IMPRINTS
MARCH 2004
NUS National University of Singapore
INSTITUTE FOR MATHEMATICAL SCIENCES

Official Opening of IMS Auditorium >>>

Chi-Tat Chong: Realizing a dream

On 9 December 2003 the usually tranquil morning of a typical weekday at the Institute was abuzz with excitement and activity. It was not the intense excitement of research generated by an on-going program. It was a more festive excitement associated with celebrations. The occasion of the celebration was the official opening of an auditorium which had already been in use for program activities during the past four months. Ostensibly named "IMS Auditorium" and managed by the Institute, it is, in reality, a university facility available for the use of all our colleagues in NUS. Its opening marked one additional step taken in an enterprise that began with a dream almost 15 years ago.

It was also an occasion of sharing a hope and a dream with about 55 guests and friends who are closely associated with the Institute in spirit and in deed. Heart-warming messages (if not testimonies) were offered by the Director, the Chairman of the Scientific Advisory Board and the Provost of NUS in a short and simple ceremony which culminated in the symbolic unveiling of a commemorative plaque by the Provost, Chi Tat Chong, himself one of the original creators and shapers of this dream. Its spirit is eloquently captured in his speech (reproduced below).

"The IMS was officially opened in July 2001. Its first scientific program was on Cryptography, Coding and Data Security. Since then, it has organized six programs with workshops and other activities, covering a wide range of subjects in the mathematical sciences, including the current one on Wavelets. On looking back, it is quite satisfying to note how far the Institute has progressed since its inception.

Establishing a mathematical research institute in Singapore was not a straightforward task. I remember that as far back as in the mid 1980s, a few of us in the Department of Mathematics talked about having an MSRI-like institute on campus. The then Head of the Mathematics Department, Professor Peng Tsu Ann, actually gathered a few colleagues to draft a concept paper. But perhaps the idea was then ahead of its time. Almost 15 years later, the dream has turned into reality. It was not an easy path to take, but we all believe that it has been worthwhile.

If you look at the well established mathematical research institutes like the MSRI and the institute at Oberwolfach, you will see that they share some common characteristics. Both are located in the woods, and somewhere up the hill. I remember that some years back when I spent a semester as a member at the MSRI, the climb up the hill from the Lawrence Hall of Science in the morning was a challenge every time, and the spectacular night view of the San Francisco Bay on the bus ride down to Evans Hall (the Berkeley Mathematics building) was always mesmerizing. And one cannot forget the long and winding road below the Institute at Oberwolfach, where a car would drive by occasionally. Whenever a mathematical idea seemed to get

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From the Editor >>>

When the American mathematician E.T. Bell unilaterally proclaimed mathematics as the "Queen of Science" (and paradoxically, also as the "Servant of Science") some fifty years ago, no physicists, chemists or biologists came running to pay homage or tribute. As far as they were concerned, the proclamation was inconsequential and irrelevant. As long as it was non-imposing and non-intrusive, mathematics could be tolerated and even allowed some concessionary corner in their backyards. In the meantime, more and more mathematical investments were made into Nature's stocks and very quickly, the mathematical dividends were being reaped. But the flow of benefits has not been unidirectional. The applied mathematician has amply demonstrated that mathematics has paid back with full interest whatever physical motivation it has borrowed from other fields to jump start its logical engine.

To the public, even the educated public, mathematics is invisible under the trappings of modern society. They only see the pictures on the television screen and they only feel the hard cash dispensed by the automated teller machine. The question of mathematical relevance does not even arise. Recently, more mathematicians, both pure and applied, are literally taking to the streets to spread their mathematical teachings to the "philistines". It is undoubtedly an uphill struggle, probably made steeper by the internal divisions that demarcate the "pure" from the "applied" domains. Handed down by priestly tradition, the dividing lines are becoming thinner and blurred in many cases.

Meanwhile, a powerful force manifested in the form of computers is making itself felt almost everywhere; one could practically see the sign on the wall: "Hail to the King of Science!" But it is a virtual force whose supply lines come from other domains, which are in turn mysteriously invigorated and recharged by the reversed infusion of this force and give birth to new domains (such as computational biology, computational science and scientific computing). It is a new world order in which the pragmatic components of mathematics are finding new niches.

Y.K. Leong

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A milestone unveiled

nowhere, a walk in the Black Forest was always a therapeutic exercise and hitting a tree with a branch sometimes helped vent the frustrations.

Here at the IMS, there is a little hill up the Ridge, and the road outside the building is certainly not straight. But perhaps it is located too close to the city or the university campus, unlike MSRI and Oberwolfach. One hastens to add, however, that hills, woods and seclusion are not necessary conditions for a successful institute. Indeed, mathematicians always search for counterexamples. And in this respect, two come immediately to mind: the Institute of Mathematics and Its Applications in Minneapolis, and the Fields Institute in Toronto. Both are located on campus, and not isolated from civilization. Hence the inescapable conclusion, which one may phrase as a theorem: it is the people and the culture, plus the facilities, that make up a successful mathematical institute.

In the Singapore context, such conditions are not automatically given, nor do they exist by decree. Our history as a community of mathematicians is relatively brief, going back to no more than 50 years, and the size of this community is modest. However, there was a dream for an institute that many of us shared, and through joint efforts this institute is now with us. The IMS is only two years old. Compared to other mathematical institutes, it is a baby just barely able to walk. It will be many more years before it reaches adulthood. At this moment the IMS remains fragile.

The Director has expended practically all of his energy in bringing the Institute to where it is today. While we applaud the progress, let us do our part in giving the Institute all the care and attention we can give, and let us look forward to celebrating its first ten years, not too far away in the future."

Scientific Advisory Board at the opening

People in the News >>>

The Chairman of the Institute's Management Board, Chi Tat Chong has been conferred the title of University Professorship by NUS for his scholarly contributions to mathematical logic and for his services to Faculty and University management during the past 20 years; in particular, for overseeing reforms in the areas of academic governance and education during his term of office as Provost and Deputy President of NUS from 2001 to 2004.


IMS welcomes UIUC visitors

A memorandum of agreement (MOA) on a Joint PhD Programme in Chemical Engineering was signed by NUS and University of Illinois at Urbana-Champaign (UIUC) on 3 February 2004. During the visit of UIUC delegation to NUS, three prominent members, Richard Herman (Provost and Vice Chancellor for Academic Affairs), Charles Zukoski (Vice Chancellor for Research) and Jesse Delia (Dean, College of Liberal Arts and Sciences) came to the Institute and had informal discussions with the Director and Deputy Director on matters of mutual interest.

The Institute's secretary, Agnes Wu gave birth to a boy on 31 October 2003.


Baby Zayne

One of the Institute's administrative officers, KP Chua tied the knot on 22 November 2003.

Programs & Activities >>>

Past Programs in Brief

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, *Agency for Science, Technology and Research, Singapore*

This program was co-funded by and jointly organized with the Institute of High Performance Computing (IHPC). Its activities were held during two disjoint periods as those originally scheduled for April and May 2003 had to be postponed because of the SARS episode in March – April.

The program focused on multiscale simulation and fast algorithms with sub-themes in computational electro-magnetics and computational acoustics, and in particular, on important issues in the development of the multiscale framework, technique details of handshake zone and some important problems in nanomaterials and nanostructures such as dislocation, grain boundary, nanoindentation, crack propagation, nanocrystalline metals, carbon nanotubes, surface diffusion and so on.

An International Conference on Scientific and Engineering Computation was held from 3 to 5 December 2002 with Thomas Hou (California Institute of Technology) and Roland Glowinski (University of Houston) as the plenary speakers. The conference was jointly organized with Institute of High Performance Computing (IHPC), Faculty of Engineering and Faculty of Science and in cooperation with Society for Industrial and Applied Mathematics (SIAM), Theoretical and Applied Mechanics Society – Singapore (SingTAM), Australian and New Zealand Industrial and Applied Mathematics (ANZIAM) and Centre for Development of Advanced Computing (CDAC). A few hundred participants attended the conference which received about 200 technical papers.

A Workshop on Fast and Advanced Computational Electromagnetics was held on 27 February 2003 and it was attended by about 50 participants.

