IMPRINTS
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World Congress in Probability and Statistics

Symposium in Honor of Kiyosi Itô >>>

Guest of Honor and other guests with main speakers, BS and IMS Executive Committees, Scientific Program Committee, Organizers and Chairs of Invited Sessions, Panel Sessions Organizers Members, Organizers of the In Memoriam Session and Local Organizing Committee

-- Louis Chen and Anthony Kuk

[*Editor's note: Louis Chen chaired, and Anthony Kuk co-chaired, the Local Organizing Committee for the recent meeting in Singapore. Their report, which appeared in Volume 37, Issue 8 of the IMS Bulletin, is reproduced here with permission of the Institute of Mathematical Statistics.*]

The joint Seventh World Congress of the Bernoulli Society and 71st Annual Meeting of the IMS took place at the National University of Singapore (NUS) in Singapore from July 14 to 19, 2008. It was jointly organized by the Department of Statistics and Applied Probability, Department of Mathematics, and Institute for Mathematical Sciences, of the National University of Singapore. The joint meeting was for the first time called the World Congress in Probability and Statistics, jointly sponsored by the Bernoulli Society and the Institute of Mathematical Statistics, a new name which will be used for all future such joint meetings of the two societies.

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The road ahead, a wilderness . . .
Chasing dreams . . .
Ah, someday, someone may follow this path.
- From lyrics of Subaru (Star) by Shinji Tanimura (1948 -)

On 7 July 2008, certain parts of Japan celebrated an age-old festival called the Tanabata (七夕 or Star Festival) in which individual wishes are written on colored strips of paper and hung with other paper ornaments from bamboo branches. It is a tradition with origins in the romantic Chinese legend of the annual celestial meeting of two stars Altair (personified by the Cow Herder) and Vega (personified by the Weaving Princess) from across the Milky Way. On a smaller scale, the colorful tradition of this festival was reflected in the multitude of origami decorations, streamers, hanging strips of paper written in Japanese calligraphy, bamboo stalks and leaves at the entrance of a ward in a hospital in Kyoto. Standing almost incongruously out of this were two printed

A small token for Kiyosi Itô presented to Masatoshi Fukushima

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The World Congress is a major international event in probability and statistics and is held every four years. It features the latest scientific developments in the fields of probability and statistics and their applications, and is one of the most prestigious meetings in these fields.

Singapore is the first city in the Asia-Pacific region to have hosted the World Congress. The six previous World Congresses were held in Tashkent (Soviet Union, 1986), Uppsala (Sweden, 1990), Chapel Hill (North Carolina, USA, 1994), Vienna (Austria, 1996), Guanajuato (Mexico, 2000) and Barcelona (Spain, 2004).The fourth World Congress in Vienna was brought forward by two years to avoid a clash with the International Congress of Mathematicians (ICM), also held every four years, and also to allow the fifth World Congress to be held in the auspicious year of 2000.

