A Mathematical Model of Bisphenol A Pharmacokinetics in the Mouse

Stephanie Abascal

Mathematics
Advisor: Chad Topaz

Bisphenol A, commonly called BPA, is the primary monomer used in making polycarbonate plastics and epoxy resins found in baby bottles, linings of cans, plastic bottles, food containers, and even dental fillings. Because BPA can be absorbed in human tissue and can even cause birth defects, it is of interest to determine how the amount of BPA in the body depends on the level of environmental exposure. I use the pharmacokinetic BPA model of Kawamoto and collaborators to address the analogous question for mice, which are considered to be a biological model organism for humans. The model consists of 27 differential equations describing the concentration of BPA and its metabolites in different tissues. Using the Matlab computing package, I solve the differential equations numerically for different levels of environmental exposure. Finally, I construct a simplified three-compartment pharmacokinetic model that retains the essential features of the full model, and use it to make predictions which may be tested in the full model.

Making Java Fly: Just-in-Time Compiler Optimization

Owen Anderson

Computer Science
Advisor: Susan Fox

Languages like Java and C# advertise the ability to "Write Once, Run Anywhere," whereby the programmer compiles their code to a bytecode file, which can then be run on any computer that supports Java or C#. How is this incredible portability achieved?

Every copy of the Java Virtual Machine contains a dynamic optimizing compiler that converts bytecode into the computer's native instruction set as the program runs. However, because the compiler is executing at the same time that the program is running, the speed of the compiler can have a dramatic effect on the perceived performance of the Java program.

The challenge of a dynamic optimizing compiler, such as those used in Java and C#, is to balance the power of its optimizations with the compile-time cost of applying them. In this talk, we'll look at this problem and some potential solutions. We'll see that, with clever caching and algorithms, we can improve the cost of important optimizations by half, without any noticeable loss of native code quality!

A New Kind of Shuffling: The Set Partition Representation of the Symmetric Group

Owen Anderson

Mathematics
Advisor: Tom Halverson

In the 1980s, mathematician and magician Persi Diaconis proved that seven riffle shuffles are required to randomize a standard deck of cards. While this might seem like nothing more than a nifty card trick, it is actually a deep proof about the regular representation of the symmetric group. The shuffling of the cards corresponds to an element of the group algebra, and its eigenvalues determine the rate of randomization.

In this presentation, we'll look at a different representation of the symmetric group: the set partition representation, and see what we can learn about about the shuffling action this corresponds to. We'll look at what we know, what we can prove, and what work lies ahead in understanding this action.

Probabilities of Rare Events: The Dove and Randy Johnson

Reed Andrews

Mathematics
Advisor: Victor Addona

Strange things happen every day. For example, in a 2001 spring training game, baseball pitcher Randy Johnson killed a dove with a 95 mph fastball. In this paper we examine this particular event in more detail and estimate the probability that any single baseball pitch will strike a bird. The methodology involves liberal use of oversimplification, some basic probability and statistics, empirical research, and even a little physics. The final probability estimate is, in the author's opinion, quite reasonable.

On the Number of Prime Numbers less than a Given Quantity

Kyle Braam

Mathematics
Advisor: David Bressoud

Bernhard Riemann's hallmark 1959 paper "On the Number of Prime Numbers less than a Given Quantity" introduced new ideas, such as complex analysis, to the study of prime numbers. These ideas would led in 1896 to independent proofs by Hadamard and de la Valle Poussin of the prime number theorem. This paper is a translation and examination of Riemann's paper and the work leading up to the prime number theorem. The Riemann Hypothesis, which was formulated from Rieman's paper, is also discussed.

Avoiding the Next Sumatra Earthquake and Tsunami: Improvement of Earthquake Forecasting Through Magnitude Error Analysis

Amy Coddington

Mathematics
Advisor: Danny Kaplan

Scientists are hard at work trying to improve their methods of forecasting earthquakes, a process that will lead to an improvement of infrastructure in areas of high seismic activity. Yet in the formulation and evaluation of these earthquake forecast models, magnitude uncertainty due to the location and technology of the stations recording the earthquakes is often neglected. Using synthetic earthquake catalogs, I investigated the effect of different magnitude error distributions on defining characteristics of earthquake catalogs. Furthermore, I analyzed the Southern California Seismic Network catalog using the Kolmogorov-Smirnov test and found a Maximum Likelihood Estimate for a best-fitting error distribution. These results will be helpful to testing laboratories as they seek to account for magnitude uncertainty in their testing programs.

