MESSIAH UNIVERSITY

DEPARTMENT OF COMPUTING, MATHEMATICS AND PHYSICS

2021 School of Science, Engineering and Health Symposium
Computing, Mathematics and Physics Presentation Abstracts
April 30, 2021

Computer & Information Science

Burkina's Promise

Joston W Chan, **Matthew S Coates**, & **Rebecca C Merendino**

We helped build a website application that is meant to store and track information concerning users, sponsors, and children for ease of looking up information. The Burkina's Promise organization started when several short-term mission trips to the country of Burkina Faso revealed a need for helping the children of pastors become educated. The need for the site itself arose when the Burkina's Promise organization outgrew its use of Microsoft Excel to handle all of its data and information. During our time developing the site, we added features such as a User Messaging feature, more visitor pages, and other features. Lastly, we tested the entire site and fixed various bugs such as getting the French translator API to work throughout the user pages and being able to delete children in the database on the frontend via a button.

Behavv

Bryce Doane, **Eddie Daniel**, **Matthew C Laven**, & **Gage L Sapp-Rahme**

Our application was built to aid special education teachers in the monitoring and tracking of students' behavior. Every day, these teachers are asked to record student's performance of specific tasks to track their progression over time. Teachers will then use this data to generate reports to share with other teachers, parents, or counselors of that student. Currently, teachers are using complex and unmanageable spreadsheets to record student's ratings on specific tasks within specific classes. Behavv serves to make reporting this data easier and more user-friendly by simplifying data entry and presenting clear visual representations of that information. Our application allows teachers to focus less on stressful spreadsheets and more on students' success.

ISeek

Nik m Mourelatos, **Sam J Gulinello**, Joseph M King, & Luke A Meads

The iSeek team has built an application to aid people that are visually impaired. If you are visually impaired and have misplaced something you own then you could spend an unwanted amount of time trying to find your object. iSeek intends to solve this problem. Through the use of your phone's camera, alongside a trained chatbot, helps users find misplaced or new objects in their surroundings. iSeek is built with the user in mind, all actions inside the app are voice-activated alongside the classic touch controls. We hope to have created an app that is unique to the market and that has real-world applications to help people live a more enjoyable, easy life.

Hit Pause

Will Newcomb, Tanner Stern, **Joshua Keong**, & Drew Weaver

We created an application that helps provide coping mechanisms for individuals struggling with anxiety. Everyone experiences stress and anxiety in different ways, so we sought after a solution, tailor made to the user, to help them find better ways that work for them to manage their stressors. By taking a few short surveys, our algorithm learns about the user's likes, dislikes, and past experiences with stress to offer handpicked suggestions generated from that data. Each suggestion comes with an excerpt on why it's effective for anxiety, and a playlist from Spotify to help calm the mind during the activity. The more they interact with the app by reviewing those suggestions, the better our algorithm gets at personalizing them for each user.

Development of a Graphical Advising Tool for Computing, Mathematics and Physics

Billy Park & Matthew J Farrar†

Effective degree planning, course scheduling, and advising are predicated upon an understandable and clear curricular hierarchy. Presently, there is no tool at Messiah University that allows students and advisors to simultaneously visualize course requirements, prerequisite structure, and course offerings in an intuitive format.

To this end, I built an application that lets the user—faculty or student—visualize these requirements for degrees in the Department of Computing, Mathematics and Physics. The output of this program is a tree diagram that provides “at a glance” mapping of course sequencing and availability.

HooDat

Eric J Weischedel, **Belosan Wubishet Jekale**, **Wesley Chong**, & Billy Park

We built a mobile app that quizzes you on peoples’ names and faces in order to help users remember them. Humans are bad at remembering people’s names. Despite really wanting to learn someone’s name, many people struggle to recall it, which can lead to feelings of awkwardness. According to Charan Ranganath, the director of the Dynamic Memory Lab at UC Davis, people underestimate the work that needs to be done in order to commit somebody’s name to memory: “People are often overconfident, and they underestimate how hard it will be later on.” It is easy to focus on making a good impression, rather than learning a new name and face. Ranganath asserts that one way to solve this problem is to test your name memory skills: “The act of actually testing yourself on the name will help you retain it better in the long term.” Our application implements this solution by providing a way to create and take quizzes on people’s names and faces. Users can group people into categories in order to associate people with certain characteristics, e.g., classmates or coworkers. Additionally, managers can create lists and share them with other users, making onboarding a new group of people a breeze.

