model can help us understand the

development of the zebrafish's pigmented pattern, which could have significant impact on future work in developmental biology, cancer, and genetic diseases.

Faculty mentor: Bjorn Sandstede

Ramsey and star-critical Ramsey numbers involving generalized fans

Paul Hazelton, Suzanna Thompson

Winthrop University

Ramsey Theory, one of the most well-studied branches of Combinatorics, can be paraphrased as the pursuit of "order amongst chaos". The Fundamental Theorem of Ramsey Theory (for graphs) states that for any two graphs G and H, any large enough red/blue edge-colored complete graph contains a red G or a blue H. The Ramsey number for G and H, then, is the smallest n so that K_n has this "unavoidability" property. Recently star-critical Ramsey number was introduced which is a slightly sharper measure on the unavoidability property. More precisely, if $R(G,H) = k$, then take Γ_m to be the complete graph on $k-1$ vertices with an additional vertex of degree m; the star-critical Ramsey number of G and H is the smallest m for which Γ_m has unavoidability. We focused on the generalized fan which is formed by taking disjoint copies of a fixed graph H and joining each to a vertex. Recently, researchers have investigated Ramsey and star-critical Ramsey numbers involving this kind of graph which motivated our work. We computed both parameters for a type of generalized fan versus a complete graph, a type of generalized fan versus disjoint triangles, and a type of generalized fan versus a K_4.

Faculty mentor: Arran Hamm

Positive solutions to a fractional Laplacian problem

Elliott Hollifield[1], Peter Girg

[1]*UNC Greensboro*

We consider a nonlinear exterior value problem involving the fractional Laplacian operator. We discuss the existence of positive weak solutions for a class of reaction terms. We also give numerical bifurcation diagrams and profiles of positive solutions, corresponding to the theoretical results, using a finite element method in one dimension.

Faculty mentor: Maya Chhetri

Low sensitivity to group members inhibits cooperation on evolving multiplayer networks

Harrison Ingram

UNC Greensboro

We model a mobile population interacting over an underlying spatial structure using a Markov movement model. Interactions take the form of public goods games, and can feature an arbitrary group size. Individuals choose strategically to remain at their current location or to move to a neighboring location, depending upon their exploration strategy and the current composition of their group. This work builds upon Erovenko et al. (2019), which investigated the effect of network topology on the evolution of cooperation. In this project, we vary the sensitivity to the group composition as part of the exploration strategy of the individuals. We find that low awareness to whom individuals interact with inhibits cooperation independently of the network topology.

Faculty mentor: Igor Erovenko

When early childhood education meets machine learning: Issues with replication and reproducibility

Wonkyung Jang[1], Nicholas Wolczynski

[1]*UNC Chapel Hill*

Currently, in the fields of psychometrics, classical inferential statistics have been increasingly scrutinized because of issues with replication and reproducibility (McNeish, 2015). Serious questions with respect to the interpretation and focus put on p-value testing have led to what has been characterized a replication crisis (Schooler, 2014), with replication rates estimated to be as little as 11% for developmental research (Begley & Ellis, 2012). Even though outcomes are reproducible, statistically significant results are often not clinically pivotal (Ioannidis, 2016). For instance, effect sizes are prone to be attenuated since early childhood development is complex involving interactions within and among physical, cognitive, emotional, and ecological systems related to each individual (Bronfenbrenner, 1979). This paper discusses potential issues with standard statistical models and offers an introduction to regularization with precise details on LASSO (Tibshirani, 1994) regarding replication and reproducibility. Due to the nesting of children within schools, the multilevel extension of LASSO (Schelldorfer et al., 2011) was used to investigate the relation between Pre-K classroom practices and children's language and literacy outcomes using data from the Early Childhood Longitudinal Study—Kindergarten (ECLS-K) Cohort, a nationally representative sample of 21,260 children who were in kindergarten in 1998–1999.