Modeling the Effect of HIV/AIDS Interventions in Swaziland

Innocent Dlamini

Mathematics
Advisor: Chad Topaz

The devastating socio-economic effects of HIV/AIDS are felt worldwide and yet there is no country in the world with a higher HIV prevalence than Swaziland. UNAIDS estimates that 33.4 percent of the sexually-active population in Swaziland is HIV-positive. In this paper I use mathematical modeling to predict the long-term effect of three of the main intervention techniques that are currently used in Swaziland namely, male circumcision, administration of antiretroviral therapy and focusing on high-risk individuals (female sex-workers and their male clients). Although antiretroviral treatment seems to be the most promising, development of drug resistance can worsen the situation. Male circumcision and high-risk intervention have less effect on reducing HIV prevalence but they are at least more reliable than antiretroviral therapy. A combination of the three intervention techniques produces the best results but that comes at a higher economic burden.

Implementing a Bluetooth and Wifi Mobile Ad-hoc Network Protocol

Christopher Dragga

Computer Science
Advisor: Libby Shoop

Mobile ad-hoc networks (MANETs) provide a useful means of connecting computers in unusual situations, such as search and rescue. However, they ignore those small, highly mobile devices that only support Bluetooth, a low-range, low-bandwidth Wifi alternative that consumes significantly less power. Allowing these devices to connect to Wifi MANETs could permit a variety of applications, from text messaging to VOIP to parallel processing. Bluetooth features several unusual characteristics that could make this difficult, though. This capstone presentation will discuss how I attempted to surmount these problems in actually implementing software that performed this integration. It will also deal with the actual performance, both physical and simulated, of this integration, giving an idea of just how well this combination will actually work.

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Do IMF loans and programs improve economic growth rates in recipient countries?

Ozkan Erguden

Mathematics
Advisor: Victor Addona

Established in 1945 with 29 member countries, the International Monetary Fund (IMF) is currently a huge international organization with 185 member countries and around $17 billion worth of loans outstanding. I analyze the effect of IMF policies and loan size on economic growth rates of borrowing countries. Specifically, I examine the effects of IMF involvement in different regions of the world separately, using a panel data for 127 countries over the period 1975-1995 and an instrumental variable approach to address endogeneity problem.

Finding Paths: An Exploration of the Connection Between the Young-Fibonacci Lattice and the Okada Algebra

Ian Goldstein

Mathematics
Advisor: Dan Flath

This work is concerned with the Young-Fibonacci lattice and the representation associated with it, the Okada Algebra. Particularly, focus has been placed on the combinatorial relationships particular to the lattice and with a study of Okada's original formulation and proofs. To this end, many of the basic elements of Okada's construction have been automated using *Mathematica* as a part of this project. The result of this was a process which can generate the matrices of Okada's algebra directly; however, this process becomes laborious at higher ranks and relies on algebraic rather than combinatorial methodology.

Algorithms that Compose Music

Mauricio Gomez Diaz

Computer Science
Advisor: Susan Fox

Algorithmic composition consists of generating musical pieces through computer code. This field draws heavily from mathematics and artificial intelligence, blending music and computer science. The main models devised for computer-generated music are organized and presented in a way that reflects their complexity and capabilities. The theoretical foundations, fundamental functioning, and abstractions implemented by each of the techniques are illustrated for each model. Practical musical examples are then provided with the purpose of demonstrating the advantages and limitations of the models. Bearing in mind that algorithmic composition is a field that differs from the general problem solving purpose of computer science, the possibilities and practical applications of this field are given after the models have been discussed.

Mathematical Models of Traffic Flow

Emily Gras

Mathematics
Advisor: Dan Flath

The purpose of this project is to investigate and examine Cellular Automaton (CA) models for traffic flow. This paper provides background information on the mathematical modeling of traffic flow and explores two particular CA models in more detail. To compare and investigate the two models more effectively, programs that implement the models are created in *Matlab* while simulations in *Mathematica* serve to visually demonstrate the execution.

Separating Data into Groups

Nisse Greenberg

Mathematics
Advisor: Danny Kaplan

Sometimes data can be best described by separating the data into smaller groups and analyzing each group individually. This presentation sets out to illustrate a method which is efficient and effective in finding those groups. The method is the Expectation Maximization Algorithm. This presentation will show different types of clusters that can be separated using this algorithm and how to implement it. Multiple dimensional groups, groups with similar slope, and groups with similar second derivatives. The methods described in this presentation to analyze data are necessary in the understanding of different data sets.

