ABSTRACTS OF TALKS PRESENTED TO THE INDIANA SECTION OF THE MAA

1. Introduction

The Fall 2016 meeting of the Indiana Section of the Mathematical Association of America is at Purdue University West Lafayette, October 8. The abstracts appearing here are based on text electronically submitted by the presenters. Contributed talks are listed in alphabetical order by presenter.

2. Invited Talks

Presenter: Louis H. Kauffman, University of Illinois Chicago
Topology, Quaternions, and Octonions
This talk begins with the history of the discovery of the quaternions by Sir William Rowan Hamilton in 1843. The quaternions mark the discovery of the first non-trivial non-commutative mathematical system of significance. Matrix algebra had not yet been discovered when Hamilton found the quaternions. Hamilton desired to generalize the complex numbers and their interpretation in terms of rotations of the plane. He finally succeeded in 1843 and could summarize his result by saying that the quaternions were generated by elements $\{1, i, j, k\}$ with $i^2 = j^2 = k^2 = ijk = -1$. The quaternions are four dimensional and they do contain the desired information about composing rotations in three-space. In the same year, John Graves discovered an eight dimensional generalization, and two years later, Arthur Cayley rediscovered these octonions. We will discuss both the quaternions and the octonions and how they are related to geometry, topology, and physics.

Presenter: Ken Ono, Emory Univeristy
Gems of Ramanujan and their Lasting Impact on Mathematics
Ramanujan's work has had a truly transformative effect on modern mathematics, and continues to do so as we understand further lines from his letters and notebooks. In this lecture, some of the studies of Ramanujan that are most accessible to the general public will be presented, and how Ramanujan's findings fundamentally changed modern mathematics, and also influenced the lecturer's work, will be discussed. The speaker is an Associate Producer of the film *The Man Who Knew Infinity* (starring Dev Patel and Jeremy Irons) about Ramanujan. He will share several clips from the film in the lecture.

3. Indiana Project NExT Panel Discussion

Panelists:

- Alexandra Alvarado, Eastern Illinois University
- Rodrigo Bañuelos, Purdue University
- Zenephia Evans, Purdue University

Moderator: Zsuzsanna Szaniszlo, Valparaiso University

Retaining students from under-represented groups in STEM

Students traditionally underrepresented in STEM face special challenges in the higher education system. Many such students seem to give up on becoming STEM majors during the Calculus sequence. The traditionally high D, F, W rate in Calculus is even higher for these types of students. While faculty often struggle to provide the appropriate help to students with different backgrounds and preparations, we as a community fail many students. Students encounter a variety of challenges; for instance: first generation college students struggle to navigate the college system, minority students feel isolated in a math class of a majority institution, and women are turned off by competition and war-related vocabulary (for example "attacking a problem") used daily in mathematics classrooms. In addition, as educators we hear about students facing stereotype threats, and faculty committing unintentional micro aggressions. Mathematics as a discipline is also often described as being unwelcoming to most students. We asked our panelists to present ideas to turn these trends around, either in a particular classroom or at the department or institution level.

4. Graduate Student Workshop

Presenter: Amanda Harsy, Lewis University, IL

Being on the Market Part II: On-campus interviews

Are you ready for the job market? This workshop builds off the Spring 2016 INMAA workshop which gave advice about the early stages of an academic job search, and focuses on the next stage in the application process: on-campus interviews. During this workshop, we will cover the details of what a typical on-campus interview is like and how one can prepare for it. In particular, we will discuss how to tailor a research talk so it is accessible to undergraduates and prepare for a teaching demonstration.

5. Contributed Talks

Presenter: Surina Borjigin, University of Louisville, KY, graduate student

Color image segmentation using information theory and 2D histogram of the image

Image segmentation is an important and fundamental task in many digital image processing systems. Image segmentation by thresholding is the simplest technique and involves the basic assumption that objects and background in the digital image have distinct gray level distributions. In this talk, we present a general technique for multilevel thresholding of color images using a criterion function based on Charvat-Havrda-Tsallis (CHT) entropy. The optimal threshold values are found by random search using particle swarm optimization (PSO) technique. The effectiveness of the proposed method will be demonstrated by using examples from the real-world and synthetic images.