During the first period, two tutorials were conducted by Jian-Ming Jin (University of Illinois at Urbana-Champaign) and Christian Hafner (Swiss Federal Institute of Technology). An average of 46 participants attended the two tutorials. During the second period, six tutorials were conducted by Alireza Baghai-Wadji (Vienna University of Technology), Alberto Cuitino, (Rutgers University), William Curtin (Brown University), Tamio Ikeshoji (Research Institute for Computational Sciences, Japan), Aiichiro Nakano

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(University of Southern California) and Michel Nakhla (Carleton University, Ottawa). An average of 26 participants attended the tutorials during this period.

The following colloquium talks were given:
(i) Heterogeneous Multiscale Methods by Bjorn Engquist (Princeton University),
(ii) Multiscale Modeling and Computation by Thomas Hou (California Institute of Technology),
(iii) Interfacial Flows and Fluid Dynamic Instabilities by Thomas Hou.

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

"As a Singaporean, I am heartened by the broad scientific vision that the creation of the Institute for Mathematical Sciences represents, and I look forward to an increased appreciation of the value, both intrinsic and extrinsic, of the mathematical research to our city-state."

"Thank you very much for your kind invitation to IMS and IHPC. I have greatly enjoyed exciting and stimulating discussions with IMS, IHPC and NUS scientists and we have identified a number of possible future collaboration topics."

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*
Zuowei Shen, *National University of Singapore*
Chi-Wang Shu, *Brown University*

This program conducted multidisciplinary studies involving mathematical perspectives and foundations of imaging science and information processing. In particular, the program emphasized the applications in imaging science and information processing of the recent developments in the areas of approximation and wavelet theory, numerical analysis and scientific computing, and statistical and data analysis.

The program activities were also spread over two disjoint periods and included two conferences, four workshops, seven tutorials and two public lectures. The two conferences were (i) the Asian Approximation and Wavelet Theory Conference held from 10 to 14 November and (ii) the International Conference on Numerical Methods in Imaging Science and Information Processing held from 15 to 19 December. The two conferences attracted 40 and 60 participants respectively.

Of the four workshops, one (the Joint Workshop on Information Processing, held from 20 to 23 October) 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). The themes of the other three workshops were (i) Information processing for medical images (8 – 9 September), (ii) Time-frequency analysis and applications (22 – 26 September), (iii) Mathematics in image processing (8 – 9 December). An average of 41 participants attended the four workshops.

A tutorial held in conjunction with workshop (i) above was given by Chye Hwang Yan (DSO National Laboratories) and Borys Shuter (Department of Radiology, National University Hospital). Another tutorial was given by Hans G. Feichtinger (University of Vienna) in conjunction with workshop (ii).

A series of tutorial lectures on Digital Watermarking was given from 29 November to 2 December by Ee-Chien Chang (National University of Singapore), Mohan Kankanhalli (National University of Singapore), Pierre Moulin (University of Illinois at Urbana-Champaign) and Nasir Memon (Polytechnic University, USA).The lectures were attended by 70 participants.

Another series of tutorial lectures on the theme of the international conference was given from 10 to 12 December by Tony Chan (University of California at Los Angeles), Jianhong (Jackie) Shen (University of Minnesota), Markus Hegland (Australian National University) and Chi-Wang Shu (Brown University). Nearly 70 participants attended the tutorial lectures.

As part of the Institute's drive to popularize mathematics, two public lectures were given:
(i) "What's Math got to do with it? Mathematics at the frontiers of sciences and technology" (15 December 2003) by Tony Chan (University of California at Los Angeles),
(ii) "Mathematics in the real world and the fake world" (18 December 2003) by Stanley Osher (University of California at Los Angeles)

Some words of encouragement from our invited visitors:

"I am impressed with the beautiful facility of IMS and the friendliness of its people. It was a privilege to visit and to attend such a useful workshop. Many thanks to all involved."

"The (Asian Approximation and Wavelet Theory) conference was very nice and perfectly organized. The facilities for research work in the IMS are excellent. The IMS people are friendly and efficient. I really enjoyed my stay here and collaborations with mathematicians from NUS. Many thanks for the hospitality."

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"Very excellent conference and well run and organized. The talks were great and I'm taking home much new information. Thanks very much to the organizers for inviting me."

"It was a superb conference and I was delighted to participate in it. Both the academic and organizational efforts were excellent. I look forward to visiting again."

"Singapore will soon be as important for applied math as the major centers of the US and Europe. I am impressed by the high level of the people here."

Asians creating wavelets

At Tony Chan's public lecture

Passing information over a cuppa: from left – Julia Neumann, unidentified, Suqi Pan, Ping Lin, Hongkai Zhao, Stanley Osher, Robert Plemmons, Charles Chui and Seng Luan Lee

Zuowei Shen in one of his frames

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*

The program was funded by the Biomedical Research Council (BMRC), Singapore. The aim of this program was to study the many new statistical methods developed and tailored to microarrays in the last few years. Originally scheduled for June 2003, the program took place from 2 to 31 January and attracted 147 participants from overseas and local research bodies within NUS and without, like the Institute of Molecular and Cell Biology (IMCB), Genome Institute of Singapore (GIS), Bioinformatics Institute (BII), National Cancer Center and Ministry of Health.

The program activities included a tutorial, a workshop and a public lecture. The tutorial lectures were given from 2 to 6 January by Lance Miller (Genome Institute of Singapore), Jean Yee Hwa Yang (University of California, San Francisco), Gordon Smyth (Walter & Eliza Hall Institute of Medical Research), Mark Reimers (Karolinska Institute, Stockholm), and Patrick Tan (National Cancer Centre, Singapore). The tutorial sessions also provided hands-on learning of special packages for microarray data analysis from experienced developers of packages such as BioConductor, LIMMA, RMA (Robust Multi-chip Analysis) and dChip.

The workshop was held from 7 to 10 January and from 13 to 17 January to address the main statistical challenges facing microarray technology.

A public lecture "Genes, Disease and Genetic Diseases" was given by Terry Speed (University of California at Berkeley and Walter & Eliza Hall Institute of Medical Research, Australia) on 7 January.

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

"A very stimulating program, with plenty of lively interaction amongst the world's experts – well worth the trip."

"Many thanks for a superbly organized workshop and an excellent program covering the most recent technology and analysis methods."

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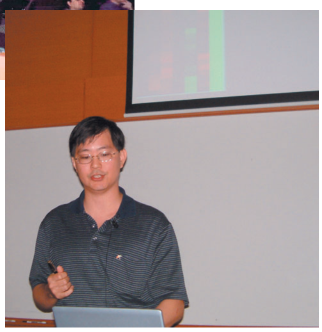
Edison Liu on genomics

Hands-on genetics with Gordon Smyth

Sylvia Richardson in a moment of gene expression

A macro array of expressions



Patrick Tan on DNA microarray

Current Program

Markov Chain Monte Carlo: Innovations and Applications in Statistics, Physics and Bioinformatics
(1 - 28 March 2004)

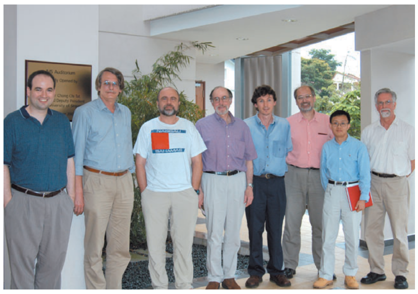
Website: http://www.ims.nus.edu.sg/Programs/mcmc/index.htm

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*

There will be seven sets of tutorial lectures spread throughout the program, on ensemble methods, cluster methods, perfect simulation techniques, statistical MCMC, MCMC in bioinformatics, and MCMC in genetics. The tutorial speakers are Bernd A. Berg (Florida State University), Julian E. Besag (University of Washington), Rong Chen (University of Illinois at Chicago), Wilfrid Kendall (University of Warwick), David P. Landau (University of Georgia), Robert H. Swendsen (Carnegie Mellon University) and Elizabeth A. Thompson (University of Washington). Throughout the period, program members will present informal seminars on recent research advances. The program will end with a workshop (22-26 March 2004), during which latest research results will be presented.

About 25 research leaders, from across the world and from a range of disciplines including physics, computer science, statistics, and engineering, have confirmed their participation as members of the program.



