Joint Summer Research Conferences in the Mathematical Sciences

Mount Holyoke College
South Hadley, Massachusetts
June 10–August 9, 2001

The 2001 Joint Summer Research Conferences will be held at Mount Holyoke College, South Hadley, Massachusetts, from June 10 to August 9, 2001. The topics and organizers for the conferences were selected by a committee representing the AMS, the Institute of Mathematical Sciences (IMS), and the Society for Industrial and Applied Mathematics (SIAM). Committee members at the time were Alejandro Adem, Paul Baum, Laurel Beckett, David Brydges, James W. Demmel, Dipak Dey, Tom Diciccio, James A. Fill, Steve Hurder, Alan F. Karr, Barbara Keyfitz, W. Brent Lindquist, Andre Manitius, and Bart Ng.

It is anticipated that the conferences will be partially funded by a grant from the National Science Foundation and perhaps others. Special encouragement is extended to junior scientists to apply. A special pool of funds expected from grant agencies has been earmarked for this group. Other participants who wish to apply for support funds should so indicate; however, available funds are limited, and individuals who can obtain support from other sources are encouraged to do so.

All persons who are interested in participating in one of the conferences should request an invitation by sending the following information to Summer Research Conferences Coordinator, AMS, P. O. Box 6887, Providence, RI 02940, or by e-mail to wsd@ams.org **no later than March 3, 2001**.

Please type or print the following:

1. Title and dates of conference.
2. Full name.
3. Mailing address.
4. Phone numbers (including area code) for office, home, and fax.
5. E-mail address.
6. Your anticipated arrival/departure dates.
7. Scientific background relevant to the Institute topics; please indicate if you are a student or if you received your Ph.D. on or after 7/1/93.
8. The amount of financial assistance requested (or indicate if no support is required).

All requests will be forwarded to the appropriate organizing committee for consideration. In late April all applicants will receive formal invitations (including specific offers of support if applicable), a brochure of conference information, program information known to date, along with information on travel, and dormitory and other local housing. All participants will be required to pay a nominal conference fee.

Questions concerning the scientific program should be addressed to the organizers. Questions of a nonscientific nature should be directed to the Summer Research Conferences coordinator at the address provided above. Please watch http://www.ams.org/meetings/ for future developments about these conferences.

Lectures begin on Sunday morning and run through Thursday. Check-in for housing begins on Saturday. No lectures are held on Saturday.

Statistics in Functional Genomics

Sunday, June 10–Thursday, June 14, 2001

Françoise Seillier-Moiseiwitsch (chair), University of North Carolina at Chapel Hill
Richard Simon, National Cancer Institute, NIH
Kay Tatsuoka, GlaxoSmithKline Pharmaceuticals

The major recent technological advances in molecular biology have brought with them an explosion of molecular data. Scientific progress has in many cases already depended on the development and application of novel statistical and mathematical methodology. This meeting will bring together researchers in molecular biology, statistics, probability theory, computer science and computational biology. The following topics will be discussed: analytical methods for micro-array data and proteiomics, linking sequences to phenotypes, structure prediction, and computing resources in functional genomics.

Fluid Flow and Transport in Porous Media: Mathematical and Numerical Treatment

Sunday, June 17–Thursday, June 21, 2001

Zhangxin (John) Chen (co-chair), Southern Methodist University
Richard Ewing (co-chair), Texas A&M University
Jose Lage, Southern Methodist University
Raytcho Lazarov, Texas A&M University

The need to study and understand the complex physical and chemical processes occurring in and around the earth, such as groundwater contamination, oil reservoir production, discovering new oil reserves, and ocean hydrodynamics, has been increasingly recognized. For example, over half of the population in the U.S. depends on groundwater for its water supply. In many regions available sources of groundwater are a fundamental constraint on development and economic activity. Groundwater supplies are increasingly threatened by organic, inorganic, and radioactive contaminants introduced into the environment by improper disposal or accidental release. Estimates of remediation costs in this country alone range into the hundreds of billions of dollars. Protecting the quality of groundwater supplies is a problem of broad societal and scientific importance.