Presenter: Dennis G. Collins, University of Puerto Rico, Mayagüez (retired)

A conjectured hypercube invariant in generalized gravity

Generalized gravity tries to predict the most-likely extent to which objects will be pulled together. In an MAA talk at the Mathfest in Columbus, OH on August 5, 2016, it was illustrated how for unit Gaussian pulses a minimum Fisher information calculation leads to a maximum entropy pattern, which leads to the same-pattern gravitational potential, in a kind of 3-step dive. Here it is calculated the optimal spacing of 2.5 for Fisher1 (gradients) remains the same for dimensions $n = 1, 2, 3, 4$ hypercubes, and it is conjectured the values and pattern remain the same for $n > 4$. Some other configurations are considered.

Presenter: Lisa Driskell, Colorado Mesa University

Ebola and Snails: Modeling scenarios for the classroom

Modeling scenarios that take students through the process of analyzing and adjusting their models will be presented. These scenarios include using data from the World Health Organization to model the 2014 outbreak of the Ebola virus in West Africa as well as using collected water temperature data to model the temperature of snails in a simulated tide pool. These projects, which involve common separable differential equations, can be adapted for calculus or differential equations courses and were developed with support from SIMIODE: Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations.

Presenter: Paul Fonstad, Franklin College

Coding for elementary education majors with Code.org

Now that the Indiana DOE has created computer science standards which require block programming to be taught to grade $3 - 5$ students, it is critical that elementary education majors be taught this form of computer programming. A math content course is a natural place to teach this, but how can it be seamlessly included without taking away the focus from other important topics? This talk will examine how this has been attempted at Franklin College and discuss the results of this trial.

Presenter: Kylie Hess, Rose-Hulman Institute of Technology, undergraduate student

Joint work with: Emily Stamm, Vassar College, and Terrin Warren, University of Georgia - Athens, undergraduate students

Faculty Advisor: Jeremy Rouse, Wake Forest University

When is $a^n + 1$ a sum of two squares?

Fermat's two-squares theorem states the sufficient condition for an integer to be written as the sum of two squares. Using Fermat's two-squares theorem and properties of cyclotomic polynomials, we prove assertions about when numbers of the form $a^n + 1$ can be written as the sum of two squares. Our first result is that $a^n + 1$ is a sum of two squares for all $n \in \mathbb{N}$ if and only if a is a perfect square. Other results include that if $a \equiv 0, 1, 2 \pmod 4$ and $a^n + 1$ is the sum of two squares, then $a^\delta + 1$ is the sum of two squares for all $\delta \mid n$, $\delta > 1$.

Presenter: Vincenzo Isaia, Rose-Hulman Institute of Technology

Joint work with: Qinmao Zhang, Rose-Hulman Institute of Technology, undergraduate student

Parker-Sochacki approaches to delay differential equations

Two computational approaches based on the Parker-Sochacki method will be discussed for a family of nonlinear differential equations with deviating arguments in their vector fields. The focus will be on one approach which is more computationally efficient, can be generalized to handle any number of nonlinear and/or state dependent delays, and applies to differential equations which may be retarded, neutral, or advanced. In addition, a modification is available for stiff equations. However, convergence has to be shown on a case by case basis. The other approach is less computationally efficient, but its convergence can be shown a priori, and possesses an explicit error estimate. It also appears to be well suited for vanishing lag problems.

