Conferences

Joint Summer Research Conferences in the Mathematical Sciences

Mount Holyoke College
South Hadley, Massachusetts
June 11–July 20, 2000

The 2000 Joint Summer Research Conferences will be held at Mount Holyoke College, South Hadley, Massachusetts, from June 11–July 20, 2000. 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, David Brydges, James W. Demmel, Dipak Dey, Tom Diciccio, Steven 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, 2000**.

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.

Symbolic Computation: Solving Equations in Algebra, Geometry and Engineering

Sunday, June 11–Thursday, June 15, 2000

Edward Green, Virginia Tech (co-chair)
Serkan Hosten, George Mason University (co-chair)
Reinhard Laubenbacher, New Mexico State University (co-chair)
Victoria Powers, Emory University (co-chair)

Symbolic computation is an important tool in many areas of pure and applied mathematics and engineering and is also an interesting and fast-growing area of pure mathematical research. Pure mathematicians can use symbolic computation to explore examples that would be impossible to work with "by hand" and to gain insight into complicated mathematical objects. In applied mathematics and engineering, symbolic computation can provide a way to compute exactly in complex models, give insight into problems, and improve the accuracy of numerical solutions. One general area in which symbolic computation has had a big impact is solving systems of equations of many kinds, from systems of polynomials to systems of differential and difference equations.

The aim of the conference is to bring together pure and applied mathematicians and engineers who use symbolic computation to solve systems of equations and those who develop the theoretical background and tools needed for solving equations. Talks will be given by a broad range of researchers and will present new developments in both theory and applications, exhibit nontrivial computations, and supply practical problems from engineering and applied mathematics. Topics covered will include the following:

1. *Systems of polynomials*. The focus will be on homotopy methods, such as nonlinear and polyhedral homotopies, and algebraic methods, including Groebner basis methods, SAGBI bases, primary decomposition, and invariant theory. Also included will be applications of the above techniques in zero-dimensional systems and real root

finding and numerical issues such as approximate solutions and sensitivity of solutions to perturbation of the input.

2. *Systems of differential equations*. The use of symbolic techniques in solving systems of differential equations is growing rapidly. In this area one line of research follows differential ideal theory, for example, Groebner type techniques in differential ideal theory. Another line of research is differential Galois theory, where one tries to understand the structure of solution spaces of differential equations. Also included will be emerging research like Groebner deformations in Weyl algebras for solving hypergeometric systems.

3. *Noncommutative systems*. The use of noncommutative Groebner bases has shown great potential for important applications. The theory has been used in the simplification of matrix equations coming from systems of differential equations. Noncommutative questions arise naturally in the study of differential operators and differential equations. Finally, in the study of commutative questions, recent work has shown that it is sometimes helpful to view the problem in a noncommutative setting.

4. *Applications to engineering*. Many real-world problems are solved using symbolic computation. Topics to be addressed include applications of solving systems of polynomial equations and real root finding in mechanics and robotics, uses of computational algebraic geometry in computer vision, graphics and computer-aided modeling, and Groebner basis techniques in integer programming.

5. *Recent theoretical advances*. The conference will also focus on exciting developments that use or have an impact on symbolic computation. For example, computing free resolutions of monomial and toric ideals and computing cohomology of toric varieties.

The preliminary list of invited speakers includes Dave Bayer, Columbia University; David Cox, Amherst College; David Eisenbud, Mathematical Sciences Research Institute, Berkeley; Ioannis Emiris, INRIA Sophia-Antipolis, France; Karin Gatermann, Freie Universitaet Berlin; William Helton, University of California at San Diego; Theresa Krick, Universidad Buenos Aires; T. Y. Li, Michigan State University; Danesh Manocha, North Carolina State University; Gregory Reid, Okanagan University College, Canada; Bernard Roth, Stanford University; Joachim Rosenthal, University of Notre Dame; Fabrice Rouillier, INRIA Lorraine (LORIA), France; Thomas Sederberg, Brigham Young University; Michael Singer, North Carolina State University; Bernd Sturmfels, University of California at Berkeley; Rekha Thomas, Texas A&M University; and Lakshman Yagati, Bell Labs.

Dispersive Wave Turbulence

Sunday, June 11–Thursday, June 15, 2000

Paul Milewski, University of Wisconsin
Leslie Smith, University of Wisconsin (co-chair)
Esteban Tabak, New York University (co-chair)
Fabian Waleffe, University of Wisconsin (co-chair)

Program Summary

Many physical systems support the propagation of *dispersive waves*: waves whose speed of propagation depends on the wavenumber (inverse wavelength). Important examples of dispersive waves are surface water waves and internal waves in stratified and/or rotating fluids. A linear superposition of dispersive waves usually describes well the small-amplitude departures from equilibrium of the given physical system for short time scales (time scales of the order of the inverse of wave frequency).

