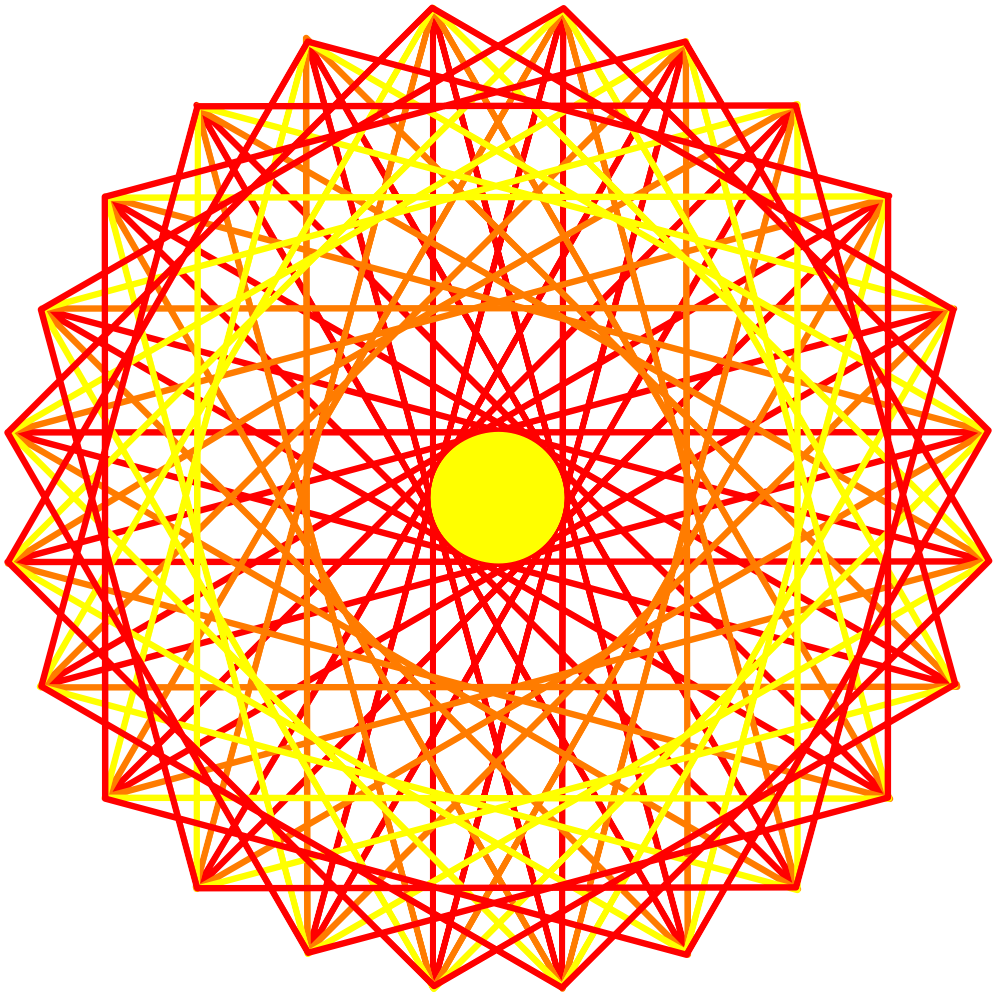
8th Conference for African−American Researchers in the Mathematical Sciences

Princeton University, June 18−21, 2002



CAARMS8
Speaker Abstracts

SPEAKER INDEX

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ON THE GEOMETRY OF LOCALLY CONFORMAL SYMPLECTIC MANIFOLDS

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We describe some basic examples of locally conformal symplectic (LCS) structures, (these are given by non-degenerate 2-forms which, locally become closed when multiplied by a local positive function). We show the connection between LCS structures and symplectic, contact, Jacobi structures. We introduce the following invariants of LCS structures: the infinitesimal and global automorphisms, a cohomological conformal invariant (living in the first cohomology group of the automorphism group), the Lee homomorphism, and the adapted cohomologies of the underlying manifold. Finally, we discuss some applications to Mechanics.

APPLICATIONS OF VARIATIONAL INEQUALITIES

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Since its birth in the mid-1960's, the area of variational inequalities has experienced a phenomenal growth. It is now considered a field in its own right. Many physical problems can be formulated as variational inequalities. I will give a few examples of such problems. I will discuss some directions in the field in which I personally have been going at the talks end.

THE MONGE KANTOROVICH THEORY AND ITS APPLICATIONS

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We discuss recent applications of the Monge-Kantorovich theory to meteorology, kinetic theory, functional inequalities, and partial differential equations. We briefly mention its connections with the KAM theory, one of the fundamental branches of dynamical systems.

