Fall 2004

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University of Dayton. Department of Mathematics

Abstracts of the Colloquium Talks: Fall 2004
Department of Mathematics

Shape Spaces, Metrics, and Object/Image Relations
Dr. Peter F. Stiller

Abstract: The study of shape is concerned with properties of geometric configurations, such as collections of points and lines that are invariant to a particular group of transformations. For example, two collections of points might be viewed as equivalent if they differ by rotation, translation and/or scale. The set of equivalence classes (shapes) often form a Riemannian manifold, where the metric gives a notion of how similar or dissimilarity two shapes are. We will discuss these notions and their application to problems in object recognition. We will also introduce object/image relations which describe constraints on all the image shapes of a particular object shape or constraints on the object shapes capable of producing a specific image shape.

Numerical Solutions of the Helmholtz Equation for Optical Applications
Dr. Shekhar Guha

Abstract: Propagation of light is governed by the Helmholtz equation. For optical systems in which the angles between individual rays of light and the direction of propagation of the overall light beam is small, the 'paraxial approximation' applies. In many systems of interest, for example, when light is tightly focused by a lens, the paraxial approximation is invalid. Some recent work will be presented on attempts to numerically solve the Helmholtz equation in the paraxial and the non-paraxial cases, using differential and integral methods. One application of this work is in accurately describing the aberrations arising from focusing of light by lenses.

Introduction of Derivative and Derivative Pricing
Dr. Ruihua Liu

Abstract: Derivative pricing is the core of financial mathematics. In this talk I'll introduce financial derivatives first, then the arbitrage pricing principle that is used to price derivatives. A simple example is presented to explain the general methodology for derivative pricing. The famous Black-Scholes partial differential equation for option prices will be derived using a mathematically less rigorous but intuitive way. Finally, recent research based on regime-switching model will be mentioned.

Pebbling Results by Undergraduate Researchers
Dr. Aparna W Higgins

Abstract: Consider a connected graph with pebbles distributed on its vertices. A pebbling move on such a graph consists of removing two pebbles from any one vertex, discarding one of those pebbles and moving the other pebble to an adjacent vertex. The pebbling number of a graph is defined as the least number of pebbles m, such that, for any distribution of m pebbles, one pebble can be moved to any designated vertex using a sequence of pebbling moves. In the fifteen years since the pebbling number of a graph was defined, undergraduates around the country have contributed significantly to the body of

results on pebbling. Their results have been published in research journals and have been presented (with contagious excitement!) in contributed talks and in poster sessions. This talk will focus on some undergraduate pebblers and their results. This talk was originally given by Aparna Higgins as an MAA Invited Address at the Providence MathFest in August 2004.

From ODEs to SDEs: Theory and Numerics of Stochastic Dynamical Systems
Dr. Henri Schurz

Abstract: Starting from some key concepts known from the qualitative theory of ODEs and deterministic dynamical systems, we will sketch some basic aspects on stochastic dynamical systems, in particular on the prototypes of stochastic differential equations (SDEs), their stochastic-numerical methods and some potential applications. These objects are often met in Natural and Environmental Sciences, Financial Markets and Marketing when ``uncertainty'' in modeling or ``erratic behavior'' of the environment plays an essential role. The formulas of Dynkin and Ito (as stochastic counterparts of deterministic chain rule) turn out to be the crucial tools to carry out a rigorous mathematical analysis. In fact, they provide existence, uniqueness, asymptotic properties and the link between continuous and discrete time stochastic dynamical systems. As a generalization, we obtain stochastic Taylor expansions of functionals of SDEs (Wagner-Platen formula). As in deterministic analysis, the latter formula is essential for the systematic construction of stochastic-numerical methods and an investigation of the qualitative behavior of their continuous time limits by approximating simulation. In particular, if time permits, we present our own results in view of the general framework. So we arrive at the main principles of stochastic approximation theory (random versions of Lax-Richtmeyer theorems), uniform estimates of nonlinear contractivity and stability exponents, the class of balanced implicit methods, preservation of boundary conditions, asymptotically exact numerical methods, stochastic dissipativity, stochastic attractivity - a fairly general stability analysis of stochastic systems and some convergence results. We shall end with some applications in Engineering (reliability of stochastic systems, Lyapunov exponents, exit times), Mathematical Finance (stochastic interest rate modelling, asset and option pricing with random volatilities, path-dependent and convex price functionals) and Marketing Sciences (innovation diffusion). We are aiming at giving some overview rather than a too technical lecture and at making this lecture as simple as possible such that the interested audience can grasp some ideas about the possible range of further application fields up to the analysis of (random) time series as met in practically oriented data analysis with financial and ecological data series.

Temporal and Spatial Evolution of Population Density and Power in a 3-level EDFA Environment
Dr. Monish Chatterjee

Abstract: The concept of optical amplification within a glass fiber transporting light emerged in the late 1960s, and was demonstrated in the early 1970s using doped erbium ions as the active particles that lead to signal amplification. The basic mechanism for light amplification in the erbium doped fiber amplifier (EDFA) is essentially the same as that in a laser oscillator, the main differences being that an EDFA requires a laser pump (instead of a wideband source or a drive current), and amplifies signal photons instead of noise photons. Due to the similarities in their physics, both laser oscillators and EDFAs are analyzed via the so-called rate equations, and associated power equations. Typically, the rate equations are solved under a temporal steady state assumption, whereby the population densities do

not change with time. Thereafter, the spatial evolutions of the laser power and spontaneously emitted power are calculated. In the case of the EDFA, the rate equations for population densities and the evolution equations for pump, spontaneous emission, and signal power are inherently nonlinearly coupled, and transient or non-steady-state solutions are analytically intractable. In this talk, we first present some of the standard steady-state solutions for the three types of power. Thereafter, we assume temporal steady state for the populations to numerically track the spatial evolution of power, without assuming spatially constant values for the populations, as is commonly done. The resulting spatial variations of the number densities and the powers are then interpreted in terms of the purely steady state results. An extension of this work would be to study the temporal stability of these spatial solutions.

