IMPRINTS
INSTITUTE FOR MATHEMATICAL SCIENCES
JUNE 2009
ISSUE 14

Visit of the SAB members and trip to the Marina Barrage >>>

Members of the Scientific Advisory Board: (from left) Former and current Deputy Directors LEUNG Ka Hin and TAN Ser Peow, Olivier Pironneau, David Mumford, Roger Howe, LUI Pao Chuen, Director Louis Chen, David Siegmund

The Scientific Advisory Board met in Singapore 9-11 December last year for their annual meeting to discuss new proposals and pre-proposals for upcoming programs at the Institute. It was a hectic three days as the board reviewed eight pre-proposals and one proposal for programs in 2010 and 2011.

The visit of the Scientific Advisory Board was not all work, however. Besides several meetings over meals with various members of the NUS academic community including the Dean of the Faculty of Science and various members of the Mathematics and Statistics and Applied Probability departments, another highlight of the recent visit of the SAB members was a trip to the Marina Barrage, Singapore's latest downtown icon. The trip was arranged by local board member LUI Pao Chuen, who is a member of the board of the Public Utilities Board (PUB), the statutory board which oversaw the construction of this massive engineering project.

The Marina barrage, a 350-metre wide dam consisting of nine crest gates built across the Marina Channel in downtown Singapore between the reclaimed lands of Marina East and Marina South, is the realization of the vision of Minister Mentor LEE Kuan Yew from nearly two decades ago. It serves three main purposes - providing water supply for Singapore, flood control for low-lying areas in the city and serving as Singapore's latest lifestyle attraction. The reservoir created by the damming of the Marina Channel results in Singapore's first reservoir in the heart of the city, and is an important step in the management of the Republic's water supply. The barrage also serves as a flood control measure for low-lying areas in the city by regulating the water level of the reservoir, either by releasing excess storm water via the crest gates into the sea during low tide, or activating giant pumps to pump excess storm water into the sea during high tide. Finally, the barrage is also part of Singapore's latest lifestyle attraction, the constancy of the water level in the reservoir allows for all kinds of water sports like dragon-boating, kayaking and sailing.

The SAB members were first treated to a fascinating account of the construction of the barrage, together with myriad interesting facts about Singapore's efforts towards the management of its water supply, and various environmental issues. They were also offered bottles of Newater to sample - one of Singapore's innovative solutions to the perennial water supply problem here. To put it bluntly, this was high grade potable water produced after treated used or recycled water has been further processed via an advanced three step process involving microfiltration, reverse osmosis and UV disinfection. The members gamely sampled the water

Continued on page 2

Contents

Continued from page 1

Marina Barrage

- without any adverse comments or effects. They were then taken on a tour of the Sustainable Singapore Gallery where six interactive galleries provide a showcase of Singapore's efforts towards environmental sustainability. The trip ended with a walk across the barrage, where members got a glimpse of the flood control function in action, as huge volumes of water was released into the sea, due to a severe downpour earlier, and a trip to the "green" roof of the building, where the members also got a view of the downtown skyline and the construction of the soon to be finished integrated resort (IR) at Marina Bay. Although a short afternoon trip, the visit gave a nice balance to the days spent inside the conference room at the IMS and gave the SAB members a brief glimpse of how the various public and private agencies of Singapore worked together in changing the landscape of downtown Singapore.

New SAB members >>>

The Institute is pleased to welcome three new members to the Scientific Advisory Board: Professor David Mumford (Brown University), Professor Olivier Pironneau (Université Paris VI) and Professor SIU Yum Tong (Harvard University).

Professor Mumford is one of the most distinguished and well-known mathematicians of his generation, and has the unique position and perspective of having done fundamental work in both pure and applied mathematics. His earlier work was in the field of algebraic geometry and his later work in vision and pattern recognition. He has been awarded some of the most prestigious prizes in Mathematics and the Sciences, including the Fields Medal (1974), the MacArthur Fellowship (1987-1992), the Shaw Prize (2006), the American Mathematical Society Steele Prize for Mathematical Exposition (2007) and the Wolf Foundation Prize in Mathematics (2008). He is a member of the US National Academy of Sciences, the Tata Institute of Fundamental Research (honorary fellow), the Academia Nazionale dei Lincei, Rome (foreign member), the London Mathematical Society (honorary member) and the American Philosophical Society and has served as the Chairman of the Department of Mathematics, Harvard University (1981-1984) and the President of the International Mathematical Union (1995-1999).

Professor Pironneau is no stranger to IMS, having co-organized the program "Wall-Bounded and Free-Surface Turbulence and its Computation" at the IMS from July to December 2004. He brings to the board his considerable expertise and knowledge on various areas of applied mathematics including mechanics, mathematical analysis, numerical analysis and optimization, and also his experience as Scientific Advisor to the National Institute for Computer Science and Control, INRIA, (1991-1996) and member of the Commission for Nuclear Waste Disposal (CNE). His many honors include the Blaise Pascal Prize (1983) and the Marcel-Dassault Prize (2001) of the French Academy of Sciences, the National Order of Merit of France (1989) and membership of the French Academy of Sciences and the Institut Universitaire de France.

The third new member, Professor SIU Yum Tong, is William Elwood Byerly Professor of Mathematics at Harvard University. Professor Siu has done fundamental work in several complex variables, complex algebraic geometry and complex differential geometry, for which he has been invited trice to speak at the International Congress of Mathematicians, twice as a plenary speaker. Professor Siu's honors include the Bergman Prize of the American Mathematical Society, membership of the American Academy of Arts and Sciences, the US National Academy of Sciences, the Chinese Academy of Sciences (foreign member), Academia Sinica (Taiwan) and the Göttingen Academy of Sciences (corresponding member).

The Institute would like to express its deep gratitude to Professors Hans Föllmer, Avner Friedman and Keith Moffatt, who, as founding members of its Scientific Advisory Board from 2001 to 2009, guided and nurtured the Institute from its inception to what it is today. We are also happy to add that Professor Moffatt continues to be actively involved in the Institute, and is the chair of the international scientific committee and the organizing committee of the Institute's Spring School on "Fluid Mechanics and Geophysics of Environmental Hazards" (19 April - 2 May 2009).

S.P. Tan

People in the News >>>

New Management Board member
Paul Matsudaira has been appointed as a member of the Institute's Management Board. Professor Matsudaira recently joined NUS as the Head of the Department of Biological Sciences and the Director of the NUS Centre for BioImaging Sciences. He was previously Professor of Biology at the Department of Biology and Professor of Bioengineering at the Department of Biological Engineering at MIT. Professor Matsudaira replaces Birgit Lane (Executive Director, Institute of Medical Biology) on the board. We would like to thank Birgit for serving on the Board over the period 1 January 2007 - 31 December 2008.

New Deputy Director
Ka Hin Leung, who served as the Institute's Deputy Director from 1 January 2007 to 31 December 2008, relinquished his position to resume full-time duties at the Department of Mathematics. He will be taking his long overdue, and well-deserved, sabbatical in 2009. Professor Leung is succeeded by Professor Ser Peow Tan of the Department of Mathematics. Prof Tan's areas of research interest are hyperbolic geometry and low dimensional topology.

New Management Assistant Officer
Cheryl Tsan left the Institute on 16 December 2008.

Nurleen Binte Mohamed joined the Institute as the new housing officer on 1 April 2009.

One More Hat for IMS Director
Institute for Mathematical Sciences Director Louis Chen has added to his roles in service of the mathematical community. He has been elected Vice-President of the International Statistical Institute for 2009-2011.

Newly Elected Academicians
The Institute offers its congratulations to Alice Chang (Princeton University), Gilbert Strang (MIT), Wing H. Wong (Stanford University) on their election to membership of the US National Academy of Sciences in 2009, and to Stanley Osher (UCLA) and Ruth Williams (UCSD), who have been elected as fellows of the American Academy of Arts and Sciences in 2009. Alice Chang gave a series of tutorial lectures at the IMS program Geometric Partial Differential Equations (3 May - 26 June 2004); Gilbert Strang was a speaker at the program on Mathematics and Computation in Imaging Science and Information Processing (July - December 2003); Wing Wong was a member of the Organizing Committees of the IMS programs Post-Genome Knowledge Discovery (January – June 2002) and Statistical Methods in Microarray Analysis (2 - 31 January 2004). Stanley Osher participated in two IMS events, the International Conference on Numerical Methods in Imaging Science and Information Processing (15 - 19 December 2003) and the program on Mathematical Imaging and Digital Media (5 May – 27 June 2008); Ruth Williams was the Chair of the Scientific Program Committee of the 7th World Congress in Probability and Statistics (14 – 19 July 2008), which was jointly organized by the NUS Department of Statistics and Applied Probability, NUS Department of Mathematics and IMS.

