Mathematics Department

Professor Mark D. Meyerson
Chair

Mathematics provides a logical framework and a language indispensable to understanding the technical world in which we live. The following description summarizes the many contributions to this field of study made during the past academic year by the faculty and midshipmen majors of the Mathematics Department of the U.S. Naval Academy. The results cited reveal the great scope, diversity, and applicability of mathematics and offer glimpses of its intellectual beauty and appeal.

Several midshipmen conducted research projects as Trident Scholars, as Honors Mathematics Majors, or in specially created projects under the guidance of Mathematics Department faculty members. Many faculty spent numerous hours serving as mentors and readers for capstone projects required of all midshipmen majors. Listed below are the two Trident Scholars with advisers in the Mathematics Department, their projects, and their Mathematics faculty mentors:

Matthew J. Ahlert, Honors Mathematics major, "Multiresolutional Optic Flow," Advisers: Professor Reza Malek-Madani and Associate Professor John F. Pierce

David Zane, Honors Mathematics major, "Efficient Academic Scheduling at the U.S. Naval Academy," Co-Adviser: Assistant Professor William N. Traves

Listed below are our four other honors mathematics majors in the class of 2003, their project titles, and their faculty mentors:

Jordan T. Levine, "An Exploration of the Black-Scholes Pricing Model" (Professor W. Charles Mylander)

Kathryn Macfarlane, "The Structure of Algebras Generated by Spin Systems" (Professor Geoffrey L. Price)

Joelle Mann, "Discriminants of Special Hypergeometric Polynomials" (Professor George C. Nakos)

Douglas Rosenstock, "Exploration of Movement Algorithms Based on Leadership in Agent Based Combat Models" (Professor Thomas J. Sanders)

Once again, the USNA Mathematics Department produced a wide range of scholarly work that appeared as technical reports or as publications in refereed journals throughout the world. Dozens of articles appeared as applications of mathematics or as pure mathematical research. Topics that Mathematics Department faculty researched include:

mathematics pedagogy, chaos and dynamical systems, mathematical physics and cosmology, algorithms for computers, wavelets, cryptology, ocean acoustics, navy ship degaussing, image recognition, quantum computing, optimization theory, and basic mathematical research in areas such as algebra, analysis, combinatorics, differential equations, differential geometry, matrices, number theory, operator theory, and statistics.

In addition to many independent research projects, several research projects were sponsored in whole or in part by a variety of sources, such as:

Department of Defense, High Performance Computing Initiative
Department of Health and Human Services
National Aeronautics and Space Administration
National Science Foundation
National Security Agency
Naval Research Laboratory
Naval Surface Warfare Center
Office of Naval Research

During the past year, members of the Naval Academy Mathematics Department presented the results of their scholarly activities on over fifty occasions at professional mathematical meetings and colloquia throughout the United States and abroad. This activity, along with publication, enhances the academic stature of the Naval Academy and promotes the professional growth and reputation of those individuals involved. Through research activity, the faculty expand their intellectual horizons and stay vital in their disciplines. They contribute to the discovery of new mathematics. And they develop new materials and ideas that they can share with midshipmen students in their mathematics courses and research projects. Of special note this year, Professor Michael E. Hoffman was awarded honorable mention for the Naval Academy Alumni Association's Civilian Faculty Award for Excellence in Research. Midshipmen 1/C Matthew J. Ahlert, a Mathematics Honors major, was awarded the Naval Intelligence Foundation Award as the best Honors student.

Sponsored Research

A New Approach to Mixed Integer Nonlinear Programming

Researcher: Assistant Professor Hande Y. Benson
Sponsor: Office of Naval Research (ONR)

The purpose of this project is to develop and distribute efficient software for solving nonlinear optimization problems that incorporate discrete choices. The approach is to start with a robust, state-of-the-art nonlinear continuous programming algorithm using interior-point methods, and investigate coupling it with established integer programming algorithms, such as branch-and-bound, Benders decomposition, and outer approximation. Problems of infeasibility detection and warm-starts will be given special consideration.

The main intended application of this project is sensor optimization. The problems of where to place and how to configure sensors to maximize coverage subject to various concerns yield a mixed integer-nonlinear programming problem. For this part of the project, the investigator will be collaborating with Mr. Jim Durbin at the Naval Research Laboratory.

Poroelastic Media

Researcher: Professor James L. Buchanan
Sponsor: National Science Foundation (NSF)

For the past half dozen or so years the investigator and his collaborators have been studying the effects of the poroelastic parameters of a seabed on sound transmission in the ocean. The investigator wrote a chapter for a book which summarizes this research.

Human bone is a poroelastic medium consisting of an outer cortical layer surrounding a high porosity cancellous interior with an interstitial lipid fluid. An important question is can the porosity of the cancellous bone be ascertained by acoustic interrogation, thereby determining whether the bone is osteoporotic. This year the investigator worked on developing a finite elements code for calculating the acoustic field arising from cancellous bone in order to determine such parameters as its porosity, permeability, pore size and moduli of elasticity, knowledge of which would permit characterization of the health of the bone. It was found that the most important parameter, porosity, could be determined quite accurately and that some of the secondary parameters such as permeability and elastic moduli could be determined to the correct order of magnitude. These results have been accepted for publication.

The Effects of Sound on the Marine Environment (ESME)

Researcher: Professor James M. D'Archangelo
Sponsor: Naval Research Laboratory (NRL)

This work is a collaborative research initiative with the Advanced Information Technologies Branch of the Naval Research Laboratory. The objectives of the project are:

a. Develop a set of software tools for evaluating the impact of diverse sound sources on organisms in the underwater environment.

b. Integrate the products of the sound source/propagation loss modeling team and the biological modeling team into a simulation that incorporates environmental effects.

c. Deliver and demonstrate operation of the resulting capabilities in a decision aid that draws on shipboard tactical databases.

The Acoustic Workbench for Marine Mammals, an integrated software system created by Dr. Haw-Jye Shyu of NRL that incorporates all of the software modules submitted as part of the ESME project was beta-tested. ESME researchers include ocean acousticians, climatologists, marine mammal biologists, etc. Integrating all of the submitted software modules into a working system was one goal of the work. As a first step, the Acoustic Workbench was developed to test the integration of these different software components and to see how they might function together.

This analysis, along with suggested improvements and directions for future research, was presented by at an Office of Naval Research conference in May 2003 by Roger Hillson of the Naval Research Laboratory.

Analysis of Admission Data

Researcher: Associate Professor Gary O. Fowler
Sponsor: U.S. Naval Academy Institutional Research Office

This research involves a preliminary multivariate statistical analysis of historic (1990-2001) admission data. The goal is to produce a model that will, in a wide sense, predict success at the Naval Academy based on information gathered in the application process. This is an ambitious goal and the summer's effort was only a start toward a solution. The professional statistical literature over the last two decades shows an increasing active interest in general techniques that may prove useful.

Potential measures of success include overall order of merit, academic order of merit, military order of merit, academic QPR, major selection, etc. In fact, combinations of these measures are more likely to be useful choices. Furthermore, global prediction functions, e.g. regression functions, are unable to make predictions over the whole range of applicants. In particular, prediction function built from data comprised primarily of males is more successful prediction success for males than for females. Characteristics like ethnicity pose similar difficulties and potentially useful characteristics like family income are unavailable.

Statistical methods investigated include principal components, factor analysis, adaptive multivariate regression, cross-validation, additive trees, clustering, and nearest-neighbors.

Nontrivially Discriminating Groups

Researcher: Professor Anthony M. Gaglione
Sponsor: Office of Naval Research (ONR)

Discriminating groups were first introduced by Baumslag, Myasnikov and Remeslennikov with an eye toward applications to the universal theory of various groups. Terminology definitions: Let G be a group. G is **discriminating** provided that for every finite nonempty subset S of nontrivial elements of the Cartesian square, $G \times G$, there is a homomorphism $\phi_S : G \times G \rightarrow G$ such that $\phi_S(s) \neq 1$ for all s in S. It is clear that if $G \times G$ embeds in G then G is discriminating. If this is the case, G is described as **trivially discriminating.**

The objectives of this project were to try to find examples of nontrivially discriminating groups and to address many of the open questions which have recently been put forth concerning them. This research was started in a paper by A.M. Gaglione (et. al.) entitled *Discriminating Groups* (*Journal of Group Theory*, 2001, 463-474. (henceforth abbreviated as FGMS) At the time of the writing of FGMS, the only examples of discriminating groups known were of two types: abelian groups and groups which embed their direct squares (i.e., trivially discriminating groups). It is easy to show that any torsion-free abelian group is discriminating. Thus nontrivially discriminating groups do exist. The real open question was did they have to be abelian. Together with my collaborators, we have discovered several classes of non-abelian nontrivially discriminating groups, *i.e.,* non-abelian groups which are discriminating but do not embed their direct squares. The methods

used here go back to classical work of B. H. Neumann on certain two-generator subgroups in an unrestricted direct product of an infinite family of finite alternating groups.

Another main question put forth in FGMS was whether finitely generated (f.g.) nilpotent groups are discriminating. We proved that f.g. nilpotent groups are discriminating if and only if they are torsion-free abelian. This was done using the method of Malcev completions. As a matter of fact we proved more, i.e., the Malcev completion of a f.g. torsion-free nilpotent group is discriminating if and only if it is abelian. We have answered several of the open questions which arose in FGMS, but these have given rise to new questions concerning discriminating groups. Thus this research project is on going.

Developing Absolute Backscatter and Extinction Techniques for HARLIE Data Products

Researchers: Associate Professor Sonia M. Garcia and
Geary Schwemmer, National Aeronautics and Space Administration (NASA)
Sponsor: National Aeronautics and Space Administration (NASA), Goddard Space Flight Center (GSFC)

The goal of this research is to develop and verify absolute backscatter and extinction calibration techniques for data from the Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE), which is a unique scanning atmospheric lidar. The work is being done with two data sets: SERDP Program, 5-25 April 2002, a measurement campaign at Fort Bliss in El Paso Texas and the International H2O Project (IHOP_2002) a field experiment that took place over the Southern Great Plains (SGP) of the United States from 13 May to 25 June 2002.

Hopf Algebras of Trees and Quantum Field Theory

Researcher: Professor Michael E. Hoffman
Sponsor: Office of Naval Research (ONR)

In his study of renormalization in perturbative quantum field theory, D. Kreimer introduced a Hopf algebra H_R whose generators are rooted trees. Later in joint work with A. Connes, Kreimer related H_R to some Hopf algebras arising in Connes' program of noncommutative geometry. Thus, the Hopf algebra H_R is of current interest in mathematics and physics, and since rooted trees have long been objects of study in combinatorics it would be useful to relate it to previous work. An attempt in this direction was made by F. Panaite, who claimed that H_R is isomorphic to a Hopf algebra constructed earlier by R. Grossman and R. Larson. However, Panaite's proof contained an error due to a failure to distinguish between two sets of multiplicities of triples of rooted trees. The author, building on work of R. Stanley and S. Fomin, developed a theory of "growth" and "pruning" operators on H_R. Using this theory it was easy to give a corrected version of Panaite's result.

Representations of Finite Groups on the Riemann-Roch Space, I

Researchers: Professor W. David Joyner and Assistant Professor William N. Traves
Sponsor: National Security Agency (NSA)

The action of a finite group on the Riemann-Roch space of certain divisors on a curve was studied. If G is a finite subgroup of the automorphism group of a projective curve X and D is a divisor on X left stable by G then the natural representation of G on the Riemann-Roch space L(D) is a direct sum of irreducible representations of dimension < =d, where d is the size of the smallest G-orbit acting on X. We give an example to show that this is sharp (*i.e.,* that dimension d subrepresentations do occur). We also show, under special conditions, that d\ >= d_G, where d_G denotes the largest degree of all irreducible representations of G.

Representations of Finite Groups on Riemann-Roch Spaces, II

Researchers: Professor W. David Joyner and Assistant Professor Amy E. Ksir
Sponsor: National Security Agency (NSA)

If G is a finite subgroup of the automorphism group of a projective curve X and D is a divisor on X stable by G then under the assumption that D is nonspecial, we compute the trace of the natural representation of G on Riemann-Roch

space L(D). A proof of an analog for toric varieties in the complex case, with no assumption on D other than it is both T- and G-equivariant, is also provided.

Computational Aspects of Toric Varieties

Researchers: Professor W. David Joyner and H. Verrill, Louisiana State University
Sponsor: National Security Agency (NSA)

This work describes a computer algebra package (written by WDJ) which deals with both affine and projective toric varieties in any number of dimensions (written in both MAGMA and GAP). Among other things, the package implements the desingularization procedure, constructs some error-correcting codes associated with toric varieties, and computes the Riemann-Roch space of a divisor on a toric variety. The GAP and MAGMA packages continue to be worked on.

A Question about Pic(X) as a G-module

Researchers: Professor W. David Joyner and R. Guralnick, University of Southern California La Jolla
Sponsor: National Security Agency (NSA)

Let X be an irreducible non-singular variety defined over an algebraically closed field F of dimension n and let G be a finite subgroup of the automorphism group of X/F. Let D be an r-cycle and assume that its equivalence class [D] is G-equivariant.

Question: Is there always a D' in [D] which is G-equivariant? This was first addressed by Lonsted, who answered the question in the cyclic case for rational equivalence but left the general case open. The case of arbitrary finite groups in the case of curves is finalized, and his result for varieties is generalized. This paper is still in progress.

Toric Codes Over Finite Fields

Researcher: Professor W. David Joyner
Sponsor: National Security Agency (NSA)

A class of error-correcting codes is associated to a toric variety associated to a fan defined over a finite field GF(q), analogous to the class of Goppa codes associated to a curve. Many examples are given. For small q, many of these codes have parameters beating the Gilbert-Varshamov bound. In fact, using toric codes, a (n,k,d)=(49,11,28) code over GF(8), which is better than any other known code listed in Brouwer's tables for that n and k, was constructed. The work concludes with upper and lower bounds on the minimum distance. The upper bounds are known to be sharp in some cases.

