Undergraduate Mathematics Conference

College of William and Mary

April 8, 2017

GEORGE MASON UNIVERSITY

WILLIAM & MARY
CHARTERED 1693

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

Location:
Jones Hall 301 and 302, William and Mary

Sponsors:

National Science Foundation
College of William and Mary
(Department of Mathematics)
(Cissy Patterson Fund)
(Vice Provost for Research and Graduate/Professional Studies)
George Mason University
George Washington University

Organizers:

Sarah Day (College of William and Mary)
Maria Emelianenko (George Mason University)
Maria Gualdani (George Washington University)
Yongwu Rong (George Washington University)
Junping Shi (College of William and Mary)

Previous Conferences in this series

- **April 5, 2008 (George Mason University)**
- **March 21, 2009 (College of William and Mary)**
- **April 17, 2010 (George Mason University)**
- **April 16, 2011 (College of William and Mary)**
- **April 21-22, 2012 (George Washington University)**
- **April 6, 2013 (George Mason University)**
- **April 2, 2016 (George Washington University**

Time		Title	Speaker
9:30-10:00	Registration and breakfast		
	Chair: Junping Shi		
10:00-10:10	Opening remark		
10:10-11:00	Keynote lecture	Leveraging Methods for Big Data Regression	Ping Ma (UGA)
11:00-11:20	Coffee break and group photo		
	Session 1 Chair: Yongwu Rong		
11:20-11:40		Saving Babies Using Big Data	Evan Dienstman (W&M)
11:40-12:00		Periodic Migration in a Physical Model of 1D Cell on Micro-patterns	Shigen Sun (GWU)
12:00-12:20		Pulse Propagation Time and its Relation to Blood Pressure in Preterm Infants	William Lawrence (W&M)
12:20-13:40	Lunch break		
	Session 2 Chair: Sarah Day		
13:40-14:00		Boom-and-Bust Dynamics in Financial Systems	Zhusong Mei (GMU)
14:00-14:20		Potential Stability of Matrix Sign Patterns	Christopher Hambric (W&M)
14:20-14:40		Fractional Dynamics for Quantum Random Walks	Lucas Bouck (GMU)
14:40-15:00		A Differential Equation Model on Age-Structured Oyster Population and Its Implications in Oyster Restoration	Yi Zhang (W&M)
15:00-15:20	Coffee break		
	Session 3 Chair: Maria Emelianenko		
15:20-15:40		Dynamics of a Two-Patch System under the Allee Effect	Margaret Swift (W&M)
15:40-16:00		Consensus vs. fragmentation in a model of opinion dynamics	Ratna Khatri (GMU)
16:00-16:20		Mathematical Aspect of the Combinatorial Game "Mahjong"	Yuan Cheng (W&M)
16:20-16:40		Data Analysis of Car Accidents	Michael Ranasinghe (GWU)
17:00-19:00	Dinner		

Abstract of Talks

1.

Leveraging methods for big data regression

Professor Ping Ma
University of Georgia

Abstract: The rapid advance in science and technology in the past decade brings an extraordinary amount of data, offering researchers an unprecedented opportunity to tackle complex research challenges. The opportunity, however, has not yet been fully utilized, because effective and efficient statistical tools for analyzing super-large dataset are still lacking. One major challenge is that the advance of computing resources still lags far behind the exponential growth of the database.

In this talk, I will present an emerging family of statistical methods, called leveraging methods to facilitate scientific discoveries using limited computing resources. Leveraging methods are designed under a subsampling framework, in which one samples a small proportion of the data (subsample) from the full sample, and then performs intended computations for the full sample using the small subsample as a surrogate. The key to the success of the leveraging methods is to construct nonuniform sampling probabilities so that influential data points are sampled with high probabilities. These methods stand as a unique development of their type in big data analytics and allow pervasive access to massive amounts of information without resorting to high-performance computing and cloud computing.

2.

Saving Babies Using Big Data

Evan Dienstman
College of William and amry
Adviser: John Delos

Abstract: Because of their underdeveloped immune systems, premature babies are at an increased risk to contract many illnesses. Thus, early detection of a disease is vital to saving a premature baby's life. Current methods of detecting illnesses, however, have been inadequate, providing many false positives and insufficient amount of warning time. However, patterns in the heart rate of babies have shown signs of predicting the onset of sepsis in premature infants. Research conducted by Prof. Delos and others suggest that low variability and clusters of decelerations in an infant's heart rate may indicate an impending septic event. Additionally, there is weak evidence that low variability may be linked to gram-positive bacteria and clusters of decelerations many be linked to gram-negative bacteria. If this statement is true, then not only will the heart rate of an infant predict the onset of sepsis, but also provide a partial diagnosis and thereby indicate the preferred treatment for the baby. However, much more work needs to be done to prove this hypothesis. Over twelve terabytes of data has been collected on premature babies' heart rate and breathing. To search through this data, one first needs to know what to look for. Unfortunately, only looking for low variability and clusters of decelerations would be inadequate since most babies experience some low variability and

