Rose-Hulman
Undergraduate Mathematics Conference

April 21 - 22, 2017

Rose-Hulman Institute of Technology
Department of Mathematics
Terre Haute, Indiana

Welcome

Welcome to the 34th Annual Rose-Hulman Undergraduate Mathematics Conference. This conference serves as an opportunity to highlight the research being done by undergraduate students which involve the use of mathematics and statistics. Students and faculty performing research across a wide spectrum are brought together by our shared interest in the mathematical sciences. This weekend is an opportunity to celebrate the accomplishments of those who are presenting, to encourage those for whom research is on the horizon, to broaden our knowledge amongst new and old friends, and to socialize with others who also have a passion for mathematics and statistics. We have a great program this weekend.

Invited Speakers: The role of mathematics in the biological sciences and the development of medicine is often unappreciated. The theme of this year's conference, *Exploring the Crossroads of Mathematics, Biology and Medicine*, emphasizes the opportunities available to those in the mathematical sciences for participating in the advancement of the biological sciences. Meg Ehm, Director of Genetics at GlaxoSmithKline, will discuss the use of impact of genetics in drug discovery and development. Mark Inlow, Lead Data Analyst with the American Institutes for Research, will discuss analysis of data contributing to Alzheimer's research.

Short Courses: We are pleased to offer three short courses to our registrants. These two-hour courses will present foundational topics in mathematics and statistics. For those interested in mathematical modeling, Dr. Mark Panaggio (Hillsdale College) will offer a course on modeling oscillation and synchronization on networks. Dr. Manda Riehl (University of Wisconson, Eau Claire) will offer a course on modeling RNA secondary structures using graphs. Dr. Mark Daniel Ward (Purdue University) will provide an introduction to data science.

Contributed Papers: The focal point of the weekend is the contributed student talks. We have 29 papers being presented by students this weekend on topics ranging from the statistical analysis and big data to mathematical theory. Regardless of your specialty, we are certain you will find something that interests you. We are grateful to all those students who are willing to share their work with us during the conference.

We are excited to host you this weekend, and we hope you enjoy the conference!

Acknowledgments

This conference would not have been possible without the dedication and service of many. We are grateful to all those who have helped this conference come together. In particular, we would like to thank the following individuals:

Mariana Lane	Administrative Assistance
Michelle Prather	Administrative Assistance
Yvonne Heiber	Hotel Representative

To all those we neglected to mention above, we truly are appreciative of all the work you put into the conference.

And to all those participating in the conference, thank you for attending; you are what the conference is all about.

Sponsors

The success of this conference is due in large part to our gracious corporate sponsors. The contributions of the following organizations allowed us to waive the registration fee for those registering early, subsidize hotel accommodations for 50 students, and provide meals during the conference. Please keep these organizations and corporations in mind as you continue your career.

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Rose-Hulman Undergraduate Math Journal

The Rose-Hulman Undergraduate Math Journal is devoted entirely to papers written by undergraduates on topics related to mathematics. Although the authors need not be undergraduates at the time of submission or publication, the work must have been completed before graduation. The journal is distributed freely in an electronic format (PDF) from the journal's web site.

In order to maintain a high level of exposition, each paper is sponsored by a mathematician familiar with the student's work and each paper is refereed. The editor-in-chief makes the final decision for publication. The journal is sponsored by the Mathematics Department at Rose-Hulman Institute of Technology.

To each of our presenters, we hope you will consider publishing your research. Should you choose to consider the Rose-Hulman Undergraduate Math Journal, please visit the journal's website or contact the following individuals:

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Terre Haute

During your stay in Terre Haute, we anticipate you will spend most of your time on the Rose-Hulman campus. Should you decide to explore Terre Haute, for those unfamiliar, there are four key roads that form a box: US 40 (Wabash Avenue) on the North, Interstate 70 on the South, US 41 (Third Street) on the West, and State Road 46 on the East.

Accommodations
The conference hotel is the Quality Inn of Terre Haute, located at 555 South Third Street (812.235.3333). As you exit the Rose-Hulman campus, turn right onto Wabash Avenue. Proceed through downtown Terre Haute until you reach the court house; turn left on Third Street. The hotel will be on the right after a few blocks. Please remember, **the conference hotel offers a hot breakfast each morning!**

We thank you for choosing to stay at the conference hotel. Your patronage keeps housing costs lower, allowing us to subsidize the cost for many students attending the conference.

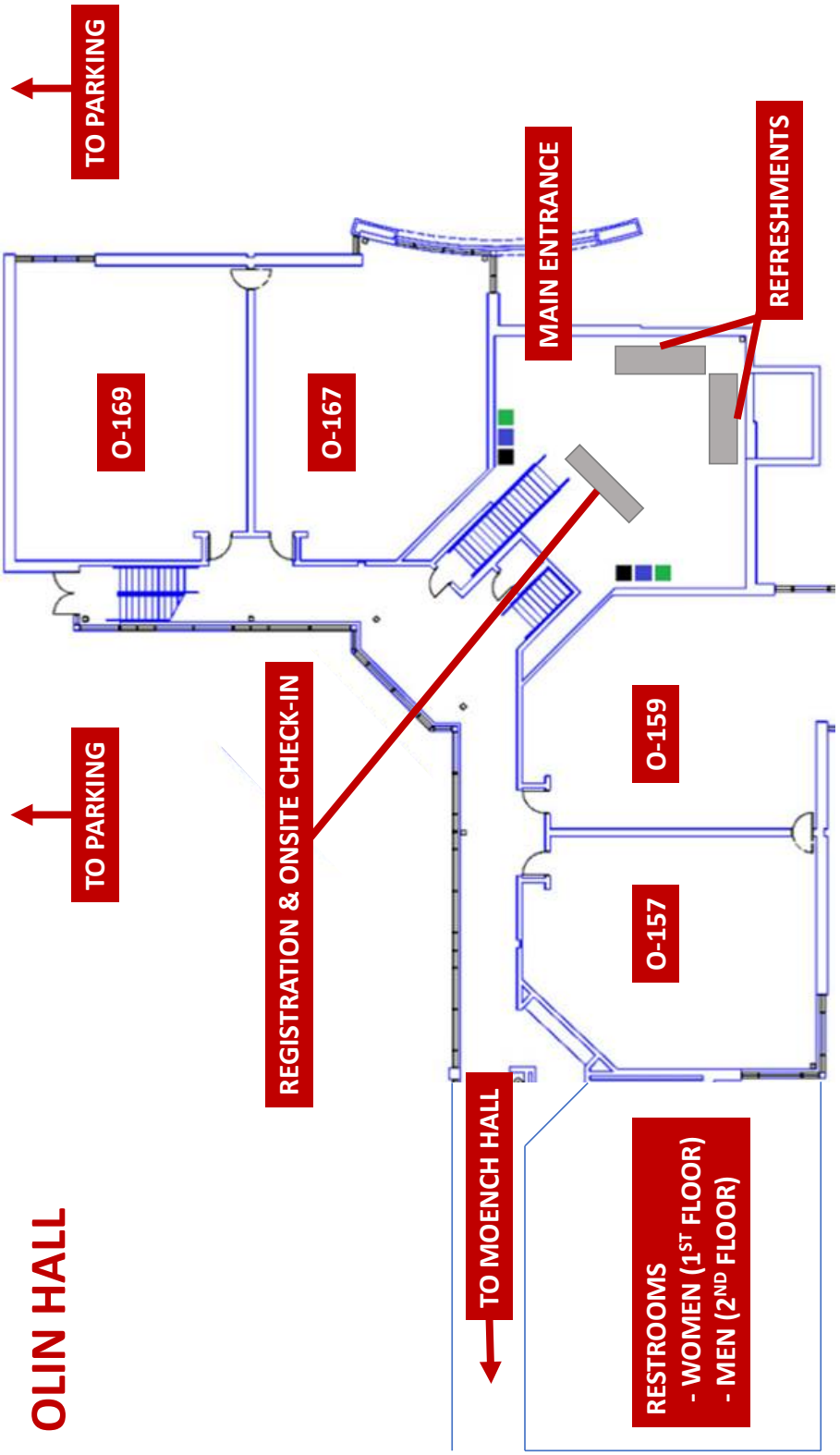
Restuarants
Terre Haute is home to many large chains. On State Road 46, just off Interstate 70, there are a few fast food options and a Mexican restaurant located near the Walmart complex. Downtown Terre Haute offers some local restaurants; local favorites include Mogger's and Saratoga. Third Street, near Interstate 70 and the Honeycreek Mall offers a plethora of options including fast food and larger chains.