Multiplicity One for SL(2)

Researchers: Professor W. David Joyner, Associate Professor Courtney H. Moen and J. Levy, University of Ottawa
Sponsor: National Security Agency (NSA)

The trace formula is applied to the study of cuspidal automorphic representations of SL(2,A) as compared with the genuine cuspidal automorphic representations of its 2-fold metaplectic cover. The main result is a multiplicity one theorem for most automorphic representations of SL(2,A), where A denotes the ring of adeles of a totally imaginary number field.

Nature of Spacetimes with Mild Singularities or Cauchy Horizons

Researcher: Professor Deborah A. Konkowski
Sponsor: National Science Foundation (NSA) Research for Undergraduate Institutions (RUI) Grant

In this work, spacetimes with mild singularities and Cauchy horizons are being studied. Mild singularities include quasiregular and nonscalar curvature singularities. In the case of quasiregular singularities, particle paths end suddenly

with no warning from infinitely-increasing tidal forces, while in the case of nonscalar curvature singularities some, but not all, particles moving near the singularity feel infinite tidal forces. A Cauchy horizon is the boundary of the causal development of spacetime. Cauchy horizons and singularities are intimately connected, including through the cosmic censorship conjecture, which continues to be debated.

In particular, the study includes (1) quantum-mechanically singular spacetimes, (2) two previously-developed stability conjectures, and (3) the global structure of mild and/or unusual singularities. This work is being done in collaboration with T. M. Helliwell (Harvey Mudd College).

In the first case, following Horowitz and Marolf and work begun by T. M. Helliwell and D.A. Konkowski, classical test particles are replaced with quantum test wave packets to test the singularity structure of spacetimes which classically possess mild singularities. Results were presented at conferences in Florence (Italy), Mao (Menorca, Spain), College Park (Maryland), and Philadelphia (Pennsylvania). Talks were given in seminars at the University of York (England), Loughborough University (England), and the University of Southhampton (England).

In the second case, conjectures proposed by T. M. Helliwell and D. A. Konkowski to predict whether various mild singularities and Cauchy horizons are stable are being investigated further. Thus far, the singularity conjecture always holds true but the Cauchy horizon conjecture misses purely Weyl singularities that occur in the plane wave and exact mass-inflation spacetimes.

In the third case, spacetimes with nonscalar and quasiregular singularities are under investigation. This includes preliminary work on: (1) spacetimes with nonscalar singularities due to Siklos, (2) quasiregular singularities in the context of dislocations and disclinations and in the context of Columbeau's extended theory of distributions, and (3) the structure of some spacetimes with directional singularities.

Twin Screw Extrusion of Energetic Materials

Researcher: Assistant Professor Anastasios Liakos
Sponsors: Naval Surface Warfare Center (NSWC), Indian Head Division
and Office of Naval Research (ONR)

Propellants used in weapon systems are usually extruded (*i.e.,* melted and forced through an opening) to create various shapes. The rapid changes in pressure during this process can greatly affect the temperature of the fluid, bringing it close or surpassing the initiation temperature (*i.e.,* temperature at which the propellant ignites.)

This project is still in progress. A substantial amount of bibliographic research had to be done to bring the investigator up to speed with the current research. A first-generation program has been written in C to try to predict the values of the flow variables (velocity, pressure, stress). The research is focusing on further development of the code so that the results can be viewed in a virtual reality cave at the University of Maryland, College Park. This work is being investigated in collaboration with Dr. H. Bruck, Dr. A. Baz and Mr. A. El Sabbagh of the Mechanical Engineering Department at the University of Maryland.

The Mortality Problem for Matrices

Researcher: Associate Professor Jody M. Lockhart
Sponsor: Naval Academy Research Council (NARC)

The mortality problem for n x n matrices is the problem of deciding, given a set of n x n matrices, whether the zero matrix is a product of elements of the set. Michael S. Paterson showed, in 1969, that the mortality problem for 3 x 3 integer matrices is recursively unsolvable. The problem remains open for 2 x 2 integer matrices.

Many other decision problems related to the mortality problem have been studied. These include the following problems. The right upper corner problem is the problem of deciding whether the semigroup generated by a set of matrices contains a matrix with the right upper corner equal to zero. The Skolem problem is the right upper corner problem for sets containing a single matrix; that is, it is the problem of deciding whether any power of a given matrix has right upper corner

equal to zero. The neutrality problem is the problem of deciding whether the semigroup generated by a set of matrices contains the identity matrix.

The purpose of the project was to study the relation between the different decision problems for matrices and, in particular, to try to obtain results in the 2 x 2 case.

A connection between the mortality problem and the left upper corner problem for 2 x 2 matrices was found. If the mortality problem is solvable then the left upper corner problem is also solvable. This result was proved by showing that a given set of matrices has the left upper corner property if and only if a certain larger set is mortal.

The following decision problems were shown to be solvable: the mortality problem for sets of 2 x 2 matrices that contain only one nonsingular matrix, the neutrality problem for sets of 2 x 2 integer lower triangular matrices, and the Skolem problem for 3 x 3 and 4 x 4 matrices with real eigenvalues.

The following interesting connection between solutions to trigonometric equations and the Skolem problem for 2 x 2 matrices with non-real eigenvalues was found. The Skolem problem was shown to be equivalent to the following decision problem: given integers m and n, is arctan(sqrt(m)/n) a rational number times pi?

An Analytic Ghost Fluid Method

Researcher: Associate Professor Thomas J. Mahar
Sponsors: Naval Surface Warfare Center (NSWC), Indian Head Division
and Office of Naval Research (ONR)

Godunov's method for the Euler equations for fluid flow was implemented in MATLAB® as vector code. The flow involves two fluids, each with its own equation of state and thermodynamic properties. The Ghost Fluid Method has been implemented to try to solve these problems efficiently. An analytic version of the Ghost Fluid Method was developed to explain the failure of the Ghost Fluid Method on Riemann problems. Besides providing a clear explanation of the source of the difficulty with Riemann problems, the analytic method has made it clear that there will be similar problems whenever a shock wave is within the band of ghost fluid cells containing the material interface – such as occurs whenever a shock reflects off an object and travels back to the material interface. While this work is restricted to one spatial dimension, it extends to higher dimensions with even more severe consequences.

Developing Analytical Methods for the Navy's Antenna, EM Propagation and Interactions Program

Researcher: Professor Peter A. McCoy
Sponsor: Office of Naval Research (ONR)

The objective of this study is to apply recent advances in the mathematics of sampling and approximation theory, wavelets and pde's to problems involving antenna design and electromagnetic wave propagation through the atmosphere. The goal is to obtain general procedures for representing solutions that will ultimately lead to more effective and efficient methods of solution by reducing computational complexity. The first thrust of this work is to exploit recent advances in sampling and wavelet theory.

The investigator constructed an integral transform pair that associate solutions of the scalar Helmholtz equation with analytic functions of a complex variable. These representations are used to specify surfaces containing the sources or targets from an analysis of the radiation patterns. The investigator developed integral transforms for the study of scattered electric fields. Representations of this type are necessary for the development of sampling methods for representing electromagnetic fields in terms of discrete sets of sampled frequencies.

The Impact of Calculus Reform on Long-term Student Performance

Researchers: Professor Harold L. Penn, Susan Ganter (Clemson University)
and Jack Bookman (Duke University)
Sponsor: National Science Foundation (NSF)

The purpose of this research project is to determine the long-term effect of the use of technology and other reformed calculus ideas on the performance of students in their upper division courses. The Naval Academy is one of several institutions participating in this study. The goals include:

- Compare the performance of reform and traditional calculus students in courses beyond calculus
- Examine students prior to graduation from college to determine these students' fundamental notions of calculus
- Determine the extent to which potential employers value the ideals supported by calculus reform efforts.

Professor Howard Penn is serving as the Evaluation Fellow for the Naval Academy. His duties include:

- Identifying student subjects for interviews
- Compiling background data on student subjects
- Compiling project data
- Analyzing data
- Developing human subjects review protocol

The Feasibility of Characterizing Surface Current Features in the Chesapeake Bay Using Lagrangean Flow Methods

Researchers: Professor Reza Malek-Madani and Associate Professor John F. Pierce
Sponsors: Defense Modeling and Simulation Office (DMSO) and Naval Academy Recognition Grant

Over the last decade, methods of dynamical systems have been used to examine fluid flow from a Lagrangean perspective to extract information about the transport of materials by surface currents. The models developed have been applied successfully to study the dynamics of transport in the Monterey Bay, producing results that were unexpected, highly provocative, quite promising and imminently verifiable. We seek to identify the factors that support or inhibit the application of these methods to the Chesapeake Bay. The factors are both analytical and empirical. Analytically, there are many issues involving the specifics of the initial and boundary value PDE problem upon which the dynamical system is based for the Chesapeake Bay that distinguish it from the model for the Monterey Bay. Empirically, an adequate sample of surface current data is essential to the success of the dynamical method. For the Monterey Bay, these data are available from high frequency radar. Because of the topography of the bay and the location of radar sites, these data alone provide sufficient samples. The topography and extent of the Chesapeake Bay and the lack of radar sites prevent us from using data a single type of sensor to obtain the sampled surface current data we need. Instead, we will examine how feasible it is to fuse the surface current measurements from tow data and the interpolations from it that the National Oceanic and Atmospheric Administration (NOAA) can provide for the Chesapeake Bay with the high frequency radar data available at the mouth of the bay to provide a sample adequate to drive the dynamic model. Data from NOAA was imported and a MATLAB® program was written to read the data.

Hausdorff Dimension of Harmonic Measure on Totally Disconnected Sets

Researcher: Assistant Professor Irina Popovici
Sponsors: National Science Foundation (NSF) Grant and Naval Academy Recognition Grant

The goal of the project is to establish the singularity of harmonic measure and of Hausdorff measure on some totally disconnected, uniformly perfect sets (subsets of the real line or Julia sets of rational functions). Fractal sets like these often appear in the analysis of the chaotic part of a dynamical system, from complex ones like weather, fluids, earthquakes and spreading of disease, to simple ones, like the game of billiards.

The results rely on estimates of logarithmic capacities, critical values of Green's function and harmonic functions near the boundary of plane domains. The techniques used combine potential-theoretic arguments with ergodic theory and dynamical systems, as introduced by Carleson, Jones and Wolff, Makarov and Bourgain.

The singularity of the harmonic measure with respect to the Hausdorff measure can be thought of as a reflection of the roughness of these sets (like the corners or the limbs present in all scales in the snowflake or the Mandelbrot set), since for smooth curves the harmonic measure and the arc-length (1-dimensional Hausdorff measure) are comparable. The geometry of the periodic domains of the dynamical system (John domains, Holder domains, quasi-disks, etc) can be used to prove the conjecture for some classes of rational functions.

This is a project with many open questions, and it is part of a very active area of research. Talks (with J. Graczik) on the results relating the geometry of the Julia sets with the expansion properties of the dynamical system have been given, and the research continues.

Semigroups of Endomorphisms on von Neumann Algebras

Researcher: Professor Geoffrey L. Price

Sponsor: National Science Foundation (NSF) Research for Undergraduate Institutions (RUI) Grant

In previous publications Price has studied the C*-algebras generated by sequences $u_1, u_2, \ldots$ of self-adjoint operators that either commute or anti-commute and that have translation-invariant commutation relations, i.e., there is a sequence a_0, $a_1, \ldots$ of 0's and 1's such that $u_i u_{i+j} = (-1)^{a_j} u_{i+j} u_i$ for all i and j. Price has shown that the C*-algebra A is simple if and only if the sequence $\{\ldots, a_2, a_1, a_0, a_1, a_2 \ldots\}$, obtained by reflecting the sequence of commutation relations, is periodic. In such a situation the algebra A is isomorphic to the CAR algebra. Given this type of construction of the CAR algebra there is a unital *-endomorphism α on A which is uniquely determined by the relations $\alpha(u_i) = u_{i+1}$ for all i. In previous work Price has classified those α's above that have commutant index 2, i.e., the relative commutant algebra $\alpha^2(A) \cap A$ is nontrivial. This is accomplished by showing that there is a one to one correspondence between conjugacy classes of these shifts and the family of polynomials p(x) over GF(2) whose only self-reciprocal factors are of degree 1 or less. In the current work Price has shown that there exist unital *-endomorphisms β on the CAR algebra of commutant index 2 that are not conjugate to the shifts constructed as above. Price has also shown that these shifts have Connes-Størmer entropy ½ ln2.

RAT-STATS II

Researcher: Professor Thomas J. Sanders

Sponsor: Department of Health and Human Services, OIG, Office of Audit Services

RAT-STATS is a suite of modules that was initially developed by the Regional Advanced Techniques Staff (RATS) in San Francisco to aid in auditing procedures. This project involved the transfer of statistical-auditing modules into the MS Windows environment. These modules had never been converted into the MS-DOS version of RAT-STATS. The modules include ratio and regression estimation for unrestricted and stratified samples, two-stage variable ratio and regression estimation, attribute discovery sample size, sample size for controlling alpha and beta risks, one-step acceptance sampling, two-step acceptance sampling, and two-step attribute appraisals.

High Performance Computation of Grobner Bases

Researcher: Assistant Professor William N. Traves

Sponsor: Department of Defense, High Performance Computing Initiative

This project sets the stage for the development of an algorithm to quickly compute Grobner bases on a parallel computer. When Bruno Buchberger introduced Grobner bases in 1965, they were seen as little more than an abstract tool for constructing and manipulating ideals in a polynomial ring. However, as new connections were found between commutative algebra and a whole host of applied problems, researchers recognized that Grobner bases are useful in many endeavors. Today, these ubiquitous algebraic objects help solve problems in integer programming, coding theory, signals processing, network reliability and computer-aided geometric design.