Breakers of (Markov) chains: from left - Mark Huber, Wolfhard Janke, Berng Berg, David Landau, David Nott, Wilfrid Kendall, Jian-Sheng Wang and Robert Swendsen

Next Program

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:
Tilak Abeysinghe, *National University of Singapore*
Roberto S. Mariano, *Singapore Management University and University of Pennsylvania*
Yiu Kuen Tse, *Singapore Management University*

This program is jointly organized with the School of Economics and Social Sciences, Singapore Management University. The activities of the program will consist of

(a) Seminars and workshops (5 - 24 April 2004)
(b) Tutorials and seminars/workshops (26 April - 6 May 2004)

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(c) Symposium of invited papers (7 - 8 May 2004)
(d) Tutorials and seminars/workshops (10 - 15 May 2004)

Seminars and workshops are presentations of about 1 to 1½ hours, and will be arranged according to the schedule of the visitors/participants. These may be presentations of completed results or work in progress.

Tutorials consist of series of four sessions of 1½ hours each, either on Econometric Forecasting or High-Frequency Data Analysis. The tutorials are suitable for advanced graduate students as well as researchers in the area. They may cover survey material and/or new research results.

The **symposium** of invited papers is the highlight of the program. There will be about 5 paper presentations each day on Econometric Forecasting or High-Frequency Data Analysis.

About 36 local and overseas visitors have agreed to participate in the program. The tutorial speakers include Wolfgang Breymann (Institut für Physik), Manfred Deistler (Technische Universität Wien), Philip Hans Franses (Erasmus University), Christian Gourieroux (University of Toronto), Jeffrey Russell (University of Chicago) and Kenneth Wallis (University of Warwick).

Programs & Activities in the Pipeline

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*

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.

To date, 30 overseas visitors have agreed to participate in the program. At present, the following people have agreed to conduct tutorials during their visits: Thomas P. Branson (The University of Iowa), Neil Trudinger (Australian National University), Frank Pacard (Universitéde de Paris XII) and Alice Chang (Princeton University).

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*
Olivier Pironneau, *University of Paris VI (Pierre et Marie Curie)*
Khoon Seng Yeo, *National University of Singapore*

To date, 22 overseas visitors have agreed to participate in the program, which will comprise a series of seminars, tutorials and workshops, including workshops on the following sub-themes:

(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) Transition and turbulence control (8 – 10 December 2004)
(e) Developments in Navier-Stokes equations and turbulence research (13 – 16 December 2004)

Mathematics and Computation in Imaging Science and Information Processing (Continued Program) (August 2004)

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

Co-chairs:
Amos Ron, *University of Wisconsin-Madison*
Zuowei Shen, *National University of Singapore*
Chi-Wang Shu, *Brown University*

The following upcoming activities form a continuation of this program:

(a) Workshop on "Functional and Harmonic Analyses of Wavelets and Frames" (4 - 7 August 2004)
(b) International Conference on "Wavelet Theory and Applications: New Directions and Challenges" (10 - 14 August 2004)
(c) CWAIP-IDR-IMS Joint Workshop on "Data Representation" (16 - 20 August 2004)

Wavelet theory and its applications as an area has been rapidly developing in the last two decades, due to its ability to provide multiscale decompositions that arrange data into strata reflecting their relative importance. This allows for rapid access to good coarse resolution of the data while retaining the flexibility for increasingly fine representations. It leads to algorithms that give sparse and accurate representations of images, medical images, acoustics, high-dimensional data as well as geometric objects, for efficient computation, analysis, storage and communication.

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Nanoscale Material Interfaces: Experiment, Theory and Simulation (24 November 2004 - 23 January 2005)

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

Co-chairs:
Weizhu Bao, *National University of Singapore*
Bo Li, *University of Maryland*
Ping Lin, *National University of Singapore*
Jian-Guo Liu, *University of Maryland*

This program aims to bring together physicists, materials scientists, computational scientists and applied mathematicians to:

(i) review the recent developments in research on materials surfaces and interfaces, from theory to simulation;
(ii) identify critical scientific issues in the understanding of the fundamental principles and basic mechanisms of interfacial dynamics in systems far from equilibrium, particularly those that are characterized by fluctuation and multiscale;
(iii)accelerate the interaction of applied mathematics with physics and materials science, and promote the highly interdisciplinary research on new material interface problems with emerging applications.

The program will consist of four parts:
(a) Research collaboration (24 November 2004 - 23 January 2005)
(b) Workshop 1 (25 - 29 November 2004)
(c) Tutorial (3 - 7 January 2005)
(d) Workshop 2 (10 - 14 January 2005)

3rd Asia Pacific Workshop on Quantum Information Science (3 – 15 January 2005)

Website: http://www.ims.nus.edu.sg/activities/quantuminfo/index.htm

Co-chairs:
Artur Ekert, *University of Cambridge*
Choo Hiap Oh, *National University of Singapore*
Kok Khoo Phua, *SEATPA and National University of Singapore*

Quantum Information Science is one of the most dynamic areas of inter-disciplinary research involving a wide range of scientists ranging from physicists to computer scientists to mathematicians and engineers. The fundamental observation in this field is that any computation is essentially a physical process. The current relentless drive towards increasing speed and miniaturization of computers will eventually lead the computer industry into a subatomic domain where seemingly strange quantum behavior takes over from familiar classical notions. Quantum physics offers an entirely new form of computational parallelism that will make quantum computers more powerful than conventional computers by many orders of magnitude.

This workshop is part of an overall effort to develop an interdisciplinary research team in quantum information science with specific emphases on communication theory and quantum algorithm. It will have a strong education component. It also aims at developing new contacts with likely users of quantum information technologies in Singapore and providing them with timely updates and briefings on the progress in the field.

Computational Prospects of Infinity (15 June – 15 August 2005)

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

Co-chairs:
Chi Tat Chong, *National University of Singapore*
Qi Feng, *National University of Singapore and Chinese Academy of Sciences, China*
Theodore A. Slaman, *University of California at Berkeley*
W. Hugh Woodin, *University of California at Berkeley*

This program will focus on recent developments in two main branches of mathematical logic: Set Theory and Recursion Theory.

Topics for Set Theory will include those related to Cantor's Continuum Hypothesis, Ω-Conjecture, Ω-Iteration Hypothesis, Inner Model Theory and Determinacy Axioms. Topics for Recursion Theory will include recursive enumerability, global Turing degrees, randomness (algorithmic information theory).

The focus of the program is on: Ω-conjecture, fine structures, recursive enumerability, effective randomness.

The 6th International Chinese Statistical Association (ICSA) International Conference (21 - 23 Jul 2004)

The conference is jointly organized with Department of Statistics and Applied Probability, NUS and is co-sponsored by Institute of Mathematical Statistics.

The program committee is chaired by Zhiliang Ying (Columbia University) and the local organizing committee is chaired by Louis Chen (National University of Singapore).

For further details, please refer to conference website *http://www.statistics.nus.edu.sg/ICSA.htm*

Asian Mathematical Conference 2005 (20 July - 23 July 2005) Venue: National University of Singapore

IMS is a joint organizer with the Department of Mathematics, NUS, Department of Statistics and Applied Probability, NUS, Singapore Mathematical Society (SMS) and South East Asian Mathematical Society (SEAMS).

There is an International Scientific Committee chaired by Kenji Ueno (Kyoto University), a Steering Committee chaired by Eng Chye Tan (National University of Singapore) and an Organizing Committee chaired by Eng Chye Tan.

For further details, please refer to conference website *http://ww1.math.nus.edu.sg/AMC/index.htm*

Mathematical Conversations

Tony Chan: On Her Majesty's (the Queen of Science's) Service >>>

Tony Chan

An interview of Tony Chan by Y.K. Leong

Tony Chan is well-known for his interdisciplinary research at the interface between applied mathematics and current rapidly developing areas in image processing, computer vision, VLSI circuit layout and advanced architecture parallel computers. He is one of the few scholars with rare administrative and organizational skills which he has put to good use in advancing the image of mathematics and mathematicians in the eyes of the public and the policy makers in the United States. His boundless energy and enthusiasm for the promotion of mathematics is legendary.

He serves on the committees of scientific bodies like the Society of Industrial and Applied Mathematics (SIAM), American Mathematical Society, National Science Foundation (US) and the Lawrence Livermore National Laboratory (US). He is also on the editorial boards of numerous well-known international journals on applied mathematics and scientific computing. He has been invited to address many international meetings.

He has been Professor of Mathematics at the University of California at Los Angeles (UCLA) since 1986. He helped to establish the Institute for Pure and Applied Mathematics (IPAM) at UCLA, and was the Institute's Director from July 2000 to August 2001. He is currently the Dean of the Division of Physical Sciences, College of Letters and Sciences at UCLA.