Robot Creativity: The Darwinian Method for developing Artificial Intelligence Visual Art

Shathel Haddad

Computer Science
Advisor: Prof. Susan Fox

Artificial Intelligence is one of the areas of computer science that is experiencing extensive research and fascinating innovations. While we try to simulate the cognitive processes of human beings, we are confronted with questions concerning machine creativity, which has been a philosophical, psychological and scientific dilemma for the last 50 years. What does it mean to describe someone as "creative"? Can the psychological models of creativity be translated into machine code? Where has contemporary artificial intelligence research succeeded and failed in reproducing creativity? One of the promising tools of machine creativity is genetic algorithms. These algorithms, inspired by the natural selection of Darwin's Theory, create highly efficient and complex results in creative fields like music and visual art. In this paper, we explore the power of genetic algorithms as creative tools, focusing mainly on the work of Karl Sims who used them to develop evolving virtual creatures and visual art. Using mainly a combinatorial model of creativity, and a dynamically-changing rule set, Karl Sims' algorithms produced surprising and aesthetically-pleasing images from random chaos. Despite this progress in artificial intelligence art, its creativity is questioned by the community of traditional artists. Will this new generation of virtual artists ever be accepted and praised by human artists? Are we approaching an era where the enigma of human creativity and genius can just be coded into a machine, or will creativity always be exclusively a human attribute?

An OCR System for Chinese Characters

Sam Handler

Computer Science
Advisor: Susan Fox

In order to process a scanned document, a computer must examine an image of text and determine the characters contained within; this process is called Optical Character Recognition (OCR). OCR is particularly challenging in a language such as Chinese, which contains thousands of possible characters, as compared to the mere dozens found in an alphabetic language such as English.

I implemented portions of an OCR system for Chinese characters, using several important principles. First, instead of comparing all of the data for a character, the system locates the lines (called strokes) that each Chinese character is composed of, and builds a graph representation of how the strokes relate to each other. Second, the system looks for common subpatterns within the characters, and utilizes a database of subpatterns and which characters contain them. This eliminates the need to compare input against each possible character, greatly increasing the efficiency of the system.

Attributed Subgraph Search

Sam Handler

Mathematics
Advisor: Andrew Beveridge

A graph is a set of points, pairs of which are connected by lines. Graphs are very useful for representing certain kinds of data (e.g. a chemical molecule). However, a graph alone is not frequently enough to represent all of the data about a collection of objects (e.g. the types of atoms within a molecule). To store this additional data, values are added to the points and lines of a graph; this forms what is called an attributed graph.

It is often useful to know if a graph contains a copy of another graph somewhere within it; such a graph is called a subgraph. For example, given a chemical molecule, one may want to know if it contains a certain molecular structure. I have explored several algorithms for performing such a search on attributed graphs, as well as a way to convert attributed subgraph search problems into ones using unattributed graphs.

The Wide World of Web Applications

Wesley Hart

Computer Science
Advisor: Danny Kaplan

Do you ever wonder how a web site like **Amazon**, **Google**, or **Netflix** works? About what is going on behind the scenes to allow users to buy products or find what they are looking for? Websites across the globe use a variety of different approaches to creating their sites. Even within a given website, developers often use multiple programming languages to handle different components of their system. However, almost all web applications can be abstracted to the same three basic components: the front end, the application tier, and the back end. The front end is the portion of the application seen by the user: the web pages, graphics, and forms through which the user submits information. The application tier is the programming code which interprets the information sent by the user and links it with the data in the database. The back end contains all of the data needed by the web application: user information, product information, etc. The construction of these components, however, varies greatly. Over the summer of 2007 I created a web application with Danny Kaplan. In my talk I will explain the structure of a web application, describe how they are implemented today, and provide analysis of the strengths and weaknesses of languages used in the myriad components of a web site.

The Mathematics of Option Pricing

Viet Hoang

Mathematics
Advisor: Victor Addona

Financial derivatives have started the revolution of the financial market in the early 1980s. Lie at the heart of all the current complex financial instruments is option. Option is a financial derivative that gives its holder the rights (but not the obligation) to buy or sell a certain underlying asset. The pricing of option has received attention from worldwide scholar and it has laid the foundation for determining the price of similar instruments. From the Binomial Option pricing method to Black – Scholes – Merton option pricing, the financial world has witnessed dramatic changes. In this presentation, I will walk you through both the Binomial Option pricing and Black – Scholes method and how they have impacted the financial market.

What is the Effect of Wal-Mart on Average Retail Wages?

Murat Ilgen

Mathematics
Advisor: Victor Addona

The retail giant Wal-Mart has a great influence on the economy with $285 billion in revenue; however, its effect on retail earnings is ambiguous. In this paper, I try to capture the effect of Wal-Mart on retail wages using the instrumental variable method, which also takes the endogeneity problem into account. My results indicate that Wal-Mart's entry to a county slightly increases the average retail wage. I also include a case study to analyze the regional effect of Wal-Mart on retail wages in the East Coast, Midwest, South and West Coast. My results, however, indicate that Wal-Mart does not have a significant effect on retail wages in these four regions separately.