The Chair of the Scientific Program Committee for the seventh World Congress was Ruth Williams. There were 13 keynote speakers, 34 invited sessions, 82 contributed sessions and 3 poster sessions, covering a wide spectrum of topics and a myriad of applications. The keynote speakers were: Richard Durrett (IMS Wald Lectures), Jianqing Fan (Laplace Lecture), Alice Guionnet (Lévy Lecture), Peter McCullagh (IMS Neyman Lecture), Oded Schramm (BS-IMS Special Lecture), David Spiegelhalter (Bernoulli Lecture), Alain-Sol Sznitman (Kolmogorov Lecture), Elizabeth Thompson (Tukey Lecture), Wendelin Werner (BS-IMS Special Lecture), Martin Barlow (IMS Medallion Lecture), Zhi-Ming Ma (IMS Medallion Lecture), Mark Low (IMS Medallion Lecture), Douglas Nychka (Public Lecture). There were also two panel discussions on challenges and opportunities in probability and in statistics, and an 'In Memoriam' session commemorating the passing of David Kendall (1918–2007) and Chris Heyde (1939–2008), past Presidents of the Bernoulli Society, and of Samuel Karlin (1924–2007), past President of IMS. More than 570 participants from 55 countries attended the Seventh World Congress, which opened on Monday, July 14 with speeches delivered by Louis Chen (Chair of the Local Organizing Committee), Ruth Williams (Chair of the Scientific Program Committee), Jean Jacod (President of the Bernoulli Society), Jianqing Fan (President of IMS) and guest of honor SHIH Choon Fong (President of NUS). A Welcome Reception followed the IMS Presidential Address on Monday evening. There was also a Special Reception on Tuesday, July 15 to honor Wendelin Werner for being the first probabilist-trained mathematician to have been awarded the Fields Medal. Werner won the Fields Medal for his revolutionary work on stochastic Loewner evolution and the geometry of two-dimensional Brownian motion, part of which was done in collaboration with Oded Schramm and Gregory Lawler. This reception was graced by the Provost of NUS, Eng Chye Tan, who spoke on how the 2006 ICM was a watershed for probability theory and probabilists [see his speech on page 3]. A half-day city tour was held on Thursday, July 19, followed by the Congress Banquet at The Pines, a town and country club. The banquet was attended by about 310 people, who were enthralled by a musical performance featuring tenor John Chen, academic-turned-politician-turned entrepreneur, pianist Bernard Lanskey, Director of the NUS Yong Siew Toh Conservatory of Music, and clarinetist Dai Le and cellist Zhou Mi, who were graduates of the Conservatory, with music by Bernard Tan, composer, physicist and former Dean of Science at NUS. Apart from the Bernoulli Society and IMS, which were the sponsoring societies, other sponsors of the seventh World Congress were NUS, Singapore Tourism Board, Saw Swee Hock, Lee Foundation, World Scientific, Singapore Management University and Elsevier. The Congress ended successfully on Saturday, July 19, 2008. There are photos on the Congress website at http://www.ims.nus.edu.sg/Programs/wc2008/gallery.htm

Opening ceremony: (From Left) Institute of Mathematical Statistics President Janqing Fan, Bernoulli Society President Jean Jacod, Louis Chen, Guest of Honor National University of Singapore President SHIH Choon Fong

Special reception

Wald Lecturer Richard Durrett

World Congress: Provost Honors Probabilists >>>

[*Editor"s note: This speech was given by the Provost of the National University of Singapore, Professor Eng Chye Tan, at the Special Reception at University Hall on July 15, 2008. It is reprinted here with the permission of the Institute of Mathematical Statistics.*]

It is a great pleasure for me to be here to participate in this special reception to honor Professor Wendelin Werner for being the first probabilist-trained mathematician to be awarded the Fields Medal at the International Congress of Mathematicians (ICM) 2006 held in Madrid. My heartiest congratulations to Professor Werner. If I may generalize, this is also an occasion to celebrate the achievements of probabilists.

I understand from the experts that ICM 2006 was a watershed for probability theory and probabilists. Of course, probability theory has always been featured in past ICMs, but before 2006 it would have been unimaginable to award a Fields Medal to someone who is primarily a probabilist. As you all know, one of the other three Fields Medalists, Andrei Okounkov, is known for bridging probability, representation theory and algebraic geometry. The Nevanlinna Prize this time around was awarded to Jon Kleinberg who also uses probability in his work.

Not only that, at ICM 2006, a newly created award called the Carl Friedrich Gauss Prize for applications of mathematics was awarded to a probabilist, Professor Kiyosi Itô, the founding father of stochastic analysis, whom the NUS Institute for Mathematical Sciences honored last week in a special symposium. Then the 2007 Abel Prize was awarded to another probabilist, S. R. S. Varadhan. When Kolmogorov axiomatized probability theory in 1933, it was considered part of analysis — measure theory, in particular. Even after the powerful analytical apparatus of probability was subsequently brought to bear to solve problems in science and other areas of mathematics, it was generally regarded as an application of analysis.

If I may say so, people in mainstream mathematics used to think of probabilists as running errands for others, either in mathematics itself or in other applied areas. But ICM 2006 seems to have shown that the mind-set of mathematicians in general has changed. Never before had mathematicians seen so many probability-related ideas and methods being propounded in other areas of mathematics, ranging from number theory to logic. It appears that many mathematicians are embracing the ideas of probability in much the same way that they use methods from well-established fields like algebra, analysis and geometry. Although I'm a Lie representation theorist, I'm aware that probabilists have been using and continue to use group representations in their work. In the other direction, I understand that probabilistic ideas have become more frequently applied in solving big problems in pure mathematics. In 1974, Norman Levinson published a highly nontrivial result that lent a probabilistic flavor to the Riemann Hypothesis, and since then, some people have been trying to crack this problem, probably the greatest prize problem of our century, using probabilistic methods like random matrices