The Editor of *Imprints* interviewed Tony Chan on 12 December 2003 when he was an invited guest at the Institute's program on imaging science and information processing and gave a public lecture. The following are excerpts of the edited transcript of a spirited interview in which he talks about the interface between applied mathematics and other scientific disciplines like engineering and computer science and about his personal efforts for the cause of the mathematical profession.

Imprints: You were originally trained in engineering and aeronautics in the early seventies, and you quickly switched to computer science for your PhD. What made you switch? Was computer science already attracting many talented students at that time?

Tony Chan: The way I switched to computer science is due to serendipity. What happened was that I went through Form 7 in Hong Kong and I was good in math and physics. I was reading a magazine in high school about Feynman and Gell-mann who had just won the Nobel Prizes in the mid-sixties. So I said "Hey, this is where I want to go, to this place called the California Institute of Technology (Caltech)." I wanted to be a physicist and I applied only to Caltech. I did not apply to any other places.

At Caltech, I took physics classes. After sophomore I had to decide what to major in. I realized what I was good at is actually solving math problems. I was never able to say where the equations came from. I just cannot imagine that I was able to come up with those equations. What I really wanted to do is more practical things. At Caltech you can do one or two things. After sophomore, either you take pure math, like abstract algebra, or you take applied math like Laplace transforms, separation of variables and things like that. So I took the second one. I graduated with a general engineering degree. But at Caltech theoretical engineering is applied math. I also took some graduate classes in the applied math department: complex analysis, CFD (computational fluid dynamics) and numerical analysis courses.

When I was graduating, I had to decide what graduate school I wanted to go to. I was learning all these applied math. Most of the applied math problems traditionally come from fluid dynamics. You know the equations but nobody was able to solve them except in very simple cases. I do not know how to go from there to, say, designing an airplane. All I can do is flow over a flat plate rather than flow over a real wing. So I asked one of the professors: Joel Franklin. He told me there was a new field in which people used computers. I said "Where do I go for this?" He said, "Stanford has this new Computer Science Department, and they have two very good people." One is Don Knuth and the other one is Gene Golub. It happened that Golub had just visited Caltech and I was at his talk. When the time came for me to apply to graduate school, I applied to many different areas. At Stanford, I applied to Computer Science. At Berkeley it was in Math. I also applied to some operations research departments. I was applying to places where I knew math could be applied.

Computer Science in those days (1973) was very, very new. The Stanford computer science department was only a few years old. You ask whether it was attracting a lot of talented student. I would say some but there was still a lot of skepticism about this new field called Computer Science.

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Remember that was pre-Silicon Valley, pre-dot-com, pre-Apple. Of course, Stanford had very talented students, so it was really a bit of pioneering spirit. People knew that this was a new area and there were a lot of new problems but people did not even know whether computer science was a real science in those days. Maybe it was a fad, maybe after ten years nobody will study computer science. It was like that.

I: Much of your research spans different areas in mathematics and computer science. Does it require a special kind of intellectual temperament or mental outlook to venture into interdisciplinary research?

C: I think it does. What you need is an open mind. You've got to have some curiosity. You have to be interested in the context of your problem more than just the problem itself - where the problem arises and its broader impact. Not every mathematician has this interest. That is how I was driven into what I do. If you look at many mathematicians, they got interested in math because they discovered that they were good at math and problem solving. You give me a problem and I know how to do it. Just a very specific task. You look at the Math Olympiad, the Putnam exams. It is just problem solving and that is the antithesis of interdisciplinary work.

When you do interdisciplinary math, you are working with someone from outside math and you are often asked the following questions. Why can't the other person do what you do? Why do they need you? Why do the engineers do this? Why do they need mathematicians? But many mathematicians say "I don't do the science or engineering stuff even though I could. But they can't do what I do." One of the most powerful things about mathematics is that it can extract ideas from one area and apply them to many different areas. The engineers and scientists are only interested in their own problems. They are not interested in other problems. So a mathematician can be a sort of broker. I personally have done it many times. For example, I am looking at imaging, but many of the problems, ideas and techniques came from computational fluid dynamics. When you come down to the mathematics it is really the same idea. That is one big advantage for mathematicians and I think it is very powerful. It is not just that you know the technical aspects of math better than the engineers.

I: In principle, the engineers could learn the mathematics themselves.

C: But in most cases they are only interested in their own problems. That is the difference between mathematicians and engineers. They don't get awards by looking at the broad mathematical theory. They get awards by solving their engineering problems. I have always said that mathematicians don't have a monopoly in doing mathematics. It's just that we are called mathematicians. The engineers do it, the scientists do it, the statisticians do it.

I: But mathematicians do it better, probably.

C: Well, it depends on what you need. Mathematicians, of course, do the internal structures and they look at extensions. They also do proofs. Nobody else does that. But if you look at mathematics in terms of being relevant and of having impact, I think some of the non-mathematicians are also very good at that. You can see this many times even in this workshop. Many ideas came from physicists, engineers and others. It is not a static world. Historically, many ideas in mathematics came from other fields.

I: But the original ideas that came were sort of non-rigorous. Mathematicians couldn't stand anything that is non-rigorous.

C: Right. I think it is good and desirable to be able to prove things and to be rigorous. But even that is not the exclusive definition of mathematics. I know that's how many people define mathematicians: we do proofs and other people don't. I don't agree with that definition.

I: But don't you think that mathematicians have some kind of compulsion to do things rigorously? It is in their nature.

C: But it should not be exclusive. In applied mathematics, it is often different. In pure math, of course, you cannot publish "kind of a" theorem. You know there is no such thing. In applied math you are willing to tolerate a bit more. You know something works, has a sound basis and has been demonstrated a lot. You also try to prove what you can. You trust your intuition. It is a different culture and a different mentality.

I: You have been actively and deeply involved with efforts to advance the lot of mathematics and mathematicians. This must have required much personal sacrifice of time for your research. Was there any special calling that you were responding to?

C: I wouldn't say calling. I have not realized how much of a sacrifice it has been. First of all, time. But the other is a change in mentality. It is often political because when you have to deal with other people there is controversy and the issues are not clean. It is not just true or false, as in mathematics. You have to deal with human mistakes and broader political issues. There is no clean answer. For mathematicians it is frustrating because we want well posed problems with unique solutions. In human and political problems there is no such thing. You have to compromise, to give and take. In a way, it is for the same reasons that I do interdisciplinary mathematics. You got to look at it from a broader perspective. What we do is just part of a whole complex of human activities. How do we relate to society, to human history?

I: Somebody has got to do it.

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C: Yes, somebody has to do it. Not every mathematician is cut out to do it. You have to be willing to think in this fuzzy way, you have to interact with people. Many mathematicians would think that the time used to deal with these other issues is time wasted because you can prove another theorem. It's certainly true at a personal level. I have been a professional mathematician for 30 years and I can continue doing it for twenty more years and then I will retire. But I can also do something else. It depends on whether you think you are only good at one thing or also good at another thing. I don't plan it. The opportunity arises and then I am willing to try new things. That is what I am like. I think my own interest, and perhaps my talent, is not limited to one area. I always say that if I don't try it now when the opportunity comes, I will regret it later. I am willing to take failure if it doesn't work out.

I: Not everybody is approached to do this.

C: Yes, it is part of a feedback system. So even though I don't seek it out, other people seek me out. I don't take myself too seriously, maybe I'm good with people and I don't offend people.

I: Do you see any improvement in the status of mathematics, or at least of applied mathematics, in the public perception?

C: Yes and no. Yes in the sense that you see it in the mass media. There is actually a lot of coverage of mathematics in the movies: John Nash, *Beautiful Mind*, *Good Will Hunting* and so on. There is a lot of awareness but if you look deeper into it, I don't think it is because people realize how important mathematicians are. Mathematicians are still viewed as a different breed. John Nash is a good example: obviously he is a genius but he is so smart that he has gone crazy. In a way, they are saying that mathematicians are just different and are not relevant to what they do. I think the big danger is that even if people are revering mathematicians, they don't know why mathematicians are doing it.

I talk to a lot of other scientists. They sometimes view us mathematicians as very, very smart people who prove theorems but are not aware of what other scientists do. They think that mathematicians are just not relevant and not part of their enterprise, not part of science. They do not know the history of mathematics. That is the big danger especially in the US where mathematics is viewed as science, not as art. In a way you can also look at math as art, I know in NUS you can get an arts degree in math.

