5th Annual UH-LSU-Texas A&M Undergraduate Mathematics Research Conference (tentative)

March 26 – 27, 2022

Schedule

March 26, 2022, Saturday (Venue: 232 PGH)

09:00 am Electromagnetic Wave Scattering in Layered Media
Joel Keller, Jacob Carter (Advisor: Dr. Stephen Shipman), Louisiana State University

09:25 am Multistationarity in Biochemical Reaction Networks
Allison Dennis (Advisor: Dr. Anne Shiu), Texas A&M University

09:50 am Free Oscillations of Coupled Strings
Lillian Powell (Advisor: Dr. Stephen Shipman), Louisiana State University

10:15 am Computing in the Cloud with Fully Homomorphic Encryption
Tammy Lam (Advisor: Dr. William Ott), University of Houston

10:40 am **Break**

11:00 am *Plenary Talk:* Mathematical and computational methods in neuroscience imaging
Prof. Demetrio Labate, University of Houston

12:00 pm *Lunch Break* (Venue: TBA)

01:00 pm $GL(1|1)$ Graph Connections
Andrea Bourque (Advisor: Dr. Anton Zeitlin), Louisiana State University

01:25 pm Cuspidal Projections of Eisenstein Series
William Frendreiss (Advisor: Dr. Hui Xue), Texas A&M University

01:50 pm Fourier Analysis on Finite Fields
Matthew McCoy, Dylan Spedale (Advisor: Dr. Fan Yang), Louisiana State University

02:15 pm Methods for passive cloaking and solutions to related inverse problems
Damon Spencer (Advisor: Dr. Daniel Onofrei), University of Houston

02:40 pm **Break**

03:00 pm Laplacian Spectra and Graph Indexes for Lattices
Lillian Powell (Advisor: Dr. Rui Han), Louisiana State University

03:25 pm Uniform Acceleration Radiation and the Equivalence Principle
Timothy Bates (Advisor: Dr. Stephen Fulling), Texas A&M University

03:50 pm Opers On The Projective Line, Wronskian Relations, and The Bethe Ansatz
Ty Brinson (Advisor: Dr. Anton Zeitlin), Louisiana State University

04:15 pm Vibration of Drumhead: Sizes in the Music
Chelsey Fontenot (Advisor: Dr. Jiuyi Zhu), Louisiana State University

04:40 pm **Break**

05:00 pm A topological approach to mobile sensing in three dimensions
Caleb Barnett, Yaseen Syed (Advisor: Dr. William Ott), University of Houston

05:25 pm Clustering and Visualization of Double-stranded DNA Curves
Benjamin Thomas (Advisor: Prof. Shawn Walker), Louisiana State University

05:50 pm *Dinner* (Venue: TBA)

March 27, 2022, Sunday

09:00 am	Poster Session Setup (Venue: UH Honors College (inside MD Anderson library))
09:30 am	**Poster Session** (Venue: UH Honors College (inside MD Anderson library))
11:30 am	**Poster Session Breakdown**
12:00 nn	**Panel Discussion**
01:00 pm	*Lunch*

Abstracts

Plenary Talk

Mathematical and computational methods in neuroscience imaging

Prof. Demetrio Labate, University of Houston

Spectacular advances in the biomedical imaging field during the last decade, e.g. microscopy, optics, molecular techniques and genetics, have massively increased the availability of data and expanded the range of the possible. High-resolution fluorescent microscopy and high-throughput technologies for instance, enable the accurate and efficient visualization of neurons, glia and their subcellular compartments both in vitro and in vivo. Despite these impressive technological advances though, there is still a critical need to develop more powerful conceptual and computational methods to extract meaningful quantitative information and provide reliable interpretation of the data. In this talk, I will illustrate state-of-the art methods for the analysis and interpretation of neuroimaging data including advanced multiscale representations and emerging learning-based algorithms targeted to problems from neuroscience. The research presented in this talk includes contributions from several graduate and undergraduate students who have worked under my direction at the University of Houston during the past 10 years.

Oral and Poster Presentations

Electromagnetic Wave Scattering in Layered Media

Joel Keller, Jacob Carter (Advisor: Dr. Stephen Shipman), Louisiana State University

The goal of this project is to create a dynamic online application that simulates electromagnetic (EM) fields for any number of layers with varied electric and magnetic tensor properties. This application allows scientists to explore phenomena of scattering, guided modes, and resonance in EM layered media and serves as a pedagogical tool for students and professionals to educate themselves on EM in layered media.

