

A Special Program in Honor of Charles Stein Research Encounters >>>



OCTOBER 2003

Charles Stein

will August 2003 be remembered by 31 mathematicians, statisticians and graduate students from Australia, Britain, Canada, China, Germany, Greece, Korea, Philippines, Russia, Slovenia, Sweden, Switzerland, Thailand, and the United States and 12 from Singapore as a unique experience of revival of interest and intense research activity in the genesis, mystique and richness of

applications of a time-tested idea with humble origins in teaching, introduced to the statistical world in a symposium in Berkeley in 1972, laid dormant for at least 15 years and resurrected in a burst of activity that resulted in its widespread applicability in such diverse fields as spatial statistics, computer science, random graphs, computational molecular biology, interacting particle systems, bootstrap, mathematical theory of epidemics, algebraic analogs of probabilistic number theory, insurance and financial mathematics, population ecology, combinatorics of logarithmic structures and possibly in other real-life problems.

What made it even more memorable is that the much revered 83-year-old originator of the idea now known as Stein's Method was himself immersed in all the activities of the Institute's program specially organised in his honor, whether they be tutorial or workshop lectures or tea (coffee)-break discussions. Accompanied by his wife

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The Institute for Mathematical Sciences (IMS) is introducing special short-term sessions, to be called "Research Encounters", for the purpose of bringing together a small group of local and foreign researchers (2 to 8 persons, in general) to undertake specific projects at the Institute, such as writing a paper or a book, or engaging in in-depth discussions on a focused research topic or topics. The projects should involve applications of the mathematical sciences; multi-disciplinary collaboration is strongly encouraged. The period of participation of each visitor in a project should normally range from 10 days to a month.

Research Encounters will complement the IMS thematic programs in achieving the Institute's objectives and will generally be organized for those periods where there is a low level of activity of the regular programs, thus helping to sustain a high level of activity throughout the year. Over time the Research Encounters should produce an impact and help create a vibrant research environment in Singapore in a way which is complementary to the efforts of the individual academic departments.

Our Research Encounters share some common features with the following short-term research collaborations organized at three well-known mathematical institutes: "Program for Summer Research" in the

Mathematical Sciences Research Institute at Berkeley (USA), "Research in Pairs" and "Mini-Workshops" in the Mathematical Institute at Oberwolfach (Germany), and "Research in Teams/ Focused Research Groups" in Banff International Research Station for Mathematical Innovation and Discovery (Canada).



Yeneng Sun Deputy Director

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From the Editor >>>

We would like to thank all our friends and readers here and overseas for their feedback on the first issue. I must, of course, bear the responsibility for any shortcomings, linguistic or otherwise, for which lack of experience is a poor excuse.

For this issue, we are fortunate enough to be able to print the interviews of three very distinguished visitors to the Institute. They are closely connected at a personal level to some of us at the University and the Institute. They share with us their rich mathematical experiences and leave us with a sobering thought: progress in the solution of real life problems eventually requires the harnessing of the power of the computer. Little wonder that the themes of the coming programs concern the effective use of mathematics in computation.

Computing power has already invaded the privacy of the mathematical mind such as in the resolution of the four-colour problem and the Kepler conjecture. While the purist believes that the computer may not have the final say in such cases, other more beneficial applications in signal processing, medical imaging and biology are not possible without powerful computers. But the purist may still be right. Without the precise mathematics, the brute force of the computer is powerless. However, many of those who use, if not formulate, the precise mathematics are economists, physicists, chemists and engineers. They are the ones who get the accolades and some even collect the Nobel prizes. There is no doubt that the mathematical spirit is generous: since time immemorial mathematical ideas have never been patented.

Mathematicians have managed to cloister themselves for a long time against the imperfections of the real world, but more and more of the mathematics done in the cloisters have proved to be essential, if not indispensable, in the continuous struggle to improve the well being of the community. More mathematical institutes are springing up around the world to open up the hitherto cloistered realm of mathematics to other disciplines. In return, new blooms appear on the traditional mathematical landscape from the new seeds blown in from outside. Milestone for IMS >>>

If man-made structures are indicators of the progress of an organization, the modest new beige-colored building that now graces the corner of the compound of the Institute that once served as the only car park space for Institute visitors must surely be considered as a kind of milestone at this early stage of development of the Institute.

Since the establishment of the Institute some two years ago, its activities were held in borrowed premises. Though there was no lack of generosity from other research centres and institutes to allow its workshops and program talks to be held in their lecture theatres and seminar rooms, there was a lack of esprit de corps among participants once the talks were over. The principal guests from overseas would return to their offices at the Institute while the others would disperse without so much as having a chance of imbibing the rustic atmosphere of the Institute surroundings, much less absorbing the osmotic benefits that often result from lingering in the vicinity of group interactions.

When the offices and auditorium in the new building were first put to good use, apparently against much odds, in time for the special program in honor of Charles Stein, the results vindicated the investment in terms of the physical cost and effort involved in planning. For the first time, there was a focal point for the program participants - this was consistently borne out in the feedback of participants.

Compared to the cost of other more ambitious projects, the cost of \$1.5 million for a building that houses only an auditorium with a seating capacity of 80 and four offices for 10 visitors on a sharing basis must be considered miniscule. With the University footing \$1.1

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Y.K. Leong

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Margaret, Charles Stein showed an indefatigable spirit of the intellect and must have been a source of inspiration to all those participants who have explored or are attracted by the richness of his ideas. To those who were his students (like our director Louis Chen and colleague Wei-Liem Loh of the Department of Statistics and Applied Probability) and his personal friends (like Andrew Barbour and Persi Diaconis), the program was like an extended family reunion with long-separated cousins. In the interview (see page 16) that took place during the workshop, he opened up rare insights into the mind of an original thinker and scholar. The scope and extent of his fascinating and powerful method may be glimpsed from the summary of the activities of the program on page 4.

million dollars of the bill, it is non-trivial for a non-profit making organization to find ways and means to finance the remaining cost. The Institute Director himself has sought the good offices of friends in business and industry to raise the necessary \$400,000. So far, generous donations have been given by Hong Leong Foundation (\$50,000), Lee Foundation (\$50,000) and Far East Organization (\$20,000). Any donation, no matter how "small" it may be to big businesses, will go a long way in helping a fledgling institute attain its long-term objectives. The Institute intends to express its appreciation of donations in the form of a prominently displayed plaque at the new building.

The need for the facilities of the new building was recognized as early as May 2002 and approval for construction was speedily given by the University to enable completion in time for use in 2003. The actual construction started in March 2003 and then nature, if not fate, intervened in the form



IMS transformed (right: new block; left: houses 3, 4)

of the SARS episode to force the postponement of much of the Institute's April - July activities. While the Institute's scientific activities came to a standstill, construction work speeded up with the expectation, if not faith, that SARS will have blown over by the end of July. The prospects for completion of the building in four months were not very bright at that time. Yet the odds were overcome. The timely completion was the result of the extraordinary efforts of many people, especially the Director and managers in the Office of Estate Development (OED), the architects at CPG Consultants Pte Ltd and the contractors and workers of Kienta Engineering Construction Pte Ltd.



The story has a happy ending. The Institute now has a new look: the two original renovated colonial-style two-storey houses and the addition of a slightly more imposing structure that is aesthetically well-designed and equipped with the full range of computer facilities for lectures and individual research. There is even a lift for physically handicapped persons. Given the physical constraints, the design of the auditorium is more than what one can ask for - carpeted flooring, spaciousness between rows of seats, wi fi facilities and conducive ambience. For a fledgling institute, it is indeed a milestone.