Post-election audits: Statistical power based methods

Katherine Lim

Mathematics
Advisor: Victor Adddona

Post-election audits are an important part of our election process because they offer one method to verify that the candidate who obtained the most votes was actually declared the winner. Currently, most states' procedures call for recounting a fixed percentage of precincts in each race; however, researchers have developed an improved method that uses the criteria of statistical power to determine the audit sample size.

This approach ensures a high probability of detecting a miscounted precinct if enough exist to have altered the election outcome. If a miscount is detected in the audit, it is not clear how the audit should proceed. The development of a "trigger" that indicates whether auditing should continue is a necessary piece of a complete audit procedure.

In my capstone, I examine possible "triggers" for further auditing based on different methods of estimating the net gain in votes for the originally reported loser. Simulations were used to compare the statistical power and false positive rates of various triggers. Two methods maintained high power throughout various miscount situations: (1) a modified bootstrap confidence interval and (2) a modified Hoeffding bound.

Spectral Analysis of Cayley Graphs through Representation Theory

Michael Bennett McNulty

Mathematics
Advisor: Andrew Beveridge

There are distinct similarities between group theory and graph theory. Intuitively, one can equate the elements of a group with the vertices of a graph and the operation of the former with the edges of the latter. This paper explores this connection by expressing both as matrices. The relation between the two serves to facilitate the spectral analysis of graphs. Our investigations consider various examples, including a proof of the isomorphism between the Cayley graph generated from the set of reflections of a dihedral group and the complete bipartite graph.

Representations of Temperley-Lieb Algebra Doing algebra with pictures

Anne Moore

Mathematics
Advisor: Tom Halverson

Everyone multiplies numbers and matrices, but algebraists have discovered ways to multiply certain types of pictures. Temperley-Lieb diagrams are easy and fun to multiply. The goal of this project was to find matrices that multiply in the same way. To find such matrices, we use another sort of picture:

structures of boxes with numbers inside called Young tableaux.

Inequality: Measurement Issues, Trends & Importance
A Cross-Country Time Series Data Analysis

Elad Rachevsky

Mathematics
Advisor: Victor Addona

This paper presents and challenges some of the prominent theories regarding inequality. These include the relationship between inequality and growth, education, health, population, savings, demographics and sector employment. The study finds that agriculture output and mortality rates are significant in determining the inequality gap, while growth rate of population is not. More important is the observation that inequality responds to different variables in distinguishing manner across-countries (e.g. Malaysia and Mexico). The assertion that inequality works through different channels in different countries appears very plausible. Consequently, policy makers should assess each case independently. Their efforts are greatly dependent on and currently limited by the availability of reliable data and aligned incentive systems. Their emphasis should be on targeting the relationship between growth and inequality as it appears to be at the core of the subject.

Exact Sampling Using Coupling from the Past

Andrey Russinov

Mathematics
Advisor: Andrew Beveridge

This work concerns with the application of the Ising model to the study of ferromagnetism. The main interest of the model concerns with the physics of phase transition, where the phenomenon of "spontaneous magnetization" occurs under a certain temperature of the system. The model is implemented on a 2-dimensional square lattice, and the effects of temperature on random alignment of the lattice sites are analyzed with the purpose of determining the critical temperature at which phase transition occurs.

Simulation of the Ising model is implemented in the framework of Markov Chains. The Gibbs sampler is used to simulate the progression of a Markov chain where at each step the spin of a random lattice site is updated according to the Boltzmann distribution. The model implements the Propp-Wilson algorithm of coupling to the past to determine the stopping time for the Markov chains. The algorithm is modified with the application of the sandwiching technique, where using the non-total ordering of the states of the model only the two extreme states are followed to detect the coalescence of all chains.

Nonlinear Dynamics and Music

Sarah C. Sutter

Mathematics
Advisor: Chad Topaz

Chaos can be used for a variety of applications. Diana Dabby has developed an application that uses chaotic trajectories to create musical variations from an existing piece. The pitch sequence of a musical work is assigned to x-values from a trajectory of the Lorenz equations. A new trajectory of the Lorenz equations with slightly different initial conditions is evaluated at the same time intervals as the initial trajectory. A chaotic mapping between the two trajectories can then be used to form a new ordering of the pitches, or a musical variation. The results of a computer program that implements this mapping are presented here, as well as an analysis of the technique and its practical applications to modern composition.