I: Would you say that public perception of mathematicians has changed over the years?

C: No. There is more media coverage, people are more aware of mathematicians. But in terms of what mathematicians actually do, the relevance to their everyday life, I don't think it has improved. I am giving a public talk on Monday. That is my reason for giving it.

I: Could it be that mathematics is something like the software? What people see is really the hardware.

C: I have said in a front page article in *Los Angeles Times* (1977) that math never gets into the story while everybody else gets the credit. For example, in medical imaging, you have computer aided tomography. Think about it. Why "computer aided"? It should be called "mathematics aided" because when you look at the basic point - it is mathematics. But the public doesn't understand. The public equates the computer as the one that solves everything. They don't think about algorithms because they are too abstract. They think about software. Software you can see, something you can buy. Computer and software replace mathematical concepts and algorithms. Even the newspaper editors don't use those words. They only say "computer", "software".

You know, in weather forecasting, viewers say the computer using this software is doing it. That's all they say even though a mathematical concept is there. I think that this is a big danger. Mathematicians are not out there reaching the public. In order to simplify and in order to reach the public, the mass media just bypasses the mathematicians at the interface. The computer is a tool. You would never say a writing pad is a great novelist even though the writing pad is an important tool. It is the intellectual ideas that should matter, not just the tools. And what goes into the computer is a part of what mathematicians do. But that is never talked about and people don't know. That really is the problem.

I: You chaired the Local Organizing Committee for the AMS conference on "Mathematical Challenges of the 21st Century" in 2000 at UCLA. From your point of view, what is the greatest mathematical challenge of this century?

C: The idea for this conference that we called the Millennium Conference came from the then AMS President Felix Browder. It was to be like the one in Paris (in 1900). One thing you realize is that, unlike what Hilbert did, one person cannot do it anymore. There were 36 experts and in fact, they were not all mathematicians. There were some computer scientists and some physicists. I'm not a pure mathematician but I went to every single talk. It was a chance of a lifetime. One thing I realized is that the connection between the different fields is one of the strong themes that came up. The connections between analysis, number theory and geometry go back to Fermat and Andrew Wiles. The Langlands program is one of the big challenges. We haven't quite come full circle but, to me, the connection between mathematics and other disciplines is the big thing - mathematics and computer science, mathematics and the biomedical world. And there are other intellectual fields. In a way, everybody knows that this century is going be the century of the biomedical world because of the genetic revolution. So the biggest challenge is what the role of mathematics is in this. I really do not think that mathematicians have grasped this opportunity yet. A lot of other people have. Certainly statisticians have. Physicists and

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chemists have also gone in there. But mathematics as a field has not really come to grips with this.

I: What about applied mathematicians?

C: Yes, some of them. Even then it is not so clear because it requires learning another field. It requires a new way of thinking about new problems. In my view, you have to learn what the relevant problems are and then you ask what are the relevant techniques that you have or what new techniques you have to develop in order to apply them. That requires a change in direction. I think one of the liabilities that a mathematician has is that it takes so much time and effort in learning the tools in a certain area, especially in a very difficult field in pure mathematics in which you have invested. It makes it very difficult to change fields. But in applied math it is a little bit easier to change.

Applied math is where you extract the ideas, like PDEs, how to compute and so on. And this can be applied to many different fields. So by this very nature we can adapt. And the problems that motivated some of the techniques change through time. The typical applied mathematician probably changes, not the field, but the problems that they solve. At least two or three times in their career. In pure mathematics you don't change as much.

I: But how do you get the topologist to be interested in a problem about protein folding and this sort of thing?

C: You probably need a few leaders. You need some people who will the take the risk. There is a famous example in computer science: Dick Karp, who won a Turing Award. A decade ago, he thought that biology was going to be important (the genetics stuff) and he probably said, "I have proven myself and won the Turing Award. I am now willing to learn about biology and I want to find out." So it takes people like him to lead and then people follow the role model.

I: What is your greatest achievement in your efforts to bring public awareness and recognition to mathematics?

C: I have a ready answer for that. I mentioned this *LA Times* article. After the article was released, I got feedback and I realized the power of the mass media. When you really want to reach the public, the mass media is so much more powerful. I think more people read about my work through the *LA Times* article then the rest of my papers combined ten times. The *LA Times* is read by several million people a day. A typical math journal: if you get over 100 citations it is very good.

I: In some sense the exact nature of mathematics works against it.

C: Yes. But we are not trying to publish a theorem, we are just trying to publicize the idea. So you have to put the precision aside. Some journalists are very good at knowing what the public wants and at translating what you say. They know that if I use this word, it is too abstract and too technical. That is why I have more respect for these science journalists after the interview. I would argue with them and say, "Look, this is the right word." They said. "No, no. Say it this way and the public will understand."

I: It seems that technological advances in computers have pushed us into the direction of using more and more sophisticated computational techniques in solving concrete and real-life problems. Is this the way to go for advancing our knowledge of the universe? Could we have missed some ideas which could revolutionize science and which are basic and "idealistic" but non-computational?

C: I know exactly what you mean and I agree. But in the end the computer is just a tool. It is a very important tool and it is becoming more and more powerful, so people are using it more. But I don't think we should abandon the thought process, the ideas, the understanding. The computer is important but it is not going to solve all the world's problems. You have got to have understanding.

I: Are we over-relying on the use of computers to solve problems which cannot be solved exactly?

C: I don't think it is over-relying. It is a relatively new tool and people are exploring it. There are still physicists who think about string theory, the grand theory of everything and they don't rely on computers. I don't think we are running into any danger.

I: Would the use of computers one day shed some light on how the brain works?

C: Yes, that I believe. People are doing that. You can simulate models. What happens if the human mind were to work this way and what can it do. You can then use the computer to simulate. People in computer vision do that. But you cannot turn it into computer software. I don't believe in that.

I: You have covered so much ground and issues. Thank you for your time.

Stanley Osher: Mathematician with an Edge >>>

Stanley Osher

An interview of Stanley Osher by Y.K. Leong

Stanley Osher is an extraordinary mathematician who has made fundamental contributions to applied mathematics, computational science and scientific computing and who has cofounded three companies based, in part, on his research. He has applied his pioneering work on level set methods and other numerical methods for partial differential equations to the field of image processing and, in particular, to video image enhancing and movie animation. He has been featured prominently in the scientific and international media such as Science News, Die Zeit and Los Angeles Times. He is perhaps the most highly cited researcher in the field of scientific computing.

He received the NASA Public Service Group Achievement Award, Japan Society of Mechanical Engineers Computational Mechanics Award and the SIAM Pioneer Prize. He was an invited speaker at the International Congress of Mathematicians.

He is currently Director of Special Projects at the Institute for Pure and Applied Mathematics (IPAM) at the University of California at Los Angeles and Director of Applied Mathematics.

The Editor of *Imprints* interviewed Stanley Osher on 17 December 2003 when he was an invited guest at the Institute's program on imaging science and information processing and gave a public lecture. The following is based on an edited transcript of an interview in which he talked about the fun and fascination of applied mathematics and his total dedication to research and applications.

Imprints: In which area did you do your PhD?

Stanley Osher**:** I did my PhD in an esoteric area in functional analysis, which is in pure mathematics. I left it immediately and switched to numerical analysis after my thesis. I was lucky enough to talk to some people, including Peter Lax, who suggested the numerical stuff.

I**:** Did you find your real inclinations in applied mathematics?

O: Yeah, but it did not happen until after I got my degree. I liked everything and I specialized more after my PhD.

I**:** Did you use functional analysis later on in your work?

O: Yes. The first thing I did in numerical analysis was an application of Toeplitz Matrices. It used functional analysis and was short and elegant.

I**:** You switched to applied mathematics and then eventually to something very practical like applying to movie animation.

O: This just happened - that's the way research leads you. You cannot predict these things. Together with colleagues and students, I was using the level set method, which is a way of determining how surfaces such as bubbles move in three dimensions, how they merge and so on. You can simulate the flow of bubbles, planes and things like that. It happened that people in the movie industry got interested in this stuff.

I**:** Are these pure mathematics problems?

O: It's a way of representing surfaces and has connections with differential geometry. People prove theorems about these things. They have applications in many areas including fluid dynamics and quantum mechanics. They arise in the movie industry because you want to see how things merge and split like in explosions or rising bubbles. You know, our Governor, Schwarzenegger, used in his latest movie, a lot of these methods done by my former student Ron Fedkiw.