Unfortunately, parallel implementations that compute Grobner bases are in their infancy. While some basic algorithms have been developed for large multiprocessors – for instance, at the Center for Communications Research – these algorithms have not been implemented on a networked cluster of PCs such as Armada, the Naval Academy's Beowulf

cluster, or Maui's 520P linux cluster. The development of such algorithms will make powerful Grobner basis tools more widely available.

This project showed that the obstruction to a good parallel implementation of Buchberger's algorithm is contained in the high amount of communication required in processing S-pairs. Though this suggests that parallel algorithms will not work well for polynomial systems, they may still have advantages in solving systems of differential equations.

Elliptic Curves, Integer Factoring and Public-Key Cryptography

Researcher: Assistant Professor William N. Traves
Sponsor: Naval Academy Research Council (NARC)

The RSA protocol is a widely used method in public-key cryptography. It relies on the difficulty of factoring large integers to secure communication across a public channel. One method of factoring large integers – and thus breaking RSA – involves elliptic curves. The main aim of this project was to study the Elliptic Curve Attack on the RSA algorithm and implement the process on USNA's Beowulf cluster, Armada.

The Elliptic Curve Attack is inherently amenable to parallelization. The procedure attempts to factor an integer using arithmetic on an elliptic curve. By using different curves on different processors, the algorithm can be speeded up considerably. Indeed, the Beowulf implementation (on 16 processors) showed linear speed-up. Though several methods exist to optimize the computations on vector machines, these are less effective on a COW (cluster of workstations). Over the course of this investigation, it became clear that one needs to be sensitive to the special properties of different computer architectures when tackling parallel programming problems.

In the end, this implementation was slower than the highly optimized serial implementation contained in MAPLE 8. Though this was somewhat discouraging, it was probably a result of the size of the problems that were being tested. These tended to be small and so the benefits of parallelization were buried in computation start-up costs. Unfortunately, it was difficult to find problems that took a reasonable length of time. Either the algorithms were successful right away or they did not complete.

Electromagnetic Signature Reduction

Researchers: Professor John C. Turner and K. Watts, Naval Surface Warfare Center (NSWC)
Sponsor: Naval Surface Warfare Center (NSWC), Carderock Division

This is an ongoing, classified project for the reduction of electromagnetic signature of steel-hulled ships. The project is undergoing a number of changes. In past years, the emphasis has been on full-scale ship trials. The project is now shifting emphasis to rely on scale model data and math modeling. At the same time, preparations are beginning for inserting this technology on ships of the fleet. The project is currently validating data and approaches in preparation for an input for tech insertion this fall.

Independent Research

Endomorphisms of von Neumann Algebras

Researcher: Assistant Professor Alexis Alevras

This is an ongoing research project concerning irreversible dynamics on von Neumann algebras; in particular, semigoups of endomorphisms of factors of type I and of type II1, as well as single endomorphisms of factors of type II1. The purpose is to investigate the behaviour of such systems, e.g. ergodic properties, equilibria, dilation theory, perturbation theory etc. In previous work we studied an index associated with the so called boundary representation of a semigroup of endomorphisms of a type II1 factor and computed it for all known examples. We have now obtained a new class of examples from the theory of Markov shifts and we intend to pursue the question of their classification. We also plan to investigate the properties of the spectral algebra associated with a semigroup of endomorphisms, which we constructed previously,

as they pertain to the general questions mentioned above. In a different direction, we have examples of semigroups of endomorphisms parametrized by the forward light cone. This is a largely unexplored area and at the moment very little is known about such a relativistic theory of endomorphism semigoups.

Notes on the Geometry of N-Dimensions with Applications to Economics

Researcher: Professor Peter P. Andre

The subject matter of this book forms the material for the course SM279 which is a link between the matrix theory and calculus in the mathematics department and microeconomics in the economics department. The book gives an elementary introduction to the world of n-dimensions and makes the connection between the mathematics and its applications in microeconomics. The text begins with a discussion of affine sets. Functions are introduced and the calculus in n-dimensions is discussed from an intuitive point of view without the formal definitions. The book covers the chain rule, inverse function theorem, implicit function theorem, unconstrained optimization and constrained optimization.

Mathematics of the Global Positioning System

Researcher: Professor Craig K. Bailey

Given the lack of availability of a suitable undergraduate level textbook for a senior level course on the mathematics of the Global Positioning Systems (GPS), the researcher began compiling notes and information to produce such a textbook. The mathematics involved includes least squares solutions of overdetermined equations, prediction of satellite positions using Keplerian elements, conversions of rectangular coordinate system solutions into geographic coordinate system solutions using earth shape parameters, and the mathematics of map projections.

Solving Mathematical Programs with Equilibrium Constraints Using Interior-Points for Nonlinear Programming

Researcher: Assistant Professor Hande Y. Benson

This project continues the investigation of ways to reformulate equilibrium constraints to fit the nonlinear programming paradigm. Of current focus is the unboundedness of Lagrange multipliers. Equivalent formulations with bounded Lagrange multipliers are being investigated, using a method recently proposed by Anitescu. Computational experience shows that the method is applicable, and we are currently developing theoretical results.

Designing Interior-Point Method Software for Large-Scale Nonlinear Programming

Researcher: Assistant Professor Hande Y. Benson

The current investigation is focusing on the problems of variable initialization, steplength control, and convergence criteria in interior-point methods for nonlinear programming. Of particular interest are the slack variables, *i.e.,* when they should be used, how they should be initialized, and what effect they have on convergence and complexity results.

Automatic Error Detection and Knowledge Discovery in a Multi-User, Multi-Discipline Scientific Databases

Researcher: Lieutenant Commander Kyle A. Caudle, USNR

Large scientific or statistical databases often receive input from many sources and deliver output around the globe. These databases might incorporate a large number of individual input sources and output users, from diverse geographical locations, across many scientific disciplines. Thus controlling the input and output of the flow of information in these databases is often problematic and fraught with errors. If left unchecked, these errors could cause significant problems both in monetary terms and in terms of selling the customer on the integrity of the database system. Data control will become

critical as scientific databases become even larger and connected to web services. This project examines the methodologies that provide data control through automatic error detection, over numerous periods, using tools from data mining and knowledge discovery. The latest statistical methods along with reliability theory might be employed to automatically detect suspect data and prompt input sources to confirm input data. Methods for checks and controls before data acceptance by the scientific database will be examined along with the latest database and software languages (e.g., XML). Data quality in both the input and output of these large databases is scrutinized using various unclassified government and military data sources.

Understanding Maintenance Data through Scientific Visualization

Researcher: Lieutenant Commander Kyle A. Caudle, USNR

Large databases exist within the scientific community. Most of these databases are designed for storing vast amounts of information that is accessed by multiple users from multiple platforms. Frequently, the wealth of information contained within these databases is never fully exploited. Far too often, people are too busy or lack the skill necessary to interpret raw numbers. Visualizing the scientific data within these databases can often paint a picture that summarizes key concepts that otherwise might have been lost. In the maintenance community, understanding reliability trends can allow engineers to effectively maintain their equipment in a way that is minimizes maintenance cost and makes the most efficient use of the engineers who are performing the maintenance. After providing an overview of the Maintenance Requirements System (MRS), the data source for all graphics contained in this paper, this paper will show how maintenance data can be portrayed graphically so that key decision makers in the budgeting community have rapid access to the data enabling them to make more informed decisions.

Image Representation for Computer Vision: Exploring New Classes of Nearest Neighbor Graphs

Researcher: Professor Carol G. Crawford

The researcher extends prior results in the development of graph representations for the pre- and post-processing of images for the purposes of image recognition and confirmation. Earlier publications presented Aspect Graphs for Robotic Vision and Sphere-of Influence Graphs for Automatic Fingerprint Identification. These results were funded by the Federal Bureau of Investigation and the Office of Naval Research.

The current research project explores graph theoretic properties, including chromatic characteristics, for these unique classes of graphs. In addition, the author explores properties exhibited by other Nearest Neighbor Graphs, such as Voronoi diagrams.

Optimizing Conceptual Understanding for Problem Solving in Undergraduate Mathematics Courses

Researcher: Professor Carol G. Crawford

In this project the author applies her prior research in mathematical pedagogy to the special issues associated with conceptual understanding in undergraduate mathematics courses. The major focus of the program explores ways to teach problem solving techniques for real world questions. Special emphasis is given to the development of specific skills in making the transition from implicit and explicit verbal relationships to the design of related mathematical algorithms.

This work updates some of the research published in the author's book, **Math Without Fear**, published in 1981. Nationally known expert Shelia Tobias encouraged the author to write this book. In the fall of 2002 they met at the Naval Academy to discuss issues related to the author's current work.

The Axiomatic Closure of the Class of Discriminating Groups

Researcher: Professor Anthony M. Gaglione

A group G is **discriminating** provided that for every finite nonempty subset S of nontrivial elements of the Cartesian square, G×G, there is a homomorphism $\phi_S : G\times G \to G$ such that $\phi_S(s) \neq 1$ for all s in S, *i.e.,* if it discriminates its direct square. This research project falls at the intersection of infinite group theory and mathematical logic. In a paper by A.M. Gaglione (et. al.) entitled *Discriminating Groups* in *Journal of Group Theory*, 2001, 463-474, it was shown that a discriminating group has the same universal theory (with respect to a first-order language appropriate for group theory) as its direct square. In an effort to further capture this property squarelike groups were introduced. These are groups universally equivalent to their direct squares. We showed that the class of discriminating groups is properly contained in the class of squarelike groups. We also showed that the class of squarelike groups is not axiomatic, i.e., it is not the model class of some set of first-order sentences. We had known for some time that any abelian squarelike group is elementarily equivalent (*i.e.,* has the same elementary or first-order theory) as a discriminating group. The main object of this research was to either prove or show to be false that the same is true for an arbitrary squarelike group, *i.e.,* any squarelike group is elementarily equivalent to a discriminating group. We succeeded in doing just that. In particular, this shows that the class of squarelike groups is the axiomatic closure of the class of discriminating groups. The methods used in the work were the model theory of ultraproducts and ultralimits.

Study of Mixed Methods with Artificial Viscosity for Viscoelastic Flows

Researcher: Associate Professor Sonia M. F. Garcia and Assistant Professor Anastasios Liakos

From this work, these researchers expect to have preliminary results for a simple theory using mixed method for equations with applications in viscoelasticity using a special type of artificial viscosity. The work revises the stabilizations through insertion of new operators enhancing the coercivity property of the problem and later eliminating the extra variables through mixed element techniques.

Science Declares Our Universe Is Intelligently Designed

Researcher: Professor Robert A. Herrmann

In this book (Xulon Press 2002), the science of mathematical modeling is discussed in general terms. It is shown how this science generates the theory of General Intelligent Design. This theory is applied to the behavior of natural-systems and this application is discussed in general and semi-technical terms. The results of 22 years of research are presented. Finally, this theory is interpreted using the language of intelligently design, a purely physical language as well as theologically.

Standard and Nonstandard Unifications for Collections of Physical Theories

Researcher: Professor Robert A. Herrmann

In this research, the possible lattice structure for the set C_f of all finitary consequence operators defined on any nonempty general language is investigated. It is conjectured that C_f is a lattice with upper and lower units. Further, it is conjectured that C_f is also a join-complete semi-lattice that is known, in general, not to be meet-complete. Using the second conjecture, it would follow that a set of physical theories that is system consistent has a unique non-trivial standard unification that is the best possible in the sense of being a least upper bound. Using the first conjecture, it would follow that there exists a hyperfinite ultralogic that unifies the same set of physical theories.

On the Variety of Borels in Relative Position

Researchers: Professor W. David Joyner and Adjunct Assistant Professor Pablo Lejarraga

There are two substantially different versions of this paper. One, as above. The second is titled: "Smoothness Properties of the Variety of Borels in Closed Relative Position."

First version:

Let G be a connected semi-simple group defined over and algebraically closed field, T a fixed Cartan,

B a fixed Borel containing T, S a set of simple reflections associated to the simple positive roots corresponding to (T,B), and let G/B denote the Borel variety. For any s_i in S, let O(s_1,... ,s_n) denote the subvariety of Borels in (G/B)^(n+1) in relative position (s_1,...,s_n). We show that such varieties are smooth and indicate why this result is, in one sense, best possible.

Our main results assume that k has characteristic 0.

Second version:

Let G be a connected reductive affine algebraic group over k, T a fixed maximal torus, and B a fixed Borel subgroup containing T, W=N_G(T)/T the Weyl group of G relative to T, and S the set of simple reflections in W defined by (T,B). We denote by X the projective variety of Borel subgroups of G. Its structure of algebraic variety is defined by the canonical G-equivariant bijection ^gB=gBg^{-1} --> gB of X onto G/B. Note that if w in W, we can also define ^wB=wBw^{-1} and wB in the usual way, and they do not depend on the representative of w chosen to define them. Let O(w), w in W be the orbit of

(B,^wB) in XxX under the left action of G, where w in N_G(T) represents w. Now we define O(s_1, ...,s_n), s_i in S, to be the closed subvariety of X^{n+1} whose points are the sequences (B_0,B_1, ...,B_n), B_i in X, where (B_{i-1},B_i) in O(s_i) for i=1,...,n.

Such varieties were first introduced by Deligne and Lusztig as a technical tool in representation theory. Lately they have appeared in other contexts. In this paper, we prove that the canonical projections π :O(s_1,...,s_i) --> O(s_1,...,s_{i-1}) are P^1-bundles, which implies that the variety O(s_1,...,s_n) is smooth.

GUAVA, an Error-correcting Codes Package in GAP

Researcher: Professor W. David Joyner

The researcher debugs and maintains the GUAVA software package, and issuing new versions when needed. "Minimum Distance" was debugged and several new commands involving a new class of codes were written and introduced.