The description of the wave field for longer times (or larger amplitudes) requires the understanding of the energy transfer between waves due to nonlinearities. In dispersive waves this energy transfer is fundamentally different from nondispersive waves, since it will occur only amongst *resonant* sets of waves, usually triads or quartets of waves. The deterministic dynamics of isolated resonant triads and quartets is well understood and has proved invaluable in understanding a wide range of wave phenomena. The dispersive wave turbulence problem is to obtain a statistical description of a large set or continuum of dispersive waves over long times. Although this problem has an almost forty-year history, there are still fundamental questions that need to be answered, and these questions are the proposed focus of the conference.

The mathematical understanding of this problem is of great importance for many relevant problems in geophysical fluid dynamics, such as: the prediction of the spectrum of ocean waves, the understanding of the spectrum of atmospheric wave turbulence and its effect on the slower nonwave dynamics, and the evolution of the internal wave spectrum in the ocean. In addition, in certain mediums and at large amplitudes light waves can be dispersive, and the characterization of optical turbulence for large intensity light in optical fibers also requires a mathematical understanding of dispersive wave turbulence theory.

The primitive equations governing dispersive wave turbulence (also called weak turbulence) in the applications mentioned above are the appropriate inviscid fluid-dynamics equations. Thus, in the regime of interest the evolution is *conservative* (usually Hamiltonian). However, this is an approximation of the real physical situations in which there is usually some energy input (such as the wind stress in surface ocean waves) and dissipation (such as viscous damping for small-scale motion). Since there often is a scale separation between the input and dissipation mechanism (for ocean waves the energy is input at low wavenumbers and withdrawn at large wavenumbers), one considers the intermediate regime as conservative, and the central question is how it transports energy between the disparate scales. The most fundamental result that one seeks is the statistical power law spectrum (or Kolmogorov spectrum, a name borrowed from nonwave turbulence in fluid flows) for this *energy cascade*.

The conference will stimulate discussion and progress on the numerical, modeling, and analytical aspects of dispersive wave turbulence and related problems. There will be a limited number of invited full-length lectures focusing on the major aspects of the subject: Modeling, Numerics, Observation, Internal Waves in the Ocean, Surface

Ocean Waves, Atmospheric Wave Dynamics, etc. There will also be half-hour lectures and considerable time for interaction between the participants. Advanced graduate students and recent Ph.D.'s are especially encouraged to attend the conference.

Radon Transforms and Tomography

Sunday, June 18–Thursday, June 22, 2000

Leon Ehrenpreis, Temple University
Adel Faridani, Oregon State University
Fulton B. Gonzalez, Tufts University
Eric L. Grinberg, Temple University
Eric Todd Quinto, Tufts University (chair)

Radon transforms were developed at the beginning of this century by at least three independent researchers: P. Funk, G. Lorenz, and J. Radon. They were motivated by problems in differential geometry, mathematical physics, and partial differential equations. In the 1970s the medical applications of these transforms produced a flurry of breakthroughs in imaging technology that resulted in a Nobel Prize. Currently, integral geometry comes up in analysis, Lie groups, differential and symplectic geometry, complex and harmonic analysis, mathematical physics, inverse problems, numerical analysis, computation, and more. It is becoming a unifying theme in a broad spectrum of mathematics. The multifaceted nature of the subject was already manifested in its birth, and today the subject has substantial cross-disciplinary interactions in both pure and applied mathematics as well as in medicine and engineering.

In the past few years an important general framework has emerged for integral geometry, based on the theory of sheaves and D-modules. In terms of this framework, one can obtain both new and classical inversion formulae and range theorems for various Radon transforms. Radon transform concepts are also of increasing interest in representation theory as double-fibration methods are used with greater emphasis. These ideas are related to mathematics physics, the Penrose transform, and complex geometry. Radon transform methods are becoming more prevalent in research on classical integral geometry, such as Finsler geometry and Hilbert's fourth problem. This includes novel ways of defining distances between as measures of planes separating them. Integral geometric techniques are being used in other fields, including Lie groups, convexity theory, and complex analysis

Researchers have recently proven that the X-ray transform is injective on a Riemannian manifold of nonpositive curvature. The general problem of understanding Radon transforms on manifolds without symmetry is exciting, and it is an important theoretical basis for geophysical and other inverse problems. The interplay between these theoretical results and algorithms is exciting and important to explore.