Wendelin Werner speaking at the special reception

and even quantum systems. The purists will, of course, view this as a sign of "desperation". However, there are also people who believe that even if the problem is not cracked by such methods, these probabilistic approaches will open up a treasure chest of new mathematical insights. Professor Werner said in an interview that the division and classification of mathematics into sub-fields should not be taken too seriously. This is certainly borne out by mathematical and scientific developments throughout the ages. For example, the well-known algebraic geometer Oscar Zariski said something to the effect that the classical Italian geometers knew all about the geometry of curves and surfaces in two dimensions but could not prove them. And it took Zariski, André Weil and B. L. van der Waerden to prove them and lay the rigorous foundations of algebraic geometry by using ideas from commutative algebra. More recently, everybody knew that the physicists knew all about conformal field theory but were unable to prove anything rigorously. It took Professor Werner and his fellow researchers Gregory Lawler and Oded Schramm to rigorously prove their predictions. The history of mathematics is full of instances of the fruitful cross-fertilization of ideas in advancing old and new areas of knowledge. Probability theory has indeed contributed to this process. I am very happy to be able to share the camaraderie of such a distinguished gathering of scholars and thinkers on this occasion. I hope this World Congress will also turn out to be a joyous and festive occasion for you, to bring back good memories of this place and this event.

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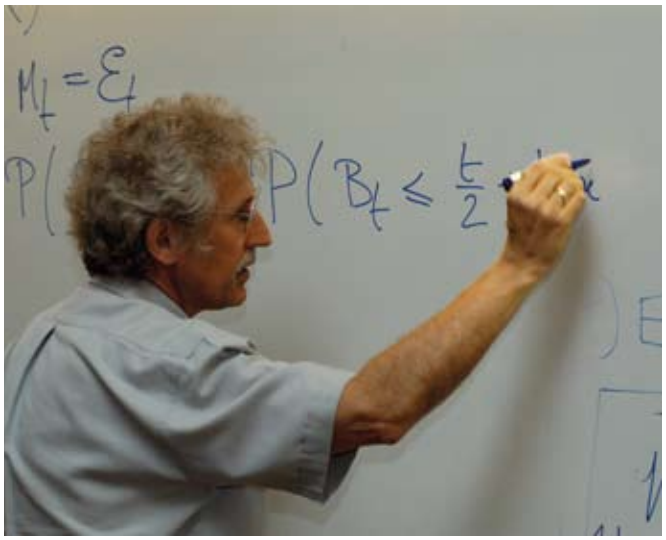

Marc Yor: Generalizing Black-Scholes

sheets of paper – one a picture of a circular pewter plate with an English inscription and the other an enlargement of this inscription.

The inscription in part read:

Formless random winds,
A scholar's stochastic dreams,
Dawns a fresh new spring.

This cryptic message must have puzzled the staff, nurses and visitors of this ward which houses one of the hospital's most distinguished patients – Professor Kiyosi Itô. In spite of his illness, he translated the English haiku (written by Y.K. Leong) into a beautiful Japanese haiku with the assistance of his daughter Mrs Keiko Kojima:

風さやぎ	Kaze sayagi
確率微分の	Kakuritsu bibun no
春きざす	Haru kizasu

As one ancient celestial festival ended, a modern terrestrial festival began. A long distance away from Kyoto, a meeting of minds took place from 10 to 11 July at the NUS Institute for Mathematical Sciences (IMS) for a mathematical festival. Formally called "Symposium in honor of Kiyosi Itô: Stochastic analysis and its impact in mathematics and science", it was organized jointly by IMS and the Research Institute for Mathematical Sciences (RIMS) of Kyoto University. During those two days, some of Itô's friends and fellow researchers gave expository talks on the new and rapidly expanding field of stochastic analysis. It was founded by Itô almost single-handedly and single-mindedly more than 65 years ago at a time when almost the whole world was mired in social upheaval caused by geopolitical and expansionist wars.

Opening remarks were made by Louis Chen (Director of IMS) and Edwin Perkins of the University of British Columbia, Canada. The former recalled how the idea of holding this special symposium was mooted by him and Hans Föllmer (a co-chair of the Symposium who unfortunately was not able to come) not long after the International Congress of Mathematicians was held in Madrid, Spain in 2006. (At that congress, Itô was awarded the newly created Carl Friedrich Gauss Prize for outstanding contributions to the applications of mathematics.) Chen related some of his personal reminiscences since his first contact with Itô in 1979 during the First Franco-Southeast Asian Mathematical Conference in Singapore. The gathering was given a glimpse of a more personal Itô who believes that one should not stop learning and that one can learn at any age. Chen also revealed Itô's exhortation to "follow a Master." (The Master whom Itô said he followed was Andrei Nikolaevich Kolmogorov.)