Inside the new auditorium

People in the News >>>

New Management Board Members

Eng Chye Tan (co-chair for the IMS Program on "Representation Theory of Lie Groups" in 2002) and Seeram Ramakrishna, the new deans of the Faculties of Science and of Engineering, have recently been appointed members of the Institute's Management Board in replacement of Choy Heng Lai (who is now a Deputy Provost of NUS) and Wun Jern Ng (former Dean of Engineering).

IMS has a new President-Elect?

The Director of IMS (Institute for Mathematical Sciences) Louis Chen will be wearing an additional (presidential) hat of another IMS (Institute of Mathematical Statistics the more well-known US-based international professional and scholarly society devoted to the development, dissemination, and application of statistics and probability). He is now President-Elect (August 2003 - July 2004) and succeeds Terry Speed (University of California at Berkeley and Walter & Eliza Hall Institute of Medical Research, Australia) who succeeds S. Raghu S. Varadhan (Courant Institute, New York University) as President. Louis Chen will go on to serve as President (August 2004 - July 2005) and Past President (August 2005 - July 2006).

Congratulations to Jean-Pierre Serre

The Institute would like to express its delight and extend its congratulations to Jean-Pierre Serre (Collège de France) on the occasion of his being awarded the (inaugural) Abel Prize by the Norwegian Mathematical Society in June 2003. He has visited NUS several times since 1987 and is regarded as a friend of and inspiration to mathematicians at NUS. He gave the inaugural lecture on *"Codes, curves and Weil numbers"* at the official opening of IMS on 17 July 2001.

National Science and Technology Awards 2003

The Institute would like to extend its congratulations to Guaning Su (President, Nanyang Technological University), a former member of the Institute's Management Board (2001 - 2002), who won the National Science and Technology Medal for his distinguished and sustained strategic contributions to science and technology in Singapore. The Institute would also like to congratulate Harald Niederreiter, San Ling and Chaoping Xing for jointly winning the National Science Award for their outstanding contributions to the application of algebra, algebraic curves and number theory in coding, cryptography, nets and lowdiscrepancy sequences. The trio from the Department of Mathematics were the organizers of the IMS inaugural program on "*Coding Theory and Data Integrity*" in 2001. These awards are given by the Agency for Science, Technology and Research (A*Star).

Programs & Activities >>>

Past Program in Brief

Stein's Method and Applications: a program in honor of Charles Stein (28 July - 31 August 2003)

Website: http://www.ims.nus.edu.sg/Programs/stein/index.htm

Co-chairs:

Andrew Barbour, University of Zürich Louis Chen, National University of Singapore

Activities:

(a) Tutorial (4 - 7 August 2003) Details at http://www.ims.nus.edu.sg/Programs/stein/tutorials.htm

(b) Workshop (11 - 15 August 2003) Details at http://www.ims.nus.edu.sg/Programs/stein/workshops.htm

(c) Public lecture (19 August 2003)
"The Search for Randomness" by Persi Diaconis, Stanford University
In conjunction with Singapore Mathematical Society, Department of Mathematics and Department of Statistics

Department of Mathematics and Department of Statistics and Applied Probability

Details at http://www.ims.nus.edu.sg/Programs/stein/files/pl_diaconis.pdf

(d) School lecture (21 August 2003) "Mathematical Modeling of Parasitic Diseases" *by Andrew Barbour, University of Zürich* Jointly organized with Singapore Mathematical Society and Victoria Junior College Details at http://www.ims.nus.edu.sg/Programs/stein/files sl_%20barbour.pdf

(e) Colloquium Lecture (26 August 2003) "Normal Approximation for Sums of i.i.d. Random Variables" by Charles Stein, Stanford University

(f) Seminars conducted by visitors and graduate students

The program on "Stein's Method and Applications", in honor of Charles Stein, took place from 28 July to 31 August 2003. Charles Stein was the guest-of-honor and he visited the Institute for the entire period of the program.



To be with Master (Charles Stein, sixth from the right in the first row)

In total, 43 people (31 from overseas), including 15 graduate students, visited the Institute. 22 visitors spent more than three weeks at the Institute and 11 visited for about two weeks.

The average attendance for tutorial and workshop lectures was 48 and 61 respectively. In addition to seminars by program visitors and graduate students, there was a public lecture (see (c) above), which attracted about 400 people, and a school lecture (see (d) above) to students of Victoria Junior College. Charles Stein also delivered a colloquium lecture (see (e) above) during his visit.

The talks given during the program touched on various aspects and applications of Stein's Method, ranging from its historical developments to applications in such fields as geometric random graphs and random matrices. The talks showed that Stein's Method had developed extensively since its beginnings. Many new problems on the method and new applications in different fields were also discussed.

As the program was focused, the visitors and participants displayed great enthusiasm and there were many discussions held during the tea-breaks and after the day's activities. There was cross–fertilization of ideas among those who shared common interests, and several visitors have either started new projects or continued with their on-going collaborations.

The Institute will publish both the tutorial lectures and proceedings of the workshop, in honor of Charles Stein, as two volumes of the Institute's Lecture Notes Series.

The Institute is very encouraged by some of the following feedback from our visitors:

"An usually enjoyable workshop. Congratulations on the excellent meeting and facilities."

"Organization, hospitality and ambience: all excellent – thank you!"

"I knew this conference would be special. I have rarely been so interested in every talk. High density of quality! The staff surpass themselves in availability and helpfulness – Thank you so much!"

"Thank you very much indeed for inviting me. I wish I could stay longer. You offer an outstanding environment for thinking, discussing and working."

"The program on Stein's Method and Applications was a great success, and much enjoyed by all: a series of fascinating talks, animated discussions in the lounge and meeting rooms, many new projects begun. My warmest thanks to all at IMS for making it possible."

"It was useful for people working in this field to get together and exchange ideas. I expect to have learned a lot, and I have also been forced to work. The staff were very helpful, and I enjoyed my stay."



In tune with new ideas: Charles and Margaret Stein



A break in a brain storm (Left to right: Gesine Reinert and Susan Holmes)



The proof is in the eating! (Left to right: Louis Chen, Friedrich Götze (foreground), Mike Steele (background), Persi Diaconis, Vladimir Rotar, Andrew Barbour, Luc Devroye, Sungchul Lee, Gesine Reinert (back), and Peter Eichelsbacher)



Exchangeable pair of ideas (Left to right: Zhidong Bai and Persi Diaconis)

Current Programs



Hans Feichtinger on Gabor analysis

Mathematics and Computation in Imaging Science and Information Processing (July - December 2003 & August 2004) Website: http://www.ims.nus.edu.sg/Programs/imgsci/index.htm

Co-chairs:

Amos Ron, University of Wisconsin-Madison, USA Zuowei Shen, National University of Singapore Chi-Wang Shu, Brown University, USA

The program, which focuses on the themes of ideal data representations and computational methods in imaging science, comprises conferences, workshops, tutorial sessions and seminars. To date, three workshops (two of them in September 2003 and the third in October 2003) were held on various sub-themes of the program. Their details are as follows.

The application of mathematics to medical imaging has made significant advances in the usage of these imaging modalities to computer-assisted surgery, diagnosis, treatment and training in medicine. A workshop on "Information Processing for Medical Images" was held from 8 to 9 September 2003 to provide an opportunity for researchers from different disciplines including mathematics, computer science, electrical engineering, physics and clinical medicine to meet and discuss the advances and latest developments in this exciting area.