I**:** How did you get into the movie animation business?

O: We had a week of movie industry people coming into UCLA (University of California at Los Angeles) giving lectures about what they did and, in fact, imaging science was highlighted by the American Mathematical Society one year. There was a week in that stuff. We invited people from the local movie industry and they were interested in what we were doing. They wound up arguing with me. The water in the "Titanic", which won many Academy awards, was very bad. It was old-fashioned stuff. Their people came to talk about that and so we decided we could do better than that. In recent movies, the water is much more realistic. The first movie that actually used sophisticated water was "Antz". Now level sets are used by movies like "Shrek", "Terminator" and many blockbusters. My former student Ron Fedkiw is

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doing this movie animation stuff very well. The stuff that my colleagues and I do has applications in many other places besides the movie industry.

***I*:** I believe that another of your dramatic achievement is the use of mathematics in catching criminals. How did this come about?

O: Well, I was living in Los Angeles when the city went up in smoke. There was a big riot in Los Angeles after this guy (Rodney King) was beaten up by the police. The riot resulted in people being arrested for looting and beating up passers-by. There was a video recording of the bad guys beating up truck driver Denny and it showed a speck on the arm of a man throwing a brick at Denny.

It turned out that I had a friend who knew the District Attorney or somebody, and I was then doing video image enhancement with my colleague L. Rudin. We were able to resolve the speck into a rose tattoo and it was a great application of what we were doing. After the Denny case trial (the tattoo led to the conviction of the suspect) we had a lot of media publicity and our company specialized in the area of image enhancement. Eventually I sold my share of the company to Rudin. He has a package on video image enhancement which is used by the police around the world, and he's quite successful.

I have left this business. It was quite fun and related to mathematics. Image processing is the real world and the graphics that is manufactured is the fake world. You want to find out what the image really is.

***I*:** Do you actually go and seek out those problems or do people come looking for you?

O: It's hard to say. Sometimes it's serendipity. Things just happen. I was lucky. In all my years of doing science, I managed to work with the right people who knew what the problems were. For example, I knew nothing about image processing at all after my PhD. Then this guy Rudin came over to me and asked me about some work I had done in fluid dynamics on supersonic flow and shock waves. I asked him what he wanted to know and I got fired up. He was a computer scientist and he realized that shock waves had something to do with imaging. It was a fantastic observation and our collaboration worked out well.

***I*:** The scope of movie animation has just opened up, hasn't it?

O: Yeah. But I'm not sure this is the best field of application for somebody to work in because the market is small except for video games which is a big business. But video games require real time imaging. What we do is not real time; it's too slow. That might change.

***I*:** It could be just a matter of computing power.

O: Yeah, yeah, and also hardwiring in level set methods, which may come in time.

***I*:** Pattern recognition used to be sort of very big.

O: I'm not sure of the definition of pattern recognition, but image processing is related to it. The key idea in everything we do is about "edges", which characterize images. Edges, and now, textures. If you look at a table, for example, the flat part is not very interesting but the boundary of it is. It's the discontinuity. If I look at you, I can see you because of the outline. The outline is very important and the mathematics that was used in other areas of science like fluid dynamics specialize in things like edges and boundaries. And now images.

***I*:** Does it mean that if you have a vague or blurred object, you can always refine it?

O: Yeah, but it's usually difficult to do so when you have edges because near the edges you will get spurious oscillations. The techniques we have developed, which came originally from fluid dynamics, are now useful for removing those unreal artifacts.

***I*:** How do you know that what you get is the actual object?

O: That's a good question. But you can get enough science behind it and you can prove theorems, algorithms converge and stuff like that.

***I*:** You look at the picture and it's so blurred. And then you do this and you get that. There's a lot of faith in that.

O: I won't disagree with that completely. But when I drop something, I expect it to fall and not go up. The probability is not zero that it might go up. But with a high degree of certainty, you can say that this is a realistic picture.

***I*:** What about problems in voice recognition?

O: It's a different kind of mathematics. I'm not an expert in it. The techniques we use in image processing involving differential equations have never been used for sound. But I understand there's some very new stuff along these lines. It's only beginning and just developing. The Institute for Pure and Applied Mathematics (IPAM) at UCLA is running a program on sound and how the ear works and the related mathematics.

***I*:** The imaging business is also very important in astronomy, isn't it? They take pictures which are so faint.

O: Very much so. Astronomers have done very good work in this area. They had to over the years. The early work in

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this stuff in astronomy was very fascinating. They did things which are precursors of what is going on now.

***I*:** You mean the astronomers actually did something mathematical?

***O*:** Yes. That's very often the case. The good thing about being an applied mathematician is that when you work in different areas you find very brilliant people in other areas of science develop mathematical algorithms without realizing what they are doing and which can be generalized to other areas. So it's a question of language.

***I*:** Are more astronomers talking to mathematicians now?

***O*:** Actually we'll be running a program on computational astronomy in IPAM a year from now. Astronomy is just one example. Throughout science mathematics is playing more and more of the key role. In the Institute in which I am involved, its mission is to do interdisciplinary work. People from different areas of science have problems which they think are mathematical. And our goal is to make mathematics out of it. Now they believe that we can do something, mainly because of the computer.

***I*:** That's interesting. So now mathematics is also contributing towards understanding the origin of the universe. This is something not many people are aware of.

***O*:** Well, I'm not an expert in the field, but yes, absolutely. I think that the world is governed by differential equations.

***I*:** Your work involves a lot of algorithms. Do you invent the algorithms?

***O*:** That's what we do. That's the fun part of it. I was interviewed by the LA Times (so was Tony Chan for the same article) and I said that I wrote the algorithms that make the computer sing. I am the Barry Manilow of mathematics.

***I*:** Talking about algorithms, some people consider algorithms to be inventions.

***O*:** Yeah, they are. You can actually patent them now. It used to be that a patent has to contain a device with wires and everything. But I understand the US Patent Office is now more liberal. I'm no lawyer, but I know that as the years go by, the Patent Office seems more and more interested in giving legal protection to algorithms.

***I*:** You could be rich. Hollywood would be paying you millions.

***O*:** People work for salaries. There is money, ego and fun. It's a very nonlinear function. I don't know which is most important. Fun is very important. It's a very good life. I would recommend people going into this stuff now. If you have the talent for it, it's the best life.

***I*:** It's something very different, something, how do you say, non-academic?

***O*:** In some sense, yes. You learn things, you read stuff and you learn new ideas, and you are fired up. Sometimes you deliver something different from what you have found. You have a vague idea that something interesting is going to come up. You wander around and something happens. Then you get very excited. It's like opening a door and you don't know what good things are behind it. You're not sure where it's going to end and what the level of success it's going to be. It's very exciting. Everyday I can't wait to go to work. People often asked me, "What kind of life is this that work is so important?" People go on vacation. My work is vacation.

***I*:** Do you have many PhD students?

***O*:** Many, disproportionately Chinese. We have many good Chinese students at UCLA.

***I*:** Have you used your methods for something more serious like weather forecasting and earthquake prediction?

***O*:** Yeah. The differential equations and some stuff I used to do in fluid dynamics and done by many other very good people are absolutely useful in weather prediction. I still do work on explosives and multi-phase flows and ray tracing. Physical phenomena apart from imaging is very much a part of my research with my colleagues and students.

***I*:** What about the theory of turbulence?

***O*:** Ah, turbulence is too dangerous. If you touch turbulence, you get burnt. One of my mentors once said he had great respect for people in turbulence, which is far more than they have for each other. Turbulence is too controversial. Turbulence has a probabilistic aspect to it, it's statistical and that's not my thing.

***I*:** I'd like to ask you a philosophical question. How does your work affect your view of life?

***O*:** In terms of how research affects my philosophy? The basic idea is to try to make order out of this life that we live. Everyday you encounter things and it's a messy world. The goal is to take this mess that we see and somehow "mathematize" it and make a prediction. In that sense, research has certainly affected my philosophy. I try to figure out what is going on. The most complicated thing is how our human nature operates. It will be fun to understand that. Many people I know at UCLA and elsewhere are using medical imaging to understand how the topology and shape of the brain affects its function. They use the mathematics that I am involved in. The greatest mystery of all is human behaviour and maybe it can be explained by level sets.

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***I*:** Would you say that your present interest and activity is, in some way, directed by your own personal philosophy towards finding order?