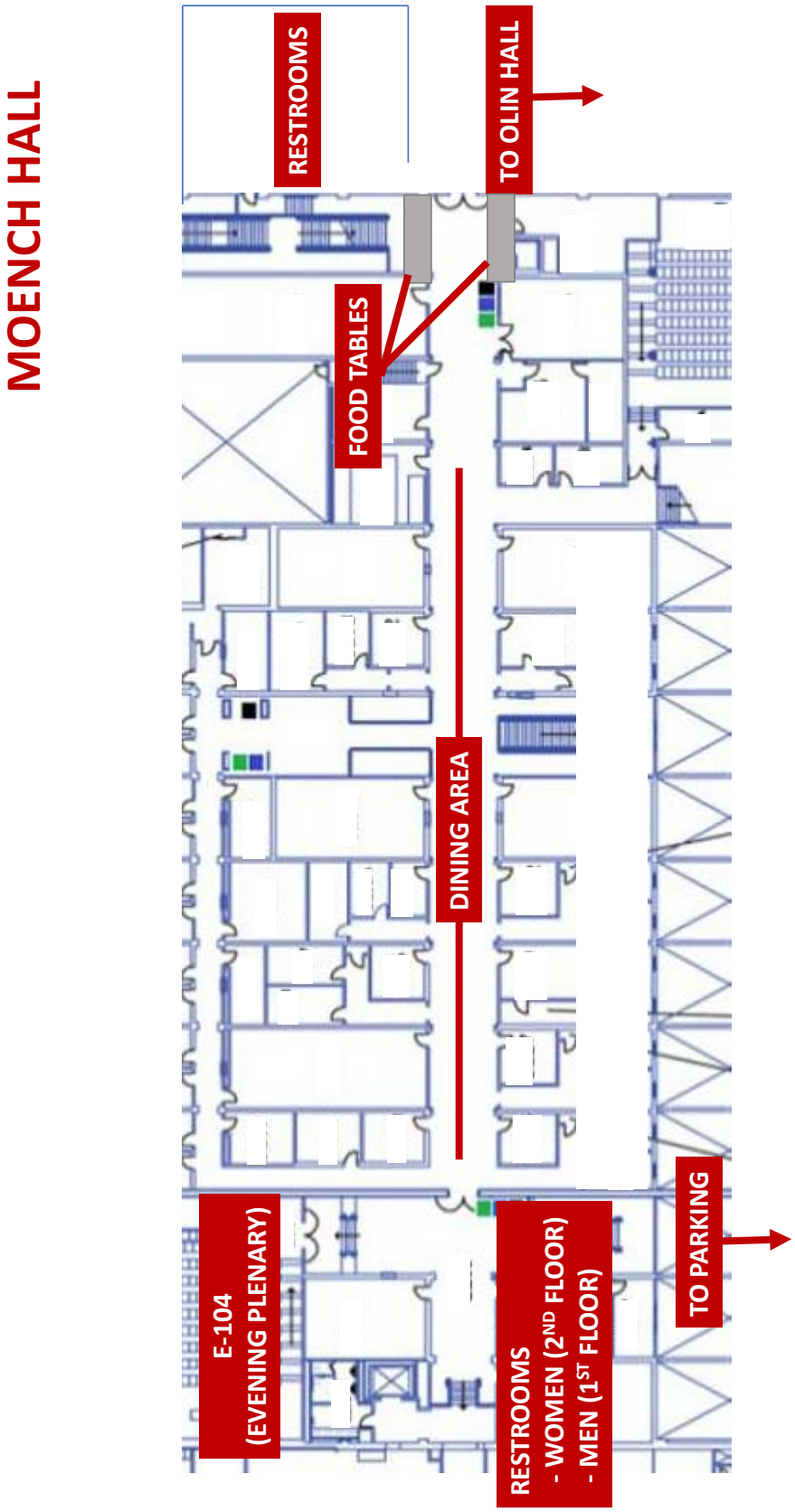
While the conference is providing dinner on Friday evening and lunch on Saturday afternoon, conference attendees are responsible for lunch on Friday and breakfast Saturday morning. The conference hotel will provide breakfast on Saturday morning for those staying at the Quality Inn. If you are not staying at the conference hotel, there are several breakfast options (Bob Evans, Cracker Barrel, Denny's, McDonald's, etc.) on Third Street. The conference will provide light refreshments on Saturday morning.

Conference App
There is a mobile app for the conference. Using the the App Store on your iPhone or the Play Store on your Android device, download the Guidebook app. Note: you **do not** need to register for a Guidebook account in order to use this app (just click the x). Open the Guidebook app and click the button "Enter Passphrase." Enter the following passphrase to install the conference app: **2017rhitugmc**

Floor Plans

Check-in and registration, as well as the short courses and contributed student talks will be in Olin Hall. Following the contributed talks, dinner and the evening plenary will be held on the top floor of Moench Hall. Please note that all academic buildings are connected so that you can move from one conference event to the next without exiting the facility.