NUS Mathematician to Deliver Invited Lecture at ICM2010
Zuowei Shen of the NUS Department of Mathematics and organizer of IMS programs Mathematics and Computation in Imaging Science and Information Processing (July - December 2003 and August 2004), Mathematical Imaging and Digital Media (5 May – 27 June 2008) and the Symposium on Mathematics and Science in Digital Media, Technology and Entertainment (1 July 2007) has been invited to deliver a 45-minute lecture in the Numerical Analysis and Scientific Computing section of the International Congress of Mathematicians 2010. Well done, Zuowei!

Programs & Activities >>>

Past Programs in Brief

Algebraic Topology, Braids and Mapping Class Groups (4 - 19 December 2008)

Website: http://www.ims.nus.edu.sg/Programs/braids08/index.htm

Chair of Organizing Committee:
Jie Wu, *National University of Singapore*

The objective of this program was to explore further the connections between algebraic topology and braids and to establish further research collaborations in algebraic topology in Asia. This program comprised of a conference on algebraic topology and a workshop on special topics. The "Workshop on Homotopy, Braids and Mapping Class Groups", held from 4 – 14 December focused on homotopy theory, braids, mapping class groups and 3-manifolds. Participants discussed research directions in mapping class groups and their connections to homotopy theory and Heegaard splittings for 3-manifolds, configuration spaces and braids, the H-spaces, and the representations of the symmetric group modules Lie(n). Introductory talks on selected topics were given by distinguished speakers such as Vladimir Vershinin (University of Monteplier II, France), David Garber (Holon Institute of Technology, Israel),

Continued on page 4

Programs & Activities >>>

Continued from page 3

Fengchun Lei (Dalian University of Technology, China), Haibao Duan (Chinese Academy of Sciences, China), and Le Minh Ha (Vietnam National University, Vietnam).

The "Second East Asia Conference on Algebraic Topology" that was held from 15 – 19 December 2008 consisted of various highly informative talks which covered a wide range of topics.

A topological group

Bouncing ideas over tea

Topologically complex musings

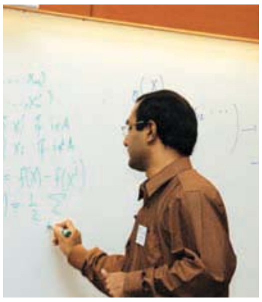
Progress in Stein's Method (5 January – 6 February 2009)

http://www.ims.nus.edu.sg/Programs/stein09/index.htm

Chair of Organizing Committee:
Andrew Barbour, *University of Zurich*

In view of recent advances which have opened up exciting possibilities for applications of Stein's method, this program was held to bring together people who are actively involved in this particular field to cement and further promote the development of the field. This program was designed to develop research in Stein's Method in Southeast Asia, where there is a burgeoning interest in the method.

The program consisted of various segments, with the first being a six-day tutorial session which touched on the fundamentals of topics related to Stein's method. The tutorial session was conducted by respected academics specializing in the field. Among the speakers were Andrew Barbour (University of Zurich, Switzerland), Larry Goldstein (University of Southern California, USA), Giovanni Peccati (University of Paris Ouest, France), Jason Fulman (University of Southern California, USA), and Sourav Chatterjee (University of California at Berkeley, USA). The second was a series of stimulating and enriching workshops designed to explore the possibilities of various applications of Stein's method. In addition, a graduate seminar was held which enabled graduate students to consolidate the knowledge learnt from the tutorials and workshops and share their insights with fellow participants. The program was wrapped up with an informal minisymposium that provided participants with an added opportunity to interact freely and discuss their research findings.



Sourav Chatterjee: Many facets of Stein's Method

Converting coffee & tea into mathematics

The Method in focus

Connoisseurs of Stein's Method

Continued on page 5

Continued from page 4

Spring School on Fluid Mechanics and Geophysics of Environmental Hazards (19 April – 2 May 2009)

Website: http://www.ims.nus.edu.sg/Programs/09fluidss/index.htm

The School was promoted jointly by two of the International Scientific Unions of ***ICSU*** *(the International Council for Science):* ***IUTAM*** *(the International Union of Theoretical and Applied Mechanics) and* ***IUGG*** *(the International Union of Geodesy and Geophysics). The School was supported also by ICSU's Regional Office for Asia and the Pacific Region, based in Kuala Lumpur, Malaysia, and it contributed to two of ICSU's priority areas: Natural and Human-Induced Environmental Hazards and Disasters and Building Scientific Capacity.*

Chair of Organizing Committee:
Keith Moffatt, *University of Cambridge, UK*

The Spring School focused on fluid mechanical aspects of environmental hazards and was aimed at students who have already graduated in mathematics, physics or engineering, and who wish to undertake research in this broad area. The School started with introductory and motivational lectures conducted by Swadhin Behera (Japan Agency for Marine-Earth Science and Technology), Kerry Emanuel (MIT, USA), Peter Haynes (University of Cambridge, UK), A.W. Jayawardena (International Centre for Water Hazard and Risk Management, Japan), Tieh Yong Koh (Nanyang Technological University), Keith Moffatt (University of Cambridge, UK), Emily Shuckburgh (British Antarctic Survey, UK), Gerd Tetzlaff (Universität Leipzig, Germany) and Pavel Tkalich (National University of Singapore). In addition, there were research seminars. One of these was given by Harsh Gupta (Hyderabad), representing ICSU; another on 'Freak Waves' by Frédéric Dias, Secretary-General of IUTAM.

The School attracted about 100 participants, of which half were graduate students (MSc or PhD) or young postdocs from Asia and the Pacific Region: Australia, Indonesia, Philippines, Vietnam, Malaysia, China, Japan, Korea, Bangladesh, Pakistan, India, Singapore, Sri Lanka, Georgia and Iran. The students were divided into groups of four or five per group, assigned to a project. The students worked on these projects, with guidance from the lecturers, in afternoon sessions during the first week of the School, and they made presentations of their results during the afternoon sessions of the second week. As part of the program, a field trip to the Tropical Marine Science Institute (TMSI) on St John's Island was arranged on a Saturday.

Thanks go to World Scientific Publishing for their support towards the Spring School.

Gerd Tetzlaff taking students through rain and wind

Keith Moffatt and students studying a model of a plume of smoke

From fluid mechanics to environmental hazards

Upcoming Activity

Eleventh Asian Logic Conference (22 – 27 June 2009)

... Jointly organized with Faculty of Science in celebration of 80th Anniversary of Faculty of Science

Website: http://www.ims.nus.edu.sg/Programs/09asianlogic/index.htm

Chair of Program Committee:
Qi Feng, *National University of Singapore and Chinese Academy of Sciences*

Chair of Organizing Committee:
Yue Yang, *National University of Singapore*

The Asian Logic Conference series is sponsored by the Association for Symbolic Logic and the meetings are major international events in mathematical logic. The series features the latest scientific developments in the fields of mathematical logic and applications, logic in computer science, and philosophical logic. It also aims at promoting activities of mathematical logic in the Asia-Pacific region and bringing together logicians from within Asia and beyond to exchange information and ideas. Singapore is

Continued on page 6

Continued from page 5

chosen to host the Asian Logic Conference 2009 by the East Asian and Australasia Committees of the Association of Symbolic Logic to honor Professor Chi-tat Chong on his 60th birthday. Professor Chong is one of the founders of the Asian Logic Conference series and a central figure in establishing Mathematical Logic in Asia. Invited speakers include Klaus Ambos-Spies (University of Heidelberg), Toshiyasu Arai (Kobe University), Bektur Baizhanov (Institute of Informatics and Control Problems), John T. Baldwin (University of Illinois at Chicago), Rodney Downey (Victoria University of Wellington), Ilijas Farah (York University), Renling Jin (College of Charleston), Iskander Sh. Kalimullin (Kazan State University), Peter Koellner (Harvard University), Manuel Lerman (University of Connecticut), Menachem Magidor (Hebrew University of Jerusalem), Michael Rathjen (University of Leeds), Gerald E. Sacks (Harvard University), Stephen G. Simpson (Pennsylvania State University), Theodore A. Slaman (University of California at Berkeley), Frank Stephan (National University of Singapore) and W. Hugh Woodin (University of California at Berkeley). In addition there will be a number of contributed talks.