The workshop comprised a series of tutorial lectures on CT and MR imaging and talks on specific research topics. The research topics include the clinical applications of high end CT/MRI, and the applications of signal processing, image processing and mathematical modeling on CT, MRI and ECG.

Time-frequency analysis provides mathematical concepts to analyze the time and frequency contents of a given signal. It is also used as a mathematical tool to optimize computational results in image and signal processing. A workshop on "Time-Frequency Analysis and Applications" was held from 22 to 26 September 2003. One of the most important branches in this area is Gabor analysis developed from applications of the short-time Fourier transform, and it was the main focus of the workshop. World leading experts were invited to conduct tutorials and give lectures on the most recent developments in the area. This enabled researchers from different disciplines including mathematics and engineering to interact on the latest advances and graduate students to be provided with valuable exposure at the frontier of research.

The workshop comprised a series of tutorial lectures on Gabor analysis as well as talks on the mathematical foundations and applications of time-frequency analysis and specific research topics.

The Joint Workshop on "Information Processing" (20 - 23 October 2003) was jointly organized with Centre for Wavelets, Approximation and Information Processing of National University of Singapore, Center for Information Science of Peking University, and National Laboratory of Pattern Recognition, Institute of Automation of Chinese Academy of Sciences. This workshop aimed to promote research interactions and explore possible collaborations with national level research centers and top universities in China.

The following upcoming activities form a continuation of the current program:

Asian Approximation and Wavelet Theory Conference (10 - 14 November 2003)

Tutorial on "Digital Watermarking" (29 November and 1 - 2 December 2003)

Workshop on "Mathematics in Image Processing" (8 - 9 December 2003)

Tutorials on "Computational PDEs and Wavelets for Image Processing", "Algorithms and Mathematical Methods in Data Mining" and "High Order Non-Oscillatory Numerical Methods for Hamilton-Jacobi Equations" (10 - 12 December 2003)

International Conference on "Numerical Methods in Imaging Science and Information Processing" (15 - 19 December 2003)

Workshop on "Functional and Harmonic Analyses of Wavelets and Frames" (4 - 7 August 2004)

International Conference on "Wavelet Theory and Applications: New Directions and Challenges" (10 - 14 August 2004) Continued on page 7

CWAIP-IDR-IMS Joint Workshop on "Data Representation" (16 - 20 August 2004)

Advances and Mathematical Issues in Large Scale Simulation (December 2002 - March 2003 & October -November 2003)

Website: http://www.ims.nus.edu.sg/Programs/lss/index.htm

Chair:

Khin-Yong Lam, Institute of High Performance Computing, Singapore

The postponed April – May activities of this program, jointly organized with the Institute of High Performance Computing (IHPC), are now being held in October and November 2003. The resumed activities started with a series of seminars on molecular dynamics, parallel, multilevel and tree type algorithms.

Some upcoming activities include:

Tutorial on "Multiscale Modeling of Crystalline and Granular Solids" (4 November 2003)

Tutorial on "Multiscale Simulation in Nanomaterials and Nanostructures" (18 November 2003)

Tutorial on "Wavelets and Wavelet Transforms" (19 November 2003)

Tutorial on "Virtualization-Aware Application Framework for Multiscale Continuum/ Atomistic/ Quantum-Mechanical Simulations on a Grid" (26 November 2003)

Tutorial on "Recent Advances in Modeling and Simulation of High-Speed Interconnects" (27 November 2003)

Programs in the Pipeline

Statistical Methods in Microarray Analysis (2 - 31 January 2004)

Website: http://www.ims.nus.edu.sg/Programs/microarray/index.htm

Chair:

Terry Speed, University of California at Berkeley and Walter & Eliza Hall Institute of Medical Research, Australia

Co-chairs:

Ming-Ying Leung, University of Texas at El Paso Louxin Zhang, National University of Singapore

This program which was originally scheduled for June 2003 has been postponed to 2 - 31 January 2004. The tutorial will take place from 2 to 6 January 2004. The workshop

will be spread out over the entire month of January, with most of the talks given from 7 to 10 January 2004.

Markov Chain Monte Carlo: Innovations and Applications in Statistics, Physics and Bioinformatics (1 - 26 March 2004)

Website: http://www.ims.nus.edu.sg/Programs/mcmc/index.htm

Chair: Wilfrid Kendall, University of Warwick

Co-chairs: Faming Liang, National University of Singapore and Texas A&M University Jian-Sheng Wang, National University of Singapore

The program will begin with a tutorial session (8-12 March 2004), in which leading researchers will introduce fundamental and advanced concepts in Monte Carlo methods, such as Markov chain and Metropolis sampling, efficient sampling algorithms, extended ensemble methods, perfect sampling (Propp-Wilson algorithm), etc. The program will end with a workshop (22-26 March 2004), during which latest research results will be presented.

Econometric Forecasting and High-Frequency Data Analysis (5 April - 22 May 2004)

Website: http://www.ims.nus.edu.sg/Programs/econometrics/index.htm

Co-chairs:

Roberto S. Mariano, Singapore Management University and University of Pennsylvania Sam Ouliaris, National University of Singapore Yiu Kuen Tse, Singapore Management University

The activities of the program will consist of

(i) a two- or three-day conference,
 (ii) tutorial sessions (these may include a session)

(ii) tutorial sessions (these may include a series of tutorials on surveying a specific topic or synopsis of new research directions),(iii) research seminars/ workshops.

The topics will be in

(a) High frequency data analysis (3 - 8 May 2004)(b) Econometric forecasting (10 - 15 May 2004)

Geometric Partial Differential Equations (3 May - 26 June 2004)

Website: http://www.ims.nus.edu.sg/Programs/pdes/index.htm

Co-chairs: Xingwang Xu, National University of Singapore Paul Yang, Princeton University

Mathematical Conversations.

Gilbert Strang: The Changing Face of Applied Mathematics >>>

An interview of Gilbert Strang by Y.K. Leong

Gilbert Strang is a prominent scholar in applied mathematics and an active promoter of mathematics and mathematical education in the United States. He has made numerous contributions to numerical analysis, wavelets and signal processing. He is also well-known for his textbooks on linear algebra and applied mathematics at the undergraduate and advanced levels. He is editor of many well-known journals and has given invited lectures throughout the world. He has received numerous honors and awards and is a Fellow of the American Academy of Arts and Sciences. He has served on many committees, in particular, as President of the Society of Industrial and Applied Mathematics (SIAM) in 1999 and 2000. He is currently Chair of the US National Committee on Mathematics for 2003-2004. He has been Professor of Mathematics at MIT since 1970.

He has been closely associated with NUS, having served as a member of the University's International Advisory Panel from 1998 to 2001 during a period of reorganization. The Editor of *Imprints* interviewed him on 18 July 2003 at the Institute for Mathematical Sciences when he visited NUS as a guest of the Institute and the Singapore MIT Alliance from 15 to 19 July 2003. The following is an edited transcript of the interview in which he spoke about e-learning and teaching, applied mathematics in the service of society and the changing landscape of applied mathematics.

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The program will focus on the following topics:

- Scalar curvature problem
 - Specially prescribed scalar curvature problem on n-sphere
 - Conformally invariant operators
 - Geometric flow problem
 - Fully nonlinear partial differential equations

In addition to seminars and informal discussions, there will be two one-hour tutorial lectures every week and a workshop (28 May - 2 June 2004) during the six-week program.