decelerations in their heart rate at some point. Therefore, sophisticated statistical analysis is necessary to quantify this data. The general concept of the analysis includes creating many different heart rate characteristics (HRCs) and measuring their predictive power through multiple methods. The results of our research indicate that the HRCs of sample entropy and asymmetry are strong predictors of illness. However, no HRC shows strong signs of indicating the invading organism that caused the illness.

3.

Periodic Migration in a Physical Model of 1D Cell on Micro-patterns

Shigeng Sun
George Washington University
Adviser: Yanxiang Zhao

Abstract: In this project, we study the one dimensional cell migration on micro-patterned substrates. This work is an extension of the study proposed in a paper of Camley et.al, in which the proposed model (later referred as 'the model') couples cell morphology with the polarizations of actin and myosin molecules. In this project, we use the model to study the effects of system parameters on the cell migration periodicity. More specifically, we study the protrusion and contraction forces and their effects on the amplitude and frequency of the periodical migration behaviors. For the numerical simulations, we show that periodic motion emerges naturally from the coupling of cell polarization and cell shape by running simulations with different values of system parameters. Both of these parameters are determined by different sharp interface results. We also show via simulations that there are important bifurcation points resulted from difference in protrusion and contraction forces. Furthermore, we have discovered an emergent phenomenon from our simulation, which shown that the protrusion stress increase resulted in an abrupt change on the amplitude of the periodic migration.

4.

Pulse Propagation Time and its Relation to Blood Pressure in Preterm Infants

William Lawrence
College of William and Mary
Adviser: John Delos

Abstract: A noninvasive alternative to continuous blood pressure measurement could allow detection of pathological conditions such as such shock in preterm infants without requiring catheterization. Using multiple days worth of ECG and pulse oximetry data collected from a neonatal intensive care unit and processed using a collection of filtering algorithms, we track pulse propagation time (PPT) and other physiological data over time. We analyzed the resulting data for correlations with blood pressure.

5.

Boom-and-Bust Dynamics in Financial Systems

Zhusong Mei
George Mason University
Adviser: Harbir Lamba

Abstract: Geometric Brownian motion is often used to simulate assets price paths but this model does not represent the 'boom-and-bust' nature of actual financial markets. I shall describe two closely-related, previously developed, agent-based models. Each of them is based upon a realistic and different source of non-rationality or efficiency, but only one of them has an analytically tractable solution.

It is therefore of interest to try and quantify any statistical differences between the price outputs of the two models. The problem of choosing comparable pairs of parameters will be explained and our results suggest that the statistical similarities between the models may be good enough for many applications (eg. Monte Carlo simulations).

6.

Potential Stability of Matrix Sign Patterns

Christopher Hambric
College of William and Mary
Adviser: Chi-Kwong Li

Abstract: A square matrix with real entries is said to be stable if each eigenvalue of the matrix has a real part that is strictly negative. We consider matrix sign patterns which may be realized by a stable matrix, and we investigate necessary and sufficient conditions for a sign pattern to be potentially stable, as well as a lower bound for the number of nonzero entries in such a sign pattern. Our approach uses a combination of graph and matrix theory in order to examine the structure and properties of these sign patterns, and we provide results which restrict the structure of a potentially stable pattern.

7.

Fractional Dynamics for Quantum Random Walks

Lucas Bouck
George Mason University
Adviser: Harbir Antil

Abstract: Quantum computing is the field focused on developing computation based on quantum mechanics. This would enable computers to solve many problems faster than those with classical methods. Quantum random walks (QRW) are vital for the development of algorithms in quantum computing. The quantum nature of these walks makes them interesting objects to study. This research specifically studies a QRW on a line that utilizes a Hadamard coin operator. We introduce a Fractional Fokker-Planck Equation to model this QRW. A spectral method is then used to compute a numerical solution to this PDE. This work then discusses similarities and differences between this model and other models in the literature.

8.

