Mathematics Conference and Competition of Northern New York 2022 (MCCNNY 2022)

March 26, 2022
Clarkson University

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Thanks to Pi Mu Epsilon and Princeton University Press for providing students prizes!

Presentation Title and Abstract

Keynote Presentation, Snell B10L

Title: ***Some Thoughts on the Current State of the Mathematical Sciences and STEM Education***
Presenter: **Dr. Katie Kavanagh, Professor and Director of STEM Institute, Clarkson University**
Time: 9:10AM—9:55AM

Abstract: In 2013, The National Research Council published a study by The National Academies called The Mathematical Sciences in 2025. Mathematics was described as a discipline with excellent vitality, making significant contributions to medicine, national defense, and business. However, a number of challenges facing higher education were further outlined. Similar challenges were described in both President Obama's and Trump's strategic plans for STEM Education (2011 and 2018). Much has happened in the last decade. How are we, as a scientific community, measuring up to the challenges and expectations laid out? What can we do locally to meet the changing needs of the workforce so that our students are prepared? In this talk we will discuss some small steps and hopefully generate discussions about strengthening our efforts to excellence in STEM Education.

Keynote Presentation, Snell B10L

Title: ***The Standard Double Bubble Minimizes***
Presenter: **Dr. Joel Foisy, Professor and Formal Chair of Department of Mathematics, SUNY Potsdam**
Time: 1:00PM—1:45PM

Abstract: It's been well known for a long time that the circle is the least perimeter way to enclose one area in the plane. In this talk, we will discuss the perimeter minimizing way to enclose and separate two fixed areas in the plane (proven by an REU group the speaker was part of), as well as a bit about how this result was generalized to 3 dimensions by Hutchings, Morgan, Ritor'e and Ross. We will use the structure of soap bubbles to guide our intuition.

Poster Presentations, 12:20PM—1:00PM, Outside of Snell B10L

Presenter: **Jonathan Shelton,** Undergraduate Student, Department of Chemical Engineering, Clarkson University

Author: Jonathan Shelton, Christian Kubicka, and Mohammad Meysami

Advisor: Dr. Mohammad Meysami

Title: ***A Study of Ransomware Attacks Prediction Using a KNN Algorithm***

Abstract: Since the advent of the internet as a source of record storage, there has been a risk of having files compromised or held for ransom by malicious entities. As the internet has increased its scope of use and the number of entities becoming reliant upon it, the number of cyber-attacks has increased to match the number of new targets. One of the most threatening types of cyber attack in recent history is ransomware. Ransomware is any malicious software that enters an entity's digital records or files, rendering the owner incapable of accessing these documents. This is generally to hold the entity that owns these records to pay a ransom to restore access to these files. Data from the Office for Civil Rights showed that hackers stole the personal information of nearly 1.6 million people only in 2020. In this study, a supervised machine learning algorithm, K-Nearest Neighbor (KNN), algorithm is used to analyze a dataset of companies that have suffered a ransomware attack. The analysis focused on developing a model that could predict the recovery times that companies experience after a ransomware attack. In this case, recovery is defined as either having their files restored to them or the resolution of legal cases resulting from the attack. The KNN model is based on several different variables that could potentially predict a company's general recovery time. We analyze the variables that are more closely correlated to the model and investigate the strengths and weaknesses of the KNN model for predicting the recovery time.

Presenter: **A M Mahmud Chowdhury**, Graduate Student, Department of Electrical and Computer Engineering, Clarkson University

Author: A M Mahmud Chowdhury; Masudul Haider Imtiaz

Advisor: Dr. Masudul Haider Imtiaz

Title: ***Computational Intelligence for Solving the Biometric Issue***

Abstract: Image restoration aims to compensate for the defects that degrade an image. Image degradation comes in many forms such as motion blur, noise, and camera misfocus. Blind image restoration usually relies on image priors, such as image geometry or reference point to restore the realness of the images. This work aims for noise elimination and restoration of the principal line of palm images and to enhance the palm wrinkles for better visualization with the help of Generative Facial Prior (GFP)-GAN. This GAN can generate high fidelity images with high variability, providing rich and diverse priors. GFP can be incorporated with the palm restoration process where super-resolution, denoising, deblurring, and compression removal are included. We have generated hundreds of palm images where the output shows the generated palm images are more reliable and have better fidelity. We believe that this method will overcome the challenges of various issues in the biometric field.

