Abstracts for 2017 SUnMaRC

Invited Faculty Talks

To Fight And Never Lose
Dr. Steve Wilson (Northern Arizona University) du Bois Ballroom, Fri 7:00–8:00PM

In this talk we will provide both weapons and armor that will make you invincible in all conflicts. Note that "all" in this context means "a number of well-chosen, purely non-violent".

Where Geometry and Topology Collide: The Unsolved (!) Inscribed Square Problem
Dr. Kathryn Bryant (Colorado College) Cline Library Auditorium, Sat 11:00–12:00PM

If you draw a curve on a piece of paper that begins and ends in the same place and doesn't cross itself, can you find a square whose vertices lie in the curve? As of February 2017 the answer to this question, known as the Inscribed Square Problem, remains unknown. In this talk I will give a history of the ISP and some related results, and then I will give a geometric proof of the slightly weaker Inscribed Rectangle Problem. We'll end by analyzing why the proof for inscribed rectangles fails for squares and we'll brainstorm ideas for how to correct this failure.

3D Shadows: Casting light on the fourth dimension
Dr. Henry Segerman (Oklahoma State University) Cline Library Auditorium, Sat 4:00–5:00PM

Our brains have evolved in a three-dimensional environment, and so we are very good at visualizing two- and three-dimensional objects. But what about four-dimensional objects? The best we can really do is to look at three-dimensional "shadows". Just as a shadow of a three-dimensional object squishes it into the two-dimensional plane, we can squish a four-dimensional shape into three-dimensional space, where we can then make a sculpture of it. If the four-dimensional object isn't too complicated and we choose a good way to squish it, then we can get a very good sense of what it is like. We will explore the sphere in four-dimensional space, the four-dimensional polytopes (which are the four-dimensional versions of the three-dimensional polyhedra), and various 3D printed sculptures, puzzles, and virtual reality experiences that have come from thinking about these things. I talk about these topics and much more in my new book, *Visualizing Mathematics with 3D Printing*.

Student Talks

Spacetime Modeling: The Geometry of 2D Minkowski Space
Etude O'Neel–Judy (NAU) Adel 162, Sat 9:00–9:20AM

One of the most significant mathematical discoveries of the 19th century was the existence of consistent geometries that were not that of Euclid. Chief among these, Hyperbolic geometry, has numerous applications to theoretical physics and relativity as it provides a model for flat spacetime. This project investigates a representation of the hyperbolic geometry of two-dimensional flat spacetime as a curved surface in 3-space. This representation can be used to provide an intuitive understanding of the structure of hyperbolic geometry and may itself have applications to physics.

The Navier-Stokes Equation
Hezekiah Grayer (ASU) Adel 164, Sat 9:00–9:20AM

This presentation is a brief background on Claude-Louis Navier and George Gabriel, and how their understanding of the physical world culminated in the independent creation of the Navier-Stokes equation. Furthermore, I will examine the physical implications, and limitations of the equation. The conclusion includes examples of current day applications of computational fluid dynamics in weather simulations.

Star reduction graphs for Coxeter groups of type A
Brittany Carr (NAU) Adel 162, Sat 9:25–9:45AM

Recall that the symmetric group S_n is generated by adjacent transpositions. Each permutation w in S_n can be expressed as a product of adjacent transpositions in multiple ways. If the number of transpositions in an expression for w is minimal, we say that the expression is reduced. If a permutation w has a reduced expression beginning (respectively, ended) with st (respectively, ts) such that s and t are a pair of non-commuting adjacent transpositions, then we say that w can be "star reduced" to the permutation give by the removal of the leading (respectively, trailing) s. This naturally leads to the construction of an edge-labeled directed graph, called the "star reduction graph" for S_n. The vertices are the permutations and there is a directed edge labeled by s from vertex w to vertex u if w can be star reduced to u by removing s from the beginning or ending of some reduced expression for w. In this talk, we will discuss our current findings concerning the overall structure of this graph, as well as a related graph, called the "expanded star reduction graph", for the symmetric group.