There are continuing breakthroughs in tomography in areas including local tomography in the plane and 3-D local tomography with sources on a curve, RADAR, impedance CT, and ultrasound. Applied mathematicians are using Radon transforms previously considered to be only of abstract theoretical interest; for example, geodesic Radon transforms have important applications in impedance and geophysical CT. Radon transforms have been used in new ways to solve theoretical problems in SONAR, and researchers are working on practical algorithms using these ideas. Many of the most exciting inverse problems in medicine, physics, and P.D.E. have integral geometric models.

Our goal is to bring together researchers from different areas who might find commonality in their shared interest in integral geometry and tomography. Perhaps the most vital such interaction is that which links pure and applied aspects of the fields. There is a great deal of activity in each category, and it is important to expand communication between them so that collaborative development takes place in a larger venue. Because of this goal, all speakers will be actively encouraged to give talks with accessible introductions. We plan to have tutorial talks on pure and applied topics related to the specific topics presented in the conference. An introductory reading list will be on the conference Web site for interested people.

We are committed to having younger mathematicians actively involved in the field. We plan to have talks by junior mathematicians as well as short thesis talks by graduate students.

Preliminary list of possible speakers: M. Agranovsky, J. Alvarez, C. Berenstein, M. Cheney, R. Clackdoyle, A. d'Agnolo, L. Ehrenpreis, S. Gindikin, A. Greenleaf, A. Gruenbaum, S. Helgason, D. Isaacson, P. Kuchment, A. Louis, P. Maass, F. Natterer, V. Sharafutdinov, G. Uhlmann, and L. Zalcman.

Noncommutative Geometry

Sunday, June 18–Thursday, June 29, 2000

Alain Connes, IHES (chair)
Nigel Higson, Penn State University
John Roe, Penn State University
Guoliang Yu, University of Colorado

The purpose of this conference is to present to a broad audience an up-to-date account of Alain Connes's noncommutative geometry.

It is an old idea that noncommutative algebras should be studied as if they were the function algebras of "noncommutative spaces". The remarkable work of Alain Connes has transformed this metaphor into a powerful and substantial mathematical theory. Connes's inspiration came from functional analysis, but the theory he constructed has reached out to homological algebra, differential geometry, and quantum theory for its basic constructions. Connes's well-known book (Academic Press, 1994) and the spirited discussion it has engendered provide an ample introduction to the subject.

Recent work has brought noncommutative geometry into lively contact with number theory, dimension theory, and renormalization in quantum field theory, to name some striking examples. Many of these developments have taken noncommutative geometry beyond the plan laid out in Connes's book. They have yet to be integrated into the literature and are indeed located at a rapidly advancing frontier. This meeting will transport participants to this frontier and equip them as independent prospectors there.

There will be particular emphasis on the following topics:

1. Noncommutative geometry and number theory.

In his book, Connes, in collaboration with J.-B. Bost, constructed a one-parameter C*-dynamical system which is intimately related to classical questions on the distribution of prime numbers. Since then Connes has developed the theory considerably, emphasizing the central importance of a beautiful but conjectural trace formula in noncommutative geometry (special cases of this formula are now known). One reviewer described Connes's work as producing a "feeling of intense jubilation"; but its breadth and depth have meant that this jubilation has so far been experienced only by a few. A series of introductory lectures will give participants the chance to acquaint themselves with this formidably deep and exciting area of mathematics.

2. Noncommutative geometry and geometric topology.

In Connes' book the guiding examples of noncommutative spaces arise from group actions or foliations. Recently a new kind of example has become important: noncommutative spaces arising from controlled topology. These are the ideas which underly, for example, the dimension-theoretic approach to the Novikov Conjecture given by G. Yu and refined by S. Dranishnikov in his 1998 ICM address. Most of the development in this area so far has been at the level of K-theory, but a more refined geometric analysis is just beginning. A series of lectures will survey the area, and recent advances will be presented.

In addition to these areas of emphasis and to the presentation of current research, the conference will include an Introduction to Noncommutative Geometry minicourse aimed at mathematicians and graduate students with only a general acquaintance with functional analysis. It will enable outside specialists in, for instance, number theory to interact profitably with researchers in noncommutative geometry. It will also provide an introduction to noncommutative geometry for graduate students.