TO PARKING
MAIN ENTRANCE
REFRESHMENTS
O-169
O-167
TO PARKING
REGISTRATION & ONSITE CHECK-IN
O-159
O-157
TO MOENCH HALL
RESTROOMS
- WOMEN (1ST FLOOR)
- MEN (2ND FLOOR)
OLIN HALL


MOENCH HALL
RESTROOMS
TO OLIN HALL
FOOD TABLES
DINING AREA
E-104
(EVENING PLENARY)
RESTROOMS
- WOMEN (2ND FLOOR)
- MEN (1ST FLOOR)
TO PARKING

Program Summary

Friday, April 21

12:00pm - 5:00pm	**Conference Registration and Onsite Check-In**	Olin Hall
1:00pm - 3:30pm	**Short Course**	Olin Hall (Lower Level)
	Introduction to Data Science Mark Ward	O-169
1:30pm - 3:30pm	**Short Courses**	Olin Hall (Lower Level)
	Mathematical models of oscillation and synchronization on networks Mark Daniel Panaggio	O-159
	Modeling RNA secondary structures using graphs Manda Riehl	O-167
3:55pm - 5:30pm	**Contributed Papers**	Olin Hall (Lower Level)
3:55pm - 4:15pm	**Electrochemical Analysis of Pyrite Dissolution** Luis Aviles	O-159
	Applying Big Data Analysis to Particle Physics Miranda Champion	O-167
	Take it to the Limit: A Fast-Slow Dynamical Model of Alcohol Addiction Monica McGrath and Kathryn Garber	O-169
4:20pm - 4:40pm	**The efficiency of spanning trees.** Taylor Derhammer	O-159
	Changes in Cell Structure and Spreading from Lowe Syndrome Brittany Griggs	O-167
	Investigation into Distribution of Prime Numbers with Modulo Classes Pradeep Ranaweera	O-169
4:45pm - 5:05pm	**Sudoku Solutions using Grobner Basis and MuPAD** Ry Gallagher and Arlan Zelenky	O-159
	Economic Equilibrium Linear Models: Module 208 Update Gabrielle Corbin	O-167
	Euclidean measurements for hyperbolic constructions Tristen Spencer	O-169
5:10pm - 5:30pm	**Preventing Decreasing Subsequences in Stack Sorting Outputs** Angela Hanson	O-159
	Automating the Effective Fragment Potential Method Peyton Puckett	O-167
	Engaging students mathematical interests beyond the classroom Fanny Chen and Jon Atkins	O-169

5:30pm - 6:45pm	**Dinner**	Moench Hall (Second Floor)
6:45pm - 8:00pm	**Plenary Session**	Moench Hall (E-104)
	Use of Human Genetics in Drug Discovery and Development Meg Ehm	E-104
8:15pm - 10:00pm	**Student Party**	Moench Hall (A-wing)

Saturday, April 22

9:00am - 9:30am	**Conference Registration and Onsite Check-In**	Olin Hall
9:30am - 10:40am	**Contributed Papers**	Olin Hall (Lower Level)
9:30am - 9:50am	**Low-cost modification of a lab scale bioreactor to simulate oxygen gradient heterogeneities present in large scale industrial bioreactors.** Alexander Armstrong	O-159
	The Mathematics of Poker: From Classical Game Theory to Machine Learning Algorithms Nicholas Brown, Junghyun Hwang, Zihan Wang, Ruoyu Zhu	O-167
9:55am - 10:15am	**Periodicity of Subtraction Games** Michael Smith, Jack Good	O-159
	The Entropy of Economics: Calculating Economic Inequality through Statistical Mechanics Anmol Lamichhane	O-167
	The Mystery of Zipf's Law: Analysis of Word Frequencies in Natural Language and Artificial Language Khoa Tran	O-169
10:20am - 10:40am	**Reanalysis of Cancer Immunotherapy Clinical Data to Elucidate Genetic information of Immunotherapy Response** Amber Young	O-159
	Information Theory Characterizes the Diagnosticity of Features in Fingerprints Haley Drabek	O-167
	Spectral Decomposition of Quantum-Mechanical Operators Daniel Halmrast	O-169
10:50am - 11:20am	**Graduate School Panel** Dr. Mark Ward (Purdue), Dr. Eugene Mukhin (IUPUI), Sarah Loeb (UIUC), Lorena Maxwell (Purdue), Jon Atkins (industry)	Moench Hall (E-104)
11:30pm - 12:15pm	**Lunch**	Olin Hall (Main Lobby)
12:15pm - 1:25pm	**Contributed Papers**	Olin Hall (Lower Level)

12:15pm - 12:35pm	**Statistical Analysis of Weather Forecasts: Accuracy of Internet Weather Forecasts vs. Statistical Models** Yantong Zheng, Yajie Chu, Sijia Huo, Yunxin Zhang	O-159
	Lower Bounds for the Splitting Numbers of Links Anthony Coniglio	O-167
	Analysis of Random Generation of Binary Trees Corinne Leopold	O-169
12:40pm - 1:00pm	**Grobner Bases of Neural Ideals** Ethan Petersen	O-159
	Imaging and Illumination of Theatrical Lighting Fixtures Addie Hanchett	O-167
	A Simulation of Anthropogenic Mammoth Extinction Matthew Klapman	O-169
1:05pm - 1:25pm	**Artificial Neural Networks Applied to Image-to-Image Translation** Peter Larson	O-159
	Planar Partitions of Specific Forms Kylie Hess	O-167
	A combinatorial study of the algorithmic compressibility of gene expressions Lin Liu	O-169
1:30pm - 2:30pm	**Plenary Session**	Moench Hall (E-104)
	New Mathematical and Statistical Analyses of Alzheimer's Brain Atrophy Dr. Mark Inlow	E-104
2:30pm - 3:00pm	**Closing Remarks**	Moench Hall (E-104)

Program | Short Courses

Introduction to Data Science

Dr. Mark Daniel Ward
Associate Professor of Statistics, Purdue University
Time: Friday, 1:00pm - 3:30pm
Location: O-169

We will have a hands-on overview of some of the tools that data scientists use for working with data, including large data sets. The workshop topics can be slightly flexible and open to discussion, depending on the interests of the participants. At a minimum, we will introduce students to R and RStudio, data visualization, and perhaps some tools for scraping and parsing XML directly from the web and processing the scraped data in R. All participants are encouraged to bring a laptop...and to be excited to learn about some of the introductory nuts and bolts of data science. No computational background is needed for this workshop.

Mathematical Models of Oscillation and Synchronization on Networks

Dr. Mark Panaggio
Assistant Professor of Mathematics, Hillsdale College
Time: Friday, 1:30pm - 3:30pm
Location: O-159

Oscillation is a fundamental feature of many biological systems. At the cellular level, oscillation is observed in spiking neurons and the contraction and relaxation of muscle tissue. Oscillation also occurs on a larger scale in the dynamics of swarms and circadian rhythms. In this short course, we will explore various mathematical models of "coupled oscillators" and investigate the internal dynamics of individuals as well as the collective behaviors of networks of oscillators. Along the way we will discuss theoretical results, applications and open questions pertaining to the emergence of synchronization in nature.

