List of student talks and abstracts (alphabetical by last name)

The Chinese Remainder Theorem

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The topic of my talk is to state the Chinese Remainder Theorem as it is found in most Elementary Number Theory texts, with the moduli being pairwise relatively prime. From there, I will then go on to discuss the more general case in which the moduli need not be relatively prime. With the general case, I will outline the proof and provide an example to illustrate it.

Nontransitive Dice

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A set of n dice (each with k sides) is called nontransitive if we can index them D_1, D_2, ..., D_n in such a way that the probabilities P(D_i > D_{i+1}) (0<i<n) and P(D_n>D_1) are all greater than 1/2. In this presentation, we discuss two computer simulations to determine how often nontransitive dice occur.

The Physics of Knots

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Knots tied in real rope-like materials, for example shoelaces, occassionally slip and untie. We present a method for predicting whether a knot will hold. The physics of the model determine a set of inequalities involving the coefficient of friction and the tension of the rope segments. If all of the inequalities are satisfied, the knot will then hold.

A Product of Cosines

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The topic of my talk will be to prove that for an odd number n, the product of all cos(kpi/n) where 1 is less than or equal to k is less than or equal to n, and k and n are are relatively prime equals 1/2^(phi(n)) in absolute value. This talk entails many different areas of mathematics including number theory, complex numbers, and trigonometry.

Every Isometry of R^n is an Affine Function

Andrew Kirby
Slippery Rock University

The aim of the talk is to present a new proof of the theorem which is the title of the talk. My proof is based on M. Laczkovich's representation theorem of isometries by means of reflections and the representation of affine maps as the composition of a translation and a linear map.

SET and All Its Glory

Heather Klink
Westminster College

By altering the original deck of cards for the game SET, an investigation into the mathematics of the new deck evolves. The cards in the new deck still have four attributes, but now the attributes vary in number of values. The investigation includes the number of cards in the deck, the number of sets given a premise at different times and the cap for the game. The game can be played by finding sets of three cards or sets of four cards. Since the new deck has attributes that vary in number, different combinations for each set must also be considered

Factorizations of Polynomials Over Finite Semifields

Brigid K. Mooney
Indiana University of PA

For any polynomial f(x) in B[x], where B is the Boolean Semifield, one would like to determine whether f(x) is factorable, and ideally also determine an algorithm for giving a factorization. To this means, we first understand and try to characterize those polynomials, f(x), which are not factorable over B. It is this problem which is being addressed and I will present some partial results and share new questions about the unique and irreducible factorizations of polynomials in B[x].

Combinatorial Game Theory

Brett Myers
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A "Short" Differential Equations Course

Scott Pellicane
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We discuss the aspects and outcomes of an introductory differential equations course designed to cover less material and offer more detail.

Beyond secure shoelaces - tightening mathematical knots

Michael Piatek
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How much rope does it take to tie a knot? In this introductory talk, we will investigate the problem of tightening physical knots. We will intuitively present the recently conjectured gradient of ropelength as well as discuss its applications. Results and visualizations of the motion of tightening knots will be shown.

Optimization Techniques for Image Restoration

Melissa Pirolli
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In this talk, we present a nonstandard diffusion model for image restoration. This model combines isotropic and total variation based diffusion in such a way that it removes noise while preserving edges. The model is implemented using optimization techniques, in particular the method of steepest descent and the conjugate gradient method. These algorithms can more easily be applied to problems of deblurring and image inpainting.

Hyperspheres and Infinite Series

Peter Schallot
Slippery Rock University

This talk will discuss a solution and generalization of a problem from the Pi Mu Epsilon journal The Pentagon.

Investigations of Wavelets with an Application in Heart Rate Analysis

Jessalyn Smith
Westminster College

Wavelets are used to numerically analyze signals that vary in both space and frequency. Wavelets are more versatile than other numerical methods because there are several different bases to choose from. Any desired base may be used to fit any application. All calculations computed are done so in a time efficient manner. This paper investigates two of the more popular wavelet bases, Haar and Daubechies. It also makes connections between wavelet methods and Fourier methods. Concluding the investigation is a practical application, which demonstrates the use of the Daubechies wavelet in heart rate analysis.