Wall-Bounded and Free-Surface Turbulence and its Computation (July - December 2004)

Website: http://www.ims.nus.edu.sg/Programs/wbfst/index.htm

Co-chairs:

B. E. Launder, University of Manchester Institute of Science and Technology

Chiang C. Mei, Massachusetts Institute of Technology Oliver Pironneau, University of Paris VI (Pierre et Marie Curie) Khoon Seng Yeo, National University of Singapore

The turbulence program will comprise a series of seminars, tutorials and workshops, including the following workshops:

(a) Computation of turbulence I (13 – 15 July 2004)

- (b) Computation of turbulence II (3 5 August 2004)
- (c) Turbulence at a free surface (31 August 2 September 2004)
- (d) Developments in Navier-Stokes equations and turbulence research (early December 2004)
- (e) Transition and turbulence control (mid-December 2004)

Highlights of other Activities

One-day Workshop on Mathematics and Statistics of SARS

(4 June 2003)

With Faculty of Science (NUS), DSO National Laboratories and Ministry of Health Details at http://www.ims.nus.edu.sg/activities/wksars

Colloquium Lecture on "Pascal Matrices" by Gilbert Strang, Massachusetts Institute of Technology

(16 July 2003)

With Singapore-MIT Alliance. Because of overwhelming response, the one-hour talk was beamed *live* to an audience in Nanyang Technological University.

Colloquium Lecture on "Introduction to Random Matrices" by Persi Diaconis, Stanford University (20 August 2003)

Colloquium Lecture on "Post-Fisherian Experimentation" by Jeff Wu, Georgia Institute of Technology (6 October 2003)



A landscape so changed

Courtesy Gilbert Strand

I: MIT recently launched an ambitious long term project to make its courses freely available on the web. How has this project influenced the teaching of mathematics at MIT?

S: Generally, the MIT OpenCourseWare is an e-learning project. I don't think anybody knows exactly how the course materials on the web are going to be used. It was by chance that I had videos taken of my linear algebra lectures (I teach a lot of linear algebra courses). About two years ago, they were video taping the freshman physics course when I came into the same room for the next hour. So, I said, "Maybe you can just keep the cameraman in the room for another hour and we will have a video tape of the linear algebra lecture". They got some financial support for it and they did it. As a result, my linear algebra course is one of the few that have videos on the web. It's absurd that I am now a movie star on OpenCourseWare, which is available at http://ocw.mit.edu. That course was in the first group and now 500 courses are available. I have two others, an applied mathematics course and a wavelets course. The linear algebra course was an early one.

From early feedback on the number of hits around the world, Hong Kong was leading in the number of users. It may be different now. I think students like to see videos which are more alive than course notes. Your question asks about e-learning and mathematics. E-learning has to be alive! The lectures have to somehow involve the student. The real challenge is for students to be a part of the learning process and not just passive viewers.

I: Is there any significant influence on people's teaching?

S: It makes teaching interesting in a new way. After my turn, they took videos of really good lectures at the Mathematics Department. For example, Professor Arthur Mattuck had given lectures for years on calculus and differential equations. I was happy that he was video taped. He is always very well organized. We are also trying to see if there is a way for us to have students answer simple questions in the class, either by pressing a button or in some other ways. You want them to follow the lecture closely, instead of sitting there till the end and then leaving. The key is active learning.

I: You were President of the Society for Industrial and Applied Mathematics (SIAM) some time ago. Could you share with us some of your experiences, challenges and achievements during your presidency?

S: I was President for two years in 1999 and 2000. For a year before, I was the President-Elect, and Past President the year after, so it was a four-year commitment. Quite a lot of time, but I enjoyed it. Applied Mathematics in the U.S. has been upgrading its efforts in connecting with Washington. I think Singapore is amazing because you are always well connected to the needs of society and to the goals of the ministry. In the U.S., we were far from Washington in the past (well, still mostly so). Mathematicians are thinking more about their own work than about the goals of the Science Minister. But now, there is more and more input to the National Science Foundation, to the Office of Management and Budget, to the Senate, to the House. This is a crucial step towards addressing the question of what applied mathematics can contribute to society. It is a challenge, and a happy experience, to speak to the House, to the Senate and to their staffs about mathematics.

One of my special experiences was getting two new activity groups started: one in the mathematics of Life Sciences, and one in Imaging Science. In SIAM, the activity groups have concentrated conferences every two years. It is really important for applied and pure mathematics to recognize what are the new directions and to help the new areas. Some problems grow more and some less, and the rate of changes varies.

The action moves into new areas like the life sciences. It's really important for SIAM to be a part of those areas. It does a lot of conference organising, but the job of the President and the Council of the society is to see what new actions and what new work the society should be doing. That depends on where applied mathematics is moving.

The Society needs to establish a better image of mathematics. The engineers are always there to sell their ideas, and the physicists and biologists are also there. You have to demonstrate the ability of mathematics to contribute and you have to show that mathematicians are needed. Of

course, that has to be proved by what actually happens so that the engineers or the biologists can see the contribution from mathematics.

I: The term "applied mathematics" seems to change over time and place. What does it mean nowadays?

S: There are different parts of applied mathematics. One person is probably not naturally prepared to work in all these parts. An important part is problem modeling. Given the physical problem, produce differential equations that capture the essential facts of the physical problem. Modeling is a big step and I am always impressed by people who do that well. Modeling may not be rigorous but people who do it will agree when it is done well. There is definitely a standard of good and bad in modeling, but it is not a theorem-proof standard. There is an intuitive agreement that, yes, the important parts of the problem are correctly accounted for.

I: How much rigor do we need to maintain in modeling?

S: Maybe not rigor in a sense of proving, but it has to be convincing. The expert in the field might say, "Ah-ha, you missed this important aspect of the problem" and that will affect the solution. There is a standard but it's not exclusively logical. After the model is created comes computing. "Computational science" is now the word that includes both these aspects. You understand the area of application and you can carry through the computing to obtain and understand the answer. But often that is shared. One person understands the application area and the other person says, "Just give me the equation and I will work on the solution."

I: Does that mean the applied mathematician must have two modes of thought?

S: Yes, if he or she is complete. The modeling mode and, we could say, the computing mode.

I: Not many people are able to do that.

S: Unfortunately so but it doesn't have to be. It's good if it is all in one person because then that person sees the full picture. But very often, say in linear algebra, there are many people who will ask, "I have a very large symmetric matrix. How do I find the five smallest eigenvalues?" To the expert in numerical algebra this is a question independent of where the matrix comes from. There is a further stage of creating good software that could be permanent and that other people could use. So there you really need to understand computer science. So, we have the modeling stage, the solution stage and the software stage. The third stage seems far from classical applied mathematics, but it is part of the whole process.

I: So it seems that the computer is really indispensable?

S: It is now, yes. In the past people could get amazing information about the solution by analytical methods and by perturbation methods. That was done by the mandarins of applied mathematics. Now it's more democratic and it's a larger world. Engineers are now part of the modeling world, using algorithms and sometimes creating algorithms. For example, the finite element method is a famous example of an idea that was already in the mathematics papers by Courant and Feng Kang but was really brought to importance by the engineers.

I had an interesting conversation with Nick Trefethen in Oxford on whether mathematicians have made the key contribution in scientific computing. He convinced me that it was probably so. He went down the list of main algorithms that are really dominant. One example would be the Fast Fourier Transform that is used almost everywhere. It came from, well, maybe statisticians (in John Tukey's case) and from mathematicians (Gauss was the first). There is a whole range of crucial algorithms in the twentieth century like the fast multipole methods, stability problems for finite differences, and applied mathematicians have been at the heart of the progress of those methods.