Multistationarity in Biochemical Reaction Networks

Allison Dennis (Advisor: Dr. Anne Shiu), Texas A&M University

Multistationarity, defined as the existence of positive equilibria is significant in the research of many cellular processes. It is significant in crucial cell behaviors, ranging from differentiation, generating oscillatory responses, and remembering transitory stimuli. I hope to answer the research question regarding the number and conditions of the set of rate constants that give multiple positive equilibria for any chemical reaction network. I analyze three different, specific examples of smaller reaction networks and investigate the unique conditions regarding the potential existence and number of equilibria for each network. I address the issue of determining both the parameters in which a reaction network displays multistationarity and the number of positive steady-states for the reaction network. I implement my approach by studying the System of Ordinary Differential Equations that model the steady-state equations of a reaction network. I also investigate the

roots of the steady-state equations using the Descartes' Rule of Signs to determine the number of positive roots. I apply the discriminant to determine the parameters of the reaction rate constants of the network that give multiple positive roots. By doing so, studying these positive roots of the steady-state equations allows me to understand the conditions of multiple positive equilibria for a reaction network, which is a widely researched problem in mathematical biology. Finally, I take a look at my three unique network examples to determine if each condition, or theorem, I found that characterized multiple positive equilibria for the specific network is path-connected.

Free Oscillations of Coupled Strings
Lillian Powell (Advisor: Dr. Stephen Shipman), Louisiana State University

Schrödinger operators come from quantum mechanics and have constituted a large part of the mathematical study of spectral theory for almost a hundred years. The Schrödinger operator is We will investigate some problems concerning Schrödinger operators on graphs that repeat periodically in space. Particularly, we are interested in the spectrum and eigenfunctions, so we can find a vast generalization of eigenvalues and eigenvectors for matrices.

Computing in the Cloud with Fully Homomorphic Encryption
Tammy Lam (Advisor: Dr. William Ott), University of Houston

Conventional methods of preserving privacy and security lack mechanisms to perform encrypted operations. Statistical and machine learning over encrypted data has major implications for cloud security and privacy. Industries requiring high degrees of privacy, such as healthcare providers, lack the ability to communicate their gathered data with research institutions and pharmaceutical manufacturers. Fully homomorphic encryption could bridge the communication gap, providing completely private modeling and analysis. Additionally, standardization agencies are searching for post-quantum encryption methods. Most research solutions employ lattice-based encryption, which are also fully homomorphic by nature. However, these emerging methods lack a developed suite of functions required for machine learning and other analytics. In this work, we implement an encrypted pipeline capable of evaluating a logistic regression model in the cloud.

$GL(1|1)$ **Graph Connections**
Andrea Bourque (Advisor: Dr. Anton Zeitlin), Louisiana State University

Supermathematics deals with the formalism of supersymmetry in physics. Our project aims to describe combinatorial models for structures that may be of interest in supersymmetric physics. The talk will explain the basics of supermathematics, and the poster will explain the key aspects of the work towards our project.

Cuspidal Projections of Eisenstein Series
William Frendreiss (Advisor: Dr. Hui Xue), Texas A&M University

We show that the projection of a product of two or three Eisenstein series of level one onto the cuspidal subspace is not a Hecke eigenform unless the dimension of the cuspidal subspace is one.

Fourier Analysis on Finite Fields
Matthew McCoy (Advisor: Dr. Fan Yang), Louisiana State University

Finite fields are at the border of Fourier analysis, number theory, combinatorics, and algebraic geometry. They have served as a perfect test-bed for conjectures and techniques in Euclidean space. We present the background of finite field, additive and multiplicative characters, Fourier transforms, and Gauss sums. We will also show how the Fourier multiplier of the spherical average operator can be reduced to a sum of Gauss sums. Understanding Gauss sums will help us to prove an ℓ^p improving estimates for the spherical averages.