Parameter estimation for a predator-prey model in cloud physics
Rafael Orozco (U of A) Adel 164, Sat 9:25–9:45AM

I consider a predator-prey model used in cloud physics where the rain is the predator and the clouds are the prey. The model consists of two delay differential equations which I solve numerically by an Euler scheme. My goal is to compute the five parameters of the model based on data. I use a Bayesian approach to formulate the problem and a Monte Carlo method (the MCMC Hammer) to solve the problem numerically. I consider two different regimes of the model, one with oscillations, one with exponential decay. My preliminary results show that I can indeed compute the model parameters from data.

Star reduction graphs for Coxeter groups of type B
Nur Emalina Binti Bidari (NAU) Adel 162, Sat 9:50–10:10AM

A Coxeter group W can be thought of as a generalized reflection group, where the group is generated by a set of elements of order two (i.e., reflections) and there are rules for how the generators interact with each other. Every element w of a Coxeter group W can be written as an expression of the generators, and if the number of generators in an expression (including multiplicity) is minimal, we say that the expression is reduced. If $w \in W$ has a reduced expression beginning (respectively, ending) with st (respectively, ts) such that s and t are a pair of non-commuting generators, then we say that w can be "star reduced" to the element given by the removal of the leading (respectively, trailing) s. This naturally leads to the construction of an edge-labeled directed graph, called the "star reduction graph" for W. The vertices are the group elements and there is a directed edge labeled by s from vertex w to vertex u if w can be star reduced to u by removing s from the beginning or end of some reduced expression for w. We will discuss our current findings concerning the overall structure of this graph, as well as a related graph, called the "expanded star reduction graph", for Coxeter groups of type B.

Quantum Two-Party Communication in the Noisy-Storage Model
Dennis Badaczewski (ASU) Adel 164, Sat 9:50–10:10AM

Quantum cryptography seeks to mitigate the weakness in classical cryptographic systems that rely on one-way functions that are computationally difficult to invert. The use of quantum cryptography as a method for securely sharing secret keys (known as quantum key distribution, or QKD) has advanced to the point that implementable solutions exist for real-world problems. However, secure two-party communication- focused not on security from an eavesdropper but from the untrusted parties themselves-faces significant theoretical obstacles not found in classical cryptography. The purpose of this presentation is to explore these obstacles under the light of the bounded- and noisy-quantum-storage models, investigating the properties of bit commitment, oblivious transfer, and secure identification in the quantum field.

Hermitian Matrix Perturbations with Zero Spectral Shift Functions: The 2×2 Case
Sarka Blahnik (UNM) Adel 162, Sat 10:30–10:50AM

Spectral shift functions (SSFs) were born out of the work of physicist I.M. Lifshits on impurities of crystalline structures in the mid-1900s. Today they remain objects of active mathematical research. Given two $n \times n$ Hermitian matrices H and V, the first order SSF is a measure of the number of eigenvalues which increase past the real argument t when H is perturbed to $H + V$. Further insight into these changes can be gained via study of higher order SSFs. This presentation considers necessary and sufficient conditions on V for SSFs of various orders to be identically zero. After briefly discussing my resolution of the general $n \times n$ case for even orders, I will focus this talk on my exploration of the 2×2 case for identically zero odd order SSFs.

A Game of Chance Inspired by Othello
Alexandria Medeck (NAU) Adel 164, Sat 10:30–10:50AM

Inspired by the board game Othello, consider a one-player game of chance on a 4 by 8 board where the new twist on the game includes choosing your color disk, white or black, and the objective is to get four disks of the chosen color in a line. The more lines you complete, the more "money" you win. Consider a mathematical generalization, representing the game board by an r by c matrix, $r \leq c$. Each entry in the matrix is an independent Bernoulli random variable (*i.e.*, either 1 or 0 with probability p and $1 - p$ respectively). The result is a random matrix. Associated with each possible matrix outcome is a score based on the number of completed vertical and diagonal lines of r ones in the matrix. The research is focused on determining the probability distribution of the score as a function of r and c. Results will be presented concerning the probability distribution of the score.

The Mathematical Physics and the Technical Mechanics of Time Travel
Brandon Hoogstra (ASU) Adel 162, Sat 1:45–2:05PM

The project analyzes both the mathematical physics and the technical mechanics associated with the theory of relativity as it applies to temporal distortion. More specifically, the research addresses the influence of relativistic time dilation and gravitational time dilation upon a point mass within a theoretical model of interplanetary travel throughout the universe. The model provides an account of the influence of a black hole upon the passage of time, including such factors as mass, angular momentum, and electrical charge. Equations are provided for calculating the discrepancy in time between that experienced by a terrestrial observer and that experienced by the traveling point mass. Examples of the empirical observations of the effects of gravitational factors and time delay are discussed. The project proposes future research into such topics of relevance as the influence of gravitational waves upon time dilation, the utilization of wormholes for purposes of time travel, and the existence of tachyons within the universe.