Oral Presentations

Session 1: 10AM—11AM, Snell B10L

Chair and Judge: Dr. Tino Tamon, Judge: Dr. Jim Greene

Presenter: Tristan Ball, Graduate Student, Department of Mechanical & Aerospace Engineering, Clarkson University
Advisor: Dr. Brian Helenbrook

***Title:* Fourier Analysis of a Moving Shock Discontinuity**

Abstract: The Fourier analysis technique has been successfully implemented by other groups to analyze the stability of various numerical schemes including discontinuous finite element methods. Moving forward, it is desirable to understand the stability of problems which include a moving shock wave discontinuity and a shock-aligned mesh. Here, we demonstrate the Fourier technique on the 1D and 2D linear advection equations followed by the 1D and 2D compressible Euler equations. Then we introduce a moving discontinuity using the Rankine-Hugoniot shock jump conditions into the 2D Euler discretization and analyze the stability of the new scheme. The oscillation rates of the shock disturbance are determined from the eigenvalues of the Fourier system and are compared to values measured from a discontinuous Galerkin finite element code with matching initial and boundary conditions for verification.

Presenter: Vijay Kumar, Graduate Student, Department of Mathematics, Clarkson University
Advisor: Dr. Sumona Mondal

***Title:* Differential Impact of COVID-19 Risk Factors on Ethnicities in the United States**

Abstract: The coronavirus disease (COVID-19) has revealed existing health inequalities in racial and ethnic minority groups in the US. This work investigates and quantifies the non-uniform effects of geographical location and other known risk factors on various ethnic groups during the COVID-19 pandemic at a national level. To quantify the geographical impact on various ethnic groups, we grouped all the states of the US. into four different regions (Northeast, Midwest, South, and West) and considered Non-Hispanic White (NHW), Non-Hispanic Black (NHB), Hispanic, Non-Hispanic Asian (NHA) as ethnic groups of our interest. Our analysis showed that infection and mortality among NHB and Hispanics are considerably higher than NHW. In particular, the COVID-19 infection rate in the Hispanic community was significantly higher than their population share, a phenomenon we observed across all regions in the US but is most prominent in the West. To gauge the differential impact of comorbidities on different ethnicities, we performed cross-sectional regression analyses of statewide data for COVID-19 infection and mortality for each ethnic group using advanced age, poverty, obesity, hypertension, cardiovascular disease, and diabetes as risk factors. After removing the risk factors causing multicollinearity, poverty emerged as one of the independent risk factors in explaining mortality rates in NHW, NHB, and Hispanic communities. Moreover, for NHW and NHB groups, we found that obesity encapsulated the effect of several other comorbidities such as advanced age, hypertension, and cardiovascular disease. At the same time, advanced age was the most robust predictor of mortality in the Hispanic group. Our study quantifies the unique impact of various risk factors on different ethnic groups, explaining the ethnicity-specific differences observed in the COVID-19 pandemic. The findings could provide insight into focused public health strategies and interventions.

Presenter and Author Kyle Monette, Graduate Student, Department of Mathematics, Clarkson University

Title: The Double Pendulum: An Introduction to Chaos and Lagrangian Mechanics

Abstract: The “double pendulum,” two pendulums coupled together from one anchor point, is a canonical example of an ordinary differential equation (ODE) system that undergoes “chaos.” It is famous for its nonlinear, bounded, and chaotic orbit. In this talk we will briefly go through the derivation of the nonlinear system of ODEs by using the Langrangian and Euler-Lagrange equations, and then we will explain the connection to the Hamiltonian system via the Legendre transformation. Simulations of the Langrangian

system created in MATLAB will be presented to illustrate how small perturbations in the initial conditions can lead to vast differences in trajectories. Such a dependence on initial conditions is a necessary characteristic of chaotic orbits. Lastly, we will use Lyapunov exponents and asymptotic periodicity to show that the double pendulum is a chaotic system.