Conservative Confidence for Means of Finite Populations of Nonnegatives

Researcher: Professor Harold M. Kaplan

The martingale inequality can be used for one-sided hypothesis tests of means of finite populations of nonnegatives, even when the sampling probabilities are unequal. The tests are nonasymptotic, and there is no need to estimate variance. The confidence intervals built from these tests have good numerical properties.

A New Parameterization of the Alexander Link Polynomial

Researcher: Professor Mark E. Kidwell

A classical link invariant, the several-variable Alexander polynomial, can be expressed in terms of new variables. The new parameterization may bring out connections with Vassiliev's finite-type invariants of links and with the Seiberg-Witten invariants of manifolds. An old question of characterizing the Alexander polynomial will be reconsidered.

Classification of Singularities with SHEEP/CLASSI

Researcher: Professor Deborah A. Konkowski

This researcher is investigating ways to apply computer algebra programs (*e.g.,* SHEEP/CLASSI) to the problem of singularity classification. This computer algebra research was begun during a recent sabbatical in London at Queen Mary and Westfield College with Professor Malcolm MacCallum's group and has been continued during periodic visits to London. Although it is impossible to classify topological singularities such as quasiregular singularities in this manner, scalar curvature and non-scalar curvature singularities should yield to analysis. Ways to study scalar and nonscalar curvature

singularities using a complete listing of C^0- curvature invariants and frames related to parallel propagated orthonormal ones are currently under consideration.

Algebraic Surfaces and Gauge Theories

Researchers: Assistant Professor Amy E. Ksir and Stephen G. Naculich, Bowdoin College

In type IIA string theory, one can set up ladder-like configurations of Neveu-Schwarz five branes, Dirichlet four- and six-branes, and orientifold sixplanes so that the induced gauge theory on the Dirichlet fourbranes is an N=2 supersymmetric theory. Choosing different configurations of these branes will modify the gauge group and matter content of the induced N=2 theory. Upon lifting these configurations to M theory, the geometry becomes smooth. The NS fivebranes and D4 branes merge into a single smooth M5 brane, whose geometry is that of a cylinder over a smooth algebraic curve Σ. The D6 branes and O6 planes will determine the geometry of a smooth algebraic surface on which this curve Σ sits.

The purpose of this investigation is to study this correspondence between gauge theories and algebraic curves and surfaces. Our main objective is to give a complete description of the algebraic surfaces and curves associated to each gauge theory. Our second objective is to explore the integrable systems associated with each theory and their geometric construction from the point of view of the algebraic curves and surfaces. We use techniques from algebraic geometry, string theory, and gauge theory. Our results so far have led to one paper (published June 2003) describing the surface in the case of two negatively charged orientifold planes. We have more recently developed a conjecture as to the surface in the case of two orientifold planes of opposite charges, and are testing this conjecture.

Representations of Finite Groups on Riemann-Roch Spaces

Researchers: Professor W. David Joyner and Assistant Professor Amy E. Ksir

If G is a finite subgroup of the automorphism group of a projective algebraic curve X, and D is a divisor on X which is invariant under G, then there is a natural action of G on the Riemann-Roch space L(D). The purpose of this investigation is to compute the trace of this representation. The main objective is to obtain a formula for the trace which depends on only the genus of X/G, the types of ramification of the cover $X \to X/G$, and the traces of irreducible representations of G, and can be easily computed. The computations are being carried out using theorems from algebraic geometry, number theory, and representation theory. Part of the formula was obtained using a result from a previous paper of Ksir's, for a special class of groups. It is expected that this part of the formula will generalize to other groups, and that this generalization can be computed using results already existing in the literature.

Goppa Codes Invariant Under Finite Group Actions

Researchers: Assistant Professor William N. Traves and Professor W. David Joyner

Goppa codes can be used to efficiently and securely transmit large amounts of information. Special properties of Goppa codes that are associated with divisors on a curve that are invariant under a finite group have been investigated. An application to reduce memory requirements on decoding devices is provided. This project is essentially complete and has resulted in a paper submitted for publication.

Conformal Anomaly and Determinants of Curves

Researchers: Assistant Professor Amy E. Ksir and Paul Green, University of Maryland

The conformal anomaly is a physical quantity calculated in the process of solving conformal field theories. However, it is derived purely from geometry. For a given curve of genus g, one can compute the determinant of the period matrix of a curve corresponding to that point. It seems *a priori* that this determinant will depend heavily on the choice of a Lagrangian subspace of homology cycles for the period integrals. However there is evidence both from conformal field theory and from small genus examples that there is a canonical choice of subspace which will allow this determinant to be well-defined. The purpose of this project, begun in May 2003, is to investigate the conformal anomaly and try to define it mathematically. The main objectives are to prove that it is mathematically well-defined and that it is additive with respect to a connected

sum, which is also expected from the physics. The methods used include results in algebraic geometry, complex analysis, and physics. So far the investigation has been carried out in a few small genus cases, with positive results.

Thomas Fuller, African American Calculating Wizard!

Researchers: Assistant Professor Amy E. Ksir and
Sarah J. Greenwald, Appalachian State University

Thomas Fuller was an African slave brought to America in 1724. His amazing talent with mental arithmetic made him famous and eventually helped to bring about the end of slavery. His story is inspiring to students and can be used as an introduction to computational efficiency and complexity. Research has shown that incorporating the achievements of women and minorities into the classroom is beneficial to all students. The purpose of this project is to investigate Fuller's life and mathematical techniques. Our objective is to develop a set of classroom activities based on his life and work which will teach students about his story, as well as the mathematical ideas behind his computational methods and more modern computational complexity theory. Our methods include library and internet research. So far we have collected and studied the most obvious sources, and Assistant Professor Greenwald has had students write a paper summarizing their content. We plan to do further research into both the historical and mathematical aspects of the project before designing classroom activities.

Mathematics of Entanglement

Researcher: Associate Professor Jody M. Lockhart

This research involved further investigation into the mathematics of entanglement. The main result of the study thus far is that in a finite dimensional quantum system every mixed state is generically the mixture of pure entangled states. Thus from the mixture point of view, separable states are not necessary. One can, in fact, say more: every rank k states is generically the mixture of k pure entangled states.

Games on Oriented Graphs

Researchers: Associate Professor T. S. Michael and
Thomas Quint, University of Nevada at Las Vegas

This research investigates a zero-sum, two-person game defined by an oriented graph. Researchers have recently shown that if the oriented graph is a tournament, then the optimal strategy is unique. Some sufficient conditions for non-uniqueness of the optimal strategies for more general classes of oriented graphs have been obtained.

Representation Theory of Covering Groups of SL(2)

Researchers: Associate Professor Courtney H. Moen and Professor W. David Joyner

This project uses the trace formula to study a correspondence between automorphic representations of covering groups of SL(2) and SL(2) itself. The goal is a multiplicity one theorem for automorphic representations of SL(2). These results are to appear in a book published by Johns Hopkins University Press.

Sums of Consecutive Powers

Researcher: Associate Professor Courtney H. Moen

This project studies how integers may be represented as sums of powers of consecutive integers, with the exponents being restricted to certain sets. For example, it can be shown that each integer larger than 52 can be written as a sum of consecutive powers starting with 1, with each of the exponents being 1 or 2. These results are now in preprint form and will soon be submitted.

Mathematical Foundation for Empirical Mode Decomposition

Researchers: Associate Professor John F. Pierce
Jorge E. Pinzon, Science Systems and Applications, Inc. (SSAI),
Norden Huang, National Aeronautics and Space Administration (NASA), Goddard Space Flight Center (GSFC),
and Ronald M. Devore, University of South Carolina

Utilizing the Hilbert transform, Dr. N. Huang developed a remarkably successful and robust empirical methodology to extract multi-resolution information from time series data in a nonlinear (signal-dependent) manner (*Proc. R. Soc. Lond. A.,* (1998) 454, 903-995; *Ann. Rev. Fluid Mech.,* 1999, 31:417-57). By an empirical "sifting" process, the method resolves the signal into a finite sum of intrinsic modes, each of which isolate features of the signal at a particular time scale. In contrast to most methods of representing signals, the intrinsic modes are not a basis set of functions imposed externally on the signal, and whose features are known prior to considering the signal. Rather, they emerge from the signal, are peculiar to it, and their features are not known prior to considering the signal.

As successful as the technique has been in its empirical applications, there are issues about the rational basis for its success, and concern for delineating its scope of validity. For example, are there time series sufficiently complex that sifting will cycle toward, but not converge to a specific intrinsic mode? Are there attributes delineating an intrinsic mode that independent of the context, by which someone "untutored" in the particular signal would infer, correctly, the sifting process delivers an intrinsic mode? Are there formal results that affirm that iterative sifting of a signal will produce a finite set of intrinsic modes and a single, residual trend?

The functional analytical perspective of R. DeVore, and G. Lorentz, *Constructive Approximation*, Springer-Verlag, 1993, was adopted. With a characterization of intrinsic modes, we can establish a semi-norm in a linear space of sequences that will define an ordered lattice of function spaces that characterize the stochastic processes wherein the time series stand as samples, as described in D. Donoho, M. Vetterli, R. DeVore, and I. Daubechies, "Data Compression and Harmonic Analysis", *IEEE Trans. in IT*, 1998. Algebraic constraints among the indices characterizing the function spaces provide the means by which we can discern when a signal manifests a process too complex to yield to Empirical Mode Decomposition, and when it will yield.

Spatio-Chromatic Transforms for Compression of Color Images

Researchers: Assistant Professor Irina Popovici and Professor W. Douglas Withers

This project seeks to provide improved compression of color images by designing a new non-linear predictive coding technique that exploits the interdependence in spatially proximate pixels between the color components of images. A raw image file is specified as three components: red, green and blue for each image location (pixel). One can think of an image as a three-dimensional matrix of size width $\times$ height $\times$ 3. Currently predominant image-compression techniques, such as JPEG and JPEG2000, consist of four steps performed in order to compress color images: a color-component transform, a spatial transform, (such as a discrete wavelet or cosine transform), followed then by quantization and predictive coding. This project focuses on the first two steps.

The color-component transform is a linear transform interrelating the three color components, independently on each pixel, yielding a new color basis: a luminance component L and two chrominance components C_b and C_r. This new basis has twin benefits of decreasing entropy and defining a basis closer to the human visual metric. Of the three new color components, the luminance carries more significant information (due to the distribution of the brightness receptors of the human retina), and plays a fundamental role in our prediction model. In contrast, the wavelet transform is a linear transform interrelating pixel values at different spatial locations, independently on each color component, but with the same two benefits.

However, even after the color-component transform and wavelet transforms, obvious redundancies exist among the three image components - redundancies which should be exploitable by an integrated transform operating simultaneously on different color components and different image locations to allow color images to be described more compactly.

Along these lines, the researchers have developed the eidochromatic transform, an additional transform step following the color-component and wavelet transforms. In experiments this transform has been found to reduce the entropy of the C_b and C_r components by up to 40% for a given level of quality (as measured by mean-square error). When JPEG 2000

is modified to incorporate the eidochromatic transform, the overall file-size required for a color image has been found to decrease by up to 15%.

Fluid Structure Interaction Simulation Using Enhanced-Discretization Space-Time Technique with Multi-Mesh

Researchers: Assistant Professor Irina Popovici and Tezduayar and S. Sathe, Rice University

This computational-math project of finding coupled solutions of fluid flows with structure interaction, stemmed from the need of simulating systems found in the aerospace, biomedical, and civil engineering industries, like a submarine, a parachute, or vein as the structure and water, air, or blood as the fluid. Various commercial finite-element programs (like FEMLAB) have proven indispensable in designing safer, more-economical products, by giving numerical estimates of the stresses on the structure while the structure is fixed. The analysis becomes a lot more difficult when the structure moves, due to the need of re-meshing the domain at each time step. Therefore a two-dimensional model is used for the fluid, and the structure is viewed as a one-dimensional moving boundary.

The interface-tracking and interface capturing technique proposed by Dr. Tezduyar was implemented for structures pinned across the flow, and some of that code was also used as a starting point for the simulation of flag-like movements of structures *along* the flow.

The fluid equations are Navier-Stokes equations of incompressible flow in a time-dependent domain whose boundary consists of a time dependent (transient beam) structure with one fixed end and a time independent outer boundary (large rectangle). An initial divergence-free, vorticity-free velocity field is specified. Even if initially the system is in equilibrium, it is an unstable position: vortices will appear in the wake of the structure and the pressure differential on the sides of the structure will make the structure move.

A finite-element approach was used, with coarser mesh near the fixed boundary and refined mesh near the moving beam. The mesh used in updating the flow needs to move with the structure, but re-meshing the entire domain is undesirable, due to the significant time cost. Re-meshing was avoided by solving the equations of linear elasticity for the nodal points in a neighborhood of the structure, therefore preserving the geometry of the mesh.

The beam equations are solved using a semi-discrete formulation. Since the structure responds to fluid flow faster than the fluid's response to beam movement, the structure time has to be smaller than the fluid time, as determined by the natural frequency of the structure.

Solving the differential equations above is reduced to solving large-size linear systems. A more efficient method of approximating the solution to such systems, based on the GMRES algorithms of Professor Atkin, has been developed.

Once the flag simulation was successfully completed for cable structures, we have started a related project on solving advection-diffusion equations on parallel processors. Progress in the computation of the inner products of the finite elements, their storage and the distribution to the 128 processors, has been made, and the parallelization of the process is on-going.

Differential Operators on Toric Schemes

Researchers: Assistant Professor William N. Traves and Mutsumi Saito, Hokkaido University

The ring of differential operators on a toric scheme (a scheme defined by binomial equations) has been investigated. This work generalizes that of Musson, Van den Bergh, Jones, Schwarz, Levasseur and Stafford. In particular, this investigation establishes that the ring of differential operators is always finitely generated and the graded ring associated to the order filtration is finitely generated precisely when the underlying semigroup is scored.