Edwin Perkins then re-lived some of the highlights of the historical development of Itô's ground-breaking work. In it, Itô combined the intuition of Paul Lévy and the rigor of Kolmogorov to create stochastic differential equations from Joseph Doob's concept of regularization. In the 1950s only a small group of probability specialists realized the importance of this work and in the 1960s engineers and physicists routinely applied Itô's theory. It was not until the 1970s that the full impact of Itô's work in mathematics itself became widely felt.

Following the opening remarks, Masatoshi Fukushima (also co-chair of the Symposium) of Osaka University read out a message from Itô to the Symposium and accepted on his behalf a pewter plate as a gift from IMS. Louis Chen then read out the English haiku inscribed on the plate. In response, Fukushima recounted how Itô was "compelled" to render a translation in the form of a Japanese haiku, possibly the first time that Itô had written a haiku (see above). Immediately after that, the two-day mathematical tour through the terrain of stochastic analysis and its applications took off with Fukushima's talk on Itô's one-point extensions of Markov processes and their recent developments. The other tour leaders for the first day were Alain Bensoussan, Shigeo Kusuoka and Marc Yor while those for the second day were Shinzo Watanabe, Donald Dawson and Terry Lyons. Participants of this unique journey were whisked through a landscape marked by infinite-dimensional affine processes, rough paths, stochastic differential equations and applications in computational finance, economics and genetics.

The gathering was a small and tightly-knit group of researchers and students held together by the respect and awe for a pioneer who blazed a trail through a mathematical wilderness and eventually lighted up domains far and

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wide beyond probability theory. At the coffee breaks, the participants experienced a free flow of mathematical adrenalin and shared their personal recollections of a scholar who as a novice pursued the masters in isolation and soon became a master himself.

After the talks were all given, a salutation to the pioneering spirit was given by a DVD presentation. It showed a video of the presentation ceremony of the Gauss Prize to Itô by John Ball, President of the International Mathematical Union at RIMS, Kyoto University, on 14 September 2006. This was followed by a display of a collection of photographs of Itô the man, who at the age of 91 exemplified the model once put forward by Itô himself to his friends that one who uses one's brain a lot lives a long life.

Contrary to the belief that all good things must end, another festival began on 14 July with the 7th World Congress in Probability and Statistics at NUS as the Symposium ended on 11 July, if only as a satellite conference of the congress.

Acknowledgement. The writer would like to thank Louis Chen and Masatoshi Fukushima for sharing their personal views and information some of which may have been included in this article.

Y.K. Leong

[*Editor's note: Professor Kiyosi Itô passed away on November 10 2008.*]

A gathering in honor of a great mathematician

People in the News >>>

Kiyosi Itô honored with Cultural Medal of Japan
Kiyosi Itô, pioneer of stochastic analysis and subject of a recently held symposium at IMS in celebration of his work (see article in this issue of Imprints), has been awarded the Order of Culture by the government of Japan. He was one of eight recipients of the Order this year, along with three Nobel Prize winners and the conductor Seiji Ozawa.

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Hans Föllmer
Hans Föllmer, former member of the IMS Scientific Advisory Board, has been appointed Andrew Dickson White Professor-at-large at Cornell University since 1 July 2008. The six-year appointment will see Hans visiting Cornell three or four times for a period ranging from one to two weeks "to enliven the intellectual and cultural life of the university."

Keith Moffatt

Keith Moffatt was elected as Foreign Associate of the US National Academy of Sciences in April 2008. Keith, a long-time friend of IMS and a former member of its Scientific Advisory Board, is organizing a Spring School on Fluid Mechanics and Geophysics of Environmental Hazards in April/May 2009.

Elizabeth Alison Thompson
Elizabeth Alison Thompson, who delivered the Tukey lecture at 7th World Congress of Probability and Statistics, was elected to the US National Academy of Sciences in April 2008. Elizabeth was also an invited speaker for our program on Markov Chain Monte Carlo: Innovations and Applications in Statistics, Physics, and Bioinformatics (1 - 28 Mar 2004).