On Hadamard Matrices of Order $4p^2$

Dr. Siu Lun Ma

Abstract: A Hadamard matrix of order n is an $n\times n$ matrix H with ± 1 entries such that $HH^T=n$. There is a well-known conjecture saying that Hadamard matrices of order n exist if and only if either $n=2$ or n is a multiple of 4. In this talk, I shall discuss a construction of Hadamard matrices of order $4p^2$, using a finite field of order p^2 where $p\equiv 7\bmod 16$.

The Work of Student Revisited

Dr. Jim Duarte

Abstract: Back in the days when working for a brewery was less socially acceptable, Gossett decided to publish under a pen name. Thus, we have the student's t distribution and the Studentized Range. Society has changed, and working for a brewer is not only acceptable but enviable. The aspects of statistics in brewing cover the so-called waterfront... or beerfront (enhanced water, as it were). Data is everywhere. Quality data is analyzed for raw materials used in brewing the beer, packaging materials and finished product. Yes, people actually get paid to taste beer. Other areas of the company where data analysis is essential include: finance, production scheduling, new product and package development, salary administration, audit, tax and procurement. Optimizing processes is the goal of all organizations. Mining data and designing valid experiments helps organizations to meet that challenge. Examples from several of these areas will be discussed as well as a few from other industries.

On Wavelets and MRI Imaging

Dr. Eric R. Kaufmann

Abstract: In this talk, we will define and give examples of multiresolution analysis. In particular we develop the Haar and Daubechies families of scaling functions and wavelets. We then discuss the Mallat algorithm for the fast wavelet transformation. As an application of wavelet analysis we consider Magnetic Resonance Imaging. Due to their localization in space, wavelet encoding has two distinct advantages over the traditional Fourier encoding. The first of these is a reduction in motion artifacts while the second is a decrease in imaging time.

An Analysis of FSIS Statistical Practices Regarding Foodborne Pathogens: Preliminary Reporting

Dr. Barb Kowalcyk

Abstract: A number of problems in the US Department of Agriculture's (USDA) Food Safety Inspection Service's (FSIS) statistical practices regarding foodborne pathogens are discussed.

In the Fall of 2003, FSIS issued three separate press releases announcing declines in three serious and potentially life-threatening foodborne pathogens, E. coli O157:H7, Listeria monocytogenes and Salmonella, in meat and poultry products. These press releases present results from regulatory verification tests to check for pathogens in individual plants and uses these results to make statements about declines in rates of E. coli O157:H7, Listeria monocytogenes and Salmonella. However, the Verification Testing Program was not statistically designed to estimate national prevalences of foodborne pathogens in meat and poultry products. Presenting the results without the proper caveats has the effect of misleading the public into thinking that national prevalence rates for these pathogens are decreasing. Other improper comparisons have also been made in these press releases. For example, FSIS made direct comparisons between totals for a 9-month period and totals for a 12-month period and compared the results of the Verification Testing Program to results from Baseline Microbiological Studies done in the 1990's. Again, this gives the impression that the national prevalence of these pathogens is decreasing.

A review of the Baseline Microbiological Studies and the Verification Testing Program found additional statistical problems. The Microbiological Baseline Studies, which were conducted in the 1990's to estimate national prevalences for selected foodborne pathogens and used to establish performance standards for HACCP in 1996, were flawed in their design and scope, especially in regard to ground meat products. Some of the problems include inadequate sample sizes and lack of testing during summer months when levels of pathogens are known to be higher. The Verfication Testing Progam is also flawed because it is not statistically designed, samples different establishments from year to year and samples are not randomly taken. Further, the program collects significantly higher number of samples from beef products which tend to have lower levels of Salmonella and smaller number of samples from poultry products which tend to have higher levels of Salmonella. Compounding this disparity is the fact that the program presents unweighted percentages rather than weighted percentages. Upon closer review of these press releases and related source documents, it becomes apparent that FSIS is not using good scientific practices in their statistical methods and reporting.

Predicting Subsurface Flow and Transport in Strongly Heterogeneous Porous Media
Dr. C. C. Huang

Abstract: The understanding of subsurface fluid flow and transport in heterogeneous porous media is very important in a number of applications (e.g., the transport of contaminants in groundwater reservoirs, brines in petroleum reservoirs.) There usually is large uncertainty in predictions for outcomes associated with subsurface flow and transport, which arises largely from the complexity of the geologic architecture of the flow regime. Most existing stochastic models for solute mass spreading relate the second order spatial bivariate moments (the spatial covariance) of the log hydrologic conductivity to the spatial covariance of fluid velocity. Though some models were claimed to be quite robust, the current theory for both flow and transport can only be applied under the assumption of small variance for log

conductivity. In this talk, I shall introduce a few stochastic model to partially overcome this smallness assumption. The model is based on a new idea for decomposing random functions, which is different from the commonly used Reynolds decomposition. In particular, the variance of a geospatial attribute will be decomposed into two parts according to the hierarchical architecture of the sediments. The first one measures the mean contrasts across different units at different hierarchical levels. The second part measures the variation arising within individual units at the smallest scale. I shall demonstrate that our stochastic model is valid under the assumption that only the second part of the variance of log conductivity is small. Analytic expressions for fluid velocity and macrodispersion coefficients will be developed. I shall then improve and use the homogenization theory for partial differential equations with oscillating random coefficients to evaluate these analytic expressions.