Faculty mentor: none

Detecting atrial fibrillation with R-R intervals

Drew Johnston

Brigham Young University

Atrial fibrillation is a common form of irregular heart rhythm that can significantly increase the risk of stroke in adults over the age of 45. This is a major problem because atrial fibrillation can be asymptomatic except for

occasional irregular heart rhythms that medical professionals cannot always detect. To remedy this we propose a simple model for atrial fibrillation classification that can be implemented in common heart-rate monitors today—including wearable devices. Using two different publicly available PhysioNet databases, we analyze the performance of classification models to determine the models' potential performance when implemented in real life scenarios. Our features are extracted from the R-peaks detected on electrocardiogram recordings to simulate heart-beats detected from everyday monitors. We observe that classification models for detecting atrial fibrillation perform better with clean, clinical data as compared to noisy, real-world data.

Faculty mentors: Yishi Wang and Cuixian Chen

Tournament scheduling: Let's play (soft)ball!

Talon LaClair

Lenoir-Rhyne University

This talk will focus on combinatorics and graph theory in tournament scheduling. We will look at different types of tournaments and different scenarios of each one. Relating to softball tournaments, we will explore the number of games played, number of rounds needed, and number of teams. In particular, we will determine what number of teams are needed so that each team plays a certain number of games without repeat opponents. Our work will help tournament organizers ensure that no team is left out and each team gets their money's worth. This work will further help coaches and tournament organizers to plan tournaments more efficiently and effectively.

Faculty mentor: Sarah Nelson

Real-time classification of atrial fibrillation using RR intervals and transition states

Jericho Lawson

University of Arizona

2.7 million Americans currently have atrial fibrillation (AFib), a heart issue that is described as a "quivering or irregular heartbeat." AFib can lead to other health issues, such as blood clots, stroke, and heart failure. Using AFib data from the MIT-BIH Atrial Fibrillation Database and the 2017 PhysioNet Challenge Dataset, as well as methods from Moody and Mark's 1983 paper, we attempt to explore simple models using various classification methods and resampling techniques to detect AFib. Proportions of transition states between RR intervals are used as covariates in logistic regression, LDA, QDA, boosting, and XGBoost models. With 5-Fold Cross Validation, we can get up to 97.1% prediction accuracy and 97.0% sensitivity using the MIT-BIH dataset. Similar results can be seen with fewer covariates and dimension reduction techniques, which are important to note if implementation of these methods are used in real-time heart rate devices, such as Fitbits. Additionally, using covariates, such as RR interval variance and dimensions from the multi-dimensional scaling of pairwise differences in the Kolmogorov-Smirnov Tests, provide potential usefulness for AFib classification.

Faculty mentor: Yishi Wang

A convergent numerical method to recover the initial condition of nonlinear parabolic equations from lateral boundary data

Thuy Le

UNC Charlotte

We solve the inverse problem how to reconstruct the initial conditions of nonlinear parabolic equations from the measurements of both Dirichlet and Neumann data on the boundary of a domain. In the theoretical part, we prove the uniqueness and logarithmic stability. Then, in the numerical part, we approximate the nonlinear parabolic equation by a system of nonlinear elliptic equations. This system of nonlinear elliptic equations is solved by an iteration scheme. The fast convergence is rigorously and numerically proved.

Faculty mentor: Loc Nguyen

Data privacy in the digital world

Tianen Liu

Wake Forest University

In the data-driven era, we as data providers want our sensitive information to be kept private and secure. However, companies and government need to use data sets that contain sensitive information to ensure accurate analysis. With a trade-off between accuracy of data set and our privacy, differential privacy sets a privacy level for a public data set that benefits both data users and data providers. A differential privacy technique modifies a data set and ensures its usability for companies who analyze it without having to directly access the sensitive information in the original raw data. At the same time, data providers do not have to worry about data breach because, based on the differential privacy, it is unknown if a piece of sensitive information is the actual raw data or not. In this talk, we present an introduction to differential privacy, including its definition, uses, and common methods. These include Laplacian noise, randomized response, and Bernoulli posterior predictives. We then conclude with an application of these techniques to create a synthetic data set on the 2017–2018 Open Sourcing Mental Illness data set.

Faculty mentor: Nicole Dalzell

Data generation for longitudinally reversible process

Romesh Ruwan Thanuja Liyana Arachchige

UNC Greensboro

In spatial statistics, there are only a few studies available for axially symmetric data generation on the sphere. In this project, we propose an algorithm for data generation on the sphere based on Karhunen–Loeve expansion and Wavelet–Galerkin Method. Initial simulations demonstrate that our generated data produce significantly smaller bias compared to existing methods in literature when calculating cross variogram estimates on the sphere.