***O*:** Yeah, absolutely. I came from being a poor boy in Brooklyn. I wanted some order in my life, to become middle-class and to have a life that I enjoy. Then I stumbled onto this thing, and wow, that's very good for creating order. I entered graduate school in New York University in 1962 when it was a fantastic place for applied mathematics, maybe one of the best ever in the world,, All the top people from Goettingen wound up in New York and it was so exciting.

***I*:** Was that the Courant Institute?

***O*:** Yes, the Courant Institute. In 1962, when I entered, it was incredible. The people who were there and the atmosphere. You felt that you were doing something important. It had a very great influence on me and many other people.

***I*:** Was Courant still there?

***O*:** He was still around, old but still functioning. He added many people all of whom I thought of being old, something like 20 years younger than I am now. They were great people and it was a fantastic time. There were many people like me who were ethnic New Yorkers and who view becoming a mathematician as a way of becoming middle-class American citizens.

***I*:** What attracted you to UCLA?

***O*:** In truth, there was a guy whom I was working with: Andy Majda. He is an excellent applied mathematician. He was there and they were building an applied mathematics group. Also I liked California. When I was in New York, I was always dreaming about the Beach Boys. Sunshine and California together with math was great - everything that I wanted. Over the years we had very nice people. The atmosphere is extremely good in UCLA. People who visited us commented on how well we get along with each other, which is unusual in academia. It has worked out quite well.

***I*:** You have given us a very interesting and illuminating view about mathematics. Thank you very much.

Terry Speed: Good Gene Hunting

Terry Speed

An interview of Terry Speed by Y.K. Leong

Terry Speed is world-renowned for his important and numerous contributions to the applications of statistics to genetics and molecular biology, and in particular, to biomolecular sequence analysis, the mapping of genes in experimental crosses and human pedigrees, and the analysis of gene expression data. A member of the NIH Genome Study Section from 1995 to 1998, he investigated fundamental problems arising from the Human Genome Project.

He has received numerous honors from the world's leading scientific bodies and has been invited to give lectures on his research; in particular, he was a Wald Lecturer at the US-based Institute of Mathematical Statistics. He has been on the editorial boards of international statistical journals, and currently of the Journal of Computational Biology. He is also the President of the Institute of Mathematical Statistics.

He holds joint positions in the Department of Statistics at the University of California at Berkeley and in the Division of Genetics and Bioinformatics at the Walter and Eliza Hall Institute (WEHI) of Medical Research in Melbourne. Each year, he divides his time equally between the two organizations.

The following is the result of an interview of Terry Speed conducted by the Editor of *Imprints* in three stages: an "electronic interview" shortly before he came to the Institute in January 2004 as invited workshop lecturer of the Institute's program on "Statistical Methods in Microarray Analysis", a face-to-face meeting at the Institute and a final "electronic interview" after he returned to Berkeley. The result is a frank and insightful revelation of an intellectual journey from a statistical beginning shrouded in abstract algebra and mundane experimental designs to one of the world's principal centers of activity responsible for the unfolding of one of the most dramatic scientific dramas of the 20th Century.

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Imprints: What did you do for your PhD?

Terry Speed: My thesis was in algebra, being entitled something like "Topics in distributive lattices". I'd started thinking I might be able to do something interesting on (elementary) probability theory within a non-classical logic known as intuitionism, and ended up studying aspects of the algebraic structure underlying that logic. I hadn't done much algebra in my undergraduate degree, so I was to some extent just catching up. It was fun. I found that I liked algebra, which was news to me, and I have continued to enjoy the algebraic aspects of what I do more than the analytical ones.

I: When and how did you get interested in applying mathematics to biology?

S: I was always interested in mathematics and in biology. My aim on leaving high school was to go do combined science and medical degrees, and to go to work in medical research. This was in 1960, the year Macfarlane Burnet, then director of my current institute, shared the Nobel Prize for medicine. On arriving at university I found that I was ok at mathematics, but less so at practical science such as lab work in biology (e.g. dissection of rats and mice, looking at cells down a microscope, etc). So I switched entirely to mathematics and statistics, but included some genetics, which didn't have labs. That was given by a former student of R.A. Fisher, Peter Parsons. I wrote an undergraduate statistics thesis on a topic of R.A. Fisher's: the survival of mutant genes in populations, elementary theoretical population genetics. Throughout my PhD I was surrounded by outstanding people in that field, but I resisted the temptation to join in. At the time I was hooked on pure mathematics… so much to learn, so little time.

I: When you first started to apply mathematics to biological problems, was there any beacon at that time in showing the way, or did you have to hack a path through virgin jungle, so to speak?

S: From my PhD until the time I went to Berkeley I did very little on quantitative biology apart from what cropped up in statistical consulting and in collaborations. It was mostly very classical, with a couple of exceptions (e.g. some baby pedigree analysis): I doubt that DNA ever got mentioned. When I was in the maths and stats part of CSIRO I was conscious that Australia's leading "genetic engineers" were also in CSIRO, doing fancy DNA-related stuff near me in Canberra. Our division did statistical consulting for them, but there was nothing involving DNA. When I asked them could we statisticians get involved in this "gene-splicing" and perhaps help them with the quantitative aspects, I was told fairly firmly: no, there's no statistics of any kind in that research, go and design some more agricultural experiments for those old-fashioned folk over in the other building, and leave us to our high-tech stuff. So we did. Of course they were wrong … elsewhere in the world bioinformatics was being created around that time (early 1980s). Naturally I wonder how things might have been different if they had been more receptive … (It's always good to get into a new area early on, so I tell my students: when the basic problems are still unsolved!)

All this changed when I went to Berkeley in 1987, for there the "routine" statistical consulting that came in the door involved DNA: molecular evolution, intragenic recombination, and other topics, still of interest today. Then I realized I had to catch up with about 30 years of molecular biology, and fast, if I wanted to have a chance of answering the questions they brought to our consulting service. Incidentally, this is one of the many good things about doing statistical consulting: you never know what might walk in the door, and it really can give you new interests, and change your research directions. Of course, it is scary too, because you are on unfamiliar or only vaguely familiar territory much of the time.

I: When you first went to Berkeley in 1987, what was the state of computational biology like? Did you have any hunch that something momentous was in the brewing?

S: Momentous is a bit strong. It was clear that very interesting things were happening on the genetics and molecular biology front in 1987. PCR had just been invented, and was helping people generate lots of interesting data, the human genome project was starting to get talked about, mitochondrial Eve was in the air (later on the cover of *Time*), the first large-scale human genetic map was published, and so on. A big player in the genetic mapping world was Eric Lander, who I was told was a former pure mathematician. (He is now an even bigger player: a key member of the public human genome project, now forging ahead with grand plans in this post-genome era.) I missed his visit to Berkeley, but got to read his papers nevertheless. Also, I knew that Sam Karlin was very active in the field, and I quickly became aware of the many contributions of Phil Green, another former pure mathematician, and Mike Waterman, an ex-probabilist. So people from our area were already key players, and I might have thought "Why not me too?" But I just plugged away, trying to find a niche, thinking that perhaps I was already too late, that all the basic problems were solved! However, the forces that kept me involved were biologists. They were (and always are) so keen to use the latest and best methods, to be first to use a new technique in their particular corner of the subject, so if you are willing to try to help them, as consulting statisticians tend to be, you get swept along. You find yourself explaining and using Lander & Botstein's program for QTL mapping, Phil Green's CRIMAP, Sam Karlin's BLAST calculation, Mike Waterman's alignment algorithm, and with a little luck you eventually have an idea, or get a student interested, and away you go. In the decade 1987 - 1997 I learned two things: that the basic problems were not always easily solved, and that you are never too late for the next train (as Piet Hein used to say). In the mid-1990s microarrays came along, and after a while just watching, I tried my luck with some basic problems.

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I: I understand that Berkeley now has a number of groups and programs that attract mathematicians, biologists and others to do interdisciplinary research. Could you tell us something about these groups and programs?

S: That is a tough question to answer briefly, and we have a web site devoted to answering it. I'd rather just refer the interested reader to it:
http://computationalbiology.berkeley.edu/

Perhaps I should add that we do have a wealth of what I abbreviate as "compbio" activity at Berkeley. So much that I could spend all my time going to seminars and sitting in lab meetings, and never find time to do my own work. That's almost my fate, but I have a number of wonderful PhD students who keep me active. I get people from other departments onto their thesis committees, I'm on the committees of students from outside statistics, and I ask my students to talk to or even collaborate with students from other departments and go to their lab meeting, and I have a small number of close collaborators of my own. If I play my cards right - and I'm still learning - I can benefit from this profusion of activity, and not get completely swamped.