I: Who provided the key ideas?

S: I have never before made the list that Trefethen has: what are the key ideas and who brought them to birth? I like engineering activities and certainly engineers deserve credit. Wavelets is a good example where work in applied mathematics has changed the direction of some area of pure mathematics. Wavelets grew out of signal processing, which is a big user of mathematics. Wavelets have their own unique direction and depth in the pure mathematics sense. Progress in that area continues. That is also well reflected in the Institute's programs and in the wavelet center here.

I: It seems that applied mathematicians would need to work with somebody else.

S: Often, yes. The new problems and excitement are now in the life sciences and biology. You need the biologists, of course. They know what the problems are but they need the mathematicians too. The border between pure and applied mathematics becomes quite permeable. It is very satisfying to contribute to the solutions that other people want. That really is a good feeling. And pure mathematicians often see those patterns and relationships that are the fundamental to mathematics.

I: Is it necessary to give special training in order to make somebody into a good applied mathematician?

S: Well, I don't know. I think that the modeling ability is partly genetic and in-born. The computing skill comes partly from experience – actually doing the computing, getting the answers and improving the algorithms. It is a field where the supply is far behind the demand. The demand is everywhere and I would like to see more and more students having the fun of contributing to a team of scientists.

I: Do you think that the ability to model is unique and that not everybody can do it?

S: Unique, yes. But it must be possible to teach something to those of us who have not got it. I suppose I may be feeling about modeling the way so many outsiders feel about mathematics: that it is a mystery. How could people do this? But mathematicians don't see it as a mystery. They see it as a natural ability. Probably modeling should be just another ability that could be developed. But the very best modelers seem to be natural and not taught.

I: Do you consider modeling to be more of an art?

S: Yes it is. The computing part (the algorithmic part as well) takes on its own creativity. It is an area where you need to experiment and if you have an algorithm, you prove that it is good by using it. A paper that just suggests an algorithm that is never tried is not really acceptable. The proof is in the solution.

I: What are the big problems in applied mathematics?

S: One of the very big areas has been computational fluid dynamics, CFD, and in the extreme case, turbulence, where the parameters are approaching the departure from a smooth flow. That is a big problem and there is good progress. There will always be wonderful problems. But I may not be the right person to name all the big problems.

I: Is turbulence a computational problem?

S: Well, you could say that it is partly computational. You need to invent new methods. There is another big area currently: multi-scale computation. Typically you create a mesh. You have a step-size close to the time scale or the length scale of the problem. But if the problem has a length scale that extends from the size of an atom or molecule to the size of the body or the size of the earth, you cannot use the molecular length scale. How do you make the computation at the molecular length scale acceptable for a model of the heart? Somehow you have to find a smart way to see the effects of very, very small scale events at the macro scale.

I: What about artificial intelligence? It used to be a hot topic.

5: Yes, it did. Maybe it did count as applied mathematics. Applied mathematics certainly goes outside of the mathematics department. But maybe artificial intelligence has remained even further outside. There is such a big range of hard problems. I'm not really qualified to talk about artificial intelligence.

I: There seems to be a gap between pure mathematicians and applied mathematicians. Some people think that it is due to the differences in philosophy and culture between them. How do we bridge this gap?

S: First of all, there has to be mutual respect. Even pure mathematics itself (or applied mathematics) is too big for anybody to bridge, much less to bridge all of mathematics. I think if we have mutual respect and cooperation and an open mind when looking for places to contribute, then the gap is not important. It is the solving of problems that is important. I feel that SIAM (which is an applied mathematics society) and the American Mathematical Society (which is more pure) have included everything, and they are cooperating more and more. I would expect that there is similar cooperation at the Institute here.

I: Should applied mathematicians have the same faith that physicists often have in their usually intuitive, ad hoc and non-rigorous methods in solving many of their mathematical problems?

S: You see physicists getting very clever, usually correct, results. There are definite differences between physicists and applied mathematicians. And probably many physicists are not as close to the computer as many applied mathematicians would be.

I: We shall round up with this question: Should mathematical rigor be imposed at the undergraduate level?

S: For teaching, I think maybe not. I am not sure if I want you to print that! The idea with examples is where students learn. My goal in teaching is always ideas and examples and not proofs. Of course, the mathematics has to be correct, but to prove that it is correct at every step, I don't see as important in teaching. Those students who naturally have that ability will go that way, but students who have other abilities should be allowed to go in the directions natural for them. That's my thought about teaching. If we want mathematics to be chosen by good students, to be liked by students and to be helpful to society, we need a broad view of our subject.

I: Thank you so much for sharing your ideas with us.

S: It is my pleasure to be in Singapore and to see the Institute developing in a great way

Persi Diaconis : The Lure of Magic and Mathematics >>>

An interview of Persi Diaconis by Y.K. Leong

Persi Diaconis is perhaps one of the most unusual mathematicians of our time. After studying the violin when young, he switched at the age of 14 to magic in which he had a successful and colorful career for almost ten years, and then, at the age of 24, he made another decisive switch to mathematics. He has made numerous contributions to mathematics, statistics and probability and is editor of many well-known journals. He has also used his expertise in mathematics and magic to investigate claims in parapsychology. He has been an invited lecturer at important meetings, notably as Wald Lecturer of the Institute of Mathematical Statistics, Gibbs Lecturer of the American Mathematical Society, plenary speaker at the International Congress of Mathematicians and Von Neumann Lecturer of the Society of Industrial and Applied Mathematics. He has won many prestigious awards and honors, and is a Fellow of the American Academy of Arts and Sciences and a Member of the National Academy of Sciences (USA). He is now Mary Sunseri Professor of Mathematics at Stanford University and holds joint positions at the Mathematics Department and the Statistics Department.

The Editor of *Imprints* interviewed Persi Diaconis on 20 August 2003 at the Institute for Mathematical Sciences when he was at the Institute as an invited speaker for the program "Stein's Method and Applications: a program in honor of Charles Stein" held from 28 July to 31 August 2003. In the following edited transcript of the interview, he talks about his two loves (magic and mathematics) and the excitement of research.



It's mathematics, not magic

I: Thank you very much for agreeing to be interviewed. You started to take up mathematics at a comparatively late stage of your life. What made you make that change when you already had a successful career as a magician?

D: At 24 years old. I really don't know why I went into mathematics. It seemed to be an esoteric subject to me when I was young. It was the Sputnik era – if you get a PhD you could get a good job as a professor (it's still the case, I think). Maybe that's the reason.

I: There must be some connection between what you did before and what you did after.

D: There was some connection in the sense that I knew Martin Gardner who was a wonderful writer of popular mathematics. He put some of my early magic tricks that were mathematical into the Scientific American and I was very happy about that. I didn't really know any other mathematician, but in the end I felt there was some similarity between mathematics and magic.

I: You already used mathematics in your magic tricks?

D: Oh yes, there are some magic tricks that use pretty elaborate mathematics. For example, magicians can perfectly shuffle a deck of cards. I learnt that if you do that eight times, the deck comes back to where it started. One of my early discoveries involved the two types of perfect shuffles, in and out. The out shuffle leaves the original top card on top, the in shuffle brings it second. If you want the top card to be in some position j say, then you express j - 1 in binary form and use the bits of j - 1 as instructions for the shuffles. That's how you get the top card to where you want it to be. Well, that's a mathematical discovery. There are all kinds of tricks that use mathematics, most of them awful, but there are some good ones.