Methods for passive cloaking and solutions to related inverse problems
Damon Spencer (Advisor: Dr. Daniel Onofrei), University of Houston

Cloaking attempts to mask vibrations in the direction of measurement. Cloaking has applications to ma-

terials, acoustics, electromagnetics, and chemistry. This work builds off of previous results from the 2020 TX-LA Undergraduate mathematics conference and a paper by Neil et al. An analytical method for solutions to 1D passive backscattered and full cloaking problems based on matrix inversion is discussed, along with methods for cloaking at frequencies with high condition numbers based off of Tikhonov regularization. We also explain why regularization is unlikely to be needed outside of a certain frequency band. Simulations supporting this claim are provided. In addition, computational results for related inverse problem solutions are provided, along with a demonstration that full cloaking with the dirac delta function initial condition is not feasible.

Laplacian Spectra and Graph Indexes for Lattices
Lillian Powell (Advisor: Dr. Rui Han), Louisiana State University

We study the Laplacian spectra of periodic lattices with pseudo-periodic boundary conditions. Our main result reduces the study of operators with large periods to that of unit periods. As applications of our main result, we compute several important graph indexes, including the number of spanning trees and the graph energies, for lattices including the bilayer graphene lattices.

Uniform Acceleration Radiation and the Equivalence Principle
Timothy Bates (Advisor: Dr. Stephen Fulling), Texas A&M University

We consider several definitions of radiation, and apply them to the situation of a uniformly accelerating source in a massless scalar field. We compute radiation via the Poynting vector flux of a scalar field with respect to an observer's proper timelike Killing vector. We address the equivalence principle paradox. We also demonstrate the vanishing of the divergence of the stress tensor on the past horizon, and explore consequences regarding the flow of energy.

Opers On The Projective Line, Wronskian Relations, and The Bethe Ansatz
Ty Brinson (Advisor: Dr. Anton Zeitlin), Louisiana State University

We focus on a correspondence between a certain class of connections on the projective line known as nondegenerate Z-twisted Miura opers and the solutions of the Bethe Ansatz equations for the Gaudin Model. To show this correspondence, we introduce what we call the differential version of the QQ-system. In my talk, I would like to explain what the QQ-system is and how we use it, as well as the background concepts needed to grasp the core concepts of the paper. More information about this topic can be found at our paper here: https://arxiv.org/abs/2112.02711

Vibration of Drumhead: Sizes in the Music
Chelsey Fontenot (Advisor: Dr. Jiuyi Zhu), Louisiana State University

This project involved diving deeper into the Chladni Pattern to modal the nodal lines of a vibrating metal plate. To narrow our focus down, we specifically researched the questions: How many nodal lines or curves are created and how many nodal curves or lines intersect the boundary? We modeled the vibration of a circular drumhead with eigenvalues problems and observed how the eigenvalues approached infinity. We worked to show the conjecture by Fields Medalist Shing-Tung Yau is sharp, which helped us understand the sharp upper bounds of the zero-level sets in the ball. Our research helps to understand how vibration on a drumhead can be modeled and what this model tells us about the music we hear from the drumhead.

A topological approach to mobile sensing in three dimensions
Caleb Barnett, Yaseen Syed (Advisor: Dr. William Ott), University of Houston

Suppose we want to monitor a domain with a network of minimal mobile sensors. By minimal, we mean that the sensors have only local sensing capabilities and have no knowledge of their absolute positions in space. Using ideas from topology, we explain how to use only local sensing data to determine whether it is possible for an intruder to evade detection. Our project builds upon recent work in two dimensions.

Clustering and Visualization of Double-stranded DNA Curves
Benjamin Thomas (Advisor: Prof. Shawn Walker), Louisiana State University

Bacteriophages are capable of packing double-stranded DNA into a protein capsid at extreme pressures. The packing process can be modeled through the energy minimization of a space curve with a given thickness. After the DNA reaches a final "packed" state, it is believed that certain configurations of the DNA will be more prevalent to account for these high pressures. To determine if these preferred configurations exist, clustering algorithms are tested on datasets comprised of many simulations with varying initial conditions. The clustering algorithms we use have the added benefit of dimensionality reduction, where the original dimension of the data is projected down to 2. The projection to 2-dimensional space gives us quantitative as well as qualitative results by allowing one to see the separation of these clusters.

Poster Presentation only

On Interdimensional Communication and novel cloaking and teleportation strategies
Kalyan Mihut (Advisor: Dr. Daniel Onofrei), Clements High School