A Differential Equation Model on Age-Structured Oyster Population and Its Implications in Oyster Restoration

Yi Zhang
College of William and Mary
Adviser: Rom Lipcius, Leah Shaw, Junping Shi

Abstract: We modify a previous system of differential equations to model the population of the oysters in the Chesapeake Bay. In the last 150 years, more than 85% of historical oyster reefs around the globe have been lost, and current restoration efforts involve building reefs to increase oyster population. The original model described the interaction between live oyster, deal oyster shells, and sediment, and in our new model, we incorporate the age structure by adding an equation describing the change in juvenile oyster numbers, which can provide a better theoretical reference for restoration in the real world.

9.

Dynamics of a Two-Patch System under the Allee Effect

Margaret Swift
College of William and Mary
Adviser: Leah Shaw, Junping Shi

Abstract: Ocean or river currents often create unequal patterns of dispersal from one patch of aquatic organisms to another. We focus on two marine population patches coupled by asymmetric dispersal. In addition, our coupled patches are subject to the positively density-dependent Allee effect: Populations below an inherent threshold decline towards extinction, while those above the threshold persist towards their carrying capacity. At high Allee thresholds, we uncover large parameter ranges in which the extinction state is the only fixed point. These regions do not occur with density-independent symmetric dispersal rates; this talk focuses particularly on the bifurcations that lead to this surprising extinction state. This discovery raises concerns forthe restoration of species that may exhibit an Allee effect and asymmetric dispersal.

10.

Consensus vs. fragmentation in a model of opinion dynamics

Ratna Khatri
George Mason University
Adviser: Matt Holzer

Abstract: We consider a continuous version of the Krause model of opinion dynamics. Interaction between agents either leads to a state of consensus, where agents starting out with nearly uniform initial opinions converge to a single opinion as time evolves, or to a fragmented state with multiple opinions. We linearize the system about a uniform density solution and predict consensus or fragmentation based upon the most unstable mode of the dispersion relation. Analytical predictions are then compared to numerical simulations.

11.

Mathematical Aspect of the Combinatorial Game "Mahjong"

Yuan Cheng
College of William and Mary
Adviser: Chi-Kwong Li

Abstract: Many research in mathematics and computer sciences are connected to games such as chess, Go, etc. In this talk, we consider mathematical and computational aspects of the combinatorial game: Mahjong. In particular, we analyze some special winning patterns appearing in the game, and study the probabilities of holding some special hands. Open problems connected to the game and other related topics will be mentioned.

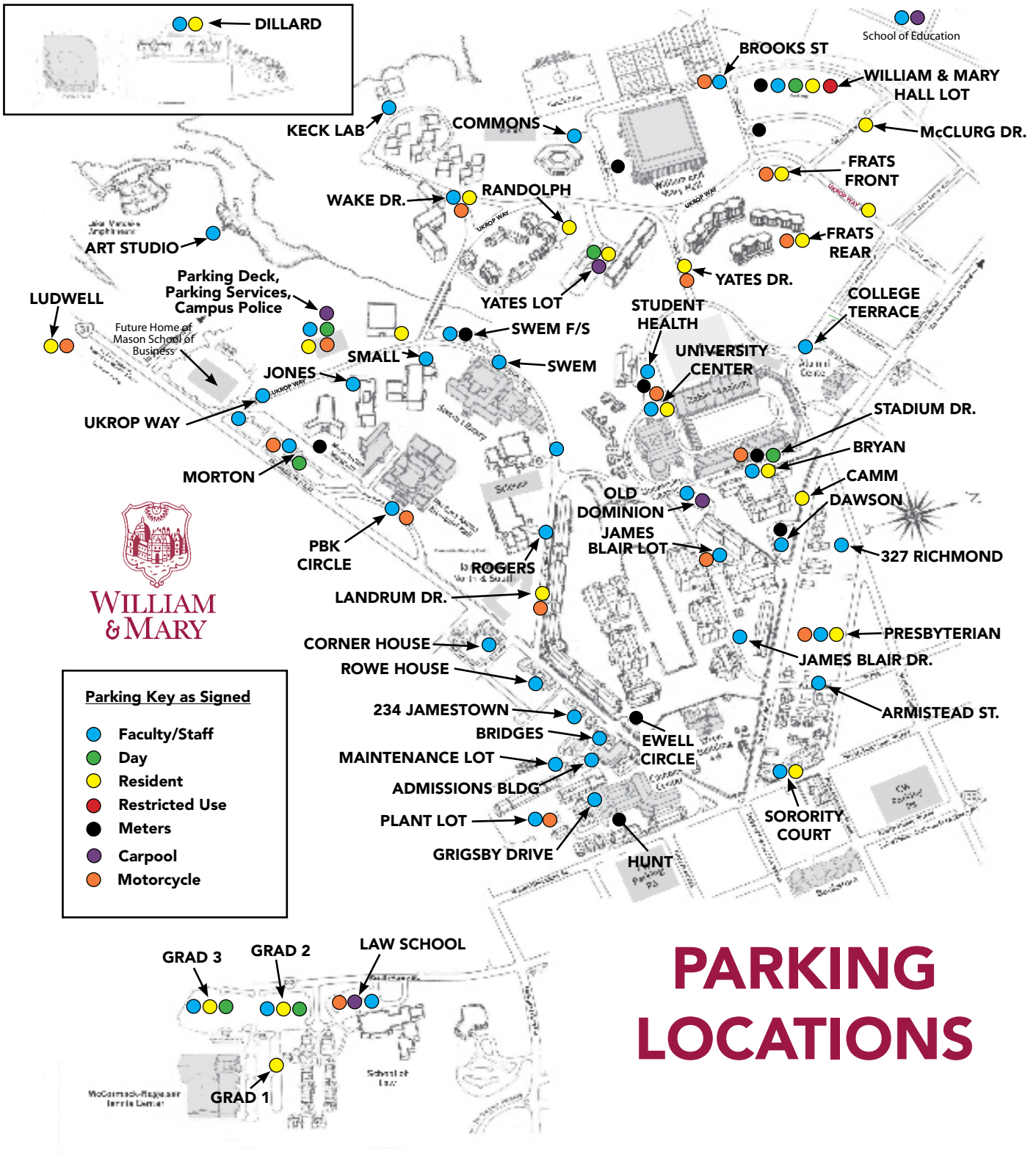
12.