Modeling RNA Secondary Structures Using Graphs

Dr. Manda Riehl
Associate Professor of Mathematics, University of Wisconsin - Eau Claire
Time: Friday, 1:30pm - 3:30pm
Location: O-167

RNA is single stranded and can form complicated base-pairings, e.g. stem-loops, cloverleafs, and pseudoknots. For many RNA molecules, the structure made by these pairings (called its secondary structure) can be as important to the function of the molecule as the sequence itself. We will investigate several graph theoretic models for RNA secondary structure, particularly matchings and trees, and the assumptions made in each model. We will also look at some of the information available on these RNA secondary structures in online databases.

Program | Plenary Sessions

Use of Human Genetics in Drug Discovery and Development

Dr. Meg Ehm
Director of Genetics, GlaxoSmithKline
Time: Friday, 6:45pm - 8:00pm
Location: E-104, Moench Hall

Before the turn of the century, there was a belief that genetics would have an important impact on drug discovery and development. Many thought that the identification of genes responsible for disease would directly identify drug targets – genes that can be modulated to achieve a therapeutic effect. Genetics was also widely touted as a method to identify patients who would likely respond to medications or who were likely to experience adverse effects. Almost 20 years later, systematic review and analysis of genetic information and drug approvals have demonstrated the importance of genetics in early discovery and for drug safety but have tempered enthusiasm for its use in predicting drug efficacy. I will review these results and highlight emerging techniques that use genetic data in drug discovery and development.

About Meg: Meg Ehm is a Director of Genetics at GlaxoSmithKline located in King of Prussia, Pennsylvania. She develops and manages external collaborations that bring together GSK with academic and industry groups to build innovative capabilities capitalizing on genetic data that will improve the next generation of medicines. Currently, she co-leads a pharmaceutical industry consortium focused on accelerating translational research with genetic evaluation of clinically important phenotypes using electronic health record data and genetics to improve pipeline portfolio decisions. She received her BS degree from Vanderbilt University in mathematics and computer science and MA and PhD from Rice University in statistics. She completed a brief post-doctoral position at North Carolina State University in 2001 where she remains an Adjunct Professor of Statistics. She is a native Hoosier and graduated from Terre Haute South High School.

New Mathematical and Statistical Analyses of Alzheimer's Brain Atrophy

Dr. Mark Inlow
Lead Data Analyst, American Institutes for Research
Time: Saturday, 1:30pm - 2:30pm
Location: E-104, Moench Hall

Alzheimer's Disease causes neuron death and tissue shrinkage throughout the brain. However some regions, especially the hippocampus, are more severely affected. Since it is believed deleterious changes begin well before symptoms occur it is important to detect these changes in the earliest stages of Alzheimer's. In this talk we discuss methods we recently developed to successfully detect and describe hippocampal shrinkage in subjects with early mild cognitive impairment.

About Mark: Mark Inlow is currently a Lead Data Analyst with the American Institutes for Research (AIR) in Washington, DC. He is also a consultant for the IU School of Medicine where he helps develop neuroimaging genomics algorithms for investigating Alzheimer's Disease. Before joining AIR he was a professor of statistics for 14 years with appointments at Rose-Hulman, the IU School of Medicine, and the University of Arizona. Prior to earning his statistics Ph.D. from Texas A&M in 2001, he worked as a statistician for DuPont, Science Applications International, StataCorp, the Naval Health Research Center, and the Naval Personnel Research and Development Center. A native Hoosier, Mark lives in Terre Haute with his wife Jen and their cat Marshmellow.

Program | Contributed Papers

Abstracts of contributed papers are listed below.

Friday, 3:55 PM to 4:15 PM

Electrochemical Analysis of Pyrite Dissolution

Luis Aviles, Saint Francis University
Location: O-159

Acid mine water drainage is a widespread environmental issue caused by the runoff of water that is collected in abandoned mines and is contaminated by metals that are dissolved in the water. Pyrite is a major contributor to acid mine water drainage as it is abundant in many mines. Using electrochemical analysis the dissolution of pyrite is studied to gain a further understanding of the processes that occur.

Applying Big Data Analysis to Particle Physics

Miranda Champion, Purdue University
Location: O-167

As researchers with the CMS project at CERN, we attempt to answer grand questions like How did the universe start. This requires large pieces of equipment, numbers of researchers, and amounts of data. Increasing data reduces statistical error, but causes known difficulties computationally. Identifying trends in phenomena starts with determining whether the error is a result of the models used or an indication of new physics. We intend to eventually uncover more information on the fundamental structure of the universe, but first we must eliminating systematic error in our methods of relating Standard Models with the true level of data.

Take it to the Limit: A Fast-Slow Dynamical Model of Alcohol Addiction

Monica McGrath, Kathryn Garber, Saint Mary's College
Location: O-169

Alcohol addiction is a prevalent mental health disorder with more than 17 million adults in the United States diagnosed in 2012. Addiction disorders are characterized by periodic episodes of sudden relapse followed by relatively long periods of recovery. In the brain, alcohol addiction is related to imbalances of certain types of neurotransmitters in the reward system, including dopamine (DA) and gamma-Aminobutyric acid (GABA). DA is responsible for creating feelings of pleasure, while GABA is a DA regulator (inhibitor). To better understand the fundamental neurochemical mechanisms driving relapse-recovery cycles, we construct a fast-slow dynamical system model of the relationship between DA and GABA in the brain of an addict. The model captures the dynamics of addiction relapse and recovery via a limit cycle. Using the model and time-scale separation, we approximate the period of the cycle, which measures relapse frequency. We also derive a formula for

the lower DA threshold which triggers a relapse (relapse threshold). Varying a parameter sensitive to certain types of treatment (treatment parameter) causes a Hopf bifurcation wherein the limit cycle disappears as the equilibrium point gains stability. After this transition, DA levels no longer fall below the relapse threshold, thus, the relapse-recovery cycle is broken. Our predictions of relapse frequency and treatment parameter threshold may help inform clinicians in improving treatment methods.

4:20 PM to 4:40 PM

The efficiency of spanning trees.

Taylor Derhammer, Saint Francis University
Location: O-159

There has always been a need to solve problems efficiently due to the finite computational capacity of technology. Low-Stretch spanning trees can be used to efficiently solve cases of linear systems and can be done so efficiently. Finding the spanning tree is a matter of reducing the matrix to a sparser version. This is done by repeatedly applying the method of star decomposition. Star decomposition reduces the graph into multiple sets that are connected to a center set by a single edge that is the shortest path between those sets. We further examine the use of star decomposition and the overall time complexity of finding lower-stretch spanning trees. Given that time complexities drop so many terms, we will also investigate the practical time complexity and compare it to more commonly used methods.