Also, over the past few decades the oil industry has recognized the need to improve methods of utilizing petroleum resources. Conventional production is so inefficient that about two thirds of the known original petroleum resources in the world cannot be extracted by it. By this measure, of all the oil discovered less than 35 percent has been recovered or earmarked as accessible reserve. As a result, petroleum engineers have been increasingly involved in developing new methods of oil production. These methods involve mathematical modeling, numerical discretization, and computer simulation of fluid flow and transport in oil reservoirs.

Despite their seemingly disparate natures, these geoscience problems have many common mathematical and computational characteristics. For example, they often lead to transport-dominated processes which typically give rise to mathematical difficulties such as nonuniqueness, bifurcation, and singularity of solutions, as well as to computational difficulties such as grid sensitivity, sharp solution fronts, interface instability, numerical complexity, and viscous fingering phenomena. The techniques used to describe and study these problems are applicable across a broad range of areas.

The aim of this conference is to bring together applied mathematicians, computational scientists, and engineers who work in the mathematical and numerical treatment of fluid flow and transport in porous media. A broad range of researchers will present talks and discuss both problems and the current, state-of-the-art techniques. Topics covered will include the following:

1. Mathematics of multiphase flow and transport. Multiphase fluid flow and transport in porous media presents a rich family of mathematical problems. These problems involve coupled systems of nonlinear, time-dependent partial differential equations that are often degenerate. The focus of this area will be on questions of existence, uniqueness, regularity, structure of solutions, and consequences for real applications.

2. High-quality discretizations of flow and transport. Numerical solutions of partial differential equations are obtained using discretization methods that preserve or mimic the fundamental properties of continuum equations. These methods reproduce many of the most important characteristics of these equations, such as maximum and conservation principles. Recent developments and advances of finite element, finite difference, finite volume methods, and nonstandard discretization methods will be presented.

3. Computational modeling of multiscale phenomena. Recent progress in the computational modeling of flow and transport processes in porous media exhibiting heterogeneities at several length scales will be presented. High-performance computing in the numerical solution of these processes will be emphasized. The computational modeling of several scale physical processes is achieved via volume-averaging approaches in conjunction with numerical methods. Several scale computations are carried out to capture the coupled hydromechanical interaction between these scales.

4. Parallel implementation. Current topics on parallel implementation of various discretization methods will be explored. These topics cover problems related to communication on different modern computer architectures, efficient scalable parallel iterative solvers, and numerical techniques for partitioning grids. Applications of parallel algorithms to numerical simulation of flow and transport processes will be emphasized.

5. Nonlinear effects on the propagation properties of numerical models. The propagation properties—such as stability, amplitude, and phase portraits—of nonlinear flow and transport processes are not easily determined, and convergence of numerical algorithms utilized in the simulation of these processes is not easily shown. Fully nonlinear analysis is limited to specific forcing terms and initial conditions. Current approaches employed in the treatment of nonlinear effects on the propagation properties of numerical models of flow and transport processes will be discussed.

For further information please visit the Web site maintained by the organizers at `http://www.smu.edu/~zchen/conferences.html`.

The Legacy of Inverse Scattering Transform in Nonlinear Wave Propagation

Sunday, June 17–Thursday, June 21, 2001

Jerry Bona (co-chair), University of Texas at Austin
D. J. Kaup (co-chair), Clarkson University
S. Roy Choudhury (co-chair), University of Central Florida

The conference will be devoted to considering the numerous strands of activity which have resulted since the mid-seventies from the development of the Inverse Scattering Transform during the sixties and early seventies. A primary focus will be to consider where the field can go in the future. Another purpose is to bring lines of research which currently are somewhat independent of each other closer together and possibly even to open up new avenues of enquiry.

Thus the conference will provide a forum for the more general exposition and assessment of recent developments in nonlinear waves and related areas and of their potential applicability in various areas. It is expected to be of strong interest to experienced and beginning researchers alike and to draw attendees from the mathematics, physics, and engineering communities, thus giving a strong impetus to new and innovative work in the field. Every effort will be made to attract a large pool of attendees of different backgrounds and at different stages in their careers.