Commutative Algebra and Graph Theory

Researchers: Assistant Professor William N. Traves and Sara Faridi, University of Quebec at Montreal

There are many commutative ideals that are naturally associated to graphs. Perhaps the best-studied is the ideal associated to a simplicial complex. Another interesting ideal is the "edge ideal" of a graph. This is the topic of a recent book by R. Villareal. The aim of this project is to extend some of these new ideas and methods to hypergraphs, producing a new series of results about simplicial complexes. This project complements previous work by Sara Faridi.

Derived Functors of Differential Operators on Stanley-Reisner Rings

Researcher: Assistant Professor William N. Traves

Stanley-Reisner rings are closely connected with simplicial complexes. Differential operators on such rings were previously studied by this researcher. In this project, the derived functions of differential operators on these rings are studied.

Local Cohomology for Stanley-Reisner rings

Researcher: Assistant Professor William N. Traves

Lyubeznick studied the local cohomology of smooth varieties (regular rings). This investigation seeks to generalize his work to the class of Stanley-Reisner rings – rings with very mild singularities.

Composition of Forms: Methods for Contructing Integral Sums of Squares of Formulas

Researchers: Associate Professor JoAnn S. Turisco and R. Kreminski

The problem of composition of forms, or equivalently, the existence of normed bilinear maps, is very old and has attracted the attention of topologists, algebraists, and combinatorists over several decades. During this past academic year, this investigation has concentrated on integral sums of squares formulas and the problem of constructing new formulas from known ones. There are very few examples of formulas which exist in dimension [r,n,s] which are not restrictions of known Radon-Hurwitz formulas in dimensions [r,n,n], and this is the problem which of primary interest.

Using the "intercalate matrices" operation method discovered by Yuzvinsky (and particularly by P. Yiu) that involves a piecing together of matrices, this work involves generating examples using the computer, as well as incorporating topological results concerning the existence of nonsingular bilinear mappings. These results are currently being prepared for eventual publication.

Row Rank Equals Column Rank

Researcher: Professor William P. Wardlaw

While perusing old journal articles I came across two "short proofs" that the row rank of a matrix was equal to the column rank of the matrix, and I knew that I could give a proof much shorter than either of these two. My proof was based on the fact that if A is a nonzero mxn matrix, then both its row rank and its column rank were the smallest positive integer r such that there is an mxr matrix B and an rxn matrix C such that $A = BC$. Moreover, this characterization of rank allowed the easy proof of several other properties of the rank of a matrix. I wrote up these results and submitted the note to the *American Mathematical Monthly*.

A Note on e

Researcher: Professor William P. Wardlaw

It is now in vogue to teach the exponential function first and then to define the logarithm as the inverse of the exponential function. One reaches a point where the existence of the exponentials a^x and the rules of exponents are accepted by students. At this point one wants to introduce the base e for the natural exponential function e^x. There is a method of using the definition of e as that value of a such that the function $f(x) = a^x$ has slope $f'(0) = 1$ at the origin in order to show that for each positive integer n, $(1 + 1/n)^n < e < (1 + 1/n)^{n+1}$. I wrote such a demonstration, along with other properties of the number e. The resulting paper has also been submitted to the *American Mathematical Monthly*.

Various Journal Problems

Researcher**:** Professor William P. Wardlaw

Ten problems with solutions have been prepared for submission to mathematical journals. Seven of these have been submitted along with three solutions to published problems. One of these problems has been published and two have been accepted.

Trident Scholar Projects

Multiresolutional Optic Flow (Trident Report # 302)

Researcher: Midshipman 1/C Matthew J. Ahlert, USN
Advisers: Professor Reza Malek-Madani and Associate Professor John F. Pierce

The irony embedded in optic flow computation is that despite its not having been studied mathematically until about 20 years ago, humans have been performing the related calculations innately since their creation. The process can be thought of as filling in the gaps that occur between the images we see changing in time. For the human mind, the transition is automatic from what an image looks like at one instant to what it looks like at the next. Our brain intuitively generates a continuous flow of what it perceives is being viewed by the eyes.

Manifested in a mathematical sense, optic flow serves as a mechanism to describe the movement of objects in a digital image sequence using a flow field of grayscale intensity. This particular study has focused upon developing a usable mathematical implementation for two of the various algorithms which have been proposed to compute optic flow. One method treats the calculation as a regularization problem while the other relies on a wavelet based multi-scale approach.

Possible applications for such research range from data compression of video sequences to the development of a more efficient way to analyze the time varying one-dimensional acoustic imagery supplied by sonar systems.

Efficient Academic Scheduling at the U.S. Naval Academy (Trident Report # 317)

Researcher: Midshipman 1/C David L. Zane, USN
Advisers: Assistant Professor William N. Traves
and Assistant Professor Christopher W. Brown (Computer Science Department)

This Trident Scholar project examined academic scheduling problems at the U.S. Naval Academy. The focus was on devising methods to construct good final exam schedules and improve existing course schedules by facilitating course changes.

The final exam scheduling problem is an example of an NP-hard problem. These difficult problems do not admit efficient deterministic solutions. Several heuristic methods to treat these problems were considered. An approach using genetic algorithms showed particular promise. Genetic algorithms involve mating “parent” schedules to form favorable

"offspring" schedules and then subjecting these new schedules to local mutation. A computer program implementing these ideas was created and tested.

Section changes at the Naval Academy had been done on an ad-hoc basis, but this project determined that it could be streamlined and improved by using a centralized barter system. The barter technique accepts input listing desired section changes and identifies multi-student section changes to accommodate their desires. A prototype computer program that uses network flow algorithms to find such section changes was devised. In addition, a method incorporating integer programming techniques was examined and tested.

Midshipman Research Course Projects

Construction of an Ethical Combat Utility Function

Researchers: Midshipman 1/C Timothy Dilks, USN,
Midshipman 1/C Jason Jones, USN and Midshipman 1/C Steven Mercer, USN
Adviser**:** Associate Professor E. John Moulis, Jr.
Sponsor: U. S. Naval Academy Center for the Study of Professional Military Ethics

This work describes the construction of a combat utility function as given in the text **Naval Operations Analysis** (3rd edition, Wagner, Mylander, Sanders, eds. 1999), and suggests a way to take into account the normative dimensions of risk exposure. The method proposed allows for a constant value of life to be associated with survivability in carrying out risky combat missions and gives an alternative to the "lottery indifference" concept of the decision maker, on which this combat utility function is based.

An Exploration of the Black-Scholes Pricing Model

Researcher: Midshipman 1/C Jordan T. Levine, USN
Adviser: Professor W. Charles Mylander

This was a research project done in partial fulfillment of the requirements for a degree in Mathematics with Honors. The first part of this project was a reading course in mathematical finance. In preparation for the research, the researcher read the book *An Introduction to Mathematical Finance* by Sheldon M. Ross and subsequently worked through many of the exercises. The first phase of the project dealt with extending the derivation of the Black-Scholes equation to account for transactions cost. The second phase was a statistical analysis testing to determine if the price behavior of different stocks and commodities were consistent with the assumption of Geometric Brownian motion. This is an interesting issue both because the derivation of the Back-Scholes equation is built on the assumption of Geometric Brownian motion and because this assumption is equivalent to the efficient market hypothesis. The statistical analysis supports the conjecture that financial markets are becoming more efficient over time and the trading volume of stocks and commodities seems to be correlated with properties of Geometric Brownian motion.

The Structure of Algebras Generated by Spin Systems

Researcher: Midshipman 1/C Kathryn Macfarlane, USN
Adviser: Professor Geoffrey L. Price
Sponsor: National Science Foundation (NSF) Research for Undergraduate Institutions (RUI) Grant

Midshipman Macfarlane took a series of three reading courses with Professor Price that culminated in her honors thesis on the structure of algebras generated by spin systems. The research problem that she addressed is related to earlier work of Price on spin systems. In a previous paper Price studied the C*-algebras generated by sequences $u_1, u_2, \ldots$ of self-adjoint operators that either commute or anti-commute with translation-invariant commutation relations, i.e., there is a sequence $a_0, a_1, \ldots$ of 0's and 1's such that $u_i u_{i+j} = (-1)^{a_j} u_{i+j} u_i$ for all i and j. Price showed that the C*-algebra has non-trivial proper ideals if and only if the sequence $\ldots, a_2, a_1, a_0, a_1, a_2 \ldots$ is periodic. In her research project Miss Macfarlane studied sequences u_{ij}, with i and j non-negative integers, that satisfy the translation-invariant commutation relations $u_{ij} u_{i+r,j+s} = (-1)^{c_{rs}} u_{i+r,j+s} u_{ij}$, for a sequence c_{rs} of 0's and 1's. This problem was more difficult than anticipated. Although Midshipman

Macfarlane did not succeed in making a complete classification of those sequences that lead to C*-algebras with no proper ideals, she did obtain some very interesting partial results.

Discriminants of Special Hypergeometric Polynomials

Researcher: Midshipman 1/C Joelle Mann, USN
Adviser: Professor George C. Nakos

This was a research project done in partial fulfillment of the requirements for a degree in Mathematics with Honors. An attempt was made to generalize Hilbert's Theorem on the Discriminants of a special hypergeometric polynomial with one numerator and one denominator parameter. Maple programs lead to the discovery of a formula for the discriminant of a general cubic hypergeometric polynomial. The new formula was subsequently proved mathematically. It does generalize Hilbert's Theorem for degree three. For higher degree hypergeometric polynomials a similar but more complicated formula appears to be true. This is currently work in progress.

Analyzing the Campaign

Researcher: Midshipman 1/C Lucas Martin, USN
Adviser: Professor W. Charles Mylander

The Campaign Game was developed by Dahl and Halck for use in studying military decision making. (See the article by Dahl and Bakken published in *Mil. Opns. Res.* **7**(2).) It is a multi-stage two-person zero sum game in which each player allocates an integer number of units to either profit missions, defense missions or attack missions. It has been used in experiments to study the decision making behavior business students and junior officers. The optimal strategy reported is not a good predictor of players' behavior. But problems exist. For one, there are different optimal strategies reflecting different measures of effectiveness (MOE). This paper solves for optimal strategies of the game where the objective of each player is to win by as large a score as possible. The solution approach used both dynamic programming and linear programming. Martin's paper reporting on this work was done as his capstone project paper for SA475E. Mylander plans to extend the work done and submit the paper for publication in *Military Operations Research*.

Exploration of Movement Algorithms Based on Leadership in Agent Based Combat Models

Researcher: Midshipman 1/C Douglas Rosenstock, USN
Adviser: Professor Thomas J. Sanders

Many computer models that simulate combat often overlook intangible variables that could affect a soldier's actions. In many models the feelings of a soldier in battle are not factored into the simulations. Instead, factors such as the kill rate and strength of both sides are formulated into the model. In a real battle however, a combatants' actions are affected by multiple factors, many of which are difficult to measure. One of the main factors that affect soldiers in battle is the strength of the leaders placed in charge of them. It is foolish to believe that two combatants having the same training but different leaders in charge of them will act identically in battle. With this project, several decision-making algorithms that determine the movement of soldiers in battle based on the quality of the leader in charge have been created. The principal tools used were agent based modeling and computer simulation in MATLAB®, as well as absorbing Markov chains.

The goal of this project was to create a decision-making movement algorithm to be used in an agent based combat model that the researcher would build as well. The investigator was interested in (1) seeing what kind of results would be obtained when a simulation using the model was implemented, and (2) seeing how changing the algorithm would affect the outcome. Observing and drawing output from these simulations, he hoped to reach some kind of conclusion as to how the agent's actions in the simulation compared to the created algorithm.

The model used a decision-making algorithm to move agents towards an absorbing point representing a leader, on a matrix representing a battlefield. The algorithm was based on the distance an agent was to the leader, and the leader's level of effectiveness. He then modeled the same algorithm as a Markov chain, and used these results to further explore

the effects of the decision-making algorithm. Next, he devised a way to display the results of the Markov chain program graphically, which allowed one to gain a better understanding of exactly how the agents were acting. Several variations of the problem, were explored, and the effect of using multiple leaders was introduced.

The way the leader was modeled greatly affected the outcome of the simulation. Several complex programs, one of which was an agent based combat simulation model, another that solved extremely large Markov chain problems that otherwise would have taken an excruciatingly long time to solve, were also written. The researcher was successful in modifying these programs in several ways, and achieved new and insightful results each time. He was also successful in showing that both the simulation and Markov chain programs were based on the same movement algorithm, and therefore could both be used to explore the movement of the agents.

Discriminants of Cyclotomic Polynomials

Researcher: Midshipman 1/C Paolo J. Singh, USN
Adviser: Professor George C. Nakos

This is an informal research effort by Midshipman Singh and Professor Nakos. In 1972, Tom Apostol computed the resultants of two cyclotomic polynomials. These computations are useful in group representation theory and classification of finite groups and in number theory. In this research project, the investigators tried to compute discriminants of cyclotomic polynomials. Many special cases were computed. Unlike Apostol's case, since the derivative of a cyclotomic polynomial is not cyclotomic, the obtained formulae are more complicated. This research is at a preliminary stage.

Modeling Combat: An Analysis of the Civil War Battle of Antietam

Researcher: Midshipman 1/C Paolo J. Singh, USN
Adviser: Professor Thomas J. Sanders

Combat modeling is a useful tool - not only for the mathematician or historian, but also for the soldier, as predicting the outcome of battles with known forces and leaders can be a very valuable asset. By knowing the manner in which the forces of each side will attrite, one may be more or less willing to take risks with one's own force. In addition, knowing how certain decisions will affect a battle, one can hope to make the best decisions based on the models.

