SUnMaRC 2016: Student Talk Abstracts

Investigations into a family of superlinear boundary value problems WXLR 103
Jeffrey Covington – NAU Sat 9:00-9:20

It is conjectured that an infinite number of solutions exist to a certain family of superlinear boundary value problems. However, only three of these solutions are actually proven to exist. There is a numerical method for finding these three solutions, and this method can be modified to find more solutions. In the one-dimensional case, this modified method can find every solution. In higher dimensions, however, it fails to find some solutions. This requires deeper investigation into the method to find these solutions, which may suggest potential research directions for proving the existence of more solutions.

Multi-scale Simulations of Hurricane Sandy at Cloud-Resolving Resolution WXLR 118
Maher Achour – ASU Sat 9:00-9:20

Hurricane Sandy made a landfall in the United States following a rare trajectory that was nearly perpendicular to the US coast causing severe damages. This study uses coupled model simulations with resolution down to cloud-resolving scales to examine the impact of grid resolution on the forecasted track of Hurricane Sandy. The finest domain in these simulations uses 490X596X40 grid points with a resolution of 5.4km in the horizontal. The results of these simulations will be presented and compared with a focus on the ability of the high-resolution run to correctly predict the trajectory of Hurricane Sandy and the synoptic blocking conditions that caused its unusual track.

Newton's method for a semilinear elliptic PDE on the unit disk WXLR 103
Kevin Luna – NAU Sat 9:25-9:45

In this talk we will consider the semilinear elliptic PDE $\Delta u + su + u^3 = 0$, with zero Dirichlet boundary conditions on the unit disk $\Omega = \{(r, \theta) \in \mathbb{R}^2 : 0 \leq r < 1, 0 \leq \theta \leq 2\pi\}$, where s is a real parameter. A Newton-Galerkin method, the Gradient Newton Galerkin Algorithm (GNGA) of Neuberger and Swift will be derived and results from its application and augmentation with a continuation method to the PDE on the disk will be presented. The method relies on the variational characterization of classical solutions to the PDE as critical points of an action functional, and on Newton's method applied to the gradient of that functional. We will sketch the proof that critical points of an action functional are precisely classical solutions to the PDE. Eigenfunctions of the Laplacian eigenvalue problem on the unit disk $-\Delta\psi = \lambda\psi$ with zero Dirichlet boundary conditions will be used as basis functions to compute Fourier-Galerkin type approximations. We also present bifurcation diagrams using the parameter s, and solutions plots.

Numerical solutions of the barotropic non-divergent vorticity equation in the presence of tropical cyclones WXLR 118
Brandon Hoogstra – ASU Sat 9:25-9:45

Simulations of twin tropical cyclones using a recent numerical method within an idealized atmospheric model that solves the barotropic non-divergent vorticity equation in the beta plane were investigated. The model yields a two-dimensional physical interpretation of the development and the evolution of twin tropical cyclones. The research analyzes the effect of both the distance between the cyclones and the planetary vorticity upon the propagation of cyclones. The results demonstrate that as the distance between the cyclones decreases, the nonlinear interaction beween the cyclones supersedes the planetary vorticity.

Perfect numbers in the Eisenstein integers WXLR 103
Jordan Hunt – NAU Sat 10:10-10:30

Perfect numbers are positive integers equal to the sum of their proper positive integral divisors. Mathematicians from Euclid to Euler investigated these mysterious numbers. We present results on perfect numbers in the imaginary quadratic field of Eisenstein integers.

Computational Modeling of Murine GL261 Brain Tumors WXLR 118
Barrett Anderies – ASU Sat 10:10-10:30

Glioblastoma Multiforme (GBM) is an aggressive and deadly form of brain cancer with a median survival of approximately one year with treatment. Treatment is informed by MR and CT images acquired at diagnosis, however, treatment seldom results in a significant increase in longevity, partly due to the lack of precise information regarding tumor size and distribution. This lack of information arises from the physical limitations of MR and CT imaging coupled with the diffusive nature of glioblastoma tumors. The imaging information is most incomplete at the edge of the tumor where the density of GBM cells is too low to be resolved. We consider a model of tumor growth based on a proliferation-diffusion PDE to better predict tumor growth. We consider both stochastic and non-stochastic parameterizations of this model, and use an error minimization (based on the Jaccard distance) algorithm to find optimal parameter values. The model is optimized on data from an animal model of GBM (GL261 tumors in immunocompetent mice). Initial results show that our model adequately predicts tumor growth for short time periods, but struggles to capture some of the long term growth behavior of certain tumor cases.