Next Program

Statistical Genomics (1 – 28 June 2009)

... Jointly organized with the Department of Statistics and Applied Probability in celebration of 80th Anniversary of Faculty of Science

Website: http://www.ims.nus.edu.sg/Programs/genomics09/index.htm

Co-Chairs of Organizing Committee:
Zehua Chen, *National University of Singapore*
Heping Zhang, *Yale University*

Members of Organizing Committee:
Jiahua Chen, *University of British Columbia*
Mark Seielstad, *Genome Institute of Singapore*
David Siegmund, *Stanford University*

Statistics has played an important role from the outset of genetic studies. With the mountainous amount of data generated by the new technologies, the use of statistics has become even more indispensable. The success in understanding the data generated from genomic studies becomes more and more dependent on the concerted effort of geneticists, biologists, statisticians, mathematicians and other scientists. The program will also provide an opportunity for young researchers and graduate students to learn directly from the experts of the field and to get inspiration for further research.

Activities

1. Week 1 (1 - 5 June): Tutorials and lectures for the summer school.
2. Week 2 (8 - 12 June): Workshop on Gene Mapping and other activities for the summer school.
   The Workshop will cover topics such as association studies (family and population based), linkage analysis and admixture mapping, which involve both human genetics and experimental genetics, and draw on recent developments in population genetics.
3. Week 3 (15 - 19 June): Workshop on Genomic Profiling and other activities for the summer school.
   The Workshop will cover topics such as inherited copy number variation (CNV) and its role in disease, somatic CNV in cancer genomics, motif detection, expression analysis, eQTL mapping, comparative genomics, origins of replication, epigenetic alternations, e.g., methylation and its role in cancer genomics, etc
4. Week 4 (22 - 28 June): Free discussions among participants.

Programs & Activities in the Pipeline

Summer School in Logic (29 June – 24 July 2009)

Website: http://www.ims.nus.edu.sg/Programs/09logicss/index.htm

Members of Organizing Committee:
Chi Tat Chong, *National University of Singapore*
Qi Feng, *Chinese Academy of Sciences and National University of Singapore*
Yue Yang, *National University of Singapore*

This is the fourth installment of the annual Summer School in Logic. It will consist of two parts, one in recursion (computability) theory and the other in set theory, running in parallel. The lectures will be conducted by Professors Theodore A. Slaman and W. Hugh Woodin of the University of California at Berkeley. In addition to lectures, there will be classroom discussions of mathematical problems for participants led by senior graduate students. The Logic Summer School is a collaboration between researchers at the University of California, Berkeley, Chinese Academy of Sciences and the National University of Singapore.

Mathematical Theory and Numerical Methods for Computational Materials Simulation and Design (1 July – 31 August 2009)

... Jointly organized with Department of Mathematics in celebration of 80th Anniversary of Faculty of Science

Website: http://www.ims.nus.edu.sg/Programs/09matheory/index.htm

Co-Chairs of Organizing Committee:
Weizhu Bao, *National University of Singapore*
Qiang Du, *Penn State University*

Continued on page 7

Continued from page 6

Yuanping Feng, *National University of Singapore*
Fanghua Lin, *Courant Institute, New York University*

Members of Organizing Committee:
Weinan E, *Princeton University*
Jian-Guo Liu, *Duke University*
Jie Shen, *Purdue University*
Chang Shu, *National University of Singapore*
David Srovolitz, *Princeton University and Yeshiva University*
John Wang, *National University of Singapore*
Ping Wu, *Institute of High Performance Computing*
Shih-Hsien Yu, *National University of Singapore*
Yongwei Zhang, *National University of Singapore and Institute of High Performance Computing*

The new paradigm of materials by computational design is a great scientific and mathematical challenge. A critical component in the materials by computational design framework is the computational prediction of materials properties which include, for instance, the multiscale properties of complex materials, properties of defects, interfaces and material microstructures under different conditions such as in the presence of compositional and structural inhomogeneities and external fields. Another extremely important aspect is the uncertainty quantification and the modeling of simulation of stochastic effects in materials.

This two-month program will provide a forum for experts from interdisciplinary fields to discuss the various issues and challenges facing the community. It will provide a forum to highlight the progress in a broad range of topics, within a coherent theme and with greater emphasis on the mathematical theory and numerical methods for computational materials simulation and design.

Activities:
1. Collaborative research: 1 July – 31 August 2009
2. Summer School: 17 July – 14 August 2009
3. Workshop on Challenges and Advances in Computational Materials Simulations and Design: 20 – 24 July 2009
4. Workshop on Mathematical Theory and Computational Methods in Materials Sciences: 10 – 14 August 2009
5. Public lecture by Fanghua Lin, Courant Institute, New York University: 11 August 2009

Financial Mathematics (2 November – 23 December 2009)

... *Jointly organized with Risk Management Institute, NUS*
Website: http://www.ims.nus.edu.sg/Programs/financialm09/index.htm

Chair of Organizing Committee:
Paul Embrechts, *Swiss Federal Institute of Technology (ETH) Zurich*

Members of Organizing Committee:
Min Dai, *National University of Singapore*
Hanqing Jin, *University of Oxford*
Hinz Juri, *National University of Singapore*
Kian-Guan Lim, *Singapore Management University*
Defeng Sun, *National University of Singapore*
Jianming Xia, *National University of Singapore*

Financial Mathematics is a fast-growing area of modern applied science. Over the last three decades, the subject has grown into a substantial body of knowledge, where quantitative methodologies have become part and parcel of the functioning of the world's financial institutions.

There will be three workshops in the two-month long program. The workshops are intended for researchers working in the specific areas to congregate, cross-pollinate ideas, exchange knowledge, and together advance the mathematical frontiers in publishing and disseminating rigorous pieces of scholastic work.

Activities:
1. Topics on Risk Measures and Robust Optimization in Finance: 12 - 23 November 2009
2. Topics on the Pricing and Hedging of Environmental and Energy-related Financial Derivatives: 4 – 9 December 2009
3. Workshop on Optimal Stopping and Singular Stochastic Control Problems in Finance: 9 – 18 December 2009

Highlights of Other Activities

Joint NUS-ISI Workshop on Recent Advances in Statistics and Probability (18 – 19 November 2008)

Website: http://www.ims.nus.edu.sg/Programs/08statprob/index.htm

Members of Organizing Committee:
Sanjay Chaudhuri, *National University of Singapore*
Kwok Pui Choi, *National University of Singapore*
Wei-Liem Loh, *National University of Singapore*

This two-day workshop was jointly organized by the Department of Statistics and Applied Probability, Institute for Mathematical Sciences, NUS and Indian Statistical Institute. Its aim at was to forge closer ties among the institutes involved and to encourage collaboration among like-minded researchers in the region. The workshop consisted of 20 half-hour talks and attracted a total of 47 participants.

Continued on page 8

Continued from page 7

Jing-Shiang Hwang: Binary network analysis

Probal Chaudhuri: Of nucleotides, proteins and genomes

Promoting NUS-ISI ties

Workshop on Computational Systems Biology Approaches to Analysis of Genome Complexity and Regulatory Gene Networks (20 – 25 November 2008)

Website: http://www.ims.nus.edu.sg/Programs/08compsys/index.htm

Co Chairs of Organizing Committee:
Vladimir Kuznetsov, *Bioinformatics Institute*
Louxin Zhang, *National University of Singapore*

The workshop focused on the integrative statistical and computational approaches for the understanding of traditional and novel types of regulatory sequences and their structural and functional roles in biological diversity and complexity of genomes, networks and pathways at the genome, transcriptome, proteome and cellular levels. The five-day workshop consisted of 39 talks and brought together mathematicians and professionals in the medical science field from Russia, Ukraine, UK, Israel, Italy, Taiwan, Sweden, Austria, Singapore and USA. The workshop was held at the IMS and Bioinformatics Institute and the turnout was overwhelming. It attracted 100 participants.

A network of computational systems biologists

Assessing progress and plotting the way forward

Jun Liu: Dictionary models

Continued on page 9

Continued from page 8

First Singapore Conference on Quantitative Finance (23 February 2009)

... Jointly organized with Saw Centre for Financial Studies

Website: http://www.ims.nus.edu.sg/Programs/09qfinance/index.htm

Organizing Committee:
Louis Chen, *National University of Singapore*
Takeshi Yamada, *National University of Singapore*

The objective of this Conference was to promote research in quantitative finance by providing a platform for researchers in Singapore to interact and share their research findings in this field. A total of 108 participants attended the one-day Conference. The Institute and Saw Centre for Financial Studies plan to organize the Conference on a yearly basis.