Infinite Trees of Primitive Pythagorean Quadruples, Part I
Marcela Gutierrez (NAU) Adel 164, Sat 1:45–2:05PM

A primitive Pythagorean triple is a 3-tuple of natural numbers sharing no nontrivial common factors that satisfies the Pythagorean Theorem. Hall (1970) and Price (2008) found distinct perfect infinite ternary trees whose vertex sets are precisely all primitive Pythagorean triples. This talk will present progress towards the construction of an infinite tree whose vertex set consist of all primitive Pythagorean quadruples—i.e; 4-tuples (a, b, c, d) of natural numbers sharing no nontrivial common factors that satisfy $a^2 + b^2 + c^2 = d^2$.

Non-Standard Methods of Doing Volumes of Revolution
Alejandro Barrientos (ASU) Adel 162, Sat 2:10–2:30PM

I will examine how one or more functions could be rotated about varying horizontal lines on the y-axis for its volume, one or more functions can be rotated about another function acting like a moving axis. In another case, a function can be rotated about a slanted line for its volume so long as the function passes the slanted line's (meeting certain criteria) orthogonal line test. There varying methods can be expanded to look at volumes of revolutions from other viewpoints.

Infinite Trees of Primitive Pythagorean Quadruples, Part II
Courtney Schmitt (NAU) Adel 164, Sat 2:10–2:30PM

A primitive Pythagorean triple is a 3-tuple of natural numbers sharing no nontrivial common factors that satisfies the Pythagorean Theorem. Hall (1970) and Price (2008) found distinct perfect infinite ternary trees whose vertex sets are precisely all primitive Pythagorean triples. This talk will present progress towards the construction of an infinite tree whose vertex set consist of all primitive Pythagorean quadruples—i.e; 4-tuples (a, b, c, d) of natural numbers sharing no nontrivial common factors that satisfy $a^2 + b^2 + c^2 = d^2$.

Modeling Japanese Knotweed Spread with a Reaction-Diffusion Equation
Alyssa Lyn Fortier (U of A) Adel 162, Sat 2:35–2:55PM

Every year, invasive species cause irreversible damage to economies and ecosystems worldwide. Preventing the spread of such species is an important step toward reducing impact on native flora and fauna, along with preserving local economies. A noteworthy example is Japanese knotweed, Fallopia japonica, a perennial native to Eastern Asia. It was introduced to the United States in the 1870s as an ornamental plant and has since displaced native vegetation and clogged rivers. Since fragments from the main plant can generate new sprouts, transport of such fragments by river networks may play a key role in its spread. To better understand the impact of a river on the spread of Japanese knotweed, we applied the Crank-Nicolson time splitting method to a reaction-diffusion model and compared our results with field data to assess its accuracy.

Forecasting Electricity Demand

Paige Weisman (ASU) Adel 164, Sat 2:35–2:55PM

Since electricity cannot be economically stored, supply and demand must be kept in balance. There is an approximate 15 minute lead time between decision making and implementation for electricity supply of SRP. This is extremely important as different sources of electricity have different costs. Thus, forecasting electricity load is important for the designing and planning of power plants.

Semilinear Elliptic PDEs on a Variable Domain

Jeffrey Covington (NAU) Adel 162, Sat 3:20–3:40PM

Semilinear elliptic boundary value problems are an important class of nonlinear differential equations. The problem under consideration is $\Delta u + f(u) = 0$ with zero Dirichlet boundary conditions with various nonlinearities, f. We study families of solutions to these PDEs with respect to a parameter of the domain, such as on a "dumbbell" region with a variable width of the corridor. The structure of these families can be studied numerically through Galerkin methods, Newton's method, and bifurcation analysis. We also use various techniques specific to the case that f is "superlinear", where several solutions are proven to exist.