RESOLUTION OF SINGULARITIES: AN INTRODUCTION TO ALGEBRAIC GEOMETRY

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Algebraic geometry is the study of solutions to systems of polynomial equations over a commutative ring, usually a field. We call the set of solutions a **variety**. These varieties have additional structures, which may depend on the commutative ring.

One area of active research is the resolution of singularities. Given a variety X with singularities, the motivating question is: Does there exist a *smooth* variety Y and a projective birational map $Y \xrightarrow{\pi} X$ such that π is an isomorphism away from the singular locus $Sing(X)$ of X? Another important problem related to resolution is principalization of ideals. For our thesis, we gave a simple and constructive algorithm for principalization of monomial ideals.

Our aim in this talk is to introduce the audience to algebraic geometry by describing the problem of resolution for curves and surfaces, including our algorithm for principalization of monomial ideals, and to give some examples.

SAT SCORES FOR SALE? PSEUDOEXPERIMENTAL ASSESSMENT OF COMMERCIAL TEST PREPARATION VIA OPTIMAL FULL MATCHING

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Stratification is an old, flexible, efficient, and conceptually plain statistical technique. If there is sufficient pre-treatment data to discern which study subjects are comparable to one another, and if every treated subject is sufficiently like some control to justify comparison to it, then with the right stratification one can rightly estimate treatment effects simply by averaging and differencing outcomes.

The right stratification need not take a simple form, in which case algorithms commonly in use won't find it. However, there is always a so-called full matching that is as good as any other possible stratification. Full matchings enjoy various practical and theoretical advantages over other matchings. Since no existing statistical software creates full matchings, I have developing S routines that do so easily; I shall illustrate their use by analyzing an observational study of effects of commercial test preparation on SAT scores.

TUTORIAL: A BRIEF INTRODUCTION TO SOLITON THEORY IN SOME NONLINEAR PDE's

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Over the past twenty years, there has been great interest in nonlinear phenomenon ranging from shallow water waves to optical pulses in glass fibers. The goals of this tutorial are: (1) to give the general listener an introduction to solitons and how they arise in nature, (2) to discuss how nonlinear and dispersion effects play a crucial role in soliton theory and (3) to give one a sense of the excitement in studying these types of problems.

TUTORIAL: A LINEAR PROGRAMMING APPROACH TO MULTIPLE SEQUENCE ALIGNMENT

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The advent of large scale sequencing of DNA has triggered a massive accumulation of DNA sequence data and data about proteins- the products of the genes encoded by DNA. Methods for applying this information to fields such as law enforcement, biotechnology, medicine or to gain crucial understanding of the biological significance and functionality of genes and proteins depend on a technique known as sequence alignment. An alignment is an array that displays the degree of relatedness of a set of sequences (either DNA or protein) through matching and equivalent substitutions and the insertion of gap characters that are used to maximize the degree of similarity. The quality of the alignment is evaluated by assigning a total "score" or "cost" and the goal is to attain the "best" alignment. The most widely used algorithms for constructing alignments are based on dynamic programming. Unfortunately a direct implementation of these methods is not suitable for aligning a large number of long sequences. In our talk we will discuss an alternative formulation of the alignment problem based on Markov decision theory. Here one seeks to minimize an average or expected cost subject to data-derived constraints. In this setting the problem is equivalent to a linear programming problem which can be solved efficiently.

DYNAMIC LOAD BALANCING IN PARALLEL QUEUEING SYSTEMS: STABILITY AND OPTIMAL CONTROL

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We consider a system of parallel queues with dedicated arrival streams. At each arrival time or service completion a decision-maker can move customers from one queue to another. The cost for moving customers consists of a fixed cost and a linear, variable cost dependent on the number of customers moved. There are also linear holding costs that may depend on which queue customers are stored. We seek a policy that minimizes the long-run average expected cost. In this talk, we motivate the problem above by describing similar scenarios in parallel processing in computer networks and work reallocation in supply chain management.

We develop stability (and instability) conditions for the most general system via a fluid model. In typical operations researcher fashion, we then divide the problem into several smaller problems and consider each separately. The one-server case yields optimal control limit policies. In the case of two-servers the optimal control policy is shown to prefer to store customers in the lowest cost queue. Furthermore, under an exponential assumption, the optimal policy is shown to be an "order up to" policy. These observations are used to suggest several heuristics for the general $n-$server problem.

DEVELOPMENT PLANNING AND PRODUCTION OPTIMIZATION IN THE OIL AND GAS INDUSTRY

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Over the past five years, ExxonMobil has been successful in applying advanced optimization technology to the difficult planning and scheduling problems of large, capital-intensive development projects. The decision process spans the entire production network: reservoirs, fields, wells, platforms, pipelines, surface facilities, and market options. Combining optimization technology with an integrated business model often leads to innovative and higher-value solutions. An integrated business model with optimization capabilities complements the traditional methods that use a case-base approach with multiple rigorous physics models for development planning. Current development planning optimization models have identified opportunities that have added significant value to project economics and capital efficiency.