Presenter: Brianna Kozemzak, Saint Mary's College, Notre Dame, undergraduate student

Joint work with: Joseph Roth, University of Dallas

Faculty Advisors: Jigneshkumar Parmar and Pedro Mendes, UConn Center for Quantitative Medicine

MSC 2010: 34, 37N, 65

A mathematical model for copper homeostasis in Pseudomonas aeruginosa

Copper is a necessary cofactor in many biochemical reactions of living systems, but it can become toxic to cells when present in high levels. We are interested in modeling the copper homeostasis system in *Pseudomonas aeruginosa*, a bacterium responsible for thousands of healthcare acquired infections each year, since understanding of this system could lead to the development of new antibiotics that target cuproproteins in the face of growing antibiotic resistance. In collaboration with the Argüello group at Worcester Polytechnic Institute, we obtained data measuring copper levels across two fluid compartments of *P. aeruginosa*. Using this data, we constructed a compartmental model for copper homeostasis using a series of ordinary differential equations that describe the changes in amounts of proteins that bind to copper in the cell. We used the biochemical modeling software COPASI to simulate the model. Furthermore, we performed a systematic comparison of several combinations of global and local parameter estimation algorithms to approximate both kinetic parameters and the concentrations of proteins in *P. aeruginosa*. During this process we found evidence that some parameters are highly interdependent and that knowledge of at least some protein levels is required to accurately estimate the kinetic parameters. In order to sufficiently fit our model to the experimental data, we discovered that it is necessary to invoke up-regulation of periplasmic cuproproteins. These results will help our collaborators design experiments that produce the most crucial information for developing a more thorough and accurate model of the copper homeostasis system in *P. aeruginosa*.

Presenter: Anmol Lamichhane, Earlham College, undergraduate student

Wavelet transformation and its application to electronic music

I introduce the concept of wavelet transformation and illustrate the utility of such transformation by applying it to saw-tooth waves and wobble-bass, both of which have important applications in electronic music.

Presenter: Kiah Wah Ong, Indiana University Bloomington, graduate student
On the onset of instability in dissipative systems
MSC 2010: 35Q35, 35Q53

To address the dynamic transition of a given dissipative system, the first step is to study the linear eigenvalue problem of the system, which is closely related to the principle of exchange of stability. The details of the transition behavior are then dictated by the nonlinear interaction. Center manifold reduction strategy is an effective way to study these nonlinear interactions, leading to detailed information on the types of transitions and the structure of the transition states. This reduction strategy will be outlined in this talk.

Presenter: Michael Xue, Vroom Laboratory for Advanced Computing
Derive power summation formulas

Students are often asked to prove by mathematical induction, the known formulas of summation of i^p, where $i, p, n \in \mathbb{N}$, and i varies from 1 to n. However, the question "How are these formulas obtained?" remains to be answered. To change the misconception that mathematics is just a collection of proved formulas, we need to teach how the formulas are derived in the first place. In this talk, we will derive the power summation formulas using a recursive algorithm. A closer look at this algorithm reveals an initial-value problem for a difference equation whose symbolic solution is the power summation formula. A computer algebra system can be used to solve this initial-value problem.

Presenter: Godfred Yamoah, Trine University
A conservative scheme for an adaptive simulation

Groundwater flow problems are often characterized by rapid changes in certain regions of the domain. Both finite element and finite difference schemes that adjust the spatial discretization as the simulation progresses are known to improve the accuracy of the solution without greatly increasing the computational costs of the simulations. Spatial adaption (moving grid) involves refining and coarsening the spatial mesh or grid based on error estimates. However, significant mass-balance errors can be introduced if care is not taken during the coarsening phase of the adaption process. In particular, when two elements or cells are merged, nodal information must be re-distributed to preserve the mass of water in the newly merged element.

In this work, we consider a Galerkin finite element approach of the model equation. Linear simplex elements are used in space with backward Euler in time. Our spatial adaption involves dividing and merging elements based on the bisection approach. To advance in time, information across the entire mesh is needed from the previous time step.

We propose an algorithm to preserve mass during the coarsening process and provide results on a one dimensional infiltration problem that has been well studied in the literature. The method is based on the L^2 projection approach and seeks to redistribute mass on coarsened elements using solution values from the previous time step.