Presenter: **Thevasha Sathiyakumar,** Graduate Student, Department of Mathematics, Clarkson University

Advisor: Dr. Sumona Mondal, Dr. Marko Budišić

Author: Thevasha Sathiyakumar, Marko Budišić, Sumona Mondal, Shantanu Sur

Title: ***Statistical inference on time-varying persistence landscape surface for analyzing coherent behavior of cancerous cells***

Abstract: We explore the collective motion in cancer cells in order to distinguish whether cells move coherently (form a consistent pattern) or randomly and estimate when a critical transition from random to coherent happens. We combine persistent homology with hypothesis testing to detect a statistically-significant change in the topology of a moving point cloud. To quantitatively investigate the transition of global topological features over time, we use the persistent homology based on density estimation. Then statistical inference is drawn by conducting a permutation test on time-varying average persistent landscape surfaces with the assumption that a critical topological transition results in a significant difference in one-dimensional topological features. We first apply the approach to a synthetic set of particles generated from the modified D'Orsogna model, which demonstrates how the technique performs on specific topologies of disorganized and coherent motion. Then, we will use the technique to identify whether and when a population of motile cervical cancer cells undergoes a transition from disorganized to coherent motion in vitro.

Session 2: 10AM—11AM, Snell B10M

Chair and Judge: Dr. Mingcheng Cheng, Judge: Dr. Dan Look

Presenter: **William E Annan**, Graduate Student, Department of Mathematics, Clarkson University

Advisor: Dr. Diana White

Title: ***Modeling the homeostatic length of rod outer segment in zebrafish***

Abstract:

Retinal photoreceptor cells, rods and cones, in the eye convert light energy into electrical signals that stimulate sight. In humans, peripherally located rods are important for night vision, while centrally located cones are responsible for daytime/color vision. Rods consist of a rod outer segment (ROS), inner segment, cell body and synaptic terminal. The ROS, consisting of stacked, discrete membranous discs, undergoes a process of continuous renewal in which newly constructed discs are added at the base (growth) and oldest discs are shed from the tip. The ROS maintains a homeostatic length by balancing growth and shedding. How this balance is controlled is unknown. If ROS homeostatic length control is lost, for example by ROS shortening, the rods can degenerate leading to blindness. We develop a model of ROS homeostatic length control, supported by experiments using data from zebrafish where ROS renewal is controlled experimentally. An ODE describes the length of ROS over time according to constant growth and ROS length-dependent shortening. Here, equilibrium analysis helps us understand the balance between growth and shortening mechanisms in maintaining homeostatic length. Also, an advection-reaction PDE describes disk addition (through a boundary condition), translocation (via advection), and shedding (reaction) in populations of ROS.

Presenter: **Emmanuel Atindama**, Graduate Student, Department of Mathematics, Clarkson University

Author: Emmanuel Atindama, Prashant Athavale, Gunay Dougan

Advisor: Dr. Prashant Athavale

Title: ***Weighted Total Variation flow for Crystallographic Data Reconstruction***

Abstract: Polycrystalline materials consist of crystal grains with distinct grain orientations. Electron backscatter diffraction is used to record the grain orientation. This orientation data might contain noise as well as the missing regions. We propose to denoise the orientation data using weighted total variation flow. We regulate the amount of denoising using the weights to preserve grain boundaries. We then fill the missing region using the TV flow. This talk discusses the application of this reconstruction technique. We also discuss the comparison of the proposed method with other techniques using simulated orientation data.

Presenter: **Mackenzie Dalton**, Graduate Student, Department of Mathematics, Clarkson University

Advisor: Dr. Emmanuel Asante-Asamani

Title: ***The Response of Myosin to Membrane-Cortex Separation During Bleb Formation***

Author: Emmanuel Asante-Asamani, Mackenzie Dalton

Abstract: One important mechanism that a cell utilizes to move toward a chemo-attractant is blebbing. When the cell blebs, the region of the cell where the bleb occurs experiences a detachment of the membrane from the cortex followed by a breakdown of the old cortex (actin scar) and a formation of a new cortex underneath the protruded membrane. The mechanism by which the actin scar is degraded is not fully understood. Our analysis of microscopy images of blebbing Dictyostelium discoideum cells migrating under the compressive force of an agarose overlay shows that when the cortex of the cell breaks down, an increase in Myosin II occurs in the actin scar prior to its complete degradation, suggesting a role for Myosin II in cortex degradation. The accumulation of Myosin II is however restricted to the local blebbing region further suggesting a role of membrane detachment in the accumulation of Myosin II. In this work, we hypothesize that the accumulation of Myosin occurs in response to a loss in membrane signal and develop an ODE model of the signaling pathway to test this hypothesis. Our results indicate that a decrease in activated Myosin Heavy Chain Kinase (MHCKA) is sufficient to yield an accumulation of cortical Myosin. Furthermore, we provide a mechanism by which membrane detachment could lead to a reduction in activated MHCKA.