Mathematics

Applications of Options Greeks and the Black-Scholes Equation

Ryan B Althoff

Options Greeks are embedded in the definition of the Black-Scholes equation and have direct applications to the financial markets, specifically through the pricing of options contracts. This presentation endeavors to provide an overview of the Greeks by contextualizing increased retail investor participation and its collective influence on short-term price volatility for select equities. In conjunction with a consideration of the underlying theoretical mathematics, a practical example is presented to demonstrate contemporary relevance and to evaluate the implications for established hedge funds and other financial firms.

Staircase Tableaux

Kasey B Caras, **Maelyn Elder**, **Ian Parzyszek**, & **Morgan Zimmerman**

In this presentation, we will discuss our research on staircase tableaux, which are mathematical objects in the field of combinatorics that have applications in physics and biochemistry. Staircase tableaux are constructed in a similar way to Sudoku puzzles. Boxes are aligned in a staircase shape and these boxes are filled with alphas and betas depending on a few simple rules. In our research, we determined the probability of staircase tableaux that have an alpha followed by a beta on the main diagonal as well as a beta followed by an alpha. These results are interesting because of the applications staircase tableaux have in other disciplines.

Is Your Professor Exaggerating? Investigating the Importance of Conditions in One-Sample Testing

Emily Decker

The conditions of a given hypothesis test should always be taken into account when deciding what test best fits the given data. But what happens when the conditions of normal, rank based, or sign based tests are not fully met? After an introduction to the nuances and power of the usual t, Wilcoxon sign rank, and Fisher sign test, this paper will analyze the efficiencies of these tests and analyze how each responds to violations of the conditions. Through the use of a significant number of iterations of SAS created data sets, it will be shown how frequently normal, symmetric, and non-symmetric data affect the theoretical outcomes of each test. These results will play an important role in understanding the impact conditional violations have on the conclusions and overall which test is best in each data setting.

Sabermetrics

Paul M Hansel

In 1971, the Society for Baseball Statistical Research (SABR) was founded. This society was the first to coin the term “sabermetrics” which refers to the empirical analysis of baseball. Prior to sabermetrics, decisions about players, teams, and coaches in baseball have always been made based upon a subjective interpretation. However, this society started a massive movement of applying an objective-based science such as mathematics to the subjective world of baseball. This combination of an objective science and a subjective sport makes sabermetrics an interesting part of mathematics to explore.

Fisher's and Neyman's Tests in Treatment Analysis

Sarah E Hartman

Fisher's and Neyman's tests are both randomization-based tests that can be used to detect effects of experimental treatments; however, they differ significantly, particularly in the construction of the hypotheses. As a result, each test has specific limitations: in certain cases, Fisher's test can result in either Type I or Type II errors, and Neyman's test relies on approximations of variance and normality. This project offers a comparison of these two tests and an analysis of their limitations through simulations.

Mathematics at Play: A Study of Game Theory Applications

Reece J Horne

The purpose of this presentation is to give an example of applied mathematics being used to enhance mathematics instruction. We show several examples of game theory applications in mathematics where connections are made to the mathematical topics of saddle points on three-dimensional graphs and the use of matrices in representing payoff functions. The main examples explored are two player games where we explore crucial information about each scenario such as the Nash Equilibrium point. The discussion follows as to how these examples can be worked into a mathematics curriculum for enrichment. We conclude by evaluating how effective practices such as game theory applications encourage appreciation, engagement, and performance in instructional settings.

Sprouts & Brussels Sprouts

Joshua J Kantner

Since its conception in the early 18th Century, graph theory, or the mathematical study of graphs, has become a useful tool in solving and analyzing a variety of problems. One of these problems is the seemingly simple pen-and-paper game of Sprouts created by John Conway and Michael Paterson in 1967. Sprouts is an easy game to learn and play for the casual player, but it has proven to be a much more difficult game from a competitive point of view. In order to get a better understanding of how to win any game of Sprouts, the game's properties can be analyzed and studied mathematically with the help of graph theory. The results of such analyses can be helpful in determining each game's outcome as well as understanding new variants of the game when changing a few mechanics.