Houdini's Great Escape

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The famous magician, Harry Houndini, used a little more than magic to complete his daring tricks. By using calculus, our job is to determine how Houdini actually completed his "magic" trick of the Great Escape. Houdini's feet were shackled to a block which was placed in a laboratory flask, which was then filled with water. Come see how this magician planned his escape and what calculus was involved in saving his life.

Describing the shape of ropelength-minimized knots

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To characterize ropelength-minimized smooth knots, ropelength-minimized polygons with increasing numbers of edges are analyzed. When comparing the number of edges to different spatial measurements of the optimal polygons, the data will eventually converge to an asymptotical limit. We approximate this limit by fitting simple functions to the sample data. If this can be done efficiently, we can predict the structure of smooth ropelength-minima.

Creating an Interactive Interface for Real Analysis

Lee J Steen
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We have created such an interface that is accessible to any student with internet access and is available 24 hours a day, 7 days a week. This interface provides students with a chance to review important concepts and definitions. At the end of each review, the student has the opportunity to take a quiz that consists of multiple choice, and fill-in-the-blanks. These quizzes provide instant feedback that immediately notifies the student of the correct solutions s/he has, and allows him/her to try again at the ones missed. We have researched other sites and decided how to "filter" them to adapt as a more user friendly enviroment. There was no information taken or used from these sites on our creation [3,4].

We will be discussing how we created this page and the possibilities it holds for improvements. We will discuss the technologies used and the programming languages used. Along with the creation of the page, we will talk about the difficulties we had creating this page and how it has helped students thus far in its life cycle.

[1] Home Page. MIT. <http://www-math.mit.edu/undergraduate/choose-subject.html>.
[2] Home Page. Lousville. <http://www.math.louisville.edu/~lee/rae/rafaq.html>.
[3] Home Page. Secton Hall University. <http://www.shu.edu/projects/reals/>.
[4] Home Page. MAA. <http://www.maa.org/pfdev/tahandbook.html>.

Nearest Neighbor Search with Improved R-Tree Data Structure

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Spatial or multi-dimensional data of images, sounds, texts and videos are being generated at a great rate by plenty of applications. To support content-based retrieval, usually we have to map each object into a point in some n-dimensional space where each object is represented by n chosen features. A set of feature attributes can be mapped into points in some n-dimensional feature spaces. In order to handle these spatial data efficiently, a database system should have an index mechanism to help it retrieve data items quickly according to their spatial locations. The spatial data index structures are built based on points of given objects in a metric space. A high efficiency of query processing is crucial due to the immense size of current databases. The search in such database is seldom based on an exact match of objects. Instead, the search is often based on some notion of similarity. The similarity between two objects is usually measured by using some metric distance function over the n-dimensional space. For many indexing methods, the search structure is built in the form of a tree. Some of the well-known trees include quad-tree, k-d tree, R-tree and its variants, like R+-Tree, R*-Tree, M-tree, X-tree, SS-tree, etc (cf. [1][2][3][4]). The most popular index structure is R-tree. Given a collection of data points and a query point in an n-dimensional metric space, the nearest neighbor search (NNS) problem is to find the data point that is closest to the query point (cf. [5]).

An R-tree is a dynamic hierarchical data structure used for indexing a collection of spatial objects. Every object is described by its covering rectangle Minimum Bounding Rectangle. In an R-tree based index structure, its performance rapidly deteriorates with high dimensions and large volume data sets because of the high overlap of the bounding rectangles in the directory nodes. Usually the number of nodes accessed in each query measures the performance of a NNS. One way of improving the performance of NNS search on R-tree is to reduce the overlap among bounding rectangles. Other way that may help to reduce the number of nodes visited per nearest neighbor search is to reduce the height of the tree. For the same size of data set, that means to store more entries in each node. In R-tree, since it uses the bounding rectangle to specify the object it encloses, the advantage is that it gives a relatively strict bounding of the object so that the overlap area can be minimized, but! on the other hand, it requires much space (two end points) to store this information. Instead of using bounding rectangles, we modified the R-tree by using hyper-cubes as the bounding objects to store the information. In this way, we built a variant of R-tree.