Kummer surfaces from extremal rational elliptic surfaces WXLR 103
Elise Griffin – USU Sat 10:35-10:55

Elliptic surfaces are of central importance for many constructions and applications in algebraic geometry and mathematical physics. Rational elliptic surfaces and elliptically fibered Kummer surfaces are prominent subcategories. Different elliptic fibrations on a Kummer surface of two non-isogeneous elliptic curves can be obtained by carrying out quadratic twists and base transformations on extremal rational elliptic surfaces. We then use this technique to find different representations for the periods of the holomorphic two-form on the Kummer surface in terms of special functions.

Logistic patch models for transmission dynamics of ebola virus epidemics WXLR 118
Tin Phan – ASU Sat 10:35-10:55

Mathematical models are necessary tools to help forecast the recent Ebola epidemic that occurs in West Africa. Often researchers approach this problem using variation of the compartmental model SIR (Susceptible, Infected, Recovered); however, we use a class of logistic patch models, which are derived from the well-known logistic equation by incorporating various migration rates between patches that individually exhibit logistic growth. Each model is fit to multiple data sets to compare the reliability in forecasting via error estimation and parameter confidence intervals as functions of trained data points. The basic reproduction number is also estimated. We conclude that the patch models improve the short-term forecasting but produce erratic behavior in long term forecasting in comparison with the logistic model.

New prime vertex labelings WXLR 103
Hannah Prawzinsky – NAU Sat 1:30-1:50

A prime vertex labeling is an injective assignment of the labels $\{1, 2, \ldots, n\}$ to the vertices of an n-vertex simple connected graph such that adjacent vertices receive relatively prime labels. I will present new labelings for several infinite families of graphs. No prior knowledge of graph theory will be assumed.

Edge detection from spectral phase data WXLR 118
Alexander Reynolds – ASU Sat 1:30-1:50

Accurate feature detection in signals is necessary in wide-ranging applications from medical imaging to computer vision. Spectral data is often collected in such applications, where many methods are used to extract information about the signal. The *concentration factor* method uses a first order relationship between the Fourier coefficients and jumps of a signal to devise filters that generate approximations which concentrate at the singular support of the signal, resulting in a highly customizable edge detector. This method has recently been expanded upon to detect edges in a signal given noisy, intermittent, or non-uniform Fourier data. (par) Typical feature detection algorithms rely on both the magnitude and phase of the collected Fourier data. However, the spectral phase carries particularly useful information about the features of a signal. Thus, the development of an edge detector using only phase data will be beneficial in applications where the magnitude information is not able to be collected or is otherwise corrupted. Recent numerical results have shown that concentration factors can be designed for these situations. An analysis of the method will lend insight to the accuracy of the phase-only edge detector and its robustness to noisy, non-uniform, or intermittent data.

The range of random walks at the time of exit from a box WXLR 103
Thomas Doehrman – U of A Sat 1:55-2:15

We studied the range of symmetric random walks at the time of first exit from a region. Both a one dimensional strip with N sites, as well as a two dimensional N by N square region were considered.

Convolutional Neural Networks Applied to Diabetic Retinopathy Detection WXLR 118
Ramy Fahim, Erin Mills, and Trevor Reed – USC Sat 1:55-2:15

We present convolutional neural networks, which make up a class of powerful machine learning algorithms. We use them in an attempt to automate the detection of the diabetic retinopathy disease - a disease which normally requires manual detection by a trained clinician. The algorithm works by careful application of tools in multivariable calculus and linear algebra, and intuitively the model mimics the structure of neurons in the brain. To implement the algorithm, we used a package installed on top of Python that is optimized for the computations with which we worked; furthermore, we used computers equipped with GPUs so as to accelerate the computationally expensive matrix multiplications.