Perhaps one of the simplest model of combat is the one developed by F.W. Lanchester. A simple model can be quite ideal - from simple models, one may draw conclusions about the overall behavior of forces, rather than focusing on the minute details which may be important, but do not affect the so-called "big picture." It is this big picture that the soldier or tactician would find most useful.

This project was based on the modeling of the Civil War battle at Antietam Creek, known as the bloodiest one-day battle of the Civil War and the bloodiest day ever for Americans. The Battle of Antietam is somewhat of an anomaly when compared with other Civil War battles. This project attempted to draw conclusions about the behavior of the forces at Antietam by applying Lanchester-type equations to the battle. Ideally, one could potentially discover that the Battle of Antietam does "follow the rules" as set by the other Civil War battles, just following along the extreme. This would produce a set of coefficients that could be applied to other battles, yet also adhere to Antietam's results with its particular numbers.

First two other battles fought by the Army of the Potomac and Army of Northern Virginia under Maj. General George McClellan and Lt. General Robert E. Lee, respectively, were examined. These were the Seven Days' Battles and Battle at South Mountain. From these, Lanchester-attrition coefficients were derived for use with comparing them to the Battle of Antietam.

Lanchester-attrition coefficients from the Battle of Antietam itself were also derived, and these were divided into its major phases. During the research, it was hypothesized that a factor affecting the battle could be the use of artillery throughout the battle, and that artillery units were a more lethal force against infantry than the Minié Rifles used by the infantry. This led the researcher to develop not just an overall Lanchester-type model of the phases of the battle, but also a heterogeneous model looking at the artillery forces involved in each Army.

From the heterogeneous model of Antietam it was not possible to produce aggregate coefficients that worked for each portion of the battle. However, one was able to draw conclusions about the battle and its behavior, which were in keeping with what one would expect from other major battles at the time.

Publications

Journal (Refereed) Manuscripts

ALEVRAS, Alexis, Assistant Professor, "One Parameter Semigroups of Endomorphisms of Factors of Type II1," *Journal of Operator Theory*, accepted for publication.

Invariants for continuous semigroups of endomorphisms of type II1-factors were studied. An index is defined, based on R. Powers' notion of the boundary representation, and computed for all known examples on the hyperfinite II1- factor R as well as for examples on the group von Neumann algebra of the free group on infinitely many generators. The analogue of W. Arveson's continuous tensor product system associated with an E0-semigroup was introduced, and it showed that it is a complete invariant under cocycle conjugacy.

Arveson, W. B. and PRICE, Geoffrey L., Professor, "The Structure of Spin Systems," *International Journal of Mathematics,* 14 (2003) pp. 119-137.

A spin system is a sequence of self-adjoint unitary operators $u_1, u_2, \ldots$ acting on a Hilbert space H which pairwise either commute or anticommute, i.e., $u_i u_j = \pm u_j u_i$ for all i and j. There is a unique infinite matrix (c_{ij}) with 0,1 entries satisfying $u_i u_j = (-1)^{c_{ij}} u_j u_i$, $i,j = 1,2,\ldots$.

In cases where the commutation matrix (c_{ij}) is of "infinite rank" it is shown that the C*-algebra generated by an irreducible spin system is the CAR algebra, an infinite tensor product of copies of $M_2(C)$. Irreducible spin systems associated with a given matrix (c_{ij}) are classified up to approximate unitary equivalence.

BENSON, Hande Y., Assistant Professor, Shanno, D. F., and Vanderbei, R. J., "Interior-Point Methods for Nonconvex Nonlinear Programming: Filter Methods and Merit Functions," *Computational Optimization and Applications* **23**(2): 257-272, November 2002.

Recently, Fletcher and Leyffer proposed using filter methods instead of a merit function to control steplengths in a sequential quadratic programming algorithm. In this paper, we analyze possible ways to implement a filter-based approach in an interior-point algorithm. Extensive numerical testing shows that such an approach is more efficient than using a merit function alone.

BENSON, Hande Y., Assistant Professor, Shanno, D. F., and Vanderbei, R. J., "Interior-Point Methods for Nonconvex Nonlinear Programming: Jamming and Comparative Numerical Testing", *Math Program, Ser. A.,* published online, March 2003.

The paper considers a current example of Waechter and Biegler which is shown to converge to a nonstationary point for the standard primal-dual interior-point method for nonlinear programming. The reason for this failure is analyzed and a heuristic resolution is discussed. The paper then compares LOQO, a line-search interior-point code, with SNOPT, a sequential-quadratic-programming code, and NITRO, a trust-region interior-point code on a large test set of nonlinear programming problems. Specific types of problems which can cause LOQO to fail are identified.

BENSON, Hande Y., Assistant Professor, and Vanderbei, R. J., "Solving Problems with Semidefinite and Related Constraints Using Interior-Point Methods for Nonlinear Programming," *Math Program, Ser. B* 95(2), 279-302, February 2003.

In this paper, we describe how to reformulate a problem that has second-order cone and/or semidefiniteness constraints in order to solve it using a general-purpose interior-point algorithm for nonlinear programming. The resulting problems are smooth and convex, and numerical results from the DIMACS Implementation Challenge problems and SDPLib are provided.

BUCHANAN, J. L., Professor, Gilbert, R. P., and Khashanah, L., "Recovery of the Poroelastic Parameters of Cancellous Bone Using Low Frequency Acoustic Interrogation," *Acoustics, Mechanics, and the Related Topics of Mathematical Analysis*, A. Wirgin, ed. World Scientific, p. 41-47.

The conditions are examined under which the poroelastic parameters of cancellous bone-like material can be recovered by acoustic interrogation of a slab specimen. It is found that several important parameters such as porosity, permeability, pore size and the elastic moduli can be recovered with some accuracy.

BUCHANAN, J. L., Gilbert, R. P., Wirgin, A., and Xu, Y. S., "Depth Sounding: An Illustration of Some of the Pitfalls of Inverse Scattering Problems," *Math. Comput. Modelling*, 35: no. 11-12, pp. 1315-1354, 2002.

The principal objective of this work is to show how various `connections' between the estimator and the predictor affect the solution of an inverse scattering problem as it is formulated in the frequency domain. We show that when there is little or no connection, it is impossible to obtain a solution. The other extreme, *i.e.,* identity of the estimator and predictor (inverse crime [ref: D. L. Colton and R. Kress, *Inverse Acoustic and Electromagnetic Scattering Theory*, Springer, Berlin, 1992; MR 93j:35124 (pp. 121, 289)]), enables solutions to be obtained, whatever the particular choices of the estimator or predictor, but these solutions are not trivial, as is written in [op. cit.], in that they are not unique. Moreover, we show that by a suitable change of external variables (e.g., frequency), one can lift the degeneracy and thereby spot the correct solution, which is unique. In this respect, the inverse crime turns out to be useful in that it enables one to devise methods for resolving the nonuniqueness issue of inverse problems. More generally, we show that successful inversion, in both the frequency and time domains, can be accomplished only when the discrepancy between the estimator and the predictor is small.

BUCHANAN, J. L, Professor, Gilbert, R. P., Wirgin, A., and Xu, Y. S., "Unambiguous Identification of the Uneven Boundary of a Halfspace Probed by Acoustic or Electromagnetic Waves," *Math. Comput. Modelling*, 36: no. 1-2, pp. 13-31, 2002.

It is shown that a nonambiguous identification of the scattering boundary is enabled by the use of (1) the physical optics approximation (POA) to simulate the response (i.e., predictor), on a line above the open cylindrical boundary in its cross-section plane, to two probe plane waves of different frequencies, (2) the intersecting canonical boundary approximation (ICBA) of the wave-boundary interaction for a trial boundary (i.e., estimator), and (3) an analysis of the comparison equation and/or cost function, employing the ICBA as estimator and either the ICBA or POA as predictor."

GAGLIONE, Anthony M., Professor, (co-author), "The Elementary Theory of Groups," *Groups St. Andrews/Oxford 2001*, November 2002, accepted for publication.

Remarkable ties between group theory, logic and algebraic geometry have come to light via the positive solution of the Tarski conjecture. This has led to further work on the universal theory of groups. Although this material has had a large impact on group theory, it is not as well known among group theorists as it should be. In this paper, we describe and survey this material a large body of which is not familiar to most group theorists.

Graczyk, Jacek and POPOVICI, Irina, Assistant Professor, "Holder Julia Sets, Uniform Hyperbolicity and the Collet-Eckmann Condition," *New Directions in Dynamical Systems*, 2002, p 405-407.

We relate a geometric rigidity condition for Julia sets of polynomials (or Holder condition for the domain of attraction to infinity) to the expansion along periodic orbits.

For quadratic polynomials we prove that if the Lyapunov exponents on periodic orbits are uniformly separated from zero and if the polynomial is not infinitely renormalizable, then the polynomial satisfies the Collet-Eckmann condition (exponential expansion on the critical orbit).

Greenwald, S. G. and KSIR, Amy E., Assistant Professor, "Thomas Fuller, African American Calculating Wizard!," North Carolina Council of Teachers of Mathematics *Centroid,* accepted for publication.

Thomas Fuller was an African slave brought to America in 1724. His amazing talent with mental arithmetic made him famous and eventually helped to bring about the end of slavery. His story is inspiring to students and can be used as an introduction to computational efficiency and complexity. We will examine what is known about his life and calculating techniques, and ways to incorporate these ideas into the classroom.

HOFFMAN, Michael E., Professor, and Ohno, Yasuo, "Relations of Multiple Zeta Values and Their Algebraic Expression," *Journal of Algebra,* 262 (2003), pp. 332-347.

We establish a new class of relations among the multiple zeta values which we call the cyclic sum identities. These identities have an elementary proof, and imply the "sum theorem" for multiple zeta values. They also have a succinct statement in terms of "cyclic derivations" as introduced by Rota, Sagan, and Stein. In addition, we discuss the expression of other relations of multiple zeta values via the shuffle and "harmonic" products on the underlying vector space H of the noncommutative polynomial ring Q<x,y>, and also using an action of Q<x,y> on the Hopf algebra of quasi-symmetric functions.

HOFFMAN, Michael E., Professor, "Combinatorics of Rooted Trees and Hopf Algebras," *Transactions of the American Mathematical Society*, accepted for publication.

We begin by considering the graded vector space with a basis consisting of rooted trees, with grading given by the count of non-root vertices. We define two linear operators on this vector space, the growth and pruning operators, which respectively raise and lower grading; their commutator is the operator that multiplies a rooted tree by its number of vertices, and each operator naturally associates a multiplicity to each pair of rooted trees. By using symmetry groups of trees we define an inner product with respect to which the growth and pruning operators are adjoint, and obtain several results about the associated multiplicities.

Now the symmetric algebra on the vector space of rooted trees (after a degree shift) can be endowed with a coproduct to make a Hopf algebra; this was defined by Kreimer in connection with renormalization. We extend the growth and pruning operators to Kriemer's Hopf algebra and related them via the inner product. On the other hand, the vector space of rooted trees itself can be given a noncommutative multiplication: with the appropriate coproduct, this gives a Hopf algebra studied by Grossman and Larson. We show that the inner product on rooted trees can be used to define an isomorphism of the Grossman-Larson Hopf algebra with the graded dual of Kreimer's Hopf algebra, correcting an earlier result of Panaite.

JOYNER, W. D., Professor, "Arithmetic of Characters of Generalized Symmetric Groups," *Archiv der Mathematik*, accepted for publication.

The result here answers the following questions in the affirmative: Can the Galois action on all abelian (Galois) fields K/Q be realized explicitly via an action on characters of some finite group? Are all subfields of a cyclotomic field of the form Q(χ), for some irreducible character χ of a finite group G? In particular, we explicitly determine the Galois action on all irreducible characters of the generalized symmetric groups. We also determine the "smallest" extension of Q required to realize (using matrices) a given irreducible representation of a generalized symmetric group.

JOYNER, W. D., Professor and Fourte, Michael, "Odd King Tours on Even Chessboards," *Journal of Recreational Mathematics*, Vol. 31 (2003) pp. 173-177.

In this paper we show that there is no complete odd king tour on an even chessboard, partially answering a question raised by C. Bailey and M. Kidwell. This paper shows, in particular, that the ordinary 8x8 chess board has no complete odd king tour.

KIDWELL, Mark E., Professor and Stoimenow, Alexander, "Examples Relating to the Crossing Number, Writhe, and Maximal Bridge Length of Knot Diagrams," *Michigan Mathematical Journal*, Volume 51, 2003, pp. 3-12.

We give examples illustrating several phenomena concerning maximal bridge length and writhe of knot diagrams, and relate these to properties of their Kauffman polynomials. Extensive use was made of the knot enumeration program Knotscape.

KONKOWSKI, Deborah A., Professor (co-author), "Quantum Singularity of Quasiregular Spacetimes, as Indicated by Klein-Gordon, Maxwell and Dirac Fields," *General Relativity and Gravitation,* 35, pp. 79 - 96 (2003).

Klein-Gordon, Maxwell and Dirac fields are studied in quasiregular spacetimes, those spacetimes containing a classical quasiregular singularity, the mildest true classical singularity [G. F. R. Ellis and B. G. Schmidt, Gen. Rel. Grav. 8, 915 (1977)]. A class of static quasiregular spacetimes possessing disclinations and dislocations [R. A. Puntigam and H. H. Soleng, Class. Quantum Grav. 14, 1129 (1997)] is shown to have field operators which are not essentially self-adjoint. This class of spacetimes includes an idealized cosmic string, i.e. a four-dimensional spacetime with a conical singularity [L. H. Ford and A. Vilenkin, J. Phys. A: Math. Gen. 14, 2353 (1981)] and a Gal'tsov/Letelier/Tod spacetime featuring a screw dislocation [K. P. Tod, Class. Quantum Grav. 11, 1331 (1994); D. V. Gal'tsov and P.S. Letelier, Phys. Rev. D47, 4273 (1993)]. The definition of G. T. Horowitz and D. Marolf [Phys. Rev. D 52, 5670 (1995)] for a quantum-mechanically singular spacetime as one in which the spatial-derivative operator in the Klein-Gordon equation for a massive scalar field is not essentially self-adjoint. The definition is extended here, in the case of quasiregular spacetimes, to include Maxwell and Dirac fields. It is shown that the class of static quasiregular spacetimes under consideration is quantum-mechanically singular independent of the type of field.