A good turnout for the conference

Kian Guan Lim expounding on volatility risks

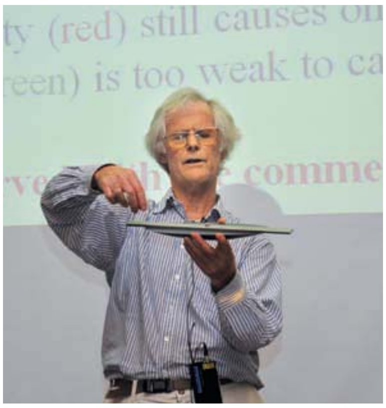
High finance: (from left): Wolfgang Härdle, Anthony Kuk, Patron of Saw Centre SAW Swee Hock

Public Lectures

Emily Shuckburgh of British Antarctic Survey gave a public lecture titled "The Scientific Basis of Climate Change" on 23 April 2009. Dr Shuckburgh reviewed the body of evidence that has led the scientific community to believe that it is very likely that most of the observed increase in globally averaged temperatures since the mid-20th century is due to the observed increase in man-made greenhouse gas concentrations. She also discussed the latest predictions of further changes in the global climate system published by the Intergovernmental Panel on Climate Change if greenhouse gas emissions continue at or above current rates.

Emily Shuckburgh: The science of climate change from someone on the front line

Keith Moffatt of the University of Cambridge gave a public lecture titled "Rattleback Reversals: a Prototype of Chiral Dynamics" on 28 April 2009. In the lecture, Professor Moffatt demonstrated with a simple toy – the rattleback – the surprising effect of "chirality" (lack of mirror symmetry) on the dynamics of a physical system. Chirality is endemic in nature: for example, turbulence in rotating fluid systems is chiral in character, and it is this property that is responsible for the spontaneous generation of magnetic fields in stars and planets.



Keith Moffatt: Serious fun with a rattleback

Mathematical Conversations

Takeyuki Hida: Brownian Motion, White Noise >>>

Takeyuki Hida

Interview of Takeyuki Hida by Y.K. Leong

Takeyuki Hida is well-known for his pioneering work in establishing and developing a new field in probability theory - the field of white noise analysis, which has now found numerous applications outside probability in quantum dynamics and biology, and within mathematics itself in differential equations and geometry.

His doctoral thesis sowed the seeds of a new type of differential and integral calculus (now called the Hida calculus) for Gaussian processes in terms of the time derivative of Brownian motion. This was developed further in his analysis of generalized white noise functionals, first proposed in his Carleton University lectures in 1975. In the decades that followed, he initiated a program of investigations into functionals of general noise, in particular Poisson noise, and the analysis of random complex systems. He has also applied his results to provide new approaches to Feynman (Lagrangian) path integrals and the Chern-Simons action integral and to problems in mathematical biology.

Born in Okazaki in Aichi Prefecture, Hida had his undergraduate education at Nagoya University and obtained his PhD from Kyoto University under the official supervision of the distinguished probabilist Kiyosi Itô, the founder of stochastic analysis. Immediately after he obtained his B.Sc., he taught for 7 years in a teachers' college, Aichi Gakugei University. Subsequently, he taught at Kyoto University (Yoshida College) for 5 years before joining Nagoya University as Professor of Mathematics. On his official retirement in 1991, he was bestowed the title of Professor Emeritus by Nagoya University and he also took up a professorship at Meijo University. Since 2000, he holds a Special Professorship position at Meijo.

At an age when others would be content to bask in past achievements, he continues to collaborate with an active team of researchers in Nagoya University in pushing the frontiers of his discipline further afield into the scientific unknown. Hida's research output includes more than 130 research papers and 7 books. He has been invited to leading universities and major scientific meetings in the west. He has served as Dean of Science at Nagoya University and as Dean of Science and Technology at Meijo University. He was Chairman of the Committee of Conference, Stochastic Processes and Applications. For his scientific contributions, he was awarded the Chunichi Cultural Prize in 1980 and made an Aoi Citizen of the city of Okazaki. More recently, in 2007, he was awarded the Zuihou Jyuukou Shoh (瑞宝重光 章), one of the highly prestigious awards in Japan.

Hida's connections with NUS go back to 1981 when he was an invited speaker at the International Mathematical Conference organized by the Department of Mathematics, NUS. Since then he has maintained close ties with mathematicians in NUS through personal visits to Singapore and official invitations. He was invited by the Institute and the Department of Mathematics to give colloquium lectures and seminars on white noise analysis in April 2007. It was during this occasion that *Imprints* had the opportunity to interview him on 2 April 2007.

The following is an edited and enhanced version of the transcript of the interview in which he traces the emergence from research isolation in a teachers' college to international prominence in the world of probability and leads us through the excitement of a newly emerging field that is as profoundly abstract as it is diversely applicable.

Imprints: You had your undergraduate education at Nagoya University shortly after the war at a comparatively late age. How did it affect your studies?

Takeyuki Hida: Not quite at a late age because the educational system in Japan at that time was different from the present. Usually you graduate at 23, starting from elementary school to junior high school, high school and university. In my case, 24 - so not much difference. However, compared to other people, I was delayed for almost two years.

I: You taught at Aichi Gakugei University for 7 years before going to Kyoto University where you got PhD. Was there any

Continued on page 11

Continued from page 10

particular reason for this comparatively long time gap?

H: Of course, I had wished to go to graduate school sooner. But when I finished my undergraduate studies, I immediately took up a job. I had to work because I came from a farmer's family and I had brothers and sisters. It was financially difficult for me to continue with my graduate studies. I had a responsibility to my family. Aichi Gakugei University is actually a teachers' college. I only had to teach and I had heavy teaching duties. I didn't have much time to do research. I corresponded with Professor Itô, of course. At that time, he had already left for Kyoto University but I was able to visit him sometimes. In addition, I communicated with Professor Paul Lévy who was in France. The reason was that as an undergraduate I was taught by Professor Itô, and the textbook used was Lévy's book [*Processus stochastiques et movement brownien*], starting from Chapter 6 on Brownian motion. So I felt very close to Professor Lévy, and also I wanted to hear from him - his comments and suggestions, etc. I was then teaching at Aichi Gakugei University.

I: Did Professor Itô suggest a topic for your research?

H: Not in particular. In my last undergraduate year, he suggested that I read about Brownian motion from the book by Paul Lévy.

I: Your PhD topic was on Gaussian processes. Why did you choose to work on this topic? Did Kiyoshi Itô have any influence on your choice?

H: He did, and so did Professor Lévy. The main reason is that I started studying Brownian motion from Lévy's book. Brownian motion is very important and more basic than the Gaussian process. Professor Itô was my supervisor in my last year as undergraduate. At the same time that I graduated as an undergraduate, he moved to Kyoto. There was no direct communication afterwards, but sometimes I did go to Kyoto, but not often. We usually communicated by mail. With Professor Itô in Kyoto, how could I continue my studies? I had wished to be directed by him. Once I asked him what action I should take. Then he replied that I should follow the pioneers' work - pioneers, he said, like Kolmogorov, Feller, Lévy. He didn't include himself but I add: I understood that a pioneer's work was difficult and not easy to understand, and I found that his [Itô's] paper was interesting to follow. However, he suggested that I should investigate the pioneer's work and find out what the pioneering idea was and that I should do it by myself. I think this is a very nice suggestion.

I: Professor Itô himself also followed the pioneers.

H: I cannot say. I followed his work.

I: Did your PhD work have any influence on your later research?

H: Sure. That was very important. Actually, in 1955, there was a famous paper by Paul Lévy at the Berkeley symposium on the Gaussian process and its close connection with Brownian motion. More precisely, we hope to express any general Gaussian process as a linear function of the Brownian motion - linear meaning some kernel function and some Brownian motion integrated with respect to it. However, Paul Lévy said that the representation is not unique. If there is a way to determine uniqueness, then the combination of kernel function and Brownian motion preserves everything about the Gaussian process. I was very impressed by this idea. I tried to prove the general theory. Unfortunately [it does] not always exist, not even for the single Brownian motion. We may need many Brownian motions that are independent. However, the important part is that the basic process is Brownian motion and the general Gaussian process is expressed as a linear function of Brownian motion. I was thinking about the uniqueness of the representation. In order to characterize the Gaussian process, if there is unique representation, one can say everything about the kernel function and the Brownian motion. For many other representations, it is impossible to say so. There is a very simple example with different kind of representation. If the kernel function is taken to be polynomial, the Gaussian process has more than two different expressions. I was thinking, and the answer was eventually very simple, but the meaning is very deep. That was the idea of the canonical representation. It took me a year to come to a better understanding of this canonical representation. I tried to find out the meaning, I computed an example and finally got the definition of the canonical representation and the uniqueness theorem and characterization. So the basic part of Gaussian theory is solved.