Given the great topicality of the area and solution methodologies, the monograph ensuing from the conference is expected to be a valuable research resource to the mathematical and physical sciences communities.

The invited lecturers are uniquely qualified to speak on both the history of the field as well as on current directions and developments. Many have pioneered much of the field and will bring a wealth of perspective and experience to their talks and thus to the overall effectiveness and usefulness of the conference.

Keynote Speakers: J. Bona (Austin), A. de Bouard (Université de Paris), A. S. Fokas (Imperial College), L. Kapitanski (Kansas State University), V. I. Karpman (Weizmann Institute), D. J. Kaup (Clarkson), C. Kenig (Chicago), M. Kruskal, (Rutgers University), A. Newell (Arizona), D. Sattinger (Utah State), J. C. Saut (Université de Paris), C. Sulem (Toronto), S. Venakides (Duke), V. E. Zakharov (Landau Institute and Arizona).

Harmonic Analysis

Sunday, June 24–Thursday, July 5, 2001

William Beckner (co-chair), University of Texas - Austin
Alexander Nagel (co-chair), University of Wisconsin - Madison
Andreas Seeger (co-chair), University of Wisconsin - Madison
Hart Smith (co-chair), University of Washington

Harmonic analysis, broadly understood as the study of the decomposition of functions and operators into their basic constituents, is a mathematical subject with roots that go back hundreds of years. Despite its age, the subject continues to flourish. Its techniques and results are central to much of modern analysis, and the area is influenced by and has applications to a wide range of other mathematical topics. These include linear and nonlinear partial differential equations, differential and integral geometry, number theory, complex analysis, representation theory, and probability and mathematical physics. In the first half of the twentieth century harmonic analysis was closely linked to complex function theory and Lebesgue integration, but during the last fifty years more sophisticated real variable methods were developed which allowed applications to a variety of new problems. The activity in this field shows no sign of abating. During the last ten years there has been important progress on a number of outstanding problems. The object of this two-week conference is to provide an opportunity for both young and established researchers to exchange ideas and to consolidate recent progress. It is impossible to briefly summarize all of the topics that may be discussed at the conference, but the following very short list may give some sense of possible directions.

1. Oscillatory integrals and geometric measure theory—Two outstanding questions in Fourier analysis are the Bochner-Riesz problem, which deals with the problem of convergence of Fourier integrals in several variables, and the restriction problem, which asks about the size of Fourier transforms on lower-dimensional sets. These questions are closely connected to questions about the behavior of oscillatory integrals depending on a parameter. Recent deep results in this area have partially depended on progress in problems in geometric measure theory concerning lower bounds for the dimension of Besicovich sets.

2. Classical singular integrals—There have been a number of important recent results on questions related to the classical theory of singular integrals. These include results and applications of the boundedness of the bilinear Hilbert transform, applications of singular integral theory to situations in which classical "doubling conditions" are not satisfied, product-type singular integrals, and discrete versions of classical singular integrals and maximal functions with applications to ergodic theory.

3. Applications to partial differential equations—Many methods in harmonic analysis were developed to solve partial problems in partial differential equations. As an example, recently a wealth of hard estimates on linear and multilinear oscillatory integrals was obtained in order to understand better the solutions of wave and Schrödinger-type equations and many of their nonlinear variants. Moreover, the use of singular integral methods has led to progress on the equations in fluid mechanics.

4. Estimates for Fourier integral operators—In many variable coefficient situations estimates for various classes of Fourier integral operators are needed. In recent years some research has focused on the situation where the wavefront relation of the operator is not necessarily the graph of a canonical transformation. Although considerable progress has been made, many questions remain wide open.

5. Analysis on Lie groups—Lie groups provide a natural setting for many questions in harmonic analysis. Moreover, the solution to a problem on a group can often be used as a model for solutions in more general situations. It is expected that some talks will address recent progress dealing with various questions on nilpotent Lie groups concerning local solvability of linear differential operators, singular integrals and applications to complex analysis. Moreover, recently there have been advances on the Kunze-Stein phenomenon on semisimple groups, on bounds for spherical functions, and on estimates for solutions of the heat and wave equations in various situations.