Bayes Frequentist and Likelihood Inference: A Synthesis

Sunday, July 9–Thursday, July 13, 2000

Gauri Sankar Datta, University of Georgia (co-chair)
Nancy Reid, University of Toronto (co-chair)
Dongchu Sun, University of Missouri (co-chair)
James Berger, Duke University
Malay Ghosh, University of Florida
Elizabeth Slate, Cornell University

Bayes and frequentist approaches to statistics are the two main paradigms for statistical inference. Recently, likelihood-based methods are also being proposed in many inferential problems. Each approach has its own advantage for some problems, but none is superior to the other. While the differences in the philosophy of these schools have generated a lot of debates and controversies in the past, there has been an effort in recent years to look for a synthesis of these various concepts. Although many statisticians feel that the frequentist and Bayesians views are different both on philosophical and operational grounds, a unification or synthesis of these ideas is much needed, at least for pragmatic reasons involving applications. It is indeed disappointing to have different Bayes and frequentist conclusions in applications while both approaches use the same evidence and beliefs about a scientific investigation. Thus a synthesis of the philosophy of the two schools should be attempted, and the interface where they produce similar conclusions and where they differ dramatically should be explored. As the area is very broad, the proposed conference will focus on a few selected topics. Some of the important topics are model selection, hypothesis testing, semiparametric inference for models with infinite-dimensional nuisance parameters, survey sampling, longitudinal data, and Bayesian and frequentist higher-order asymptotics, including probability matching priors and Bartlett corrections.

Statistical modeling is an indispensable tool in analyzing data and drawing valid inference. Two important areas where there are extensive ongoing efforts to discover the relationship between default Bayes and likelihood approaches to these problems are model selection and hypothesis testing. Development of default Bayesian analysis in these two problems is very challenging, because the use of any improper priors makes no sense due to the fact that such priors have an indeterminate multiplicative constant so that the pivotal quantity, the Bayes factor, remains undetermined. Many recent advances in Bayesian model selection will be presented in the conference.

Comparison of two models is equivalent to testing a null hypothesis against an alternative hypothesis. Hypothesis testing has been a main source of disagreement between the Bayesian and frequentist approaches to inference. While the reporting of Type I error and Type II error probabilities is a standard practice in the classical frequentist approach, it is not entirely satisfactory, as it fails to reflect the strength of evidence provided by given data. The use of P-value as a data-dependent measure is not entirely satisfactory either. Bayesians are not comfortable in using P-value in model selection or hypothesis testing. Although the P-value is in general agreement with posterior probabilities in testing a one-sided null hypothesis against a one-sided alternative hypothesis, it has dramatic conflict with the Bayes factor in testing point null and precise hypothesis. In the recent Bayesian literature there are a few modifications of the P-value such as the predictive, posterior predictive, and conditional predictive P-values, which are suggested as tools in measuring surprise. The main reason for devising many of these alternative measures is that the likelihood, not the tail area as used in P-value, should be the basis in measuring any statistical evidence. Extensive discussion on these alternative measures and their calibration were recently discussed by researchers who have already expressed their willingness to participate in the conference.

Semiparametric models or models with infinite-dimensional parameter space provide a large class of models that enhance the scope of statistical modeling. Neyman-Scott problems and the Cox regression model are some examples of such models. Despite an added flexibility, the asymptotic theory of inference for such models requires nontrivial extensions of results for usual parametric models. This is a growing area of research, and it appears that the Bayesian, likelihood, and frequentist paradigms all have a place for such inference.

Survey sampling plays an important role in providing reliable government and business statistics. A design-based approach is dominant in classical survey sampling. However, in recent years there has been a growing popularity of model-based approaches in sampling. Model-based approaches explicitly use auxiliary variables from administrative records or other surveys and are very popular in small area estimation. Small area estimation, an important topic in survey sampling, is gaining increasing popularity in government agencies due to a growing demand for reliable small area statistics from both public and private sectors. While a frequentist view is more dominant in small area estimation, the Bayesian approach to small area estimation is receiving favorable attention from the governments of the USA, Canada, and other countries. Although practitioners of small area estimates are less receptive to use of arbitrary priors in Bayes estimates, they feel comfortable when such estimates have a dual justification. In view of the importance of model-based inference in sampling generated by growing use of model-based estimates by the practitioners, it is really important to compare both the frequentist and the Bayesian methods that are currently in use. A synthesis of the two schools of thought will serve the survey samplers by presenting the current state of research in survey sampling. Such synthesis may result in estimates with an associated measure of uncertainty which have both frequentist and Bayesian justification.