Opinion dynamics: how to enforce consensus WXLR 103
GuanLin Li – ASU Sat 3:45-4:05

We would like to study the dynamics of opinion formation and in particular the emergence of so-called consensus. In this work, we would like to go further and modify the dynamics such that connectivity will be preserved. We introduced a local control to guarantee that the dynamics will converge to a consensus, provided that the initial condition is connected. We completed 1D case, with global convergence proof and numerical simulations. We are still working on the multiple dimension case now.

A polymorphic variable binding extension of system-F WXLR 118
Zhanlin Shang – ASU Sat 3:45-4:05

Introducing a new variant of System-F byextendingthe HindleyMilner with polymorphic variable binding, named System-FL, L stands for LoLi, the Lisp dialect designed by myself that using System-FL as its core. That enables same term to be bound to different values that distinguished by the type of the value bound to it. This paper will just be a brief introduction to it, with some basic definitions and examples.

As random as it gets: survival analysis dimension reduction techniques WXLR 103
Ivan Rodriguez – U of A Sat 4:10-4:30

Although formal studies across many fields may yield copious data, it can often be collinear (redundant) in terms of explaining particular outcomes. Thus, dataset dimensionality reduction becomes imperative for facilitating the explanation of phenomena given abundant covariates (independent variables). Principal Component Analysis (PCA) and Partial Least Squares (PLS) are established methods used to obtain components eigenvalues of the given data's variance-covariance matrix such that the covariance and correlation is maximized between linear combinations of predictor and response variables. PCA employs orthogonal transformations of covariates to reduce dataset dimensionality by producing new uncorrelated variables. PLS, rather, projects both predictor and response variables into a new space to model their covariance structure. In addition to these standard procedures, three variants of Johnson-Lindenstrauss low-distortion Euclidean-space embeddings (random matrices, RM) were also investigated. Each technique's performance was explored by simulating 5,000 datasets using R statistical software. The semi-parametric Accelerated Failure Time (AFT) model was utilized to obtain predicted survivor curves. Then, total bias error (BE) and mean-squared error (MSE) between true and estimated survivor curves was determined to find the error distributions of all methods. The results herein indicate that PCA outperforms PLS, the RMs are comparable, and the RMs outdo both PCA and PLS.

Cheating in Reproduction: An Agent Based Model WXLR 118
Lauren Engel – ASU Sat 4:10-4:30

Harvester ant colonies typically have anywhere from one to five queens. A queen can control the ratio of female to male offspring she produces, field research indicating that this ratio is genetically hardwired and does not change over time. Further, a queen has an individual reproductive advantage if she has a small reproductive ratio.

A colony, on the other hand, has a reproductive advantage if it has queens with large ratios, as these queens produce many female workers to further colony success. We have developed an agent-based model to analyze the cheating phenotype observed in field research, in which queens extend their lifespans by producing disproportionately many male offspring. The model generates phenotypes and simulates years of reproductive cycles. The results allow us to examine the surviving phenotypes and determine conditions under which a cheating phenotype has an evolutionary advantage. Conditions generating a bimodal steady state solution would indicate a cheating phenotypes ability to invade a cooperative population.

Bounding the number of commutation classes of the longest element in the symmetric group WXLR 103
Dustin Story – NAU Sat 4:35-4:55

How many commutation classes does the longest element in the symmetric group have? We review the definitions and theory necessary to understand this open question. Furthermore we focus on one of the several representations of the problem, and how it has allowed us to find a new upper bound on the number of commutation classes.

Neural mapping using Gröbner bases WXLR 118
Ihmar Aldana – University of Guam Sat 4:35-4:55

A major area in neuroscience research is the study of how the brain processes spatial information. Many of these studies focus on the encoding properties of neurons and therefore assume that the structure of the stimulus space is known. However, the brain frequently encounters situations where the stimulus space is unknown, which begs the question, how does the brain learn the structure of the stimulus space?

In a recent paper by Carina Curto, Vladimir Itskov, Alan Veliz-Cuba, and Nora Youngs, they define a binary code to represent neural activity, and a polynomial ideal to contain all combinatorial data from that code. To extract the stimulus space structure, an algorithm is proposed to transform the ideal into readable generators called the canonical form.