The optimization technology used in ExxonMobil's development planning models determines the optimal solution to an economic-based objective function subject to constraints specifying physical and economic models defined over a planning horizon. Since value is also driven by economic factors such as the tax and royalty regimes that may significantly vary from field to field, these must also be considered simultaneously in the development planning process. The use of both discrete and continuous variables over a non-convex nonlinear domain yields models in the most difficult class of optimization problems: the mixed integer nonlinear programming (MINLP) class. Development of proprietary modelling and solution procedures was necessary to solve the resulting large and difficult optimization problems.

THREE NEW R'S: RANDOM WALKS, RIORDAN ARRAYS, AND RNA SECONDARY STRUCTURE

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In this talk we use an algebraic and combinatoric technique, which is based on Riordan arrays, to count two classes of random walks. It is interesting that certain subsets of the walks are counted by the RNA numbers $\{1, 1, 1, 2, 4, 8, 17, 37, \ldots\}$. These numbers also count RNA secondary structures of length n from molecular biology. A bijection is constructed between the set of RNA structures of length n and a subset of random walks of a given length and height. Asymptotic and probabilistic results are also given as well as other appearances of the RNA numbers that involve the classical Narayana numbers and Berstein-Sloane inverse sequences.

THE COADJOINT REPRESENTATION OF THE SUPER-VIRASORO ALGEBRA AND SUPERGRAVITONS

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We describe the physical actions that correspond to the interaction of the Super Virasoro algebra with supergravitons. These new field theories introduce a superfield that corresponds to dual elements of the super Virasoro algebra. Such elements already appear as background fields in the geometric action associated with two dimensional Polyakov supergravity. The actions describe a new symplectic structure that is transverse to the coadjoint orbits.

THE SPECTRAL ANALYSIS OF FRACTAL NOISE IN TERMS OF WIENER'S GENERALIZED HARMONIC ANALYSIS

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Although Wiener's Generalized Harmonic Analysis (GHA) provides a theory for the analysis of functions that were previously not accessible, GHA does not yield an adequate spectral analysis of large classes of functions, including nonstationary processes, and in particular, $1/f$ or fractal noise. In this presentation we investigate both a statistical and deterministic point of view of the adaptation of GHA to deal with fractal noise.

COMPUTATIONAL FLUID DYNAMICS: TURBULENT CONVECTION INSIDE A HELE-SHAW CELL

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Fluid dynamics inside a Hele-Shaw cell is investigated computationally. A Hele-Shaw cell is a rectangular chamber, filled with fluid, that consists of two closely placed parallel plates, i.e., it is very thin in one direction as compared with the other two. It effectively turns a three-dimensional situation into a "quasi" two-dimensional situation. Whenever a denser fluid is above a less dense fluid, a potentially unstable situation is created. For large enough density differences, convective motion occurs in the chamber. The fluid dynamics that result due to such an odd density arrangement is a specific example of the better known Rayleigh-Benard convection. Whereas, classic Rayleigh-Benard convection is temperature driven, the fluid dynamics in our chamber will be driven by a solute concentration gradient (an isometric problem). The incompressible Navier-Stokes equations in the Boussinesq approximation are used to model and simulate the fluid motion. An additional energy equation is coupled to describe the solute concentration evolution. These equations are addressed numerically using pseudo-spectral techniques that utilize Fast Fourier Transforms. A stability analysis is performed to evaluate the strength of the simulation process.

TUTORIAL: NEW PERIODIC ORBITS TO THE N-BODY PROBLEM

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By numerically solving the minimum action principle, we find several new periodic solutions to the equimass n-body problem. We will present animations and discuss stability issues.

THE DISTANCE BETWEEN TWO STOCHASTIC PROCESSES

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One of the principal aims of probability theory is to explain the statistical regularity associated with a macroscopic view of uncertainty. This is accomplished by the law of large numbers and the central limit theorem. This is also accomplished by stochastic process limits, i.e. limits in which a sequence of stochastic processes converges to a limiting stochastic process. The familiar example is a sequence of appropriately scaled random walks converging to Brownian motion.

But what is a stochastic-process limit? To specify what we mean by convergence for a sequence of stochastic processes, as well as what we mean by rates of convergence, it suffices to define a *metric* on the space of stochastic processes, which gives the distance between any two stochastic processes that we might encounter.

Perhaps the key idea is to regard a stochastic process as a random function. Then we can define a metric on the space of stochastic processes in two steps: First, we define a metric on the space of all probability measures on an abstract metric space. Second, we define a metric on the function space containing the possible sample paths of the stochastic process. These two metrics together determine a metric on the space of stochastic processes. We review some of the specific metrics that have proved to be useful.