Faculty mentor: Haimeng Zhang

Robust high-dimensional M-estimator framework for bi-level variable selection

Bin Luo

UNC Greensboro

Covariates often function group-wisely in many applications and model sparsity can appear either at the group level or within certain groups. An ideal model in high-dimensional data analysis should be able to encourage the bi-level variable selection consistently. This bi-level variable selection has become even more challenging when data are contaminated by heavy-tailed distribution and/or outlier in random errors and covariates. In this paper, we proposed a robust high-dimensional bi-level variable selection method through a two-stage penalized M-estimator framework: penalized M-estimation with a concave penalty achieving the group selection at the first stage, and a post hard thresholding operator to achieve the within-group sparsity at the second stage. In theory, we provide sufficient conditions under which a two-stage penalized M-estimator possesses simultaneous local estimation consistency at the minimax rate enjoyed by LS Group Lasso (LS-GLasso) and the bi-level variable selection consistency. Our simulation studies and real data analysis demonstrate satisfactory finite sample performance of the proposed estimators under different irregular settings.

Faculty mentor: Xiaoli Gao

Accounting for location measurement error in atomic resolution images of crystalline materials

Matthew Miller[1], Matthew Cabral, Elizabeth Dickey, James LeBeau

[1]*NC State University*

Scanning transmission electron microscopy can directly image the atomic structure of materials. To resolve this structure, the material must be aligned along a direction such that columns of atoms are projected onto the image. The local relationships between the intensities and distances of these projected atom columns can inform our understanding of structure–property relationships to ultimately further improve the materials. Measurement error in the atom column locations can, however, introduce bias into parameter estimates. Here, we create a spatial Bayesian hierarchical model that treats the locations as parameters to account for measurement error, and lower the computational burden by approximating the likelihood using a non-contiguous block design around the atom columns. We conduct a simulation study and analyze real data to compare our model to standard spatial and non-spatial models. The results show our method corrects the bias in the parameter of interest, drastically improving upon the standard models.

Faculty mentor: Brian Reich

Abracadabra: math, magic, and more!

Andrew Mosteller

Lenoir-Rhyne University

In this talk, we will briefly discus the history of math, magic, and how they interact. We will also explore two very powerful, self-working (relying fully on mathematics, no sleight of hand required) card tricks. In addition, we will reveal the underlying mathematics and method behind these tricks which use key concepts from Group Theory and Number Theory. We will also go over how generalizations of this method can be used to create new possibilities of self-working card tricks.

Faculty mentor: Jennifer Garbett

Singular reaction diffusion equations where a parameter influences the reaction term and the boundary condition

Amila Muthunayake[1], N. Fonseka, Byungjae Son

[1]*UNC Greensboro*

We study the singular semipositone problem:

$$\begin{cases} -u'' = \lambda h(t) f(u); \ (0,1) \\ u(0) = 0 \\ u'(1) + \mu(\lambda) u(1) = 0 \end{cases}$$

where $\lambda > 0$ is a parameter, f is a C^2 increasing function on $[0,\infty)$ such that $f(0) < 0$, $\lim_{s\to\infty} f(s) = \infty$ and $\lim_{s\to\infty} \frac{f(s)}{s} = 0$. h is a C^1 nonincreasing function on $(0,1]$ with $h(1) > 0$ and there exist constants $d_0 > 0$, $\alpha \in [0,1)$ such that $h(t) \le \frac{d_0}{t^\alpha}$ for all $t \in (0,1]$, and μ is a continuous nonnegative function on $[0,\infty)$ such that $\mu(0) \ge 0$. We will establish a unique positive solution for $\lambda \gg 1$.

Faculty mentor: Ratnasingham Shivaji

A numerical method for an inverse source problem for parabolic equations and its application to a coefficient inverse problem

Phuong Nguyen

UNC Charlotte

Our aim is to solve an inverse source problem for parabolic equations. This is the problem to reconstruct a source term from external observations. Our method to solve this inverse source problem consists of two stages. We first establish an equation of the derivative of the solution to the parabolic equation with respect to the time variable. Then, in the second stage, we solve this equation by the quasi-reversibility method. The inverse source problem considered is the linearization of a nonlinear coefficient inverse problem. Hence, iteratively solving the inverse source problem provides the numerical solution to that coefficient inverse problem. Numerical results for the inverse source problem under consideration and the corresponding nonlinear coefficient inverse problem are presented.