One of our major contributions to the field is an implementation of the pseudocode outlined by Curto et al. We found that this implementation is less efficient than computing a Gröbner Basis. Consequently, we focus on developing interpretations of the Gröbner Basis and finding conditions under which it is equal to the canonical form. Our paper provides the foundation for further, extensive research about properties of the stimulus space from the intrinsic structure of a neural code alone.

A numerical investigation of intake geometry on the four stroke engine WXLR 103
Teo Brandt – UNM Sun 9:00-9:20

The internal combustion engine can be thought of as an air pump. In this sense the most efficient engine is the one that flows the maximum amount of air per cycle that it is geometrically and physically capable of flowing. This means by which a given engine may be improved without changing the geometry of the engine block and head is by improving the routing into an out of the cylinder head by re-designing the intake and exhaust ducting. This report will focus on the effect that altering the intake geometry has on engine performance measured in power output and efficiency. First, a description of the intake and its components will be provided along with the proposed alterations and a mathematical treatment of the implications that these proposed design changes pose to the expected performance of the engine. Next, a description of the numerical methods will be provided with a focus being on the software package Ricardo WAVE. Finally, a results and conclusions section will organize outcomes of this experiment and the possibility of using these results in an effort to engine design in the after-market setting for power and efficiency.

Exploring cominiscule elements in Coxeter groups of type affine C WXLR 118
Joni Hazelman and Ryan Wood – NAU Sun 9:00-9:20

Coxeter groups can be thought of as generalized reflections groups. In particular, a Coxeter group is generated by a set of elements of order two together with a set of braid relations. A cominiscule element is one in which every reduced expression in the generators avoids a particular braid relation. In this talk, we will discuss our current work in classifying and enumerating the cominiscule elements in Coxeter groups of types B and affine C. No familiarity with Coxeter groups will be assumed as we will introduce all of the necessary terminology.

Conditions on flocking for 3 zone-model WXLR 103
Christopher Stokes – ASU Sun 9:25-9:45

We study a model, which mimics the ideal behavior of a flock. The model is based on three rules: First that individuals align with their neighbors. Second, if two members of a flock are far away they will move closer to each other. Third, if two members are too close they will distance themselves in order to avoid collision. We investigate when this model will result in a “flock”, (meaning all members have the same velocity). We have discovered that with strong enough attraction combined with alignment flocking is guaranteed.

Unexpected internships for math majors WXLR 118
Nicholas Callahan – U of A Sun 9:25-9:45

Not all internship opportunities available to Mathematics students are immediately obvious. The study of mathematics lends itself to a variety of work in various STEM communities that students often are not aware of. I will present on some of the opportunities I have had in the past year solving big data problems in the geoscience community and developing distributed simulation systems for the defense contract industry.

Cycles in various nonlinear, age-structured population models WXLR 103
Felix Theobald – NAU Sun 10:15-10:35

We consider N-dimensional, age-structured models of the normally 1-dimensional Beverton-Holt, Ricker, and Pennycuick population models. Our particular interest is in the impossibility of certain p-cycles in models of corresponding dimension as well as the impossibility of certain q-cycles in p-dimensional models where q divides p.

A simplified version of Conway’s Sylver Coinage WXLR 118
Parker Monfort and Robert Voinescu – NAU Sun 10:15-10:35

Sylver Coinage is a game in which two players, A and B, alternately name positive integers that are not the sum of non-negative multiples of previously named integers. The person who names 1 is the loser! This seemingly innocent looking game is the subject of one of John Conway’s open problems with monetary rewards. One such open problem is: If player A names 16 to start, and both players play optimally thereafter, then who wins? In this talk, we will discuss a simplified version of the game in which a fixed positive integer n (greater than 2) is agreed upon in advance. Then A and B alternately name positive integers from the set $\{1, 2, \ldots, n\}$ that are not linear combinations with positive coefficients of previously named numbers. As in the original game, the person who is forced to name 1 is the loser. We will investigate who wins under optimal play for given values of n and determine the Nim-values for the simplified game under certain conditions.