Longitudinal models arise frequently in many statistical investigations. Such data occur often in clinical, environmental, and other scientific studies. Even in many repetitive surveys such models are found useful. Statistical analyses in longitudinal studies are based on models that express a relationship between the response and covariates that evolves in time. Besides handling unbalanced series and unequally spaced observations, recent longitudinal methods have focused on connections to survival analysis, detections of change points, and identification of latent classes. Bayesian and frequentist analyses of these models often use mixed linear models or generalized linear models. Transition models, which are useful generalizations of longitudinal models, explicitly represent the response for a subject at a given observation time as dependent not only on the subject's covariates at that time but also on the history of response values for that subject. MCMC methods play a powerful role in the analysis of these models.

Higher-order asymptotics play a crucial role in the unification of Bayesian and frequentist approaches to inference. In particular, frequentist validation of noninformative Bayesian solutions is attained through higher-order asymptotics. Noninformative priors which provide Bayes credible sets with approximate frequentists validity for moderate sample size are known as probability matching priors. Higher-order asymptotics are also useful in the comparison of different adjusted versions of the profile likelihood. These modifications to the usual likelihood play an important role in providing improved inference in likelihood-based inference in the presence of nuisance parameters. These adjustments and their interface with higher-order Bayesian asymptotics have received a lot of attention from researchers.

The five-day conference will focus on the topics discussed above and many other related topics in an effort to present a synthesis of the available Bayes, frequentist, and likelihood methods. Many leading and young researchers of international reputation have already expressed their interest in participating and presenting many stimulating research discussions in the conference.

Algorithms, Computational Complexity, and Models of Computation for Nonlinear and Multivariate Problems

Sunday, July 16–Thursday, July 20, 2000

Eugene Allgower, Colorado State University
Kurt Georg, Colorado State University
Christopher Sikorski, University of Utah (chair)
Frank Stenger, University of Utah

Nonlinear systems of equations arise in practically all areas of scientific computation. In some cases, such as the polynomial systems arising in the modelling of robotics problems or complementarity problems, the modelling equations are immediately finite dimensional. In other instances the systems derive from the discretizations of operator equations which model a physical system. In general, nonlinear systems are solved by iterative algorithms. Some examples are quasi-Newton methods, inexact Newton methods, interior point methods, continuation methods, etc. In addition, generalizations of bisection and some simplicial methods have been applied for systems which lack smoothness. Aspects of the effectiveness of algorithms for solving nonlinear systems include their convergence and complexity. The issue of complexity has been examined from differing viewpoints by investigators in scientific computation (who work with floating point computations) and, e.g., by groups of scientists who often work from the standpoint of the real number model of computation or a general theory of information-based complexity.

The aim of the proposed conference is to bring together some of the leading investigators presently working on algorithms for solving nonlinear systems and multivariate problems deriving from various areas of applications and to allow them an opportunity to discuss and compare their concepts and models of complexity.

Though scientists always had a concept of convergence and efficiency for numerical algorithms, the modern complexity theory has its origins in the work of J. Kiefer in 1953 and J. Traub in 1961. In the 1980s Traub and Wozniakowski initiated a general complexity theory for solving continuous problems, presently known as information-based complexity. In the late 1980s a new vein of research on models of continuous computation was originated by the work of Blum, Shub, and Smale, and their joint work with Cucker. More recently, Sikorski summarized some optimal complexity results for nonlinear equations and published a bibliography of this field.

Multivariate problems play a very important role in many applications. For instance, in financial applications there is a need to approximate integrals of functions of hundreds of variables. It is a challenging problem to design and analyze algorithms for such high-dimensional problems. Sloan and Wozniakowski provided a first step of a new theory for understanding tractability of high-dimensional problems.

The complexity theory complements the more traditional ideas of convergence and computational efficiency and stability. The latter, for example, is less formal but more practically oriented e.g., rounding effects are included. However, all address the fundamental problem of optimally (in some sense) computing approximate solutions to problems of science and engineering. They utilize the real number (or the floating point number) model of computation to address the optimality issues.

The focus of our conference will be to examine these issues and the relationships of the various efficiency concepts in the context of some important current examples of nonlinear and multivariate problems, in particular:

1. Nonlinear algebraic equations and fixed points
2. Nonlinear optimization
3. Quasi Monte Carlo techniques for multivariate integration
4. Models of continuous computation

The speakers will address the issues of optimal or nearly optimal algorithms, as well as the fastest known methods for computing approximate solutions to the above problems.

For further information, please visit the Web site maintained by the organizers at `http://www.cs.utah.edu/~sikorski/joint.html`.