I: So you actually discovered some mathematics while you were in magic.

D: Something about binary numbers, also Fermat's Little Theorem $2^{p-1} \equiv 1 \pmod{p}$, and some elementary number theory.

I: You mentioned before that doing mathematics is like doing magic. How is that?

D: One similarity is this: you have to solve a problem and you have certain tools that you are able to use and others that you are not allowed to use. And as in problem-solving there is the notion of elegance. The difference is that mathematicians have hundreds of years of tools whereas in magic you use whatever you can get. The similarity is especially so in applied mathematics in which the problem

comes from somebody else. The chemist or biologist might have a question for you, and you don't have any ready tools. You have to start thinking about it and start using whatever tools you have or invent new ones. That's pretty similar to solving magic problems.

I: In some sense, magic is as logical as mathematics.

D: In some way, but magic is not logical enough to allow everybody to see the trick. If you think about it, magic involves principles of deception. I once taught a course on the history of deception. It was an interesting course about the history of magic and the psychology of lying and things like that.

I: Did your experience with magic give you some advantage when you took up mathematics?

D: The only advantage would be first of all that I had the ideal of inventing something of my own from my magic tricks. Also I had a great mentor (Dai Vernon) who taught me the difference between mere variation and something that is really original. Another thing is speaking before the public. It makes a difference to be able to give a talk to people. To make them understand a talk is like doing a show. You have to make them follow it and enjoy it and not just sit there thinking how smart the guy is.

I: When you prove a theorem do you try to find the best way to do it?

D: Sometimes. Erdös once had a theorem about the order of a random permutation. He and Renyi had a very long paper on the distribution of the order of a random permutation. I managed to prove it in about five or six pages, and I showed it to him and he looked at me, surprised that I was right. And I remember that.

How do you know that something that you use a lot is true? I'm opposed to the recent thing about proofs from "The Book". They are wonderful, amazing proofs but they are useless. They are not the work of mathematicians because that's not the way we work. You want to tell people how you think about your problems.

If you can follow the proof why that's true, that's great. But these very sleek proofs ... are only beautiful like magic tricks

- *I*: You don't go back to re-prove things?
- **D:** Sometimes, but not often.

I: Do you choose to work on a problem because of its potential applicability?

D: Not necessarily. I'm always happy if a problem has an application. I used to just make up the problems on my own, or work on a simpler version of a real problem if it's too hard now. I work on mathematical problems with biologists and problems from computational group theory which involve computing with large finite groups. One of the main tools in group theory is the representation theory of finite groups. I have used this extensively but also contributed by working out a noncommutative Fast Fourier Transform.

I was recently working with group theorists to try to understand why the product replacement theorem works. One of the ingredients is that you have two giant matrices, say 100 by 100, which generate a group over a finite field. You want to know something about its irreducible representations. You take a random element from the group algebra and do something like a random walk on the matrices, and it works pretty well. You can prove a theorem about it. Well, I asked myself what can you say about the general linear group over the integers modulo 2. The question led to a simple urn problem. It was an urn problem which I could not do until I came here and discussed it with Zhidong Bai and we could do it. I was working on the general linear group. It was too hard but I looked at a simpler problem and we solved it. I'm working on problems in group theory by applying probability. You have to know a lot of group theory and vice versa. I'm fascinated by problems from group theory.

I: Is this a new approach to group theory – applying probability?

D: No, not really. Many people have used this kind of approach. Erdös has used probabilistic methods to prove that an element of a group has certain properties. If you want to know whether a group is simple or whether a certain modular representation is irreducible, there are algorithms which can be used to show that they have the required properties with probability close to one. But it raises a philosophical question: if something is true with probability $1 - (1/2^{100})$, is it the same as saying it is really true?

I: How important is collaboration with people in other fields?

D: I learn many things in that way – things that I don't know about. It's very hard to read something from the papers in a different area. But we can talk to each other and in ten minutes you know what it is about. That's one of the great joys in mathematics – to get to talk to somebody.

There is something I once learned from Erdös very early on. We were working on a number theory problem. It came down to an algebraic topology question, and he said, "Oh, I'll just call so and so, and I'll ask him." And I was shocked because I thought that we were learning from the topology books and shouldn't we work it out ourselves, but he said, "But why? If we call him, in five minutes we'll get the answers." I thought that if we want to learn some algebraic topology, we would be better off learning on our own. Anyway, there's the question of when do you ask somebody else and when do you learn it yourself?

I: How do you describe yourself with respect to your research?

D: When people ask me what I am, I say I am a statistician. I certainly do a lot of probability, but I never had a proper course in probability. I taught many courses in probability and I worked with great probabilists who taught me. When I was at Harvard, which is a very mathematical department, we didn't really have a probability course. There was a course I took on probability given by Gleason who would just teach it without knowing the literature. And he taught it in an original way. Then I try to learn group theory, and now I know more group theory than most probabilists.

I: What is the most satisfying piece of research work that you have ever done?

D: I would say the work on perfect shuffles and random permutations.

I: What are your effective working habits?

D: Well, they have changed. It used to be that I would wake up early in the morning and work till late at night. And then ten years ago, I met Susan. Now I wake up early before the others and work for a little while and then I have to find a place to hide. If I go to the office, there are students, the email and the secretary. So I have to find some place to hide for an hour or two. My work is now more sporadic than it used to be, but I still work at night.

I did a lot of work with other people on the phone. I would call people on the phone and tell them I was stuck with this problem and asked them would they tell me about this and that. It's nice to talk to people.

I: Do you think about your problems when you are doing something else?

D: Sometimes. I love to solve problems, I love to think about them. Sometimes I just have to relax. It's a hard thing to do.

Some people ask me whether I work on big problems. I just work on the next problem in front of my nose. I work and think hard about it. When I came to Singapore, I started to think about new problems. Before that, I was thinking about some problems about symmetric operators commuting with groups of transformations.

I: How much of the computer do you use?

D: I used the computer a lot in my PhD thesis. I love to think about algorithms, about better ways of computing, but mostly I leave the computing to others.

I: Have there been any surprises in the way your research work has developed?

D: Sometimes. There have been wonderful surprises. To study the perfect shuffles used in magic tricks, you have to take two permutations and look at the order of the group they generate. It turns out that they are very useful for certain parallel processing algorithms. Well, some people don't like their work to be useful. But I wrote a book about representation theory of groups and probability theory and try to understand what it means for two matrix representations to be close together. I wrote a few papers about that and had some PhDs writing their theses on that too. It's wonderful for me to have a bunch of computer scientists reading my papers and asking technical questions which I considered twenty years ago. That's amazing and really surprising. Several times, I'm worked hard on a problem for my own reasons, and then somebody else is interested in it too. Some of my colleagues screen their problems. I'm just the opposite – though I do screen my problems. If I work on a problem and I have to talk to other people or to learn some new mathematics, that's a good reason for doing it.

I: Are there any problems you would like to solve?

D: I worked hard on Stein's Method when I came to Stanford. I thought I knew about it but I didn't do very much. Now I'm thinking about it again. In the airplane, I was thinking about eigenvalues. When I came here I worked hard with Zhidong Bai and we got some work done. I don't know what problems I would really like to solve. If you think about it, wouldn't it be wonderful to solve the Riemann Hypothesis? But I just don't work like that.

I: What about problems in computational biology?