LIAKOS, Anastasios, Assistant Professor, and Lee, H. K., "Two-level Finite Element Discretization of Viscoelastic Fluid Flow," *Computer Methods for Applied Mechanics and Engineering,* 24 February 2003, accepted for publication.

We propose and analyze a two-level method of discretizing the equations of steady-state flow of a viscoelastic fluid obeying an Oldroyd-type constitutive equation with no-slip boundary condition.

The two-level algorithm consists of solving a small non-linear system of equations on the coarse mesh and then using that solution to solve a larger linear system on the fine mesh. Specifically, following Najib and Sandri, we linearize the Oldroyd-type constitutive equation about the coarse mesh solution thus nullifying the difficulties brought by the advection term. Our theoretical error estimates show that it has optimal order accuracy provided the true solution is smooth and its norm is sufficiently small. In addition, our computational error estimates exhibit the validity of our analysis.

Liu, Y, Bank R., Dupont T., GARCIA, Sonia M. F., Associate Professor, and Santos, R., "Symmetric Error Estimates for Moving Mesh Mixed Methods for Advection-diffusion Equations", *SIAM, Journal on Numerical Analysis* (SINUM ms#038073) (2003), accepted for publication.

A mixed method allowing a general class of mesh movements is proposed for an advection-diffusion equation in either conservative or non-conservative form. Various symmetric error estimates are derived for the method under certain conditions. In one space dimension (1-d), optimal order L^2 convergence and superconvergence are proved as a corollary of the symmetric estimates.

LOCKHART, Jody M., Associate Professor and WARDLAW, William P., Professor, "Chain Addition Cycles," Linear Algebra and Its Applications, 362, (2003) pp 1- 10.

Chain addition is a technique employed in cryptography for extending a short sequence of numbers, called the seed, to a longer sequence of pseudorandom numbers. In chain addition modulo m, the sum (modulo m) of the first two numbers of the seed is placed at the end of the seed; then the sum of the second and third numbers is placed next. This process is continued eventually using the newly generated numbers. We investigate the maximal period of chain addition cycles with seed length n (modulo m). This problem was previously studied in the case n = 2 by Green and Liebeck ("Bracelets," Math Gazette 1990) and Wall ("Fibonacci series modulo m," Amer Math Monthly, 1995).

The general problem is first reduced to the case when m is a power of a prime by showing that this maximal period is submulitplicative in m. The relationship between the maximal period modulo p^k for different values of k is then investigated. It is shown that there is a positive integer r such that the periods modulo p, modulo p^2, … , modulo p^r are all equal and the period modulo p^{r+t} is p^t times the period modulo p^r for all positive integers t. The question of whether r is always 1 is investigated but not resolved.

MARUSZEWSKI, Richard F. Jr., Professor, "A Unifying Probability Example," *MACE Journal*, Vol 36, #3, pp 213-17.

Discusses an example from Probability and Statistics that ties together several different topics including the mean and variance of a discrete random variable, the binomial and Poisson distributions, the sum of independent random variables, and the central limit theorem.

MARUSZEWSKI, Richard F. Jr., Professor, "Launching a Projectile into Deep Space," MACE Journal, accepted for publication.

A mathematical investigation into finding the amount of energy needed to launch a projectile from the surface of the earth into deep space.

MCCOY, Peter A., Professor, "On the Singularities of Fractionalized Potentials," Complex Variables: Theory and Application, an International Journal, Vol. 47, no. 6 (June 2002) pp. 507-512.

The singularities of harmonic functions generated under the action of an integral transform with a fractionalized kernel are studied. A simple relationship arises connecting pairs of singularities.

MCCOY, Peter A., Professor, "Electromagnetic Field Singularities," Journal of Math Analysis and Applications, 275, (2002) pp. 761-770.

An integral transform based method is given for determining information about the location and properties of singularities of electromagnetic fields associated with axially symmetric radiating sources.

MICHAEL, T. S., Associate Professor, "Impossible Decompositions of Complete Graphs into Three Petersen Subgraphs," Bulletin of the Institute of Combinatorics and Its Applications, accepted for publication.

We prove that it is impossible to decompose the complete graph on 9 vertices into three copies of the graph obtained from the Petersen graph by deleting a vertex. This result generalizes a theorem of Schwenk.

MICHAEL, T. S., Associate Professor, "Signed Degree Sequences and Multigraphs," Journal of Graph Theory, Vol 41, (2002) pp. 101-105.

We give necessary and sufficient conditions for a sequence of integers to be the signed degree sequence of a signed multigraph. Our main theorem completely solves a problem in the recent literature of graph theory.

MICHAEL T. S., Associate Professor, and Pinciu, Val, "Art Gallery Theorems for Guarded Guards," *Computational Geometry: Theory and Applications,* accepted for publication.

Let P be a polygon (the art gallery) with n sides. We wish to select a set G of points (the guards) so that (a) every point in the polygon is visible to some guard; and (b) every guard is visible to at least one other guard. What is the minimum number of guards g(n) that is guaranteed to suffice for all polygons with n sides? We prove that g(n) = floor[(3n-1)/7] for n at least 5. Also, if we restrict to rectilinear galleries the function is floor (n/3) for n at least 6.

MICHAEL, T. S., Professor, and Quint, Thomas, "Sphere of Influence Graphs and the L-Infinity Metric," *Discrete Applied Mathematics,* accepted for publication.

We introduce sphere of influence graphs (SIGs) in the L-infinity metric and study their fundamental properties. We argue that SIGs defined with the L-infinity metric are superior to the Euclidean SIGs of Toussaint in capturing low-level perceptual information in certain dot patterns. Every graph without isolated vertices is a SIG in the L-infinity metric for all sufficiently high dimensions, and this allows us to define a graphical parameter, the SIG-dimension, that is akin to boxicity. We determine the SIG-dimensions for some classes of graphs and obtain inequalities for others.

MICHAEL, T. S., Associate Professor, and TRAVES, William N., Assistant Professor, "Independence Sequences of Well-Covered Graphs: Non-Unimodality and the Roller-Coaster Conjecture," Graphs and Combinatorics, accepted for publication.

A graph G is well-covered provided every independent set of vertices has the same cardinality. The k-th term of the independence sequence of G equals the number of independent vertex sets of cardinality k in G. We disprove a recent unimodality conjecture for independence sequences of well-covered graphs and replace it by a more complicated conjecture. We prove our conjecture for several infinite families of graphs.

Saito, Mutsumi and TRAVES, William N., Assistant Professor, "Finite Generation of Differential Algebras on Semigroup Algebras," [in Japanese], *Research Institute of Mathematical Sciences (Kyoto) Bulletin*, Fall 2002, accepted for publication.

This is a Japanese summary of some of the authors work. It also contains some comments on Serre's S-2 condition and the Cohen-Macaulay property for semigroup algebras.

WARDLAW, William P., Professor, Problem 171, *Math Horizons*, X, 4 (April 2003) p. 32.

Problem 171. The Fibonacci sequence $\{f_k\}$ is defined recursively by $f_0 = 0$, $f_1 = 1$ and $f_{k+1} = f_k + f_{k-1}$ for $k \geq 1$. Determine the last three digits of $f_{123456789}$.

Conference Proceedings

BENSON, Hande Y., Assistant Professor, and Ogden, J. M., "Mathematical Programming Techniques for Designing Minimum Cost Pipeline Networks for CO2 Sequestration," *Proceedings of the Sixth Greenhouse Gas Technologies Conference*, Kyoto, Japan, September 2002.

It has been proposed that the CO_2 produced at sources such as fossil energy conversion facilities and industrial process plants could be captured, compressed to supercritical pressures, transported via pipelines and stored in underground geologic formations such as depleted oil and natural gas reservoirs and deep saline aquifers. In this paper, we describe the initial phases of a project using mathematical programming techniques to find the minimum cost network for transporting the CO_2 from the sources to the sinks. A non-linear model of the CO_2 pipeline system is described, with appropriate constraints, and the lowest cost system is found using state-of-the-art nonlinear

optimization software called LOQO. We also present ways to model the behavior of the system over time, and to model the impact of uncertainties. In future work, we plan to extend these methods to look at the larger system of fossil energy complexes with CO_2 capture and sequestration and distribution of hydrogen.

BENSON, Hande Y., Assistant Professor, Shanno, D. F., and Vanderbei, R. J., "A Comparative Study of Large Scale Nonlinear Optimization Algorithms," Proceedings of the Workshop on High Performance Algorithms and Software for Nonlinear Optimization, Erice, Italy, October 2002.

In recent years, much work has been done on implementing a variety of algorithms in nonlinear programming software. In this paper, we analyze the performance of several state-of-the-art optimization codes on large-scale nonlinear optimization problems. Extensive numerical results are presented on different classes of problems, and features of each code that make it efficient or inefficient for each class are examined.

KONKOWSKI, Deborah A., Professor (co-author), "Quantum Singularities," Gravitation and Cosmology, Proceedings of the Spanish Relativity Meeting, ed. L. Gutierrez and L. Alberto (Barcelona, Spain: University of Barcelona Press) 2003.

The definitions of classical and quantum singularities in general relativity are reviewed. The occurrence of quantum mechanical singularities in certain spherically symmetric and cylindrically symmetric (including infinite line mass) spacetimes is considered. A strong repulsive "potential" near the classical singularity is shown to turn a classically singular spacetime into a quantum mechanically nonsingular spacetime.

KSIR, Amy E., Assistant Professor and Naculich, S. G., "Elliptic Fibrations and Elliptic Models," Topics in Algebraic and Noncommutative Geometry: Proceedings in Memory of Ruth Michler, American Mathematical Society, Providence, RI, June 2003.

We study the Seiberg-Witten curves for N=2 SUSY gauge theories arising from type IIA string configurations with two orientifold sixplanes. Such theories lift to elliptic models in M-theory. We express the M-theory background for these models as a nontrivial elliptic fibration over C. We discuss singularities of this surface, and write the Seiberg-Witten curve for several theories as a subvariety of this surface.

NAKOS, George C., Professor and Williams, Robert M., "Methods for the Object-Image Equations of N Points," Proceedings of the 8th International Conference on Applications of Computer Algebra, University of Thessaly, Volos, Greece, 28 June 2002, pp.72-82.

We assume that a set of three-dimensional points produces a two-dimensional image. Our goal is to describe relations between the coordinates of the object points and the image points without using the parameters of the transformation that has produced this image. These are known as *object-image equations*. Both the object points and the image points are determined up to a projective colineation. We base our approach on earlier work by Quan. Stiller, Asmuth, and Wan have produced a different set of object-image equations.

POPOVICI, Irina, Assistant Professor and WITHERS, W. Douglas, Professor, "A New Transform for Lossy Image Coding," *Proceedings of the 2003 International Conference on Imaging Science, Systems, and Technology*, June 2003.

Luminance and chrominance components of a color image have redundancies often exploited for coding the image with a reduced number of bits, while maintaining good visual quality for the decoded image. Most existing image-coding algorithms use spatial correlation between pixels in each color-transformed image component via wavelet or other spatial transform, but applied separately to the luminance and to each chrominance component.

This paper introduces a non-linear predictive transform that exploits the interdependence between spatially proximate pixels of different color components. The eidochromatic transform reduces the entropy of a quantized chrominance component up to 40% or more over a wavelet transform alone. Combined with JPEG 2000 coding techniques, the eidochromatic transform reduces the bit-rate for the entire image at a specified mean-square error by up to 10% or more when compared to JPEG 2000 alone.

Books

JOYNER, W. David, Professor, Kreminski, R., and TURISCO, JoAnn S., Associate Professor, *Applied Abstract Algebra,* Johns Hopkins Univ Press, accepted for publication.

This text is based on notes which have been used in teaching at Texas A& M at Commerce, and at the U.S. Naval Academy, for several semesters. The notes were used to teach three different courses. One was a first course in modern algebra that emphasized applications and had once-a-week computer labs. This course was for students who only had a "fundmentals in mathematics" course and a matrix theory course as background. (So, they knew, for example, mathematical induction and how to compute eigenvalues of a matrix). This course covered some of chapters 1,2,3,4 and 5 in this new text. The second course was one on error-correcting codes. This course covered chapters 2 and 3 in more detail, and chapter 6 in this new text. The third course was given to a class consisting mostly of computer science graduate students.

On one hand, this book aims to teach some undergraduate modern algebra with an emphasis on applications. These applications are mostly focused on error-correcting codes, the Rubik's cube and cryptography. Each chapter has exercises in GAP (a free computer algebra system) and MAGMA (a non-commercial but not free computer algebra system). Both have extensive capabilities to do modern algebra. Since many of the applications are oriented to communications, it is natural to use computers to understand these applications. In fact, for coding theory and cryptography, many systems use such large parameters that working practical "by hand" is virtually impossible and computers are not just useful but required. Moreover, most chapters end with some "special projects", which might be useful for a student class project.

On the other hand, it can be used to teach an undergraduate course in error-correcting codes or an upper level course in computer science. The GAP and MAGMA exercises are especially helpful for giving the student a grasp of examples. After such a course, the student should be prepared to move onto a more serious treatment.