Given a Gaussian process satisfying some conditions, we can construct a Brownian motion which leads to the canonical representation. The Gaussian process and Brownian motion have the same information - otherwise there is no meaning at all. Given a stochastic process, it would be fine, if we can find some nice basic processes (independent increment process like additive process) such that any process can be expressed as a function of those independent increment processes. Suppose we find the required properties of the process, then we can combine a (non-linear) kernel function and the basic processes just obtained. The Gaussian case is a very particular case and is, in some sense, elementary. We should generalize. We now come to the general idea. Given a general random complex system, we can find independent (increment) systems and non-linear functions

Continued on page 12

Continued from page 11

to express the random complex phenomenon in question. We can think of the general theory of the analysis of those random systems. This is a very big problem. In some sense, it is vague. But still, I wish to extend from the Gaussian process to the general random complex system, including stochastic processes and random fields.

I: Is this a kind of program you are proposing?

H: Yes. This is the original idea of white noise analysis. This is, of course, a very big program. We can do it step by step. First, the basic process is an independent increment process, or I would say, white noise, time-derivative of the Brownian motion. For that purpose, we need some detailed analysis where the functional is non-linear. I was not dreaming. Actual program was there. That is what I wrote in the Carleton Lecture Notes Series in 1975. Two years ago, we celebrated its 30th anniversary. Many people have referred to the notes. It is included at the beginning of the publication of my selected papers.

I: Has this got to do with your calculus (the Hida calculus)?

H: Yes. That's the origin of it. At the beginning of 1975, at the request of Don Dawson of Carleton University, I gave a series of lectures in the summer, mainly for researchers and some graduate students.

I: You taught at Kyoto University for only 5 years.

H: There is an unusual story behind this. Because I followed the suggestion of Itô in following a pioneer (Paul Lévy's direction), I communicated with Itô and Lévy when I was in Aichi Gakugei University. Prof Itô suggested to Prof Akizuki, who was then director of the department of mathematics of Kyoto University, to invite me to Kyoto - that was very unusual because Kyoto University is a very prestigious university and I was only an instructor in a teachers' college which was of not so high a standard. I was extremely happy and honored about it, and because of this, my studies very much accelerated.

I: You were in Nagoya University for a long time until you retired. Were you very strongly attached to your prefecture?

H: Nagoya University knew and appreciated what I was doing in Kyoto, and was kind in inviting me as a professor. I consulted with Prof Itô and he agreed that I should move to Nagoya. That was why I moved to Nagoya University. I worked there for 27 years. My hometown is actually Okazaki, not Nagoya.

I: Nagoya University has two parts, one is the School of General Education and the other School of Science, isn't it?

H: Formally, I spent 2 years in the Mathematics Department of School of Education. Two years later, I formally moved to the School of Science. Nagoya University is very famous in science. There are seven national universities which are very prestigious in Japan - Tokyo, Kyoto, and so on. Nagoya is one of them, and in fact, the youngest.

I: Was there much work done on white noise analysis before 1960 (the beginning of your second research period on white noise analysis)?

H: 1960 was the year of my thesis dealing with Gaussian processes. It is difficult to say [it is] the origin of white noise analysis. White noise theory is, in a sense, a generalization of the study of Gaussian processes. For 5 years I studied very hard to understand the meaning of canonical representation using the methods of stochastic analysis. My thesis came from the work of those 5 years.

I: Could you give us a brief idea of white noise?

H: Take the time derivative of Brownian motion, $\dot{B}(t)$. It is an independent basic system, and the structure is linear. I wish to come to the nonlinear case. That is the first idea. The second step is Paul Lévy's proposal in 1937 in his famous book *Addition des variables aléatoires* (*Addition of random variables*) to have integration. There he took a discrete time random process X_n. Suppose we know all the information of X_n until time n, then at the next step X_{n+1} is a function of the known value plus independent variable. That was the innovation theory for a discrete time series. Then in 1953, Lévy wrote a booklet published by the University of California, Berkeley, in which he proposed to think of the innovation for a continuous time parameter stochastic process $X(t)$ - he didn't say differential equations - but variation of $X(t)$,

$$\delta X(t) = \phi(X(\tau), \tau \leq t, Y = \dot{B}, t, dt).$$

To obtain δX, of course, depends on the parameters t and dt - that are nonrandom and not of much interest. The important part is that within time dt, the stochastic process brings new information, and this new information is independent of the past. He gives a formal expression for the stochastic process, and it serves, in a sense, as a generalization of the classical stochastic differential equation. He asked for a general expression theoretically. I was very much impressed by this idea. So we should find an independent system that will serve to express a given complex random system. The basic

Continued on page 13

Continued from page 12

variables are independent, the function is a nonrandom function. So we can combine two mathematical theories. One is a system of independent random variables, and the other is functional analysis. We can then establish a general theory for random systems.

One more motivation comes from Norbert Wiener's approach. In 1940, he wrote about time series and proposed prediction theory. Linear prediction is rather easy but nonlinear prediction is difficult and more important. Sometime later, in 1958, Wiener wrote a famous book on nonlinear problems in random theory. There he discussed many applications of the nonlinear function of the white noise $\dot{B}$. I was inspired, I would say, by this approach. I thought I should study nonlinear functions of $\dot{B}$, not the Brownian motion B, and even more we should establish calculus. So we have to introduce partial derivatives and integration with respect to the variable $\dot{B}$.

In 1967/8, I was invited to the mathematics department of Princeton University by William Feller. He had listened to my Berkeley lecture and agreed very much with what I was thinking and with my plan of research. At Princeton I was able to give a graduate course and undergraduate course too. Feller appreciated my white noise approach. He had published the third edition of a famous book on probability theory (Volume 1) and at the time I was there. Volume 2 was published a little bit earlier. In the preface of his book, he wrote that he wished to make probability theory a part of pure mathematics. Many people think that probability theory is about gambling and related topics. Feller was not willing to do it in that way. He said that probability theory should be one of the branches of pure mathematics with good connections with analysis. In the weekends, I often met him and he was fascinated by the picture of the chromosome. He was very much interested in applications of probability theory to biology. Two viewpoints are important: one is that it is part of pure mathematics and the other is that we should have good contact with applications to discover good problems in mathematics. The important thing is that though we are applying the theory to applications, it is not quite applied mathematics. We should investigate concrete problems and if we are lucky, we can discover mathematics in the applications. Even though you are studying biology, you are not a biologist - you are a mathematician. We should try to find mathematical theory in biology. That was the way of Feller's research so far as applied mathematics is concerned. I was very much impressed by his idea.

I: Were you surprised by all those connections with conformal groups and geometry?

H: Yes. And it is quite natural. I have not yet obtained good results so far in group theory or good connections with Lie groups. Only for the simple case like $SO(\infty)$. I observed those groups through white noise. The basic part is conformal invariance. That was in Princeton, 1967-68.

Don Dawson agreed very much with what I did and he invited me to give lectures in Carleton University. Sometime later, I visited Carleton again, in 1975, and he asked me to give a series of lectures in summer, mainly for researchers and graduate students. In this case, I started with a function of $\dot{B}$, starting from Paul Lévy's expression. I had dreamed of a new way to study stochastic differential equations, and I thought it would be fine if we could obtain differential equations in the variable, not x, but in $\dot{B}(t)$. I was inspired by Norbert Wiener's nonlinear networks whose input is white noise, and output is a non-linear function of white noise. How do you identify the unknown nonlinear network device in between input known and output known too?

I: What are some of the most important applications of white noise analysis?

H: Physical applications - the most important one is the Feynman path integral and related topics in quantum dynamics. Feynman proposed functional integration. Starting from the Lagrangian, he wished to introduce infinite-dimensional integration to obtain the propagator in quantum dynamics. I think we can imagine the original idea in Dirac's book [*Principles of Quantum Mechanics*, 1930]. Of course, Feynman improved it very much so that we can do more. However, the general idea was proposed at that time. It is known that a constant trajectory is determined uniquely by the Lagrangian. In quantum mechanics, the trajectory fluctuates and the fluctuation is expressed as a Brownian bridge - we are suggested that description from Dirac. I have discussed with Streit (German physicist) and he agreed with me. The problem is that the velocity and kinetic energy of the particle are white noise functionals, and we have to perform integration and establish a calculus.

I: What about applications to biology? For example, could one view the "junk DNA" in the human genome as some kind of white noise at the molecular level?

H: A friend of mine called Naka who used to be in New York University Medical Center had applied white noise to identify the action of the retina of catfish, which is simple compared to that of other animals. Naka was clever enough to consider the non-linear part of the action. He did some very complicated computations, but unfortunately he passed away last year after returning to Japan. It's a very sad story. Much of his work, however, can be seen in the literatures by him and his colleagues.

Continued on page 14

Continued from page 13

I: Are there people continuing his research work?

H: I hope so. Another application is in the study of polymers.