Data Analysis of Car Accidents

Michael Ranasinghe
George Washington University
Adviser: Murli Gupta

Abstract: The National Highway Traffic Safety Administration has documented the various types of car crashes and their times of occurrences (i.e. drunk driving, bad weather, alcohol, etc.) in the United States. This data is vital in order to create effective measures to prevent future incidents of car crashes as well as formulate cost effective insurance plans for such companies. After careful inspection of the data, we can create a probability analysis to predict the maximum probability of a certain consequence resulting from a car accident. Given that an accident had occurred, we intend to use Bayesian statistics to create these formulas that assess the maximum probability of acquiring a certain effect (death, incapacitating injury, capacitating injury, possible, no injury). We find these probabilities of risk by using optimization techniques from Maple 17, graphically interpreting these results in three-dimensional cross sections.

Name	Institute	Title
Ping Ma	University of Georgia	Faculty
Maria Emelianenko	George Mason University	Faculty
Ratna Khatri	George Mason University	Graduate student
Zhusong Mei	George Mason University	Undergraduate student
Igor Grieve	George Mason University	Undergraduate student
Lucas Bouck	George Mason University	Undergraduate student
Maria Gualdani	George Washington University	Faculty
Yongwu Rong	George Washington University	Faculty
Eric Wen	George Washington University	Undergraduate student
Michael Ranasinghe	George Washington University	Undergraduate student
Shigeng Sun	George Washington University	Undergraduate student
Jing Zhang	Virginia State University	Faculty
Yongjin Lu	Virginia State University	Faculty
Joel Goddot	Virginia State University.	Undergraduate student
Chi-Kwong Li	College of William and Mary	Faculty
Gexin Yu	College of William and Mary	Faculty
Guannan Wang	College of William and Mary	Faculty
John Delos	College of William and Mary	Faculty
Junping Shi	College of William and Mary	Faculty
Sarah Day	College of William and Mary	Faculty
Larry Leemis	College of William and Mary	Faculty
Mainak Patel	College of William and Mary	Faculty
Anh Ninh	College of William and Mary	Faculty
Ross Iaci	College of William and Mary	Faculty
Abid Rizvi	College of William and Mary	Undergraduate student
Christopher Hambric	College of William and Mary	Undergraduate student
Evan Dienstman	College of William and Mary	Undergraduate student
Haoge Chang	College of William and Mary	Undergraduate student
Margaret Swift	College of William and Mary	Undergraduate student
Mark Agrios	College of William and Mary	Undergraduate student
William Lawrence	College of William and Mary	Undergraduate student
Yi Zhang	College of William and Mary	Undergraduate student
Yuan Cheng	College of William and Mary	Undergraduate student
Xin Zou	College of William and Mary	Undergraduate student
Xiang Liu	College of William and Mary	Undergraduate student
Oliver Stein	College of William and Mary	Undergraduate student
Joel Monroe	College of William and Mary	Undergraduate student



PARKING LOCATIONS

Google Maps Shields Tavern