D: I tried to teach myself biology for several years. It's quite embarrassing how little I managed to learn, to tell you the truth. When I first came to Harvard, there was a

young assistant professor who took one of my courses and who was involved in the university's work on the human genome. He came to me with some combinatorial problems and he tried to teach me some biology. I wrote some papers on computational biology but only if somebody posed the problem as a mathematical problem. My wife Susan really learned the biology and all the other business. It's several years of work. When it came to learning biology or learning about another part of mathematics, like unbounded operators or extraspecial pgroups, I had to choose, and I chose extraspecial p-groups. It's some internal reason.

I: If a graduate student has to choose a field of research, what kind of advice would you give him?

D: I had a lot of graduate students coming to see me about research. After going through graduate school, they should know what they want to do for their PhD thesis. (I did my thesis on Tauberian theorems in number theory - but this is not what I do nowadays.) If a student has a topic, well, let's find some problem that is relatively hard to do. Another way is to take a harder field and learn about it, Sometimes I say to students "Do what you can do best." All students are different. I remember one student in my class who was spectacular with his homework problems. People were telling him "You're good. Why don't you read this." But he wouldn't sit down and read those things. He was a problem solver. So I said, "Okay, here are some problems. Solve them and that will be your PhD thesis."

I had another student who wanted to do something real. I didn't help him very much but I didn't get in his way. I didn't make him do work that I thought he should do. I let him do something real – character recognition to read Bengali. It's partly pattern recognition and it uses algebraic topology and curves, and it really works. I'm very impressed by that. My students are free to do all sorts of things.

I: There is a lot of pure mathematics being applied to statistics, isn't it? Like Jordan algebras.

D: Absolutely. Jordan algebras in multivariate analysis, symmetric function theory, Charles Stein's work on amenable groups. Statistics used to be more theoretical but now the computer has taken over. Statistics has become very computationally oriented. They are not interested in group theory. I'm half in the mathematics department and half in the statistics department. It's not clear what we are doing is relevant to statistics.

I: What do you see are the directions in statistics?

D: Well, very big data sets. For example, I'm working on this problem on protein folding with enormous data sets and the problem is how to simplify them and make them comprehensible – data mining. How do you adjust to the richness and the power of the computer? It's an important problem. The technology is changing rapidly. So I may not be the right person to ask.

I: You have been very enlightening on many aspects of research which we don't see from journals and books.

D: People don't talk about what it is really like to be doing mathematics. If you work in a new area like me, you go and talk like a child to somebody who has been doing it for twenty years. If you can tolerate feeling stupid, something will come out of it. When you can finally think your way out for five minutes, you will say, "It's nice, How can I have missed that?" I often think that most of us who keep going have pretty thick skins.

I'm very happy that you have the IMS. It's something important to have and it's a wonderful idea. You don't have anything like this in the area. It's great for the country.

I: But we are a bit isolated. We are grateful that people do come. It's a long way away for many of them.

D: Well, you can bring people in. If you put up some good meetings and you do as well as you have done, people will come to this place. You gain some reputation for good work and it has been a wonderful conference to me. I feel really invigorated and I learn something I didn't know about new problems. Some of the youngsters are very good and I've been working hard. Everyone is working hard. It's a pleasure working. We don't know ourselves. We don't know how happy we are to be allowed to do what we do.

I: Thank you for your kind words. It's encouraging for us at the Institute.



Charles Stein: The Invariant, the Direct and the "Pretentious" >>>

An interview of Charles Stein by Y.K. Leong

Charles Stein (b. 1920) is considered to be one of the most original thinkers who made fundamental contributions to probability and statistics. He has received many honors and awards and is a Member of the National Academy of Sciences (USA). He has given many invited lectures, notably as plenary speaker of the International Congress of Mathematicians, and as the Institute of Mathematical Statistics Wald Lecturer, Rietz Lecturer and Neyman Lecturer. He is now Emeritus Professor of Statistics at Stanford University and continues to be active in research in statistics.

The Editor of *Imprints* interviewed him on 26 August 2003 at the Institute when he was the guest-of-honor of the Institute's program, "Stein's Method and Applications: a program in honor of Charles Stein" held from 28 July to 31 August 2003. The following is based on an edited transcript of the interview and subsequent follow-up by electronic mail. Here he reflects on his work and expresses his views on teaching, research and statistics.

I: Professor Stein, thank you for agreeing to be interviewed. I'm sure it will be of great value to many people. The first question concerns the statistical work which you did for the Air Force during the War. Presumably statistics was then not yet established as a rigorous discipline. What was it like to do statistics without the benefits of its modern foundations? Was that work instrumental in leading you to think about basic questions in statistics?

S: First I should say that I am strongly opposed to war and to military work. Our participation in World War II was necessary in the fight against fascism and, in a way, I am ashamed that I was never close to combat. However, I have opposed all wars by the United States since then and cannot imagine any circumstances that would justify war by the United States at the present time, other than very limited defensive actions.

Statistics was already a well-developed field by 1940, going back to work of Gauss, Laplace, Galton, Karl Pearson, Student, Fisher, Neyman and Pearson, and many others. On the other hand, one can argue that statistics is not yet established as a rigorous discipline. I do not think that my work on the verification of weather forecasts had much influence on my later work.

The actual type of work I did at that time was not really instrumental in leading me to think about basic questions. However, we had a very strong group of people there, Kenneth Arrow, George Forsythe and Gil Hunt among them. Certainly discussions with them helped broaden my understanding of statistics, in particular, with Gil Hunt. Gil Hunt is a very accomplished mathematician and I profited a great deal from his knowledge of group theory in particular although not as much as I could have.

I: You mentioned Gil Hunt ...

S: Gil Hunt is a mathematician, Kenneth Arrow is an economist and George Forsyth became a computer scientist and numerical analyst.

I: Did you do something on groups with him (Hunt)?

S: We considered the question of whether, given a statistical problem invariant under a group of transformations, there exists an invariant procedure possessing desirable properties, such as being minimal or admissible. We showed that if the group is, in an appropriate sense, composed of groups each of which is abelian or compact, there exists a minimax procedure that is invariant under that group. Realistic counter-examples came much later. The full linear group in two or more dimensions does not satisfy this condition, and in fact the conclusion does not hold. Thus, for example, it is usually inappropriate to assume automatically that a sample covariance matrix is essentially the right estimate of the population covariance matrix. The question of admissibility also came later. Unfortunately, both Hunt and I were very slow to publish, but proofs were eventually published by other people, with full acknowledgement of course.

I: Often, work done for one's PhD thesis shapes one's future conception of the field. Is this the case for you?

S: No, this is not really true of my PhD thesis, which dealt with a topic related to Wald's sequential analysis. Kenneth Arrow had lent me Wald's first work on sequential analysis and asked me whether it provided a sequential test for Student's hypothesis having power depending only on the Continued on page 17



Mind behind the Method

mean, and when I replied that it did not, he indicated that his was a serious shortcoming. A night or two later, I was officer of the day and had to prepare a forecast starting at about two in the morning. After finishing the forecast, I worked out most of the details of a two sample test which did have power depending only on the mean, vaguely similar to earlier work of Dodge and Romig on a different problem. This became my PhD thesis. Neyman was impressed, because George Dantzig, who was a student of his, had proved rigorously the intuitively obvious fact that no single-sample test can accomplish this. However, I think of this work as relatively unimportant, and it did not have much effect on my later work.