Biologists study the mechanism underlying what happens when a polymer is cut. They conduct a lot of experiments and computer simulations. I have a good friend in Kyoto who proposed some principles and compared it with actual phenomena.

Another friend of mine (Oosawa) is studying the movement of paramecium with the help of some kind of differential equations, and there is involved a fluctuation which is some kind of white noise. There was a conference on biocomputation in Italy organized by a friend of mine, Ricciardi. He asked me to give a lecture on white noise. Biologists understood that many non-linear fluctuations can be expressed in terms of white noise.

I: Do biologists understand the mathematics?

H: Honestly speaking, I don't describe everything systematically in advanced mathematics and I don't include everything in the lecture. There are many applications in biology which are interesting. I think a systematic approach will achieve something good. I was once heavily involved in the work on polymers and I even wrote a paper on it with Okada and Kiho. But I don't have any other mathematical results.

I: What about other applications?

H: Let me summarize the applications within mathematics - not in probability, but outside of probability. One is in fractional functional analysis. Fréchet, Lévy and others discussed non-linear functions, $\mathcal{L}^2$ functions essentially, not random, however, from the viewpoint of infinite-dimensional calculus. We can see very intimate connections between white noise analysis and classical functional analysis. Second is in harmonic analysis. There is a duality between $\dot{B}$ and $\dot{P}$ which is Poisson noise. I have recommended people to discuss the infinite-dimensional rotation group O_∞, symmetric group $S(\infty)$ and their subgroups to see their roles in infinite-dimensional analysis.

I: What are the future directions of white noise analysis?

H: I would answer in the following way. Many people are more interested in Gaussian noise, but Poisson noise is also interesting. In the linear additive process, the noise can be decomposed into two parts, Gaussian and compound Poisson. They can be discussed separately. One may think that Poisson noise can be similarly treated to Gaussian, but I claim that dissimilarity is more important. There should also be a duality. To the Gaussian case, we can associate the infinite-dimensional rotation group. To the Poisson case, my colleague Si Si has associated the infinite symmetric group. The future direction is to discuss the duality between the Poisson and Gaussian cases in terms of harmonic analysis arising from groups.

Another direction is to work on the foundations of white noise analysis. There is mathematical beauty to be found regarding invariance, optimality, symmetry, duality and others, which should be investigated. There are also connections with other fields - in quantum dynamics, quantum information theory (quantum probability), molecular biology. For the last field, we are still at the stage of case-by-case study. Random fields should also be investigated, hopefully, in line with white noise theory. An application is to the Tomonaga-Schwinger equations - our group at Nagoya has kept up the interest. Once I had a conversation with David Mumford, the very famous algebraic geometer, and found that he now has an interest in probability. Random fields appear on his homepage. We should revisit the ideas of Lévy and Itô.

I have organized Lévy seminars in Nagoya; last year's was our fifth Lévy seminar, and we proposed a new program for his ideas.

Publications >>>

Volume 16:
Mathematical Understanding of Infectious Diseases Dynamics
Edited by **Stefan Ma** *(Ministry of Health Singapore)* & **Yingcun Xia** *(National University of Singapore)*
Publisher: World Scientific Publishing Co. Pte. Ltd.
Edition: Dec 2008, 220 pages
ISBN: 978-981-283-482-9
981-283-482-6
Order direct from publisher at http://www.worldscibooks.com/mathematics/7020.html

Volume 17:
Interface Problems and Methods in Biological and Physical Flows
Edited by **Boo Cheong Khoo** *(National University of Singapore)*, **Zhilin Li** *(North Carolina State University)* & **Ping Lin** *(National University of Singapore)*
Publisher: World Scientific Publishing Co. Pte. Ltd.
Edition: May 2009, 188 pages
ISBN: 978-981-283-784-4
981-283-784-1
Order direct from publisher at http://www.worldscibooks.com/mathematics/7147.html

Doug Roble: Computer Vision, Digital Magic

Doug Roble

Interview of Doug Roble by Y.K. Leong

Doug Roble is world renown for his important contributions to computer vision and computer graphics and for pioneering applications to movie special effects and animation.

Roble did a joint degree program in engineering and computer science at the University of Colorado and went on to Ohio State University (OSU), where he did his PhD in computer science (on computer vision). He was an assistant faculty at OSU for a year before joining Digital Domain in Venice, California as a software engineer in 1992. Expanding on his PhD work, he developed the 3D tracking software TRACK for camera position calculation and scene reconstruction. This helped artists determine where to best fit graphics into images that have been filmed. For this software, Roble received a Technical Achievement Academy Award (Academy Certificate) from the Academy of Motion Picture Arts and Sciences in 1998. His subsequent work in the development of fluid simulation system earned him, together with Nafees Bin Zafar and Ryo Sakaguchi, a Scientific and Engineering Award (Academy Plaque) in 2007. This work allowed graphic artists to create large scale surging water effects for the movies *The Lord of the Rings: The Fellowship of the Ring*, *The Day After Tomorrow* and *Pirates of the Carribean: At World's End.*

He has been the Creative Director of Software at Digital Domain since 1993. He is the Chief Editor of the Journal of Graphics Tools and is on several panels and committees of SIGGRAPH (Special Interest Group in Graphics), the most prestigious computer graphics conference, including its Advisory Board. He has given invited lectures and keynote addresses at many major conferences, most recently at the Annual Meeting of the American Association for the Advancement of Science in 2007. He received the Distinguished Alumnus Award from Ohio State University in 2002. He is a voting member of the Academy of Motion Picture Arts and Sciences, Visual Effects Branch.

Roble was one of 4 invited speakers at the Symposium on Mathematics and Science in Digital Media, Technology and Entertainment held at the Raffles City Convention Centre on 1 July 2007 and organized by the Institute jointly with the Department of Mathematics, NUS. The symposium was supported by the Media Authority of Singapore to introduce and publicize the new field of interactive digital media to the general public. *Imprints* took this opportunity to interview Roble during the symposium. The following is an edited and unvetted version of the transcript of the interview in which he spoke with passion and animated enthusiasm about his early work on computer vision and its subsequent breath-taking impact on digital media and the entertainment and movie industry.

Imprints: Your B.S. was in electrical engineering and computer science way back in 1984. Was it some kind of joint program or major?

Doug Roble: It was a joint program actually because there was no full computer science degree in the University of Colorado at that time. The only way to get into computer science, which I knew I wanted to pursue, was to do an electrical engineering and computer science degree. Also I wasn't sure what I wanted to pursue – I knew that electrical engineering was interesting as well. It turned out to be a good thing because an electrical engineering degree offered much more math than a typical computer science degree, especially at that time. Computer science at that time sort of required you to have linear algebra, maybe a little bit of Boolean math, but electrical engineering gave me a good foundation in calculus, multivariate calculus and signal processing. I've come to use a lot of those basics much more than I thought I would. So it was a joint degree, a sort of double major.

I: Was a double major common in those days?

R: Kind of. Computer science was an emerging field. If you wanted to get a computer science degree, that was the way to do it. There was no pure computer science degree at that time, as I recall it. I think it was only a couple of years later that the University of Colorado had one.

I: What attracted you to Ohio State University subsequently to do your graduate studies in computer science?

Continued on page 16

Continued from page 15

R: Remember that, way back in 1984, Ohio State University had, and still has, a very strong graphics program. Back in 1984, they were associated with a company called Cranston/Csuri Productions, Inc which was a pioneer in computer graphics. They did a lot of the first commercials using computer graphics. In fact, they had done this famous commercial with a very shiny robot woman talking about the beauty of canned food. It was associated with Ohio State University. It was one of the pre-eminent computer graphics school at that time. Stanford hadn't even started its computer graphics program at that time. Ohio State was doing it, so I wanted to go there.

I: Did it ever occur to you to take up engineering instead?

R: Well, no. After my bachelor's degree, I used that time to figure out what I wanted to do. I knew it was computer graphics. I was fascinated with what I saw was happening with the movies. Remember it was 1984. *Star Wars* and *The Empire Strikes Back* had already come out. *The Return of the Jedi* had just been finished. I wanted to do that. *ET* and all those great films that were using traditional effects could have used computer graphics as well. This is what I wanted to be doing.

I: After your PhD, you were in academia for less than one year in OSU. Was it a calculated plunge to go into the digital industry at a time when digital media was at its infancy?

R: Absolutely. I knew I didn't want to be in academia. I wanted to work in films. It was a good opportunity because it allowed me to jump into the beginning of the bit of the domain. The company [Digital Media] had just been formed. It opened its door in 1993 and I was its 31st employee hired. So I was right there at the beginning, and it was a bite of a bullet, and I was a bit scared that the company might not last very long. But it did work out fine.