Faculty mentor: Loc Nguyen

Modeling NCAA tournament picks

Simon-Peter Nyamoko-Agata

Elon University

Millions of college basketball fans across America participate in the March Madness Bracket Challenge each year. People utilize different strategies, ranging from simple tactics to complex computational strategies. Due to the overwhelming number of possible outcomes, no one has been able to create a perfect bracket. My research studies how people choose which teams will advance in the tournament. To do this I collected a variety of data including traditional ranking information, advanced team performance data, and previous NCAA Tournament success. My project models the percentage of people who will pick a team to advance to the following round. Specifically, I produced a model for each of the six rounds that reflects the odds ratio of a team being picked to advance. My research selects the statistically significant variables for predicting the odds ratio of a team advancing in that particular round and compares it to those in the other rounds. Via this method, I was able to find that seed and previous tournament wins were significant predictors of the odds ratio for all six rounds and rank was significant for the first three rounds only.

Faculty mentor: Ryne VanKrevelen

Lexell's theorem on the hyperboloid model of the hyperbolic plane

Dylan O'Connor[1], Ramon Suris-Rodriguez

[1]*UNC Chapel Hill*

Euclidean, spherical and hyperbolic are three different geometries with many common threads. We believe that every Euclidean result has an analogous result in the other two, and, likewise, that every spherical result has an analogous hyperbolic result. Lexell's theorem on the sphere, a result discovered in the 18th century, concerns the locus of points preserving the area of a triangle. In this presentation we will introduce the basics of spherical and hyperbolic geometry, then explore a new construction and proof of Lexell's theorem in hyperbolic geometry. This research was conducted as part of the 2019 REU program at Grand Valley State University.

Faculty mentor: William Dickinson

A reversed S-shaped bifurcation curve

Cac Phan[1], Amila Muthunayake

[1]*UNC Greensboro*

We study positive solutions to the steady state reaction diffusion equation:

$$\begin{cases} -u'' = \lambda\left[\dfrac{A}{u^{\gamma}} + M\{u^{\alpha} + u^{\delta}\}\right];\ (0,1) \\ u(0) = 0 = u(1) \end{cases}$$

where $A < 0$, $\alpha \in [0,1)$, $\gamma \in [0,1)$, $\delta > 1$ are constants and $\lambda > 0$ and $M > 0$ are parameters. We discuss the existence of a $\lambda_0 > 0$ such that there is at least one solution for $\lambda < \lambda_0$, uniqueness when $\lambda \approx 0$, and at least least three solutions for a certain range of λ when $M \gg 1$. We employ the Quadrature method to establish our results.

Faculty mentor: Ratnasingham Shivaji

The space of persistence diagrams has infinite asymptotic dimension

Neil Pritchard[1], Austin Lawson, Dan Yasaki

[1]*UNC Greensboro*

We define an obstruction to finite asymptotic dimension for metric spaces, that we call k-prisms. This structure allows us to embed a space with infinite asymptotic dimension into the metric space in question, showing that the metric space cannot have finite asymptotic dimension. In particular we show that the space of persistence diagrams in a Wasserstein metric has infinite asymptotic dimension.

Faculty mentor: Greg Bell

Analysis of positive solutions for a reaction-diffusion model where the reaction term grows linearly at infinity

Juan Quiroa[1], Nalin Fonseka

[1]*UNC Greensboro*

We discuss existence and multiplicity results for a steady-state reaction-diffusion model, where the reaction term grows linearly at infinity. We also discuss the evolution

of the bifurcation curve of positive solutions when a parameter varies.

Faculty mentor: Ratnasingham Shivaji

Examples of class fields over local fields

Sandi Rudzinski

UNC Greensboro

We give an introduction to the beauty of local class field theory and present methods for constructing class fields. We introduce p-adic fields and their unit groups and give an overview of local class field theory. We give examples of the construction of class fields corresponding to a given finite index subgroup of the ground field using extensions of degree p and Lubin–Tate extensions. The latter, in addition to the class field, also yields the Artin map which gives the isomorphism between the quotient of the unit group and the Galois group of the class field.