Changes in Cell Structure and Spreading from Lowe Syndrome

Brittany Griggs, Purdue University
Location: O-167

Lowe Syndrome (LS) is an X-linked congenital disorder caused by mutations in the gene OCRL1. Male children are born with defects in eyes, brain and kidney. So far the disease has no cure and children die by late adolescence from renal complications. This project aims to better-understand the causes of this syndrome and to develop a therapeutic strategy against LS. Our lab was the first to identify cellular defects in patient cells, namely membrane remodeling abnormalities such as cell spreading. Importantly, our lab has also identified one FDA-approved candidate compound that can ameliorate membrane remodeling defects. To assess the dose-response relationship of LS patient cells to candidate drugs, and to investigate their mechanism of action, we have developed a quantitative classification method to track the time-course of spreading. Importantly, our approach has allowed us to better elucidate the characteristics of the cell spreading phenotype. Our data strongly suggests that LS cells have an adhesion defect in early stages of cell spreading and also progress slower through later spreading stages compared to normal cells. Further, our candidate compound improves the adhesion of LS cells and helps them mature through later stages in a dose-dependent manner. This study hopes to contribute to the development of a most needed treatment for LS. Brittany Griggs is supported by NSF grant DMS #1246818.

Investigation into Distribution of Prime Numbers with Modulo Classes

Pradeep Ranaweera, Sienna Heights University
Location: O-169

Throughout the history of mathematics, characteristic patterns of prime numbers have been a mystery. They do not follow any pattern. To predict the next prime number, mathematicians have been trying to find various methods. Using different modulo, prime numbers seems to have strings of grouping. This paper will examine patterns of prime numbers in modulo classes.

4:45 PM to 5:05 PM

Sudoku Solutions using Grobner Basis and MuPAD

Ry Gallagher, Arlan Zelenky, Saint Francis University
Location: O-159

Algebraic Geometry studies geometric objects that can be described as zero loci of polynomials. To further understand the structure of a system defined by polynomials, such as its dimension, singularities, intersections and unions, hence to obtain applicable solutions, it is essential to perform intensive computations using Computer Algebra Systems. MATLAB (a mathematical program) contains a Computer Algebra System that does computation in this subject area but there has not been an effort to utilize the Computer Algebra System that MATLAB has. We will implement computation in Algebraic Geometry using MuPad. In this project we will also solve sudoku puzzles using Grobner basis in Matlab.

Economic Equilibrium Linear Models: Module 208 Update

Gabrielle Corbin, Sienna Heights University
Location: O-167

The purpose of this project was to complete the provided exercises that are included in Phillip M. Tuchinskys Economic Equilibrium Linear Models module. Using the modules included readings, a study was done to create a simple mathematic model of price equilibrium. Brief outlines and excerpts of Tuchinskys readings are included in this presentation in order to aid with the completion of the exercises.

Euclidean measurements for hyperbolic constructions

Tristen Spencer, Aquinas College
Location: O-169

We can use Euclidean compass and straightedge to construct hyperbolic objects in the Poincare disk. The calculations have some interesting shortcuts when we use Gregory numbers ($t_a = arctan(1/a)$). We will prove our theorem that the hyperbolic area of a hyperbolic circle divided by its hyperbolic circumference is equal to the Euclidean radius of the circle measured from the center of the disk.

5:10 PM to 5:20 PM

Preventing Decreasing Subsequences in Stack Sorting Outputs

Angela Hanson, Rose-Hulman Institute of Technology
Location: O-159

A permutation of length n is stack sortable if and only if it avoids the pattern 231. Sorting such permutations will output the increasing sequence 12...n which is equivalently characterized as having no decreasing runs of length 2. This talk examines which patterns to avoid to prevent an output with decreasing subsequences and/or runs of length 3 or greater using both infinite and finite-depth stack sorting. The patterns that need to be avoided are generalizations of the 231 pattern for the infinite stack case, and modifications to these patterns account for stack overflow in the finite-depth stack case.

Automating the Effective Fragment Potential Method

Peyton Puckett, Purdue University
Location: O-167

Effective Fragment Potential Method is used to compute and describe intermolecular interactions between molecules. This process is relatively simple for small molecules, however it can become quite complex when trying to describe larger and more complex molecules. In order to streamline the process, I was tasked with automating the calculations in the EFP method. Implementing python code and bash scripts allows this process to be run with a single command. After the interactions are calculated, the data collected must be analyzed. I am currently working on the data analysis using packages in R and machine learning libraries for Python.

Engaging students mathematical interests beyond the classroom

Fanny Chen, Jon Atkins, Math-M-Addicts
Location: O-169

The Math-M-Addicts program seeks to enrich students outside of the traditional school curriculum. We discuss the program and potential opportunities.

Saturday, 9:30 AM to 9:50 AM

Low-cost modification of a lab scale bioreactor to simulate oxygen gradient heterogeneities present in large scale industrial bioreactors.

Alexander Armstrong, Rose-Hulman Institute of Technology
Location: O-159

Fermentation provides a variety of valuable chemical and biological products. These range from biofuels to antibodies. Fermentation takes place in vessels known as bioreactors. While small bioreactors are able to maintain homogenous conditions and short mixing times, scale-ups of fermentation processes often suffer from longer mixing times due to the larger volumes and dangers of shearing. The larger volumes and slower mixing times makes homogeneity difficult to maintain and gradients in dissolved oxygen (dO), pH, and substrate often form (1). Scale-down procedure is a method of modeling and evaluating environmental gradients in bioreactors and their effects on the cell culture (2). To apply this in practice, we need appropriate experimental tools. The purpose of this project was to design a laboratory-scale bioreactor that could be used to simulate oxygen gradients present in large scale bioreactors through use of a two compartment plug flow reactor / stirred tank reactor (PFR-STR) setup with residence times in the oxygen limited zone of 120s and 180s. Based on the statistical analysis of the data collected, there is significant evidence that there is a difference in growth, glucose consumption, and biomass yield between the unmodified STR, the 120s PFR-STR, and the 180s PFR-STR. The 20.6% decrease in biomass yield in the 120s runs is similar to the decrease seen when scaling from 3L to 9 m3.

The Mathematics of Poker: From Classical Game Theory to Machine Learning Algorithms

Nicholas Brown, Junghyun Hwang, Zihan Wang, Ruoyu Zhu, University of Illinois
Location: O-167

We begin by describing John von Neumann's mathematical model of poker and its subsequent generalizations by others, including notable World Series of Poker champion Chris Ferguson. We then present a game theoretic analysis of 'Indian Poker', an interesting variant of poker that introduces a novel twist to the existing models. We illustrate these models with interactive visualizations and simulations.