MELLES, Caroline G., Associate Professor, coordinating editor; additional editors: Brasselet, Jean-Paul, Kennedy, Gary, Kristen Lauter, Kristen, and McEwan, Lee, *Topics in Algebraic and Noncommutative Geometry: Proceedings in Memory of Ruth Michler*, AMS Contemporary Mathematics Series, Volume 324, June 2003, 233 pages.

Associate Professor Melles was the coordinating editor of this book, which presents the proceedings of two conferences, the Annapolis Algebraic Geometry Conference (Annapolis, MD) and Résolution des singularités et géométrie non commutative (Luminy, France). Associate Professor Melles was the main organizer of the Annapolis Algebraic Geometry Conference and was co-organizer of the conference in France. Research articles in the volume cover various topics of algebraic geometry, including the theory of Jacobians, singularities, applications to cryptography, and more. The book is intended for graduate students and research mathematicians.

TURNER, John C., Professor, Solutions Manual for *Introduction to the Practice of Statistics*, 4th Ed, by Moore and McCabe.

The Moore and McCabe text is one of the best sellers in introductory probability and statistics and is authored by a past president of the American Statistical Association. I prepared both the answers to appear in the back of the text and the instructor's manual. This involved working over 1200 problems in the text, as well as preparing directions for instructors who might not be familiar with the topics.

TURNER, John C., Professor, "Statistics in Research," a supplement to *Introduction to the Practice of Statistics*, 4th Ed, by Moore and McCabe.

This contribution is half of the supplement text. It consists of 7 journal articles in a variety of fields. The students are to apply the ideas of the text to the articles. This includes identifying variables and analyses. In many instances, enough data is given to reproduce the calculations in the article.

Technical Reports

CRAWFORD, Carol G., Professor, "Educational Effectiveness and General Education at The University of the Sciences," Commission on Higher Education, Middle States Evaluation Team Final Report, November 2002.

JOYNER, W. David, Professor, "An introduction to Group Cohomology and Homology."

This expository paper surveys with some proofs homology and cohomology theories for a finite group.

SANDERS, Thomas J, Professor, "RAT-STATS II User's Guide," Department of Health and Human Services, OIG, Office of Audit Services, September 2002.

RAT-STATS is a suite of modules that was initially developed by the Regional Advanced Techniques Staff (RATS) in San Francisco to aid in auditing procedures using a mainframe computer. This software and companion User's Guide contains a portion of those modules that were converted to the MS Windows environment. The RAT-STAT modules include ratio and regression estimation for unrestricted and stratified samples, two-stage variable ratio and regression estimation, attribute discovery sample size, sample size for controlling alpha and beta risks, one-step acceptance sampling, two-step acceptance sampling, and two-step attribute appraisals.

Presentations at Professional Meetings and Conferences

ALEVRAS, Alexis, Assistant Professor, "Irreversible Flows on von Neumann Algebras," Vanderbilt University, 18 February 2003.

ALEVRAS, Alexis, Assistant Professor, "L2-Betti Numbers for Groups and Equivalence Relations," Mathematics Colloquium, U.S. Naval Academy, 22 and 27 January 2003.

Andre, Linda and ANDRE, Peter P., Professor, "A Mathematical Walk Through the Sculpture Garden of the Baltimore Museum of Art," Bridges Conference, Towson MD, July 2002.

Andre, Linda and ANDRE, Peter P., Professor, "Mathematics and Art," Anne Arundel Community College, Severna Park, MD, 8 May 2003.

BENSON, Hande Y., Assistant Professor, "Designing an Interior-Point Method for Large-Scale Nonlinear Programming," INFORMS 2002 Annual Conference, San Jose, CA, 17 – 20 November 2002. (Invited talk)

BENSON, Hande Y., Assistant Professor, "Solving Nonlinear Complementarity Problems Using Interior-point Methods for Nonlinear Programming," INFORMS 2002 Annual Conference, San Jose, CA, , 17 – 20 November 2002. (Invited talk)

BUCHANAN, James L., Professor, "Determination of the Poroelastic Parameters of Cancellous Bone Using Low Frequency Acoustic Measurements," Acoustics, Mechanics and the Related Topics of Mathematical Analysis, Frejus, France, 19 June 2002.

CRAWFORD, Carol G., Professor, "Interactive WEB Based Labs for the Calculus Sequence," Math Fest National MAA Conference, Burlington, Vermont, 2 August 2002.

CRAWFORD, Carol G., Professor, and MEYERSON, Mark D., Professor, "Interactive Web Based Labs for the U.S. Naval Academy - Real World Applications Designed with Java for the 3-semester Calculus Sequence," Maryland Council of Teachers of Mathematics 2002 Fall Conference on *Discovering Interrelationships as You Visualize and Explore Mathematics*, 18 October 2002. (Invited workshop)

GAGLIONE, Anthony M., Professor, "Discriminating and Squarelike Groups," American Mathematical Society (AMS) Annual Conference, Baltimore, MD, January 2003.

GAGLIONE, Anthony M., Professor, "Nontrivially Discriminating Groups," Zassenhaus Group Theory Conference, Indiana, March 2003.

GAGLIONE, Anthony M., Professor, "Probability and Group Theory," Fairfield University, Fairfield, CT, October 2002.

GAGLIONE, Anthony M., Professor, "Examples of Discriminating Groups," Temple University, Philadelphia, PA, March 2003.

GAGLIONE, Anthony M., Professor, "The Axiomatic Closure of the Class of Discriminating Groups is the Class of Squarelike Groups," New York Group Theory Seminar, May 2003.

GARCIA, Sonja M. F., Associate Professor, "Overview of HARLIE Measurement Capabilities," Oceanography Department, U.S. Naval Academy, Annapolis, MD, 23 October 2002.

GARCIA, Sonja M. F., Associate Professor, "From Numerical Analysis to Analysis of the Numerics," Computational Science & Engineering Branch, Computational & Information Sciences Directorate, AMSRL-CI-HC, Bldg. 394, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, 2 June 2003.

HANNA, Charles C., Professor, "Related Rates Problems," Teachers Teaching with Technology Regional Conference, Wilmington, DE, 28 February - 1 March 2003.

HANNA, Charles C., Professor, "Related Rates Problems," Teachers Teaching with Technology International Conference, Nashville, TN, 7 - 9 March 2003.

HOFFMAN, Michael E., Professor, "Algebraic Aspects of Multiple Zeta Values," International Symposium on Zeta Functions, Topology, and Quantum Physics, Kinki University, Osaka, Japan, March 4, 2003. (Invited talk)

HOFFMAN, Michael E., Professor, "Multiple Zeta Values: The View from Osaka," JAMI Conference on Primes and Knots, The Johns Hopkins University, Baltimore, MD, 16 March 2003. (Invited talk)

HOFFMAN, Michael E., Professor, "Updown Posets," Mathematics Colloquium, U.S. Naval Academy,. Annapolis, MD, 18 September 2002.

JOYNER, W. David, Professor, "Representations of Riemann-Roch Spaces," American Mathematical Society (AMS) Annual Conference, Baltimore, MD, January 2003. (Invited talk)

JOYNER, W. David, Professor, "The Toric Package in GAP/MAGMA," poster session at ECCAD, April 2003.

JOYNER, W. David, Professor, "Toric Codes," National Security Agency (NSA), Ft. Meade, MD, February 2003.

JOYNER, W. David, Professor, "Representations of Riemann-Roch Spaces," U.S. Naval Academy, Annapolis, MD, Fall 2002.

JOYNER, W. David, Professor, "Toric Codes," U.S. Naval Academy, Annapolis, MD, Fall 2002.

KAPLAN, Harold M., Professor, "A Two-Sample Sign Test with Unbalanced Matching," Mid-Atlantic Probability and Statistics Day, George Washington University, Washington, D.C., 16 November 2002.

KONKOWSKI, Deborah A., Professor, "Quantum vs. Classical Singularities," Meeting of the American Physical Society, Philadelphia, PA, 6 April 2003.

KONKOWSKI, Deborah A., Professor, "Classical vs. Quantum Singularities," 6th East Coast Gravity Meeting, College Park, MD, 29 March 2003.

KONKOWSKI, Deborah A., Professor, "Quantum Singularities," XXI Texas Symposium on Relativistic Astrophysics, Florence, Italy, 8 – 13 December 2002.

KONKOWSKI, Deborah A., Professor, "Are Classically Singular Spacetimes Quantum-Mechanically Singular as Well?" Mathematical Physics Seminar, Loughborough University, Loughborough, England, 20 November 2002.

KONKOWSKI, Deborah A., Professor, "Are Classically Singular Spacetimes Quantum-Mechanically Singular as Well?" Mathematical Physics Seminar, University of York, York, England, 7 November 2002.

KONKOWSKI, Deborah A., Professor, "Quantum Singularities," Spanish Relativity Meeting, Mao, Menorca, Spain, 22 September 2002.

KONKOWSKI, Deborah A., "Are Classically Singular Spacetimes Quantum-Mechanically Singular as Well?" General Relativity Seminar, University of Southampton, Southampton, England, 22 May 2003.

KSIR, Amy E., Assistant Professor, "Representations of Finite Groups on Riemann-Roch Spaces and Goppa Codes," Institute for Advanced Study Program for Women in Mathematics, 10th Anniversary Reunion, 16-18 May 2003.

LIAKOS, Anastasios, Assistant Professor, "Slip Boundary Conditions in Viscoelastic Fluid Flow," SIAM Annual Meeting, Philadelphia PA, 7 – 12 July.

MAHAR, T. J., Associate Professor, "The Ghost Fluid Method and Godunov's Method for the Euler Equations of Fluid Flow," Joint U.S. Naval Academy – Naval Surface Warfare Center, Indian Head Program Review, U.S. Naval Academy, Annapolis, MD, August 2002.

MARUSZEWSKI, Richard F., Jr., Professor, "Elliptic Curves and Factoring," Cryptology Seminar, U.S. Naval Academy, Annapolis, MD.

MCCOY, Peter A., Professor, "Electromagnetic Field Singularities with p-fold Symmetry," Special Session on High Power Microwave Technology (Antennas), AMEREM 2002, International Symposium on Electromagnetics, 5 Annapolis, MD, June 2002.

MCCOY, Peter A., Professor, "Electromagnetic Field Singularities," SIAM 50th Annual Meeting in the Mini-symposium on H-Infinity Methods in Electromagnetics, Philadelphia, PA, 12 July 2002.

MYLANDER, W. C., Professor, "The State of OR at the U.S. Naval Academy," MORS Educational & Professional Development Colloquium, Monterey CA, 2 April 2003.

NAKOS George C., Professor, "The Object-Image Equations of N Points," Clarkson University, Potsdam, NY, September 2002.

PENN, Howard L., Professor, "The Impact of Technology in Calculus Courses on Long-Term Student Performance and Employment, Registration Data," Joint Mathematics Meeting, Baltimore, MD, January 2003.

POPOVICI, Irina, Assistant Professor, "Holder Julia Sets, Uniform Hyperbolicity and The Collet-Eckmann Condition," Satellite Conference of International Congress in Mathematics, NDDS 2002, University of Kyoto, Japan, 11 August 2002.

POPOVICI, Irina**,** Assistant Professor, "Green's Function Estimates for The Thickness of Julia Sets," Jubilary Session of Scientific Reports at the Romanian Naval Academy, Constanta, Romania, 14 November 2002.

POPOVICI, Irina, Assistant Professor, "Fluid Structure Interaction Simulation Using Enhanced-Discretization Space-Time Technique with Multi-Mesh," High Performance Computing Project, U.S. Naval Academy, Annapolis, MD, 17 April 2003.

PRICE, Geoffrey L., Professor, "Spin Systems and Toeplitz Matrices," Non-commutative Geometry and Operator Algebra Seminar, Vanderbilt University, 12 November 2002.

PRICE, Geoffrey L., Professor, "Shifts of Minimal Commutant Index," American Mathematical Society Annual Meeting, Special Session on "A Centennial Celebration in Honor of J. von Neumann and M. H. Stone," Baltimore, MD, 18 January 2003.

SANDERS, Thomas J., Professor, "Using RAT-STATS II," Statistical Specialists' Meeting, 10-12 June 2003.

Shyu, Haw-Jye, R. Hillson, and D'ARCHANGELO, James, Professor, "An Integrated ESME (Effects of Sound on the Marine Environment) Workbench," Office of Naval Research (ONR) Conference: The Environmental Consequences of Underwater Sound (ECOUS), San Antonio, TX, 12-16 May 2003.

TURNER, John C., Professor, "Teaching the Assumptions of the Binomial Distribution," Probability and Statistics Day, George Washington University, Washington, D.C., 16 November 2002.

TRAVES, William N., Assistant Professor, "Homological Uses of Rings of Differential Operators", AMS International Meeting, Special Session, Seville, Spain, 21 June 2003. (Invited speaker)

TRAVES, William N., Assistant Professor, "Higher Derivations and the Steenrod Algebra," INGO European Invariant Theory Conference, Göttingen, Germany, 27 March 2003. (Invited speaker)

TRAVES, William N., Assistant Professor, "Higher Derivations in Algebraic Geometry," Mathematics Department Colloquium, U.S. Naval Academy, Annapolis, MD, 19 March 2003.

TRAVES, William N., Assistant Professor, "Solving Equations at the Naval Academy," Maui High Performance Computing Center, Maui, Hawaii, 28 June 2002. (Invited lecture)

WARDLAW, William P., Professor, "Minimum Cardinality of Finitely Non-associative Groupoids," Annual Meeting of the AMS-MAA, Baltimore, MD, 16 January 2003.

WARDLAW, William P., Professor, "The Set S' of Accumulation Points of the Set S of Totient Ratios," Spring Meeting of the MD-VA-DC Section of the MAA at Norfolk State University, Norfolk, VA, 12 April 2003.

WITHERS, W. Douglas, Professor, "Hardware vs. Software: A Case Study," Applied Mathematics Seminar, U.S. Naval Academy, Annapolis, MD, 5 December 2002.