Online Proceedings

Poster Session 1

MGH 241, Easel 129

11:00 AM to 1:00 PM

Counting Densities of Discrete Sets

Kimberly B. Bautista, Senior, Mathematics
Mary Gates Scholar
Madeline E. (Maddy) Brown, Senior, Physics: Comprehensive Physics, Mathematics
UW Honors Program
Pilhyun Andrew (Andrew) Lim, Senior, Mathematics
Mentor: Jayadev Athreya, Mathematics and CHID
Mentor: Samantha Fairchild, Mathematics

If you're tiling a circular room with square tiles, how many do you need? What if your tiles are parallelograms? As the circle gets larger, is there a pattern? Mathematically, this can be framed as counting integer points in a large circle. We're interested in how this count changes as you change the shape of the tiles, and to understand this better, we started by counting the number of integer vector pairs within a ball of radius R so that the parallelogram they make has a fixed area (determinant). We created a Python program that would generate all of the primitive points out to radius R, which we then extended to count the number of vector pairs with a certain determinant k. We were able to compute the limiting density of this count, extending known results for the case of determinant 1. We are now studying other discrete sets, such as ones generated by objects from hyperbolic geometry, known as Hecke triangle groups. In the future, we plan to use our research for counting pairs of vectors in different spaces and generalize it for counts of k-tuple vectors. Come for floor tilings, stay for beautiful pictures!

Poster Session 1

MGH 241, Easel 132

11:00 AM to 1:00 PM

Exchange Strategies in Book Sharing Systems

Chuxuan Sun, Junior, Applied & Computational Mathematical Sciences (Biological & Life Sciences)
Emma Deng, Senior, Applied & Computational Mathematical Sciences (Social & Behavioral Sciences)
Mentor: Sara Billey, Mathematics

WMlife Network Technology Company Ltd builds shared bookcases located in kindergartens to rent picture books at a low annual fee. WMlife builds bookcases of different sizes based on the number of students in the kindergartens. For all existing kindergartens in the system, WMlife has been choosing the same set of books for every kindergarten. However, now they are considering supplying different book sets to different kindergartens and exchanging books between them each year to provide new books while reducing total cost. To minimize the time investment by WMlife, we modeled the problem as a periodic traveling salesman problem and used a modified Prim's algorithm and brute-force to find the route with the shortest traveling time. We also constructed a feasible book exchanging algorithm. With our new strategy, WMlife could get a dynamic instruction for book exchanging instantly with kindergarten locations and starting locations as input. WMlife can exchange books easily according to our instructions and significantly reduce cost by 30% in book reallocation approximately. As WMlife expand their services in more cities in China or adding more new kindergartens to the existing city, they could have a smart start of purchasing the book for future cost saving. The system not only solves a one-time problem but also can support WMlife to provide better books and more book types for kindergarten children, help them to form reading habits, widen their horizon and raise Chinese average reading rate.

Session 1L

Mathematical Modeling in the Sciences

Session Moderator: Elizabeth Thompson, Statistics

MGH 271

12:30 PM to 2:15 PM

* Note: Titles in order of presentation.

Mathematical Studies of Data Storage in CD-ROM and DNA
Iuliia Dmitrieva, Sophomore, Engineering Physics, Lake Wash Tech Coll
Dylan Dean, Sophomore, Computer Engineering, Lake Wash Tech Coll
Taylour Mills, Sophomore, Aeronautical Engineering, Lake Wash Tech Coll
Mentor: Narayani Choudhury, School of Science, Technology and Math, Lake Washington Institute of Technology, Kirkland

Current data storage elements have reached their threshold capabilities due to extensive data and limiting size requirements. Digital storage in DNA has aroused considerable interest as the next generation miniaturized high capacity storage device. Deoxyribonucleic acid (DNA) forms the genetic blueprint of life and is the primary carrier of genetic information in living cells and organisms. Data storage in DNA involves encoding of digital binary data into synthesized DNA strands. Here, we employ calculus-based methods to provide a comparative study of data storage capacities of conventional CD ROM and DNA. We use parametric equations to model the spiral structure in CD ROM and double helix of DNA and employ calculus-based methods to study the arc length, curvature and topological properties of DNA. The data storage densities for binary, base 3 and base 4 in DNA are estimated. The calculated data storage densities are found to be in good agreement with reported estimates. Recent studies demonstrate that magnetic nano-knots can be used for data storage. The topological properties of DNA including twists, links and knots thus provide additional attributes which may in future be used for data storage.