Mathematically Modeling Photoreceptor Interaction in Cone-Dense Zebrafish

Javier Urcuyo (ASU) Adel 164, Sat 3:20–3:40PM

In an attempt to impede photoreceptor degeneration in various rod and cone dystrophies, the interplay of rod, cone, and retinal pigment epithelium cells has been the focal point of numerous experiments and research studies. However, despite these countless investigations, a complete understanding has yet to be achieved. In this work, we examine the role of this retinal interplay in the progression of photoreceptor degeneration by mathematically modeling the zebrafish retina subject to a pde6 mutation, which causes degeneration in cone photoreceptors. We use bifurcation and stability analysis to trace the various paths to blindness. By doing so, we are able to understand the various progressions of the disease, showing each stage of degeneration. Although zebrafish are able to regenerate cells such as photoreceptors, we find that the mutation progresses similarly to as it would in humans. Ultimately, our results show that the nutrients, namely the energy uptake and consumption, are at the heart of further understanding photoreceptor death.

Obstacles, Boundaries, and Control in Flocking Behavior

Kevin Winseck & Edward Martinez (ASU) Adel 162, Sun 9:30–9:50AM

Flocking behavior observed in birds, fish and insects, can be modeled by a system of differential equations. This talk will focus on a model in which agents' behaviors are determined by equations describing alignment, attraction and repulsion. Of particular interest is the inclusion of several variable sets of boundary conditions. Furthermore, we will explore the effects of obstacles within the domain, specifically if these obstacles prevent emergence of a flock. The existence of flocking is quantified by examining the variance in velocity of all the agents, with a flock forming as variance in velocity approaches zero. Finally, we will discuss the implementation of a control factor and the effect this has on flocking.

Effects of Immigration Legislation on the Arizona Labor Market

Neil Gaynor (U of A) — Adel 164, Sun 9:30–9:50AM

I use the passing and implementation of Arizona Senate Bill 1070 (SB1070) in 2010 as a quasi-natural experiment to study the effects that immigration, particularly undocumented immigration, has on wages in the labor market in Arizona. Using individual-level data from 2009 and 2012 provided by the Census Bureau, I use a difference-in-differences regression design with New Mexico as a counterfactual to control for non-state specific effects such as recovery from the Great Recession during this time period. To accurately calculate effect size and confidence, a simultaneous estimation model is used to reduce selection bias in addition to a minor extension of a previous estimator of marginal effect in similar nonlinear models.

A Cubic Residue Version of Chapman's Evil Determinant Problem, Part 1

Pauline Gonzalez (NAU) — Adel 162, Sun 9:55–10:15AM

In 2001, R. Chapman conjectured that a special infinite class of matrices, constructed using quadratic residues symbols, had constant determinant values. This conjecture, known as Chapman's Evil Determinant Problem, was resolved in 2014. In this series of two talks, we will present a generalization—involving cubic residues—of Chapman's problem. Basic knowledge of number theory and linear algebra is helpful but not required.

Numerical and asymptotic methods for pattern-forming systems

Montie Avery (UNM) — Adel 164, Sun 9:55–10:15AM

Nonlinear evolution equations are central to the study of a variety of physical phenomena. Certain evolution equations, such as the Swift-Hohenberg equation, provide a model for the formation of coherent patterns in fluid convection experiments and biological systems. This talk will focus on both numerical simulations and perturbative approaches to analyze such equations with an overview of how the two approaches interact with and can inform one another. With time and circumstance permitting, the talk will also include results on a pattern forming system involved in the study of ion bombardment of binary surfaces.

A Cubic Residue Version of Chapman's Evil Determinant Problem, Part 2

Ryan Wood (NAU) — Adel 162, Sun 10:20–10:40AM

In 2001, R. Chapman conjectured that a special infinite class of matrices, constructed using quadratic residue symbols, had constant determinant values. This conjecture, known as Chapman's Evil Determinant Problem, was resolved in 2014. In this series of two talks, we will present a generalization—involving cubic residues—of Chapman's problem. Basic knowledge of number theory and linear algebra is helpful but not required.

The Expected Range of Terminating Random Walks

Thomas Doehrman (U of A) — Adel 164, Sun 10:20–10:40AM

We compute the expected range of a symmetric, nearest neighbor random walk on a lattice up to the time of first exit from a rectangular region of side length N. We found that the expected range is of order N in one dimension, and order $\frac{N^2}{ln(N)}$ in two dimensions. The constants associated with these limits are computed as a function of the starting point.