Because of the large number of topics, this conference will last for two weeks. There will be a number of invited lectures as well as an opportunity for shorter talks. Information about the conference with a preliminary list of participants will be available at a Web site maintained by the organizing committee at `http://www.math.wisc.edu/~src/src.html`.

Hydrodynamic Stability and Transition

Sunday, July 22–Thursday, July 26, 2001

James J. Riley (co-chair), University of Washington
Peter Schmid (co-chair), University of Washington

Information to be announced.

Lusternik-Schnirelmann Category in the New Millennium

Sunday, July 29–Thursday, August 2, 2001

Octav Cornea (co-chair), Université de Lille
Gregory Lupton (co-chair), Cleveland State University
John Oprea (co-chair), Cleveland State University
Daniel Tanré (co-chair), Université de Lille

The subject of Lusternik-Schnirelmann category is now experiencing a renaissance. Although its origins are in variational analysis and dynamical systems, Lusternik-Schnirelmann theory has proved to be an important ingredient in other subjects as well. This is a perfect time for a conference on category: old problems and conjectures have fallen, and new questions have opened up a treasure chest of potential applications in dynamics, symplectic geometry, and algebraic topology.

Lusternik-Schnirelmann category is an integer associated to a manifold (or, more generally, a space) which is an invariant of the homotopy type of the space and which gives a numerical measure of the complexity of the space. In particular, category is an indicator of the complexity of possible dynamics on the manifold by providing a lower bound on the number of critical points required of any function on the manifold. Lusternik and Schnirelmann themselves applied category to geometry as well as to dynamics, proving the existence of (at least) three closed geodesics on a two-dimensional sphere with any metric, a remarkable accomplishment in the early days of infinite-dimensional variational analysis. The theory itself may be considered a cousin of Morse theory; and just as Morse theory may be used to understand the homotopical structure of spaces, so too has category found a place in algebraic topology. For instance, a result of G. W. Whitehead says that the set of homotopy classes of maps of a space X into a group-like space is in fact a nilpotent group with nilpotency class bounded above by the category of X. In recent years Lusternik-Schnirelmann category ideas have had a significant influence in areas and problems ranging from Conley index theory to rational homotopy theory to the Arnold conjecture on Hamiltonian symplectomorphisms.

In algebraic topology one focus of study in the last several years has been the Ganea conjecture. This conjecture states that the category of a product of a space X and a sphere should be the category of X plus one. The simplicity of the statement belies the deep structural questions at its heart. In fact, it is only the recent construction of counterexamples to the conjecture which reveal a whole underlying edifice of homotopical structure built around Hopf invariants. Of course, category was invented to solve problems in dynamics, so it is not surprising that it still finds a niche in the study of dynamical systems. It is more surprising, however, that various offshoots of category lead to a place for Hopf invariants in dynamics also. Finally, recent approaches to Arnold's conjecture that Hamiltonian symplectomorphisms on a symplectic manifold have at least as many fixed points as any function on the manifold has critical points reveal the strategic position Lusternik-Schnirelmann theory occupies in symplectic topology.

The goal of this conference is to bring together mathematicians from areas on which category has had an impact to review the state of the art, set the course for future investigations, and foster cross-fertilization among areas. Lectures are expected to cover the broad range of topics mentioned above, presenting new developments in both theory and applications. In addition to specialized talks, survey talks will be given devoted to the aspects of homotopy theory, dynamical systems, and symplectic topology where Lusternik-Schnirelmann category plays a vital role.

For further information please visit the Web site maintained by the organizers at `http://www.csuohio.edu/math/oprea/LScatconf/lscatconf.html`.