However, Wald did have a strong effect on my work. My work with Hunt grew out of Hunt's remark that, in my attempt at generalizing a result of Wald, I was essentially doing group theory, and all of my work on statistics has been in the framework of statistical decision theory, developed by Wald following ideas of Neyman and Pearson, and also von Neumann and Morgenstern. Wald also encouraged me to work on mathematical statistics while I was in the Army Air Force, and to come to Columbia after the war.

I: If you were asked to list your three most important contributions to statistics and mathematics, what would you list?

S: Certainly the work that is most important is what is called Stein's Method, which was developed further by Louis Chen, whose work inspired much other related work. The second most important is my work on invariant problems, which started with my discussions with Hunt, and continued with my paper in the third Berkeley Symposium on the inadmissibility of the usual estimate of the mean of a multivariate normal distribution in three or more dimensions, and the paper with James in the Fourth Berkeley Symposium, which studied a reasonably good estimate for this problem. Efron and Morris also proposed an important improvement on this estimate. Others, including many of our students, such as Eaton and Loh, did important work involving unknown covariance matrices.

Most people seem to think that my other paper in the Third Berkeley Symposium is my third most important contribution. In response to the problem of estimating the median of an unknown symmetric distribution, Vernon Johns and others proposed a sensible solution, an "adaptive" symmetric average of order statistics. In response to the same problem, I wrote a rather pretentious paper in that symposium, which tried to develop a general theory applicable to this problem. I got nearly everything wrong but the paper is believed to have had considerable influence on the development of semiparametric statistical methods."

I: I think you are modest about that. You mentioned Stein's Method as your most important contribution. Many people would like to know what led you into formulating the method that is now known as Stein's Method?

S: Well, Persi Diaconis has already touched on that in his lecture. Briefly, it is that I was teaching a course on non-parametric statistics and I decided to prove what is called the combinatorial Central Limit Theorem. I could have presented the published work of Wald and Wolfowitz and Hoeffding but instead I decided to try my own approach. That involved the idea of exchangeable pairs to approximate the characteristic function. After a while I realized that there was nothing special about the complex exponentials. I introduced an arbitrary function and thereby avoided the need to invert the characteristic function.

I: You were looking at it in a different way. Most people would just teach it in the standard way from the books or papers. Not many people would actually try to find a novel way of looking at it. It is quite well-known that teaching does contribute to research, isn't it?

S: Many people, including notably David Blackwell, have mentioned that teaching is the most important stimulant to their research.

I: Did you foresee the wide applications that your Method brought to other fields some fifteen years after it was introduced?

S: No, but I guess that I always thought it ought to have applications. I never really pursued it.

I: I understand that you do not have a personal pressure to publish. Don't you think it would be a loss to the community if you don't publish the results you have?

S: I have always had great difficulty writing things up and also difficulty in forcing myself to submit something even after it is written. I suppose this has slowed progress somewhat in a few cases, and I regret it.

I: Do you have many graduate students?

S: No, I had about ten graduate students personally. Louis Chen and Wei-Liem Loh are among them.

I: Your students will invariably pick up your ideas and extend them. In some sense, they are doing what you are doing.

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I: In research, which is more important: conceptual foundations or technical perfection?

S: That is a hard question to answer. I find it hard to get all the details right, and yet that is important. But I am stronger on the conceptual aspects than on the technical aspects.

I: Would you say that your approach to a problem is intuitive?

S: To some extent. I would look at problems which are not always very well clarified at first, and then I go on to clarify them, I hope.

I: What is your view on breadth versus depth in research? For example, some people work deeply on a small topic while some people have a wider interest.

S: I must say that I have not solved a wide range of problems though the problems I studied are formulated over a broad range, like the invariance problems and the question of using direct elementary methods rather than complex variable methods in probability theory. Of course this was not new, going back at least to Lindeberg in the modern period, but elementary methods had become unfashionable and my approach is much more widely applicable.

I: The next question is about the explosion in information and knowledge that we are faced with nowadays. Is it necessary to keep up with this explosion in information and knowledge?

S: For young people it is important and, to some extent, it may be possible for them. At my age it is not important. I am incapable of keeping up with, for example, the Fermat conjecture. I have tried reading books on it but have not made much progress in understanding it.

Everyone is exposed to some aspects of computational theory and practice, but that is more important for young people.

I: Do you use the computer in your work?

S: I have done some computing although my colleagues tend to discourage me. In a recent work on simulation, my co-authors did most of the computing.

I: I suppose you give them the ideas and they do the computing.

S: They may be stronger in computing then I am but they are also strong theoretically.

I: Could you give us your projections for statistics in this new century?

S: Not really. Clearly the field continues to develop. The computational aspects will be perhaps even more important than they are today. There will probably be a mixture of good work and bad work. There will be a lot of statistical packages to enable people to solve problems, often without understanding them. But I am unable to anticipate the directions of the important changes.

I: What do you think of the importance of statistics in computational biology?

S: Statistics is, of course, important and people are interested in applying it.

I: In some sense, what you have done plays an important role in computational biology.

S: I have not followed the field of computational biology enough to know whether my ideas have really been useful.

I: You mentioned the computational aspects of statistics. So we are going to be faced with a lot of data generated by computational statistics and then the theory has to keep up with it. We seem to be like in physics where there is more information than theory. Do you think there will be a revolution in statistical theory?

S: I cannot anticipate that. There is one big question on which I am not really competent, and that is the extent to which elaborate models are useful in applied statistics. Elaborate models can give an impression of providing results that are in fact not justified whereas with simpler models, it is more apparent if the results are not justified. The elaborate models are like black boxes which are supposed to give you the answers. And you do not know if anything goes wrong.

I: Do you find it surprising that statistics can do so many things and solve many problems in real life?

S: No, it is not clear that it does. It certainly plays an important role but one should not put too much confidence in this claim.

I: But statistics takes the guess work out of solving problems. In the old days, you did not know what is going on and you did it by trial and error. Now statistics gives you a way of doing things.

S: It gives you a way of thinking about things, but you may not come out with correct conclusions.

Forthcoming Publications

Continued from page 18

I: You have given us a very good view of your philosophy of statistics and other subjects. We would like to thank you for the time you have given us.

The main objective of the Lecture Notes Series is to make the original or final version of the notes of the tutorial lectures given at the Institute's programs available to a wider audience. The Series may also include special lectures and workshop proceedings organized wholly or jointly by the Institute.

The following volumes of the Series will be published in 2004.

Volume 2:

Representations of Real and p-adic Groups

Edited by Eng-Chye Tan and Chen-Bo Zhu (National University of Singapore)

Contents:

- On Multiplicity Free Actions (C. Benson and G. Ratcliff)
- Lectures on Harmonic Analysis for Reductive p-adic Groups (S. DeBacker)
- Multiplicity-Free Spaces and Schur-Weyl-Howe Duality (*R. Goodman*)
- Dirac Operators in Representation Theory (J. S. Huang and P. Pandzic)
- Three Uncertainty Principles for an Abelian Locally Compact Group (T. Przebinda)
- Lectures on Representations of p-adic Groups (G. Savin)
- On Classification of Some Classes of Irreducible Representations of Classical Groups (M. Tadic)

Volume 3:

Selected Topics in Post-Genome Knowledge Discovery Edited by Limsoon Wong (*Institute for Infocomm Research*) and Louxin Zhang (*National University of Singapore*)

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- The Representation, Comparison, and Prediction of Protein Pathways (J. Tillinghast, Y. Yang, J. Au-Young and Y. Tang)
- Gene Network Inference and Biopathway Modeling (S.Miyano)
- Data Mining Techniques (M. J. Zaki and L. Wong)





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