In this paper, we discussed the NNS based on the modified R-tree. A theoretically mathematical analysis is given to compare the time and space efficiency with the algorithm based on the traditional R-tree. We proved that the space efficiency of the algorithm almost double when the dimension of data set is high. The time efficiency is also improved. A simulation Java program is created to verify our results. It shows how the modified R-Tree is built and how the NNS algorithm works on the tree. The basic ideas of building our modified R-tree is similar to building an R-tree by using a bounding object to specify the space that the objects in the sub-tree occupy. The difference is that we will use cubes as the bounding objects. Because each child node of the tree needs less information to be stored in the parent node than R-tree does, so each node can contain more information-has more children. Thus, the height of the modified R-tree is less than that of R-tree and fewer nodes w! ill be accessed in the nearest neighbor search. Furthermore, because of the size of tree is smaller, our modified R-tree has more efficient storage for the same size of data than the R-tree has.

REFERENCE:

1. C. Böhm, S. Berchtold, and D. A. Keim. Searching in high-dimensional spaces: Index structures for improving the performance of multimedia databases. ACM Computing Surveys, 33(3):322-373, September 2001.
2. N. Beckmann, H.P. Kriege, R. Schneider, B. Seeger, "The R*-tree: An Efficient and Robust Access Method for Points and Rectangles", Proc. ACM SIGMOD Int. Conf. on Management of Data, Atlantic City, NJ, pp. 322-331, 1990.
3. P. Ciaccia, M. Patella, and P. Zezula, "M-tree: An efficient access method for similarity search in metric spaces", Proceedings of the 23rd VLDB Conference, Athens, Greece, 1997.
4. A. Guttman, "R-trees: A dynamic index structure for spatial searching", ACM SIGMOD, pp 47-57, Boston, MA, June 1984.
5. N. Roussopoulos, S. Kelley, and F. Vincent, "Nearest neighbor queries", ACM SIGMOD, pp 71-79, San Jose, CA, May 1995.

A brief introduction to thickness and ropelength of mathematical knots

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In this talk, we define the thickness and ropelength of mathematical knots. The thickness of a knot configuration is the radius of the largest non self-intersecting tube about the core configuration. Thickness is controlled by two important factors, the minimum radius of curvature and the DCSD (doubly critical self distance). The minimum radius of curvature controls the thickness when the points on a knot are close to each other with respect arclength, while the DCSD controls the thickness when the points on a knot are further away with respect to arclength.

The Topological Dimension of Limits of Graph Substitutions with More Than One Replacement Graph

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By using methods from the mathematical fields of Topology and Real Analysis, I determine the topological dimension of a set X, where X is the limit of a sequence of graphs G, R(G), R2(G), R3(G), ... These sequences are important because they can be used for data compression. For example, we can consider that a limit set X represents an exceedingly complicated set of data. Rather than storing the whole X, we can just store a very simple set G and a simple rule R, which could give X back to us when we repeatedly apply the rule R to G. Moreover, understanding the topological dimension of X will help us determine which types of data that can be compressed by using this technique. Furthermore, this work will be an essential part of a proof that these limit sets are fractals, a mathematical object of great interest both inside and outside of mathematics.

Optimizing Strategies for Using Calculus Techniques to Predict Stock Market Fluctuations

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The project stems from research conducted by Amanda Hovis, in which a stock market buy/sell strategy was proposed using concepts from calculus and numerical analysis, based on historical stock data. The current research examines NASDAQ Level II data; real-time data of each bid and ask for a given stock. Mathematical tests are run on the Level II data in an attempt to optimize a buy/sell strategy.