Deus Absconditus and Game Theory

Devan K Miller

Deus Absconditus is a Latin phrase used by Martin Luther and John Calvin in explaining the hiddenness, or unknowability of our God. In Isaiah 45, the prophet Isaiah writes "Truly you are a God who has been hiding himself, the God and Savior of Israel." Why is it that Christian faith accepts that God cannot be known to us? The study of Game Theory might have an answer. Game Theory is a fascinating extension of Mathematics that seeks to understand risk, analyze social interaction, and provide researchers with an understanding of why "players" behave the way they do. By researching Game Theory, I hope to support my Christian faith by providing an understanding of why our creator has chosen to be unknowable, and require belief without seeing.

Ordering Polynomial Rings

Abigail Mitchell

Polynomial rings are a foundational concept in understanding the characteristics of number systems. Through the examination of specific polynomial rings and their properties, it is possible to develop methods of ordering the polynomials within these rings. In this presentation, a broad introduction to polynomial rings will be provided in addition to an in-depth exploration of ordered polynomial rings and their properties. An understanding of ordered polynomial rings is useful for further development in both number theory and calculus.

Proof and Application of The Central Limit Theorem

Ian Parzyszek

The broad applications of the Central Limit Theorem cannot be understated. It allows one to approximate other distributions with that of a normal distribution, which is crucial in hypotheses testing and modern day statistical analysis. The properties of this theorem have been observed for hundreds of years but its actual discovery and proof did not happen until 1810. The elegance of this mathematical proof is shown in this paper, along with its applicability to modern day hypotheses testing using real world data.

The Tower of Hanoi and Recursive Sequences

Sunny Shao

The Tower of Hanoi is a famous puzzle invented by a French mathematician Edouard Lucas in 1883. The task of that is we are given a tower of eight disks, initially stacked in decreasing size on one of three pegs. The objective is to transfer the entire tower to one of the other pegs, moving only one disk at a time and never moving a large one onto a smaller. How do we solve this problem? This problem may not appear to be related to mathematics, but we can actually use a recursive sequence to solve it. Sequences are mathematical objects discussed in Calculus II and the Tower of Hanoi is just one example of how sequences can be applied in the real world.

The Black Scholes Model

Katie R Stottlemyer

In this presentation, I will discuss the Black-Scholes Model which is an important mathematical model in financial theory for pricing options. I will discuss the background of this model and an example of how it is used. I also will discuss some contradictions that have been found when using the model and how it is still being used.

Mathematical Approaches to Political Gerrymandering

Morgan Zimmerman

With the speculation that electoral maps are divided into boundaries that favor one election outcome over another, the Supreme Court has deemed political gerrymandering as unconstitutional. Various mathematical models have been proposed in an attempt to combat the lack of standardized parameters for detecting the extent to which this occurs. The efficiency gap metric is a simple formula introduced as an evaluation of how extensive districting has favored one party over another within a specific boundary. With the desire to produce a more statistical-heavy method, a hypothetical state is explored and various iterations of boundaries are illustrated in an attempt to find the most effective algorithm. It is concluded that Markov chains could prove useful in the area of redistricting.

Physics

Interaction of Dark Matter Dark Photon Particles with Plasma in the Universe

Nathan Branson & Abaz Kryemadhi†

Dark matter is hard to detect because it does not interact with normal matter with a few exceptions. A dark matter candidate of interest is the dark photon which could convert with some probability to a regular photon. The dark photon is not directly detectable due to small interaction. There is theoretical motivation however to increased conversion to regular photon when it is in the presence of a plasma. We have explored what dark photon masses and what plasma conditions create favorable conditions for its detection. Previous works look at the extreme cases of mass being much larger or smaller than the plasma frequency, while we look for plasma frequency at a similar magnitude to the dark photon mass. We use the earth's ionosphere as the medium for this project. The areas of focus are the regions of plasma frequency matching the dark photon mass where high conversions might occur due to resonance.

This is a computational research project, which uses many concepts from computer science in addition to physics. The analysis for this project is done using the python programming language.

