Thursday, November 30, 2017
4:00–5:00 p.m.
SAS 2102

Undergraduate Research Presentations

*Low Rank Randomized Standard Value Decomposition*
Bryan Chu

*Numerical Methods for Fractional-Order Calculus Operators*
Graham Pash

*Modeling the Collective Dynamics of Host Cell Defense Against Virus Infection*
Hayley Russel

*Detecting Dense Structure in Networks with Spectral Analysis*
Jean-Claude Shore

NCSU Society for Undergraduate Mathematics

**SUM Series**
Mathematics and pizza!
**Low Rank Randomized Standard Value Decomposition**

Bryan Chu

The low rank randomized standard value decomposition is a fast, stable method of computing the dominant singular values of a real, large matrix $A$. For a large scale system we use a randomized matrix method, a so called, randomized SVD (rSVD). We improve the existing rSVD method to obtain an optimal low rank approximation of $A$. This is a fast way of finding the principal components of a matrix in order to solve linear systems, i.e. $Ax=b$. We evaluate a low rank singular value decomposition of $A$ which captures the essential component of a large scale matrix $A$, providing a reduced approach to linear problems. There are many applications of a low rank rSVD, the most common is solving a linear system $Ax=b$. In practice, the data, $b$, is given, and the goal would be to construct the unknown, $x$, by a linear system $A$, like a tomography problem or inverse scattering problem. We examine the example of Tomography by the radon transform. (Faculty mentor: Dr. K.Ito)

**Numerical Methods for Fractional-Order Calculus Operators**

Graham Pash

Fractional-order calculus deals with integrals and derivatives of arbitrary ? i.e., non-integer ? order, and has several useful applications due to its “time history” properties. In this presentation, we will discuss some of the history and various definitions of fractional-order operators and, importantly, numerical methods for evaluating these operators. We will illustrate the various results in the literature, as well as new methods, in the context of a linear viscoelastic model. (Faculty Mentor: Dr. R. Smith)
Modeling the Collective Dynamics of Host Cell Defense Against Virus Infection

Hayley Russel

The success of a virus infection depends on its ability to evade the immune system at both the intracellular and intercellular level. The first line of defense of the immune system is the innate immune response, primarily driven by the interferon (IFN) response. In infected cells, cell pathogen recognition receptors can detect viral genomes, which lead to the transcription of interferon genes and subsequent production of interferon. Interferon works as signaling molecules, diffusing rapidly into the surrounding area, to induce antiviral gene expression in neighboring cells and thus rendering them refractory to viral infection. Although the molecular mechanisms of the interferon response have been under intensive study, the underlying principles of cell-to-cell communication through IFN and how the cell population collectively responds to viral invasion as a whole are not well understood. Here, we implemented an agent-based cellular automata model to describe the production, packaging, and spread of virus particles in addition to the activation of IFN production and cell-to-cell communication through IFN signaling on a lattice. Our model represents a monolayer of host cells that can be used to observe the spatial-temporal patterns of infection and complex behaviors of interferon regulation. The wave speed of infection, viral load, and percentage of infections suppressed by IFN was measured to determine the threshold of successful infection events. With this, we gain a quantitative understanding of virus-innate immune interaction and the emerging principles underlying the collective behavior of host cells that is required to develop novel therapeutic approaches and mitigate disease symptoms. (Faculty mentor: Dr. R. Ke)

Detecting Dense Structure in Networks with Spectral Analysis

Jean-Claude Shore

In today’s Big Data era, there is a great need for efficient ways to analyze enormous datasets. This analysis can require huge amounts of computational resources and time, which drives a need for faster and more efficient algorithms. Certain structural properties, if present in these datasets, enable the use of specialized algorithms that provide for more efficient data analysis. However, many structural properties of this variety are quite difficult to detect. In this project, we represent data as graphs and study when we can detect the presence or absence of dense regions using eigenvalue and eigenvector analysis. We show that, in certain cases, the eigenvalue distribution of a graph allows a yes/no answer to the question “Does this graph contain a dense pocket of nodes?” We find that once a graph is known to possess a dense substructure, certain eigenvectors can sometimes determine which nodes are present in the dense substructure. Exploring these questions requires the generation of thousands of different graphs with controlled structural properties, and so we implement several existing random graph generation algorithms. Our experiments show that for graphs that are too uniform, it is quite easy to detect these dense structures. We therefore design a new algorithm focused on hiding these sub-structures while still maintaining a high degree of random structure and show that graphs produced with this algorithm possess dense pockets that are entirely invisible to our detection tools. Future researchers can use these graphs to provide a meaningful baseline against detection tools. (Faculty mentor: Dr. K. Kloster and B. Sullivan)