Fast Algorithms in Mathematics, Computer Science and Engineering

Sunday, August 5–Thursday, August 9, 2001

Georg Heinig, Kuwait
Franklin Luk, Rensselaer Polytechnic Institute
Volker Mehrmann, TU Chemnitz
Vadim Olshevsky (chair), Georgia State University
Robert Plemmons, North Carolina State University

The *Fast Fourier Transform* (FFT) is perhaps the most widely known among fast algorithms. Its practical essence is as follows: though the straightforward computation of discrete Fourier transform uses $n(2n-1)$ arithmetic operations, the cost of the FFT algorithm is nearly linear: $O(n \log n)$ operations. Reducing the computational burden is an important issue in any applied area, and it is not surprising that in recent years the design of fast algorithms has become an increasingly important activity in a diverse variety of branches of applied and numerical mathematics, computer science, and electrical engineering. Among remarkable fast algorithms one could mention the classical algorithms of Euclid, of Schur, of Nevanlinna, and many others. There clearly is a certain parallelism, and several algorithms have independently been rediscovered in different areas. For example, the Chebyshev continuous fraction algorithm, the Stiltjes procedure for generating orthogonal polynomials, the Lanczos algorithm for computing the eigenvalues of a symmetric matrix, and the Berlekamp-Massey algorithm for decoding of BCH codes are variations of the same theme.

Fortunately, it is not always the case that such close developments are easy reformulations of each other. Typically such connections between different branches are not one-to-one, thus being useful in both directions. They can often provide new areas of applications for the existing results as well as new methods to attack difficult problems emerging in new applications. In fact, as a result of a little interaction between different branches we now have a variety of different mathematical/engineering languages to derive fast algorithms. Among various fields providing these different languages one can mention rational matrix interpolation, theory of displacement structure, the use of signal flow graphs for digital filter structures, theory of reproducing-kernel-Hilbert-spaces, diagonal calculus, orthogonal polynomials, Pade approximations, lifting of commutants approach, inverse scattering, and several others. Though the problems in each of these areas may look completely different, the resulting *fast algorithms* can be closely related. It is often the case that a certain algorithm is very difficult to derive using one approach and much easier by utilizing another.

In the past few years important progress has been made in several directions; among these we would like to mention the design of a number of fast algorithms that blend speed-up *and* numerical accuracy (in the past these two requirements often have been regarded as competitive).

There are still many applied areas where there is no characteristic technique to design fast algorithms, but there is nevertheless an increasing demand for them. Among such branches we would like to specifically mention the theory of error-correcting codes that has attracted a lot of attention lately due to the ever-growing desire for fast and reliable communications.

Our goal is to bring together active researchers interested in developing fast algorithms for solving actual problems in different areas, including operator theory, linear algebra, control, signal and image processing, system theory, numerical analysis, coding theory, and theoretical computer science. We hope this meeting will stimulate an exchange of ideas and methods originated in different applications, will foster integration between different schools, and will help to find connections between seemingly unrelated results, thus allowing a continuing expansion of the "fast algorithm theory".

The preliminary list of invited speakers includes: Dario A. Bini (University of Pisa), Albrecht Boettcher (TU Chemnitz), Angelika Bunse-Gerstner (University of Bremen), Biswa Datta (Northern Illinois University), Patrik DeWilde (Delft), Harry Dym (Weizmann Institute of Science), Miroslav Fiedler (Prague Academy of Sciences), Joachim von zur Gathen (University of Paderborn), Israel Gohberg (Tel Aviv University), Georg Heinig (Kuwait University), Erich Kaltofen (North Carolina State University), Peter Lancaster (Calgary University), Franklin Luk (RPI), Clyde Martin (Texas Tech University), Volker Mehrmann (TU Chemnitz), Vadim Olshevsky (Georgia State University), Haesun Park (University of Minnesota), Robert Plemmons (Wake Forest University), Phillip Regalia (Institut National des Telecommunications, France), Lothar Reichel (Kent State University), Amin Shokrollahi (Bell Labs), Gilbert W. Stewart (University of Maryland), Gilbert Strang (MIT), Paul Van Dooren (Université Catholique de Louvain), Charlie Van Loan (Cornell), Harold Wimmer (University of Wurzburg).