In the second part of our presentation, we discuss our investigation of a large database of poker hands, collected on the IRC Poker Channel during the late 1990's, using machine learning and statistical techniques.

This work is based on research carried out at the Illinois Geometry Lab in Fall 2016 and Spring 2017.

9:55 AM to 10:15 AM

Periodicity of Subtraction Games

Michael Smith, Jack Good, Purdue University
Location: O-159

We use data driven analysis to make conjectures about the periodicity of the structure of nim, a two player subtraction game in the field of game theory. The approach is computationally intensive (building on a database consisting of terabytes of data about the game) and utilizes tools of data science and visualization. We are working towards an understanding of the structure of the game from a data driven perspective in an effort to characterize the precise periodicities. This work is supported by NSF grant DSM #1246818.

The Entropy of Economics: Calculating Economic Inequality through Statistical Mechanics

Anmol Lamichhane, Earlham College
Location: O-167

Have you heard of the 1%? Can we use thermodynamics and statistical mechanics to predict and understand economic or other socio-political inequalities that leads to the creation of the 1% class? I present various statistical mechanics models that could be used to better understand such inequalities.

The Mystery of Zipf's Law: Analysis of Word Frequencies in Natural Language and Artificial Language

Khoa Tran, University of Illinois
Location: O-169

Zipfs Law states that when observations are ranked from most to least frequent, the frequency of observations is inversely proportional to their rank. This law has been found to hold for a large variety of data sets such as word frequencies, citations of scientific papers, magnitudes of earthquakes, intensities of solar flares, wealth of the richest people, and populations of cities. In this presentation, we will mainly focus on the applications of Zipfs Law to word frequencies in natural and artificial language. We will also delve into some of the reasons and mechanics behind this phenomenon and speculate on the future of Zipfs Law.

10:20 AM to 10:40 AM

Reanalysis of Cancer Immunotherapy Clinical Data to Elucidate Genetic information of Immunotherapy Response

Amber Young, Donglai Chen, Jun Xie, Purdue University
Location: O-159

Immunotherapies have emerged as highly promising approaches to treat cancer patients. A specific type of immunotherapy, called Immune Checkpoint Inhibitors, has proven effective in the treatment of lung cancers, melanomas, lymphomas, and others. However, these treatments are not effective in all patients. One of the critical challenges is to determine which patients will respond to a specific immunotherapy, so that the cancer immunotherapy can be tailored to the individual patients. Here, we present a reanalysis of a cancer immunotherapy clinical study, which was reported in a paper published in Science 2015, entitled "Mutational landscape determines sensitivity to PD-1 blockade in nonsmall cell lung cancer" by Rizvi et. al. The paper concluded that higher nonsynonymous mutation burden, higher neoantigen burden, and the presence of the molecular smoking signature all individually correlated with greater patient response to the PD-1 (programmed cell death protein 1) inhibitor drug pembrolizumab in non-small cell lung cancer. We were able to retrieve the corresponding clinical data from cBioPortal (http://www.cbioportal.org/study?id=luad_mskcc_2015#summary), which contains 34 patients with clinical characteristics as well as mutation information for over 5,000 genes. We conducted statistical data analysis to search for significant predictors of immunotherapy response. In addition to confirming the conclusions made by the original paper, we identified specific mutations on patient response and potential mutation indicators of PD-L1 (PD-1 ligand) expression. Our reanalysis results may be used for an enhanced understanding of the tumor/immune interface and improved prediction of immunotherapy response.

Information Theory Characterizes the Diagnosticity of Features in Fingerprints

Haley Drabek, Indiana University
Location: O-167

When examiners visually compare two fingerprints to decide whether they come from the same source, they look for features that carry specificity, meaning that they look for features that are not likely to appear in many other impressions. However, the definition of feature and likely currently lack mathematical foundations. In this project I explore different parameterizations of feature spaces using the information reduction method, independent component analysis. I am working to build a models of diagnosticity based on information theory to characterize the rarity of individual regions of fingerprints. The results will strengthen the evidentiary value of latent prints and reduce errors by examiners.

Spectral Decomposition of Quantum-Mechanical Operators

Daniel Halmrast, Hillsdale College
Location: O-169

Applications of the spectral theorem for self-adjoint operators in quantum mechanics are examined. While classical physics provides differential equations (in the form of Newton's laws) that describe deterministic evolution of phase space variables, quantum mechanics evolves the more abstract wavefunction, an element of the quantum Hilbert space. To find measurement probabilities for a phase space variable (an "observable"), the observable is identified with a self-adjoint operator on the corresponding Hilbert space. The spectral decomposition of the quantized operator gives information on the values possible for such an observable. Furthermore, the different parts of the spectrum of a quantum observable will be shown to correspond to different types of states, an idea which will be demonstrated with concrete examples. Finally, different formulations of the spectral theorem are explored, including the projection-valued measure and direct integral approach. These different formulations will yield further insights into physical understandings of quantum mechanical states.

12:15 PM to 12:35 PM

Statistical Analysis of Weather Forecasts: Accuracy of Internet Weather Forecasts vs. Statistical Models

Yantong Zheng, Yajie Chu, Sijia Huo, Yunxin Zhang, University of Illinois
Location: O-159

When your favorite weather website predicts sunny weather with 80 degrees 5 days from now and a 70% chance of rain 7 days from now, how reliable are these predictions? Are weather forecasts more reliable in San Francisco than in Chicago? Are 5 day forecasts more accurate than 7 day forecasts, in a statistically significant sense?

This project is motivated by such questions. We analyze the accuracy of hourly temperature and precipitation forecasts obtained from the website wunderground.com and of predictions based on historical climate data using statistical models such as the persistence, climatology, and time series models. The analysis is based on over 50 million individual predictions collected hourly from 30 locations over a period of about one year, and historical weather data from over 10,000 locations in the U.S..

Lower Bounds for the Splitting Numbers of Links

Anthony Coniglio, Indiana University
Location: O-167

The "splitting number" of a link is defined to be the minimal number of crossing changes that must be made in order to unlink its components. Because there is no known algorithm for computing this number explicitly, one can determine lower bounds for what the splitting number must be. Two of these bounds are the "linking number bound" and the "sigma bound." The linking number

bound is computed by orienting the link components, systematically assigning a value of +1 or -1 to each crossing, and constructing a sum involving these values. The sigma bound is computed by finding an orientable surface in R^3 whose boundary is the link, constructing a Hermitian matrix based on the structure of this surface, and calculating a sum involving the nullity and signature of this matrix.

Analysis of Random Generation of Binary Trees

Corinne Leopold, Purdue University
Location: O-169

This project involves a simulation of random binary trees to observe the relationship between tree height and the number of possible binary trees that can be generated from a uniform probability distribution. We study the effect of increasing tree size on the number of possible binary trees, in which every possible binary tree has an equal probability of occurring at a given height. We develop a recurrence relation that is used to calculate the number of binary trees of height n, and then we proceed to recursively generate all possible trees of height n in Java. Our simulation ultimately allows us to analyze the asymptotic properties of randomly generated binary trees as their height increases. Further analysis may be performed to observe the behavior of specific types of binary trees as their height increases.