I: It must be quite fun to start at the beginning.

R: It was. It was amazing. It was crazy.

I: How recent is this discipline of IDM [interactive digital media]? How do you define it?

R: When you put the word "interactive" in front of "digital media", it becomes a whole different thing. Interactive digital media tends to mean games graphics, maybe even visualization. I'm in digital media, not so much interactive digital media, which really started in the nineties with video games and things, when *Doom* and the first 3-D games came out. Now movies and games are coming closer and closer together. It's all so crazy. I tend to define interactive digital media as that where in response to the user's input, something on the screen changes. I work in films where it doesn't matter what the user is doing. The user can leave the room and it still gets projected on the screen. The problems we are trying to solve are vastly different. Most of the things we render take ages and ages to render, from an hour to 24 hours. With video games you work with 60 frames a second or you're in trouble.

I: Some time ago there was some kind of movies where the audience actually participates in choosing what is going to follow.

R: There was this little teeny experiment where you get to choose between (1) and (2) endings. It was just an experiment. Maybe it will change some time but you don't want the majority to win. I think much more likely you will have DVDs where one person gets to choose the plot rather than the majority who's watching a film. It's democratic but that doesn't make sense.

I: Could you tell us something about your most exciting research work? Is your PhD research related to your later research work in industry?

R: Indeed, my PhD work was in trying to use computer vision to help computer graphics. I took the basics of that and re-did it for Digital Domain when I first started the program *Track* which is a computer vision toolkit that basically allows artists to look at an image in some film and extract as much information as possible – where the camera was, what the scene looks like, all the 3-dimensional information you can possibly get from a photograph. This has been something that I've been working on for the 13 years I've been there. I continuously backtrack to add new features to it. It got me the Academy Award. That was the best thing that could have happened and was probably my most exciting research work although the third generation stuff that I am doing is very, very cool. It's such a visceral feeling when you see things that are flowing like water and look like water. It's very fun. Right now, I'm looking at all sorts of stuff. One of the things that interest me right now is hair. That's probably my most current research work along with other people at Digital Domain. By the way, nothing happens by yourself. It's all part of a team. There's a group of people working on hair and it's fascinating.

I: What do you mean by working on hair?

R: Well, hair is a big deal. There are three aspects of hair. There's modeling hair, styling hair – putting hair on some head or body so that it looks like a human head. Once it's in that position, you want to animate it, simulate it so that when wind is blowing or when somebody runs his hand through the hair, the hair moves correctly. And third, render

Continued on page 17

Continued from page 16

hair. How do you render hair with a hundred thousand very thin little strands that are semi-transparent and light bounces off it in a very interesting way? How do you render it so that it looks correct? By the way, everybody has different hair than you do. It's all very different.

I: It sounds extremely computationally difficult.

R: Exactly. It's a huge computational problem – a hundred thousand strands of hair, each one continuously curving – simulating them in a discrete fashion is very difficult. So you have to make simplifications and adjustments that are good enough so that the audience is fooled.

I: Do you actually apply the laws of fluid mechanics to the motion of the hair? It sounds incredible.

R: Absolutely. It's hard – it goes back to mathematical archeology, things like Cossart curves, ringed together in a chain to represent continuous curving segments. This was invented back in the 1930s to deal with bending objects. Hair is wonderful, it doesn't stretch though. You got to make sure that the hair does not stretch and building that into the math is important.

I: Did you have to invent some new concepts or techniques to resolve some of these issues?

R: We're working on it. A group in France has laid down the foundations. We're trying to take some of their ideas and modify them so that we can use them. We're not finished yet. Maybe ask me again in a year. Indeed, we invented some cool stuff.

I: Has anybody written some kind of foundational textbook on such things?

R: Not so much. Actually there is a very good researcher in Switzerland, named Nadia Magnenat-Thalmann. She's been working on clothing and hair for her entire life, and has been doing some very good research answering some very good questions. She has a paper in a book on hair and clothing simulation. It's a computer graphics book with a lot of math in it.

I: Were there any IDM problems that contributed significantly to the development of any area in mathematics or computer science?

R: Ah, things that feed back into computer science and mathematics. Absolutely. From me, not so much. I haven't really had a lot of impact outside... well, some of the stuff I have done, things like fluid simulation. We started looking at fluid simulation – basically, the computer graphics community, not just me – in terms of how to create water that look realistic, which was a completely different approach from what computational fluid dynamics people were doing. They wanted to model water or fluid in a very precise way. Towards that end, they had to simplify the problem constraints because you can't model water realistically if you've got a very complex domain. We looked at it from an entirely different angle. We didn't care that much if it was totally realistic, but we wanted to put it in a very, very complex domain indeed. We have arbitrary boundaries, moving boundaries and all those stuff, and we wanted water to look real. We stood on the shoulders of a whole bunch of computational fluid dynamics rather than feeding back into it because we approach the problem in a totally different way. So we have attracted some of the attention of pure fluid mechanics people. And they said, "Oh, you're doing it that way. That's very interesting." So, Stanley Osher, Tony Chan invented level sets. I don't even know if they realized how important it was going to be. They took it and applied it with Ron Fedkew to fluid, and this is a brand new field. It's a new way of doing it and the computer graphics media have adopted level sets to do all sorts of amazing things, and that has gone back into the mathematics. I think that's one example.

I: What about the classical Navier-Stokes equations? Any contribution to it?

R: We use a subset of the Navier-Stokes equations. The ones for inviscid fluid are pretty puzzling. For the ones we do use, we are trying to push solving them faster and faster. Also, we have pushed ahead trying to capture the details. Whenever you are solving the Navier-Stokes equations numerically, there is a lot of filtering going on. You always lose details. All this stuff get lost in the mathematics of fluid. We recently (when I say "we", I mean the computer graphics teams – people in Berkeley and Stanford are really leading the way) are coming up with ideas of putting back the detail into the fluid simulation so that the detail isn't lost, or if we do lose it, we put it back in a possible way so that it looks good. The goal is always to try to render water that looks exactly like water. Water is very non-viscous, and that kind of fluid simulation is very hard to do. We're getting closer; we can do milk. Milk is easier, it's viscous and doesn't have all the sharp edges that water has.

I: Are creative computer programming skills necessary for a successful career in IDM? Can such skills be taught to any beginning mathematics graduate student?

R: Sure. Thinking in terms of math is very similar to thinking in terms of computer programming. When we hire new people, no matter where they're coming from, we expect that they know how to write code. Teaching programming

Continued on page 18

Continued from page 17

to mathematics students is such an important part – using the computer nowadays, no matter what. That's just Mathlab or Mathematica. But having to write your own piece of software, to implement something you have done, at least in applied math – I don't see how you can get by without it. It gives you that ability to say, "Oh, I wonder if I can write this as a code and see it on a grand scale."

I: There are people who seem never to be able to write computer programs.

R: And they can do proof? What? No. Computer programming is easy, come on.

I: Certain computer programming is not as straightforward as proof and can be quite tricky. Don't you think so?

R: I don't believe that. When it was first invented, it was tricky. You have to be very careful. When I was first doing computer programming, I did it on ancient machines. You have to do it in assembly language and it was all very arcane. Now there are so many tools available in computer programming. Modern C++ languages or Java or any kind of programming language gives you so many advantages that once you learn the basics of looking at a problem – you learn iterative, looping statements, recursion, you learn how variables work – all of a sudden, you are writing code.. All these things are mathematical concepts. It's not hard. You do use them when you are doing proofs.

I: The older generation of mathematicians somehow or other seems to loathe computer programs. There's a perception that computer programming is a young man's game.

R: You can do it, you just don't want to. What younger generation writing codes. I won't buy it. Certainly young men are doing it. But you can do it. No excuses. You're being lazy [*laughs*]. If you are good at math, you can do computer programming.

I: Reconstructing a three-dimensional object from a two-dimensional image like a photograph seems amazing, if not unbelievable. Is it theoretically possible for known methods of reconstruction to fail in at least some contrived cases?

R: Oh, absolutely. If you just have a single image of a 3-dimensional scene (you just take one photograph), it's impossible to figure out what's going on. There's no way, without any extra information, to know the 3-dimensional nature of that scene. Even if you have multiple photographs of some scene, where you can do triangulation and the various computer vision techniques to figure out what's in that scene, there are still things like scale invariance. There's no way of telling whether the photograph of the fire truck you are taking a photograph of was a real fire truck or a toy fire truck. You can't tell the difference without some measurements you actually took at the scene.

I: How many photographs do you need to reconstruct a solid object?