Faculty mentor: Sebastian Pauli

Tessellations of hyperbolic 3-space

Kristen Scheckelhoff[1], Kalani Thalagoda

[1]*UNC Greensboro*

The space of positive definite binary Hermitian forms is a 4-dimensional cone, and homothety equivalent forms in this cone can be identified with hyperbolic 3-space. A generalization of work of Voronoi shows that configurations of minimal vectors of perfect Hermitian forms give rise to tessellations of this space by three-dimensional ideal polytopes. These polytopes depend on the choice of imaginary quadratic number field. In this joint work with Kalani Thalagoda and Dan Yasaki, we study the types of polytopes that arise in these decompositions and prove that the number of vertices of such a polytope is bounded above by 12. We then investigate the action of the general linear group on the polytopes for a given field; using the well-rounded retract of Ash and McConnell, along with an adaptation of work of Brown, we compute explicit group presentations.

Faculty mentor: Dan Yasaki

How big is that number? A brief introduction to p-adic numbers

Katelyn Settlemyre

Lenoir-Rhyne University

We all know how to find the size of a number—just find its distance from zero on the number line! But what if we change how we calculate distance? Some small numbers might become big, some big numbers small, and all sorts of strange things might happen! Specifically, we can choose our favorite prime number p and define the size of any integer based on how divisible it is by p. This leads to the idea of the p-adic numbers. In this talk, we will discuss this p-adic distance, the resulting p-adic numbers, and some of their unusual properties.

Faculty mentor: Timothy Goldberg

Eigenvalue distributions of random iterated block matrices

Wanqiao Xu[1], Keller Blackwell, Neelima Borade, Charles Devlin VI, Renyuan Ma

[1]*University of Michigan*

Random matrix theory has successfully modelled many properties of L-functions. However, there are situations where it is silent. One instance is the number theory process of Rankin-Selberg convolution, which creates a new L-function from an input pair. Our work investigates a possible RMT analogue of this process through the parallel study of random matrix ensembles constructed from existing families. Let A denote a symmetric Toeplitz matrix whose first row is palindromic and B denote a real symmetric matrix; it is well-known that the limiting distribution of the normalized eigenvalues of these ensembles converge to the Gaussian and semi-circle distribution respectively. We consider the "disco" $\mathcal{D} = \begin{bmatrix} A & B \\ B & A \end{bmatrix}$. We apply Markov's method of moments to derive the limiting spectral measure of $\mathcal{D}(A, B)$; the primary obstacle is analysis of non-commutative matrix polynomials, which we reformulate as a combinatorial problem of independent interest. We prove convergence of the hybrid distribution, show it has unbounded support and is sharply bounded away from the constituent distributions, explore generalizations of our construction, and discuss potential applications to open inquiries in number theory.

Faculty mentor: Steven Miller

Mean estimation of sensitive variables under non-response and measurement errors using optional RRT models

Qi Zhang[1], Sadia Khalil

[1]*UNC Greensboro*

This study mainly consist of three issues we are facing in survey sampling: non-response, measurement error and social desirable bias. In this paper, we propose a generalized population mean estimator under optional RRT models in the presence of measurement error and non-response. We present a comparison of the proposed estimator with some other commonly used estimators. A simulation study is also conducted to validate the theoretical results.

Faculty mentor: Sat Gupta

Poster Presentations

Using statistical models and machine learning algorithms to detect atrial fibrillation

Christian Austin

UNC Wilmington

Atrial fibrillation is a condition of the heart during which the heart beats irregularly, and can lead to heart problems later in life. In our goal to use machine learning algorithms to automatically detect and classify atrial fibrillation given only heartbeat data (the locations of R peaks and durations of RR intervals), we extracted multiple features about the heartbeat. We then trained and tested multiple binary-classification machine learning algorithms on two different datasets. The MIT-BIH atrial fibrillation database was the much cleaner dataset, and we were able to achieve over 98% accuracy and sensitivity using a boosting model. On the noisier, messier dataset, the Computing in Cardiology 2017 Challenge training set, AFib sensitivity achieved just over 80% in our best model types, which were logistic regression and support vector machine with a linear kernel.