I: If a mature mathematician wants to work on fundamental problems in biology or computational biology, how much biology does he or she need to master?

S: Short answer: lots. Longer answer: even more. Longer answer still: how much does a person need to know about the internal combustion engine to be a good motor mechanic? How much mathematics do you need to know to teach a course on group theory? Of course you can get by, perhaps get a few papers published in journals with little or no biology, if someone else has done the job of phrasing the problem in mathematical form for you. Then you may solve it, but that's not doing computational biology, that's doing mathematics.

No offence meant, but I sometimes say (and am doing so again now) that if you ask that question, you are already doomed (not to go far in computational biology). To put it another way, if you are not genuinely interested in biology, at least to the extent that you enjoy learning what you can about the area in which you are working, then it's probably not a great idea persisting in that area. Do what you like, I say.

I: Has statistical genetics discovered any general rules and principles about the mechanism of gene formation or combination? Do you see any parallel in the state of biology now and the state of physics one hundred years ago in the sense that there are many empirical rules and observations but a paucity of underlying theory?

S: Genetics has lots of general rules, and lots of exceptions. As for your second question, I don't accept the implicit assumption that physics is a useful model for biology. Perhaps it's just my lack of imagination, but I don't see us understanding life any century soon. We might think that physics has made great leaps towards understanding the universe at the level of particles and the universe, what with nuclear weapons, space travel, and laser scanners at supermarkets, but in my view this is easy compared to understanding cells. Wait a few centuries and you'll see what I mean.

I: Could you give us some idea of the problems on which you are working. What is your most memorable achievement?

S: That's hard for the reasons I outlined above. I'm not working on the Speed program or conjecture or hypothesis, I'm thinking (when I get the time) what I can do at all with some problems, and what I can do a little better with others. What are those problems? Well, they are always parts of bigger problems that belong to other people: what genes, if any, have their patterns of expression changed in the brains of people with bipolar disorder, in comparison with otherwise similar healthy people. What gene expression patterns change as we age? Finding ways of distinguishing real from apparent gene expression differences, in a variety of contexts, occupies a good deal of my time. At the "continuing challenge" level that is my aim: to distinguish the real from the apparent. This, of course, is a statistical problem with no single, final answer. There are others: I help people analyze their data to get better measurements of the things they want to measure. Then I sweat over questions such as: how can we tell this method of analyzing the data gives a better measurement than that method? My most memorable achievement? I'm still waiting. I hope to make a little progress on problems like the ones I just mentioned, and if I did, that would be memorable.

I: It is often said that this century will be the century of molecular biology. In your opinion, how much of this is hype and how much of it is scientifically justified?

S: Perhaps the best answer here is yes. That is, yes, it is hype, and yes it is scientifically justifiable. Beyond that I don't care to go. But don't count physics out.

I: Is there some kind of mathematical definition for a gene?

S: The history of the notion of a gene is almost the same as the history of genetics, at least in the period since the field had a name, which is essentially the 20th Century. So bear in mind that for biologists, the notion of gene is an ever-changing one. In the 15 years or so since the advent of large-scale genome sequencing, there has in essence been a mathematical definition of a gene, because people have used mathematical models to "find" genes - putative genes might be a better way to put it - in genomic DNA sequence. Of course, the definition of a gene computational biologists use is at best a crude approximation to what biologists understand by the term "gene", but if the computational definition does the job, i.e. if it finds "real" genes, no-one is going to mind too much. Nevertheless, a model that works in one context

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is still just a model, and is necessarily different from the real thing, so no one should expect that the computational person's gene model embodies all important aspects of a gene.

With that preamble, let me say that a (protein-coding) gene could be defined as a DNA sequence structure consisting of a number of parts (promoter, transcription and translation start and stop signals, exons, introns, etc), each having characteristic features (base composition, dependence, specific motifs, …) and all arranged in a characteristic way. The complete specification today might be given via a generalized hidden Markov model (GHMM), with a given state space and set of parameter values, but do realize that this would hardly be recognized by a biologist. And furthermore, that before 1993, the GHMM view didn't exist. At that time a mathematician's gene might have been a neural network, and perhaps after 2010, the GHMM model will have been superceded by another, more complex mathematical object, embodying some aspects of alternative splicing, say, or post-transcriptional or post-translational regulation. This is standard in the history of science.

I: Could you share with us some of your experiences in learning biology?

O: I was always interested in evolution, and share the now conventional view of T. Dobzhansky: "Nothing makes sense in biology except in the light of evolution." Of course this doesn't mean everything that gets said in an evolutionary context is sensible or correct. Indeed I frequently think "What a total 'just-so' story" (or thoughts to that effect) about some evolutionary pronouncements, but it is undoubtedly true that intricate and wonderful biological phenomena can be made even richer, and more insights gained, by putting everything into an evolutionary context. And the comparative method (my definition: exploit historical or evolutionary considerations whenever you can) is a great thing. So that's experience number one.

The second experience I'd like to share concerns controls. Good experimental practice in biology typically involves the use of lots of controls: positive, negative, perhaps also calibration controls. In this context, controls are aspects of the experiment where the experimenter "knows" the outcome. For example, if you are obtaining aspects of a DNA fingerprint with an assay kit, you prepare a blood sample (say) in a prescribed way, and then you do the assay. The positive controls should give you the expected positive result (e.g. a bright pink spot) in a clear and unambiguous way, while the negative controls should unambiguously give the expected negative result (e.g. a blank spot). Crudely, if all went well, you should get something where there should be something, and nothing where there should be nothing, and the appropriate scale at the appropriate place. Such controls play an enormously important role in biological experimentation, and my point is this: it would be wonderful to have controls all the time, in all circumstances, and if we don't, wonderful if we could devise them. Statistics has a great need for controls, and so have many sciences that clearly don't (you can think of them).

My third experience concerns facts and interpretations. I've learned that facts and interpretations are different but more similar than we might like, and that Joe Friday's "Just the fact, Ma'am" is at best a gross oversimplification. Naturally, scientists like facts: that's why they do experiments. But they also like to draw conclusions: what do these facts suggest might be going on? Some of my most enjoyable experiences sitting in biology lab group meetings have been listening to discussions of alternative interpretations of the same set of facts, and of planning the collection of more facts, in an attempt to narrow down the range of interpretations. In such discussions you can see argument as the nature of the fact. It is even more interesting when one realizes that from time to time discoveries are made which were totally unexpected, for this reveals that no sensible interpretations of the data could have been made within the old framework, and the "fact" that an experiment delivered had to be refined before it could be interpreted. I like it a lot when dichotomies are revealed to be illusory. In physics people like to go on about relativity: how great it was when such and such an experiment involving the transit of Venus demonstrates the validity of some theory, and they have a few more examples. In biology this sort of thing happens almost daily. New, unexpected phenomena abound: restriction enzymes, retrotransposons, introns, microRNAs, … (look at the discoveries which have gained people Nobel Prizes in medicine over the last 30 years). Each can force a refinement of the "facts" (for example, was this or that controlled for? Was a certain contaminant present?) and a re-evaluation of the interpretation. That makes learning biology a great experience.

I: After all those years in Berkeley, you have now decided to spend half of each year in your home country (Australia). Is there any motivating reason for this?

S: The answer here is quite simple. My wife and I moved from Australia to Berkeley in 1987 for "a few" years. After a few more years than a few years, her pressure to return to Australia built up. Initially I was not very enthusiastic about most job possibilities back in Australia. I really wanted to stay in Berkeley. Then I found a job (my present one at WEHI) that I could get excited about, and my first thought was: can I do both? The answer so far seems to be yes, but it is an issue that gets revisited every year. One view would simply be that what evolved is a compromise, and like many compromises, there is always a tendency to want to go towards the simpler "pure state". As the guy who fell off the cliff said to someone half-way down: so far so good!

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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.

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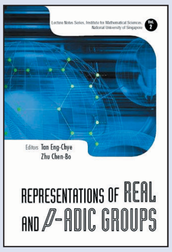

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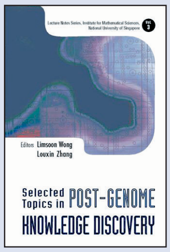

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