R: You usually get away with two. Three helps. Of course, you can always reconstruct the object that you see, you have to have coarse refinement between the two. If the camera didn't move very much, then there are limits to the accuracy because the pixels are a discrete measurement of the world and there is a built-in error. Computer vision is all about managing the error. So if you identify a feature within an accuracy of a pixel or two, and then you move the camera only a little wee bit, then the error involved in that feature identification overwhelms the mathematical induction that you can do. So the result that you get is not so good. But if you have a couple of, or multiple, photographs with decent baseline, then you can do amazing reconstruction nowadays. But you have to be able to identify a correspondence between a feature on one photograph and the feature on the other photograph. So if I take a picture of a chair, and then I move the camera and take another picture of the chair, there are parts of the chair I can't see that I could see in the first. So those pixels are fine and I have to infer the details and kind of make them up.

I: This must have been applied in astronomy.

R: Oh, of course. That's exactly how they determine how far the stars are. You use a telescope and wait a couple of days for the earth to have moved, and then you get a very long baseline and you can use triangulation.

I: The first animation in films was based on a frame-by-frame representation. How does the current animation in films differ qualitatively, and not just quantitatively, from those earlier ones?

R: Well, first of all, your question ignores one of the aspects of cinematography of the early animation. It wasn't frame by frame representation; it was frame by every other frame representation. If you go back to old Disney cartoons, hand-drawn Disney cartoons, because it was such work to animate every frame, to draw picture for every frame, Disney said, "Okay, we don't have to do that; we will only animate every other frame." Animation on two. If the motion is very rapid, sometimes you have to draw animation on one, where you actually draw a separate image for each frame. If you look at the old Walt Disney films that were poorly animated, you can see the difference. If you step through it on a DVD, you will see the fact that the images were held for 2 frames and then they move to the next frame. So right after that, qualitatively and quantitatively, we now

Continued on page 19

Continued from page 18

animate every frame. Because the computer is doing it, it's pretty much as easy to do it on one as it is on two. There's no advantage doing on two. In fact, it looks smoother. But other than that, the technology of computer graphics has to do a lot of other things that you could not do on a hand-drawn animated way like motion whirl. Every film that is done nowadays renders not only the image but the image as it is moving, and so you get motion whirl. Without that, it looks very harsh and rigid. You pick it up and say, "Oh, it's fake. That looks like a computer-generated thing." With motion whirl, that makes it look more real. Unfortunately, motion whirl is very expensive. It's a sampling problem. It's a big signal-processing problem where now not only do you have the image rendered, but now you have to move it through time in order to get that broiled. And time is very continuous. Whenever you hear the word "continuous", you go, "Ooohhh, it's continuous, there's a lot of data there." So figuring out how to do motion whirl exactly in a reasonable amount of time is a tricky thing that we work on all the time.

I: IDM is becoming visible in many fields other than the entertainment industry, like medicine, robotics, telecommunications, geography and architecture. Will the coming future of IDM depend largely on advances in engineering and technology, for example nanotechnology?

R: Nanotechnology? Maybe not so much. Certainly, if you really think about it, the latest chips from Intel and AMD are very much nanotechnology – they are cramming 4 full-blown processors in a single chip. That has a huge impact – the fact that we can do things in parallel. A lot of what goes on in computer graphics is embedded in what we can do in parallel. This is very good for us. We love the fact that processors are now becoming multi-processors all the time. We buy the latest things from Intel with 8-core or quadcore quad processors. We get 16 processors in the machine. We immediately jump on it and start using it. That's nanotechnology that has a direct impact on us. Other than that, there isn't much nanotechnology. Quantum computing, maybe. There have already been some theoretical uses of quantum computing for computer graphics.

I: Does that mean you have to develop new techniques of software or computational methods?

R: After we had third-generation computer graphics and computer vision, both have adjusted themselves to take advantage of the parallelism of processors. It's a big thing. The artists love it because it makes everything faster. It's not hard to do. With fluid simulation, it's tricky because you need to write optimization parts of the fluid simulation like conjugate gradient, preconditioned conjugate gradient, and other tricks. Once you've done it, then all of a sudden, your fluid simulation comes on.

I: Do you give courses on digital media? Do you have any students?

R: The courses that I give are typically SIGGRAPH courses which are one or two-day courses at annual conferences. People who sign up go there to be educated. In terms of students, for courses, no, but we do have internships. We have interns, Masters or PhD interns, people who come here constantly. Right now, I'm working with a student of Tony Chan, UCLA and there's also a student from a Swedish University working on hair simulation. Yes, there are students. Internships usually last about 4 months. Either I or another one of our R & D staff is the advisor of these guys.

I: What is your advice to a mathematics student who wants to have a career in your field?

R: If you are in applied math and you know how to program, I suggest you look at the last couple of years of SIGGRAPH's proceedings. SIGGRAPH is the pre-eminent conference on computer graphics and usually there are 90 to 100 papers accepted to the conference each year. Take a look at those and see what kind of mathematics is currently going on. At this conference we have Peter Schroeder talking about differential geometry, very hard, very cool stuff, and you will immediately get a sense of the kind of mathematics that is useful to computer graphics and interactive digital media. I'd just focus on that kind of stuff. Going back to what we talked about programming, if you want to work in our industry, you have to know how to program. We don't hire pure math people who just sit and do math. You have to come up with an idea and make a tool that the artists could use, and then the artists... that's the best part of the whole deal, especially in the film industry. There's that lovely feedback when you're working hand in hand with some very creative artistic people. You create something and they will immediately turn around and use it the way you haven't thought to do and they give you a new idea. And you say, "Okay, I'll be taking that back and use it differently." It is so satisfying, it's much better than writing a paper and summing it up in a journal and getting some people saying, "Oh, I saw your paper." This is writing something where people are immediately using it to create brand new things and entertain people and show people new concepts. That immediate feedback, sitting next to the artists and they have great ideas from a whole different perspective than what I can offer. That's the best part of the job. Just that constant creativity from all different sources – we have mathematical creativity, some people read a new paper and say, "Look at this new technique" and then they go and show that to an artist, and he said, "Oh, look, I can do that, it's so fun."

Obituary >>>

Leading probabilist Kai Lai Chung passed away

Kai Lai Chung, one of the leading probabilists of the second half of the 20th century and Professor Emeritus at Stanford University, passed away on June 1, 2009. He was 91 years of age and living in the Philippines with his wife, Lilia, at the time of his death. He is survived by his wife, three children and four grandchildren.

Kai Lai Chung was born in 1917 in Shanghai and moved to the US in 1945 under the auspices of the prestigious Boxer Rebellion Indemnity Scholarship. He received his PhD from Princeton University in 1947. After holding positions at several universities, including University of Chicago, Columbia University and UC Berkeley, he joined Stanford University in 1961 and remained there until his retirement in 1988. He supervised 14 PhD students and authored 133 research papers and 11 books, including the widely used textbook A course in Probability Theory, which is currently in its third edition.

Chung made major contributions in several areas of probability including the theory of sums of independent random variables, Markov chains, time reversal of Markov processes, probabilistic potential theory, Brownian excursions and gauge theorems for Schrödinger equations. In addition, he played a significant role in aiding the research community in China in the years after the Cultural Revolution. Starting in 1978, he made many scientific visits there and helped Chinese students to find opportunities to study in the US. He had also visited Singapore twice in the 1980's as an external examiner for the Department of Mathematics of the National University of Singapore.

Ruth Williams, *UC San Diego*

Institute for Mathematical Sciences
National University of Singapore

3 Prince George's Park
Singapore 118402

Phone: **+65 6516-1897**
Fax: **+65 6873-8292**

Email: ims@nus.edu.sg

Website: http://www.ims.nus.edu.sg

Editors: TAN Ser Peow
mattansp@nus.edu.sg

Denny LEUNG
matlhh@nus.edu.sg

Drafts & Resources: Claire TAN
Web: Stephen AUYONG
Printer: World Scientific Publishing Pte Ltd

For calls from outside Singapore, prefix **65** to local eight-digit telephone numbers.
For email, add the following domain name: **userid@nus.edu.sg**

IMS Staff

Louis CHEN	Director	6516-1900	imsdir
TAN Ser Peow	Deputy Director	6516-1898	mattansp
Emily CHAN	Senior Executive (Finance)	6516-1893	imscec
Claire TAN	Executive (Human Resource)	6516-1891	imstlf
Stephen AUYONG	IT Manager	6516-1895	imssass
Jolyn WONG	Laboratory Technologist	6516-1890	imswwy
Agnes WU	Management Assistant Officer (Secretary)	6516-1897	imswua
Nurleen BINTE MOHAMED	Management Assistant Officer (Housing)	6516-1891	imsnm
Rajeswri	Operations Associate		imsrs