12:40 PM to 1:00 PM

Grobner Bases of Neural Ideals

Ethan Petersen, Rose-Hulman Institute of Technology
Location: O-159

A major area in neuroscience is the study of how the brain processes spatial information. Neurons in the brain represent external stimuli via neural codes. These codes often arise from regions of space called receptive fields: each neuron fires at a high rate precisely when the animal is in the corresponding receptive field. Much research in this area has focused on understanding what features of receptive fields can be extracted directly from a neural code. In particular, Curto, Itskov, Veliz-Cuba, and Youngs recently introduced the concept of neural ideal, which is an algebraic object that encodes the full combinatorial data of a neural code. Every neural ideal has a particular generating set, called the canonical form, that directly encodes a minimal description of the receptive field structure intrinsic to the neural code. On the other hand, for a given monomial order, any polynomial ideal is also generated by its unique (reduced) Gröbner basis. How are these two types of generating sets – canonical forms and Gröbner bases – related? Our main result states that if the canonical form of a neural ideal is a Gröbner basis, then it is the universal Gröbner basis (that is, the union of all reduced Gröbner bases). Furthermore, we prove that this situation – when the canonical form is a Gröbner basis – occurs precisely when the universal Gröbner basis contains only pseudo-monomials (certain generalizations of monomials). Our results motivate two questions: (1) When is the canonical form a Gröbner basis? (2) When the universal Gröbner basis of a neural ideal is *not* a canonical form, what can the non-pseudo-monomial elements in the basis tell us about the receptive fields of the code? We give partial answers to both questions.

Imaging and Illumination of Theatrical Lighting Fixtures

Addie Hanchett, Rose-Hulman Institute of Technology
Location: O-167

Electronic Theatre Controls' Source Four Ellipsoidal series are comprised of different parts that translates light from the source to the stage floor. This process images the light from a specific point in the fixture such that the final image is of a specific size depending on the lens. The series has different lenses with varying focal lengths and diameters. These parameters affect the size of the final image. The parameters of the fixture not only affect the size of the image but also affects the irradiance and the illumination at the stage floor. Using data collected from actual fixtures, the final image size, fixture degree, irradiance, and illumination can be compared to data that the fixture states. For some of the fixtures tested, there was a significant difference. The difference in data comes from rounding and simplifing data and the degradation over time of the fixtures.

A Simulation of Anthropogenic Mammoth Extinction

Matthew Klapman, Valparaiso University
Location: O-169

The cause of the extinction of the Columbian mammoth (Mammuthus columbi) and other species of megafauna during the end of the Pleistocene epoch is unknown. The current proposed hypotheses are climate change, disease, a meteor impact, and overkill. In this study, we used mathematical modeling to test the overkill hypothesis first proposed by Paul Martin in 1973. The overkill hypothesis claims that early humans migrating from Asia through Beringia and into North America hunted the majority of the continent's megafauna to extinction. Previous research has been conducted on the overkill hypothesis for the Columbian mammoth using a continuous differential equations model. We improved on this work by developing a computationally more efficient and more realistic discrete stochastic model. Most model parameters were obtained directly from the literature; migration parameters were calibrated to the model. Our results provide evidence in support of the overkill hypothesis.

1:05 PM to 1:25 PM

Artificial Neural Networks Applied to Image-to-Image Translation

Peter Larson, Rose-Hulman Institute of Technology
Location: O-159

Artificial Neural Network and Deep Learning are effective at solving many problems. Image-to-image mapping is one area that has improved greatly. Image-to-Image mapping is typically between two distinct sets of images. In one form of the problem the images are paired together, while in another the sets do not have an explicit pairing. This paper investigates the unpaired image mapping problem, and evaluates an architecture that combines Generative Adversarial Networks, and a Content Loss function. Experimental results show that the architecture is capable of learning to colorize images from sets of images without overlap, where one set has been decolorized.

Planar Partitions of Specific Forms

Kylie Hess, Rose-Hulman Institute of Technology
Location: O-167

Planar partitions are natural extensions of ordinary partitions into two dimensions. This talk will briefly summarize some basic properties of planar partitions before discussing some formulas relating to the number of planar partitions of particular shapes.

A combinatorial study of the algorithmic compressibility of gene expressions

Lin Liu, Westminster College
Location: O-169

The use of DNA microarrays offers biologists the ability to measure a large number of gene expression levels in parallel. The biological significance of each gene expression is characterized by its algorithmic compressibility, which quantifies the amount of information encoded therein. This talk illustrates a combinatorial approach to estimate the lower bound of the compressibility for gene expressions in terms of the lengths of the longest increasing or decreasing subsequences. In particular, the Robinson-Schensted-Knuth correspondence for representations of symmetric groups is introduced alongside necessary combinatorial identities to obtain number counts for permutations associated to gene expressions.

Conference Attendees

Yasmeen Abuzeid	University of Wisconsin-Madison
Ty Adams	Rose-Hulman Institute of Technology
Samad Ahmed	Rose-Hulman Institute of Technology
Vibha Alangar	Rose-Hulman Institute of Technology
Shannon Anderson	Indiana State University
Oscar Rodrigo Araiza Bravo	University of Illinois
Alexander Armstrong	Rose-Hulman Institute of Technology
Joshua Arroyo	Rose-Hulman Institute of Technology
Jon Atkins	Math-M-Addicts
Luis Aviles	Saint Francis University
Suman Balasubramanian	DePauw Univeristy
Arica Bartee	Rose-Hulman Institute of Technology
Emma Beck	Purdue University
Chauncey Becker	Rose-Hulman Institute of Technology
Megan Bennett	Earlham College
Avni Bhalgat	Purdue University
Aaradhana Bharill	Rose-Hulman Institute of Technology
Emily Bochnowski	Rose-Hulman Institute of Technology
James Brand	Purdue University
Hannah Bredikhin	Purdue University
Nicholas Brown	University of Illinois
Kurt Bryan	Rose-Hulman Institute of Technology
Sylvia Carlisle	Rose-Hulman Institute of Technology
Miranda Champion	Purdue University
Shreeya Chandra	Rose-Hulman Institute of Technology
Cynthia Chang	Purdue University
Fanny Chen	Math-M-Addicts
Avery Chezem	Sienna Heights University
Nabeeha Chowdhury	University of Houston
Margaret Christy	Purdue University
Yajie Chu	University of Illinois
Ryan Coffman	Rose-Hulman Institute of Technology
Anthony Coniglio	Indiana University
Gabrielle Corbin	Sienna Heights University
Jessica Corso	Rose-Hulman Institute of Technology
Madeline Crews	Rose-Hulman Institute of Technology
Michael Crowell	Rose-Hulman Institute of Technology
Hope Cullers	Rose-Hulman Institute of Technology
Danielle Dattilio	DePauw Univeristy
Taylor Derhammer	Saint Francis University
Haley Drabek	Indiana University