Presenter: **Alissa Whiteley**, Graduate Student, Department of Mathematics, Clarkson University

Author: Alissa Whiteley, Dr. Joseph Skufca

Advisor: Dr. Joseph Skufca

Title: ***Crime and the Community***

Abstract: There exists a long history of mathematical tools being applied to the problem of reducing crime. In 2020, the mathematical community called for mathematicians to boycott collaborations with police departments due to concerns that such work could lead to racially biased policing. We acknowledge that concern, but believe that math may still have a role in helping to establish and maintain community safety. We see two shortfalls in the historical approach to this problem: (1) police are viewed as external to the community, and (2) the only goal is reduced crime, without considering other impacts on the community.

As an alternative, we explore community policing, via modeling and simulation. Our intention is to identify strategies that improve overall community well-being. We model police as part of the community, which consists of the police, criminals, and at-risk members. Many modeling techniques are applicable (agent-based, ODEs, patch, PDEs, etc.). In this talk we focus on our ODE model that considers police resources spread across three key activities: community outreach, crime prevention, and crime-fighting. We examine the implications of this resource allocation problem. Fundamental to our approach is understanding that "crime reduction" cannot be the only goal. Other considerations (community trust, recidivism, loss of human capital, quality of life impacts due to fear, and many others) make this decision problem sufficiently complex that mathematical models will be essential to assisting policy-makers toward better solutions.

Session 3: 1:45PM—2:30PM, Snell B10L

Chair and Judge: Dr. Mohamad Meysami, Judge: Dr. Blair Madore

Presenter: **Sathsara Dias**, Graduate Student, Department of Mathematics, Clarkson University

Advisor: Dr. Marko Budišić

Author: Sathsara Dias, Brian Helenbrook, Pat Piperni, Marko Budišić

Title: ***Sliding-window Dynamic Mode Decomposition approach to tracking the onset of a buffet in a transonic airfoil***

Abstract: The transonic buffet is a type of oscillation of the aircraft wing that can harm the aircraft's wing; hence, it must be carefully considered when designing an aircraft. Using Koopman analysis and Dynamic mode decomposition (DMD), we were able to demonstrate how to track the onset of the shock-induced buffet during transonic flight. We analyzed the DMD eigenvalue spectrum of time-accurate Reynolds-Averaged Navier–Stokes simulations of an airfoil. To account for transient behavior, we applied DMD with a sliding time window to get an organized eigenvalue spectrum, and it helped track the onset of buffet with changing Angle-of-Attack of the airfoil. Furthermore, we tracked the dominant modes of each sliding time of each angle, and the stability of these dominant modes and spatial structures help detect pre-buffeting, buffeting, and post-buffeting regions.

Presenter: **Daniel T. Fuller,** Graduate Student, Department of Mathematics, Clarkson University

Advisor: Dr. Sumona Mondal, Dr. Shantanu Sur

Author: Daniel T. Fuller, Austin Marshal, Shantanu Sur

Title: ***Investigating the role of probability in bacterial identification with the 16S rRNA gene***

Abstract: Molecular sequencing methods have become mainstay procedures for the identification of bacteria. Such methods are especially efficient when using the targeted amplification of highly conserved genes such as the 16S ribosomal RNA gene (16S rDNA). While 16S rDNA analyses are relatively standard, the choice of sequencing technology, choice of identification methodology, and choice of variable region to sequence can greatly affect the results. Additionally, there are many additional choices to be made in the classification process that involve cleaning and denoising the resulting sequencing reads. Many of these decisions, it turns out, have consequences with probabilistic connotations for how the results of these analyses are interpreted. Recent rapid advances in both technology and compatible analytical methods in bioinformatics have the potential to overshadow the importance of understanding the underlying concepts at work in sequence-based identification. This presentation aims to quantify the uncertainty that various bacterial classification workflows have beneath the surface as well as provide real world examples from aerosol science about how a failure to properly incorporate probability and uncertainty into bioinformatics analysis can have impactful consequences.

Presenter: **Weichen Xie**, Graduate Student, Department of Mathematics, Clarkson University

Advisor: Dr. Christino Tamon

Title: ***Gaps in Spatial Search***

Abstract: Given a vertex in a connected graph, a spatial search occurs if the continuous-time quantum walk on a scaled adjacency matrix of the graph along with a rank-one perturbation induced by the vertex succeeds in mapping the principal eigenvector of the graph to the characteristic vector of the vertex. It is known that spatial search on complete graphs is a natural analogue of Grover search; but to fully characterize all the graphs where a spatial search occurs is still an open problem. In this talk, we will show that the spatial gap of the adjacency matrix plays an important role in the characterization.