Laser Sheet Imaging of *Arabidopsis thaliana* Roots

Dalton J Daugherty & Matthew J Farrar†

Plant root systems are inherently 3-dimensional structures. To effectively understand these root systems—such as the model organism *Arabidopsis Thaliana*— it is necessary to develop and employ imaging methods capable of generating 3-D data sets. One such method is laser sheet imaging of plant roots grown in transparent media, such as in hydroponic/aquaponic cultures or hydrogels. We have been working on a custom-built laser sheet system to achieve this end. This modality requires the coordination of smooth translation stage motion, camera exposure, and camera frame rate settings. Multiple graphical user interfaces (GUIs) written in custom Python software are necessary to guide the user through the imaging process. This software communicates with the stage, controls laser power, and triggers the camera in order to synchronize motion and imaging to get clear images with definite dimensions. This system can then be used to perform time-lapse imaging of plant root structures to analyze how environmental factors affect root structure and development.

Development of a Detector System for Dark Photon Dark Matter

Ryan J Thurber, Abaz Kryemadhi†, & Niklas Hellgren†

Dark Matter is assumed to exist because of the gravitational effects on stars as they move around galaxies. Efforts have been made to discover its properties in ways such as studying possible inelastic collisions in particles, but they have not yielded conclusive results. Dark photons have been motivated from theory as dark matter candidates. They can convert to regular photons at a small rate. Therefore, my study will strive to discover the regular photons emitted by the dark photons. This can be done by setting up an experimental area shielded from all light sources where the existence of a dark photon would be manifested by the appearance of regular photons in a completely dark area. To increase the chance of detection, a spherical mirror will be used to reflect the photons towards our detector, which increases our effective surface area. So far, I have worked with the photodetector and the data acquisition system in order to understand detector performance in a vacuum, which allows for photons of a shorter wavelength to last longer before they are absorbed, and how to determine the background noise from actual signals.

Development of a Detector for High Energy Gamma Ray Studies

Brandon J Weindorf, Aeowyn Kendall, Al W Mokris, Abaz Kryemadhi†, & Matthew J Farrar†

Despite the rapid progression of knowledge present in the field of particle physics, many mysteries still abound that have yet to be fully solved and understood; one such example is that of dark matter as there is relatively little known about it and many experiments today endeavor to detect it. This project focuses on the use of a relatively new technology, Silicon Photomultipliers (SiPMs), to detect high energy particles incident from space. It is currently hypothesized that dark matter serves as the source of high energy particles that are particularly more energetic than those incident from the sun and supernovae. The Silicon Photomultipliers are coupled with deionized water and scintillating materials to generate and absorb Cherenkov Radiation. While classic photomultipliers (PMTs) can solely be used for this experiment, they cost more and require significantly more power than that of SiPMs. While SiPMs are significantly smaller than PMTs, use of a large volume of water can increase the effective detection range of the SiPM. We detail the design, construction and overall development of multiple Cherenkov Radiation detectors. Moreover, we report on the performance of each design and discuss comparisons among each combination of models. Finally, we present the new data programming tool that has been developed to aid in the analysis and visualization of all collected data.

Acridine Orange as a Novel Tool for Identifying Partially Double-Stranded DNA

Eli Whitehead-Zimmers & Matthew J Farrar†

One of the distinguishing features of hepadnaviruses is the presence of partially double-stranded DNA. Hepatitis B is one of the well-known examples of this virus family, yet there remains a paucity of effective methods for probing this nucleic acid structure. This study investigates the use of the dye Acridine Orange (AO) as a possible probe for understanding these genomes. AO is of interest for identifying partially double-stranded DNA because of its unique spectral properties. Specifically, AO fluoresces red (~650 nm) if bonded to single-stranded DNA (ssDNA), or green (~525 nm) if bonded to double-stranded DNA (dsDNA) by intercalation. To test this system, confocal optics and single-photon counting modules were used to probe dsDNA or ssDNA at the single-molecule level. The ratios of green/red fluorescence by AO-stained DNA in varying concentrations of AO were assessed.

Bold text indicates presenters, † indicates a mentor, and ‡ indicates an external mentor.