Isaac Dragomir	Trinity International University
Riley Dunnagan	Rose-Hulman Institute of Technology
Joe Eichholz	Rose-Hulman Institute of Technology
Sam Eschker	Purdue University
Cailey Farrell	Purdue University
Adam Finer	Rose-Hulman Institute of Technology
Ry Gallagher	Saint Francis University
Jonathan Gannon	Rose-Hulman Institute of Technology
Kathryn Garber	Saint Mary's College of Notre Dame
Adam Gastineau	Rose-Hulman Institute of Technology
Alexander Goebel	Rose-Hulman Institute of Technology
Jack Good	Purdue University
Dave Goulet	Rose-Hulman Institute of Technology
Thomas Grier	DePauw Univeristy
Brittany Griggs	Purdue University
Ralph Grimaldi	Rose-Hulman Institute of Technology
Jacob Guttman	Rose-Hulman Institute of Technology
Croix Gyurek	IUPUI
Katy Gyurek	IUPUI
Daniel Halmrast	Hillsdale College
Addie Hanchett	Rose-Hulman Institute of Technology
Samantha Hansen	Rose-Hulman Institute of Technology
Angela Hanson	Rose-Hulman Institute of Technology
Daniel Havern	Rose-Hulman Institute of Technology
Megan Heinold	Purdue University
Kylie Hess	Rose-Hulman Institute of Technology
Megan Heyman	Rose-Hulman Institute of Technology
A J Hildebrand	University of Illinois
Jared Hoffman	Rose-Hulman Institute of Technology
Joshua Holden	Rose-Hulman Institute of Technology
Allen Holder	Rose-Hulman Institute of Technology
Leanne Holder	Rose-Hulman Institute of Technology
Sijia Huo	University of Illinois
Tim Husband	Sienna Heights University
Junghyun Hwang	University of Illinois
Christian Jasper	Rose-Hulman Institute of Technology
Xingcheng Jiang	Rose-Hulman Institute of Technology
Jeffrey Kallenbach	Sienna Heights University
Michael Kelly	Transylvania University
Matthew Klapman	Valparaiso University
Alexa Kovacs	Rose-Hulman Institute of Technology
Sonia Lai	Rose-Hulman Institute of Technology
Yuxiao Lai	Rose-Hulman Institute of Technology

Anmol Lamichhane	Earlham College
Mariana Lane	Rose-Hulman Institute of Technology
Tom Langley	Rose-Hulman Institute of Technology
Simon Langowski	Purdue University
Peter Larson	Rose-Hulman Institute of Technology
Barbara Lawson	Aquinas College
Corinne Leopold	Purdue University
Hannah Levine	Rose-Hulman Institute of Technology
Keri Li	Rose-Hulman Institute of Technology
Yifei Li	Rose-Hulman Institute of Technology
Ying Li	Saint Francis University
Ziyi Lin	University of Illinois
Lin Liu	Westminster College
Bochuan Lu	Rose-Hulman Institute of Technology
Maria Maguire	Aquinas College
Namaluba Malawo	Purdue University
Nicole Markley	Purdue University
James Marshall Reber	Purdue University
Matthew Martin	Transylvania University
Lorena Maxwell	Purdue University
Emmett McDaniel	Aquinas College
Michael McDaniel	Aquinas College
Ryan McDonald	Rose-Hulman Institute of Technology
Monica McGrath	Saint Mary's College
Michael Miron	Sienna Heights University
Matt Moon	Rose-Hulman Institute of Technology
Cameron Mooney	IUPUI
Nicholas Moorman	University of Houston
Lester Moreira	University of Houston
Mitchell Murray	Rose-Hulman Institute of Technology
Christian Nunnally	Rose-Hulman Institute of Technology
Daniel Onofrei	University of Houston
Mark Panaggio	Hillsdale College
George Peters	Greenville College
Ethan Petersen	Rose-Hulman Institute of Technology
Mary Petersen	Rose-Hulman Institute of Technology
Forsythia Pezel	Indiana University
Maxx Philiposian	Rose-Hulman Institute of Technology
Zoe Phillips	Purdue University
Anna Poznyak	Purdue University
Peyton Puckett	Purdue University
David Rader	Rose-Hulman Institute of Technology
Pradeep Ranaweera	Sienna Heights University

Pavani Rannulu	University of Maryland, College Park
John Rickert	Rose-Hulman Institute of Technology
Manda Riehl	University of Wisconsin - Eau Claire
Chris Sadler	Rose-Hulman Institute of Technology
Dakota Selburg	Rose-Hulman Institute of Technology
Mykhaylo Severinov	Indiana University
Phillip Shepard	Rose-Hulman Institute of Technology
Charlie Shepherd	Sienna Heights University
Yosi Shibberu	Rose-Hulman Institute of Technology
Michael Smith	Purdue University
Wyatt Smith	Rose-Hulman Institute of Technology
Tristen Spencer	Aquinas College
Shawn Sunshine	Rose-Hulman Institute of Technology
Felicia Tabing	Rose-Hulman Institute of Technology
Seiji Takagi	Rose-Hulman Institute of Technology
Ishank Tandon	Rose-Hulman Institute of Technology
Brady Tanguay	Sienna Heights University
Wayne Tarrant	Rose-Hulman Institute of Technology
Elizabeth Tigner	Purdue University
Erin Tooley	Purdue University
Khoa Tran	University of Illinois
Hollee Trent	Rose-Hulman Institute of Technology
Paige Underwood	Rose-Hulman Institute of Technology
Dylan Vener	Rose-Hulman Institute of Technology
Jiawen Wang	Rose-Hulman Institute of Technology
Tianhe Wang	Rose-Hulman Institute of Technology
Zihan Wang	University of Illinois
Mark Daniel Ward	Purdue University
Han Wei	Rose-Hulman Institute of Technology
Dan Wetklow	Saint Francis University
Matthew Wilkie	Sienna Heights University
Briana Wood	Westminster College
Yilun Wu	Rose-Hulman Institute of Technology
Lin Ye	DePauw Univeristy
Amber Young	Purdue University
Chengzheng Yu	University of Illinois
Arlan Zelenky	Saint Francis University
Tengji Zhang	Rose-Hulman Institute of Technology
Yunxin Zhang	University of Illinois
Muqing Zheng	Rose-Hulman Institute of Technology
Yantong Zheng	University of Illinois
Yifan Zheng	Rose-Hulman Institute of Technology
Ruoyu Zhu	University of Illinois