Faculty mentors: Yishi Wang and Cuixian Chen

Combinatoric analysis of non-flow in heavy ion collisions

Aidan Lytle

UNC Greensboro

Collisions of nuclei at relativistic energies create a phase of deconfined nuclear matter called the quark-gluon plasma (QGP). The QGP evolves as a nearly inviscid fluid, and is well-described by relativistic hydrodynamics. The fluid flow is experimentally analyzed using Fourier series, but non-flow effects must be taken into account. In this study we seek to isolate the non-flow using combinatorics, which in principle allows determination of few-particle correlations as a function of multiplicity. Utilizing CERN's ROOT analysis framework, a toy Monte Carlo, and the event generator Pythia, we show that the correlations do not follow the expected combinatorics, indicating that our expectations require modification to account for the non-trivial nature of the correlation. We show our empirical observations on the multiplicity scaling and speculate on possible resolutions.

Faculty mentor: Ron Belmont

Modeling dengue fever using agent based modeling

Timothy Redgrave

Elon University

Dengue fever is a mosquito born tropical illness caused by the dengue virus. Approximately 400 million individuals are infected each year, and this number is expected to rise as global temperatures increase. There is currently no vaccine for the dengue virus, and traditional methods of combating the spread of mosquito born illnesses such as the use of bed netting is ineffective as the species of mosquito that carries dengue is active during the day rather than at night. The intent of this project was to build a model that could be used to predict how dengue fever would spread when introduced to a population of people and mosquitoes. This was achieved by building an agent-based model in NetLogo. This model accounted for both male and female mosquitoes, along with humans, different serotypes of dengue fever, and other factors including temporary immunity. Multiple trials of the simulation model were run in order to determine general trends in the model, including what percentage of people and mosquitoes became infected over time, and the rate at which the virus spread.

Faculty mentor: Crista Arangala

On Nesbitt type inequalities

John Risher

University of South Carolina

The famous inequality, $a/(b+c) + b/(c+a) + c/(a+b) \geq 3/2$ for positive a, b, c, was introduced by Nesbitt at 1903. Since then, many proofs have been introduced. Among these proofs, one was introduced by Mortici at 2012, using power series approach. Adopting this new approach, we analyze several cases of the similar form as Nesbitt inequality and notice that they can all be proved using this new technique. In this presentation, we will introduce these new Nesbitt type inequalities along with our proofs.

Faculty mentor: Wei-Kai Lai

The impact of climate change on the distribution of buzz pollinators

Abigail Williams[1], Ellie Lochner, Brandyn Ruiz

[1] *Salem College*

Many crops are dependent on pollinators for the production of fruit and seeds. Several, such as the tomato plant, are significantly impacted by buzz pollination, in which bees vibrate indirect flight muscles at a specific frequency to release pollen. Managed honey bees are unable to buzz pollinate, which creates a demand for wild buzz pollinators to assist in the pollination of tomato plants. However, climate change is impacting the distribution of these wild pollinators, which could lead to a deficit of pollination services for tomato crops. Through the use of ecological niche modeling we were able to assess the potential habitat suitability shift of sixteen buzz pollinators native to North America. We acquired known species occurrence data and used climate projections based on

different emission scenarios to detect regions where climate change will impact buzz pollinator habitat suitability. We compared areas where decreases in buzz pollinator habitat suitability will likely impact tomato production. Our results feature regions where tomato pollinator habitat suitability is likely to decrease, particularly in the eastern United States in states such as Indiana and Ohio. Habitat management and climate change mitigation measures should be prioritized in these regions to preserve the quality and production of tomatoes.

Faculty mentors: G. Wiggins, M. Papes, L. Carrasco

All presenters are invited to submit manuscripts to the *North Carolina Journal of Mathematics and Statistics* (NCJMS):

`http://ncjms.uncg.edu`

NCJMS is a broad-based journal that publishes high quality, peer-reviewed, open access articles and software. There is no publication charge to the authors. We encourage submission of

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- a package or a collection of functions for a computer algebra system
- a package or a collection of functions written in a general-purpose programming language
- a library
- a stand-alone program

Software submissions must consist of an article that contains a description of the functionality of the software and also the source code of the software.