Session 4: 1:45PM—2:30PM, Snell B10M

Chair and Judge: Dr. Emmanuel Asante-Asamani, Judge: Dr. Jim Greene

Presenter: Dawit Gebremichael, Undergraduate Student, Department of Mathematics, Clarkson University

Advisor: Dr. Sumona, Department of Mathematics, Dr. Shantanu Sur, Department of Biology, Dr. Prashant Athavale, Department of Mathematics, Clarkson University

Title:* *Ethnic Differences in COVID-19 infection and mortality rates during the second wave in the United States.

Abstract: The Novel Coronavirus pandemic (COVID-19) has claimed millions of lives around the world since the winter 2019. COVID-19 has affected everyone regardless of race, ethnicity, and social status. Nevertheless, disenfranchised racial minority groups in the US have been heavily impacted by the pandemic. Previous study results showed that the infection and mortality rates are disproportionately high among African Americans and Hispanic Americans, while it is relatively low among White Americans with respect to their population. On the other hand, the mortality rate for White Americans is higher than the respective population in the second wave. In this project, we want to quantify the unique impact of various risk factors on infection and mortality rates of four major ethnic groups which are Non-Hispanic White (NHW), Non-Hispanic Black (NHB), Non-Hispanic Asians (NHA), and Hispanics to explain the ethnicity-specific differences observed in the second COVID-19 pandemic. For clarity and simplification purposes, the States are grouped into four different regions namely Northeast, South, Midwest, and West given by the US Census Bureau. In finding the cause for the disproportionately high infection and mortality rates, seven risk factors which are age over 60, diabetes, poverty, blood pressure, existing cardiovascular disease (CVD), obesity, and education were taken into account. After eliminating variables with high multicollinearity, the results of the linear regression models show risk factors impacting the infection and mortality rates among Hispanic, NHW, and NHB groups differently. According to the analysis, diabetes, obesity, and CVD were the most significant factors for both infection and mortality rate in Hispanics, NHW, and NHB respectively. In this presentation, we will explain how we extract, visualize and examine the publicly available data as well as relevant statistical methods that led to my conclusion.

Key words: Infection rate, Mortality rate, Second pandemic wave, Risk factors, Ethnicity R2

Presenter: Eduardo Puerta, Undergraduate Student, Department of Mathematics, St. Lawrence University

Advisor: Dr. Daniel M. Look

Title:* *The Knot Determinant: A Linkage of Linear Algebra and Topology

Abstract: Knot theory is a sub-field of topology focusing on the classification and properties of mathematical knots. The study of knots has applications in statistical mechanics, molecular biology, and DNA unfolding. Intuitively, mathematical knots can be viewed as knotted strings where the ends are glued together to form a knotted loop. Much of knot theory revolves around distinguishing knots from each other. This talk will explore basic knot theory with the goal of motivating a concept known as the knot determinant, an invariant used to distinguish knots. Namely, we will discuss how methods in linear algebra simplified a problem in coloring knots, and how this insight helped build stronger classification tools. We will also explore how to calculate this determinant and interpret the value in the context of a given knot. Finally, we close by discussing future research on the relationships between the knot determinant and other properties of knots.

Presenter: Martin Veresko, Undergraduate Student, Department of Electrical & Computer Eng, Clarkson University

Advisor: Dr. Ming-Cheng Cheng

Author: Martin Veresko, Ming-Cheng Cheng

Title:* *An Effective Simulation Methodology of Quantum Nanostructures based on Model Order Reduction

Associated Colleges of the St. Lawrence Valley
SUNY Canton • Clarkson University • SUNY Potsdam • St. Lawrence University

Abstract: A quantum simulation methodology developed previously based on model order reduction is applied to a 2D nanostructure. The approach is derived from proper orthogonal decomposition that projects the nanostructure from its physical domain onto a function space represented by a finite set of POD modes. Numerical solution data of the wave function are collected from the Schrödinger equation to adapt the variation of the energy band induced by electric fields. The POD modes generated from the data are thus able to account for the variation of electric field. The efficacy and accuracy of this method is investigated.