SESSION 1L

MATHEMATICAL MODELING IN THE SCIENCES

Session Moderator: Elizabeth Thompson, Statistics
MGH 271
12:30 PM to 2:15 PM
* Note: Titles in order of presentation.

Interactive Construction and Exploration of Hexagonal Mosaic Knots
Kalen Mills, Fifth Year, Applied Computing, UW Bothell
Mentor: Jennifer McLoud-Mann, Engineering and Mathematics, UW Bothell

Mathematical knots are non-intersecting closed loops which may be tangled; links are knots that are possibly intertwined. These 3-dimensional paths often resist description, so mathematicians choose nice ways to describe them. One such way is to project them onto a plane. Even more, it is interesting to build knots in discrete ways such as placing them on tiles in a plane. In this poster we are considering hexagonal mosaic knots, knots that are projected on a plane tiled by the honeycomb hexagonal tessellation. In this way, knots can be built from a small collection of hexagonal tiles with loops. We create an interactive tool which presents hexagonal tile types, a grid on which to lay them, and options for analysis. The researcher uses a point-and-click tool to lay down a mosaic grid, and in so doing, creates an underlying data structure representing the segments contained in the mosaic. When requested, the software traverses this data structure like a linked list. In this manner, one may determine if the data structure represents a suitably connected hexagonal mosaic knot or if it contains dead ends or stray segments; that is, determine if a data structure represents a knot/link or not. This process helpfully assigns segments to their respective knots, distinguishing not only ‘over’ and ‘under’ but also ‘self’ and ‘other’. We hope to continue exploring automatic generation of information about knots from their tiled representations. Once more developed, we hope to be able to answer more questions about the knot or link represented by the data structure. We also hope to continue exploring the use of rapid, flexible feedback from prototypes in aiding exploratory research.

SESSION 2M

MCNAIR SESSION - FROM CHAOS TO ORIGAMI: ADVANCES IN MATH, PHYSICS, CHEMISTRY AND ENGINEERING

Session Moderator: Therese Mar, OMAD and Department of Environmental and Occupational Health Sciences
MGH 288
3:30 PM to 5:15 PM
* Note: Titles in order of presentation.

Homotopy Type Theory and the Foundations of Mathematics
Jordan Leoron Charles Brown, Junior, Mathematics (Comprehensive)
McNair Scholar
Mentor: James Morrow, Mathematics

We investigate recent developments in the foundations of mathematics, particularly homotopy type theory, to determine their viability as foundations of mathematics. Related foundations such as Martin-Löf type theory, topos theory, and category theory are also discussed. We evaluate the possible benefits of a type-theoretic formulation of mathematics and the nature of constructive axiomatic foundations. The research involves a review of the existing literature in these areas and a comparative analysis of the methods used across frameworks. This research is the first step towards the development of languages easily used by computers and mathematicians which incorporate the power and flexibility of non-standard deductive procedures.

Session 2M

McNair Session - From Chaos to Origami: Advances in Math, Physics, Chemistry and Engineering

Session Moderator: Therese Mar, OMAD and Department of Environmental and Occupational Health Sciences

MGH 288

3:30 PM to 5:15 PM

* Note: Titles in order of presentation.

Examining Chaos in a Dynamical System: The Double Pendulum

Brian Nguyen, Senior, Applied Mathematics, Univ New Hampshire

McNair Scholar

Mentor: John Gibson, Mathematics, University of New Hampshire

Periodic orbits provide an underlying structure to chaotic attractors, which provides order and low-dimensionality to complex, chaotic systems. The trajectory of chaotic systems proceeds to infinity for an arbitrary initial condition; for this reason, periodic orbits are useful as a finite set of finite mathematical objects to characterize the infinite, complex behavior of a chaotic system. In particular, the mathematical framework of chaos, chaotic attractors, and unstable periodic orbits allow for a new understanding of self-organization in complex physical systems like turbulence. In this study periodic orbits as an organizing principle will be examined in the Lorenz system and the double pendulum system. This study will find the unstable, periodic orbits of the Lorenz system and the double pendulum system using Newton's method. The expected results of the study are that periodic orbits of both systems will both be found. This study presents an opportunity for an understanding of chaotic behavior which will lead to engagement with the current research on turbulence.