The IMS congratulates Hans, Keith and Elizabeth on their achievements.

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Personnel movements at IMS
Wendy Tan, former administrative officer, left IMS on March 3 2008. Claire Tan has been promoted to administrative officer and taken over the position. Cheryl Tsan is the latest staff arrival at the Institute, having joined as management assistant officer on 7 August 2008.

Emily's baby boy
Emily Chan, our administrative officer, became the proud mother of a baby boy, Xavier Loh, on 7 May 2008.

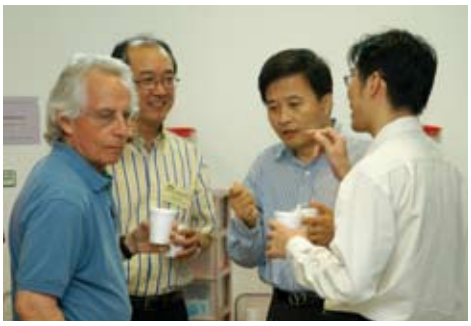
Emily's baby boy Xavier Loh

Programs & Activities >>>

Past Programs in Brief

Mathematical Imaging and Digital Media (5 May – 27 June 2008)

Website: http://www.ims.nus.edu.sg/Programs/imaging08/index.htm



An image of amiable discussion

Imaging scientists captured in an image

Co-chairs
Tony Chan, *University of California, Los Angeles, USA & The National Science Foundation, USA*
Zuowei Shen, *National University of Singapore*

Members
Say Song Goh, *National University of Singapore*
Hui Ji, *National University of Singapore*
Seng Luan Lee, *National University of Singapore*
Andy M. Yip, *National University of Singapore*

This program comprised of two workshops and a Summer School. The "Chinese-French-Singaporean Joint Workshop on Wavelet Theory and Applications" was a joint event between wavelet groups from China, France and Singapore. It provided a platform for researchers from the three countries to communicate new developments and explore research collaborations in the areas of sparse data representation and approximation by wavelets and redundant systems, noise removal, stochastic wavelet analysis, and inverse problems via wavelet methods. The workshop on "Mathematical Imaging and Digital Media" focused on the topics of computer graphics, computer vision, image restoration, image segmentation, computer vision, image representation, and image compression. Among the distinguished speakers were Tony Chan (University of California, Los Angeles, USA & National Science Foundation, USA), Charles Chui (University of Missouri, St. Louis, USA & Stanford University, USA) and Stanley Osher (University of California, Los Angeles, USA). Both workshops attracted an average of 60 participants.

The Summer School that was held from 26 May - 6 June 2008 consisted of student-oriented seminars and two weeks of tutorials. It covered basic mathematical theory of imaging, PDE and variational methods, graph-cut methods, wavelet methods and applications to digital media and biomedical imaging. Graduate students from Canada, China, Hong Kong, Germany, Singapore and USA came together to interact and learn from the experts in the field.

Mathematical Horizons for Quantum Physics (28 July - 21 September 2008)

Website: http://www.ims.nus.edu.sg/Programs/mhqp08/index.htm

... Jointly organized with Centre for Quantum Technologies, NUS

...Partially supported by Lee Foundation and Faculty of Science, NUS

Program Coordinator
Huzihiro Araki, *Kyoto University*

Co-chairs
Berthold Georg Englert, *National University of Singapore*
Leong Chuan Kwek, *Nanyang Technological University and National University of Singapore*

This program consisted of four overlapping three-week sessions, with each devoted to a selected topic.
Session 1: Quantum Control and Dynamics
Session 2: Operator Algebras in Quantum Information
Session 3: Non-equilibrium Statistical Mechanics
Session 4: Strongly Interacting Many-Particle Systems

Included at the end of each session was a round-table discussion led by the organizer. During the discussion, the

Round-table discussion

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participants brought up problems and issues on the topic and talked about how they could be resolved. These discussions were conducive to forming future collaborations.

Two public lectures "Knot and not Knot" by Burkhard Kümmerer (Technical University of Darmstadt, Germany) and "Are Quantum Computers the Next Generation of Supercomputers?" by Reinhard Werner (Technische Universität Braunschweig, Germany) also took place during the program.

Upcoming Activities

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

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

Chair of Organizing Committee:
Wei-Liem Loh, *National University of Singapore*

This workshop is jointly organized with Indian Statistical Institute and NUS Department of Statistics & Applied Probability. There will be 20 half-hour talks in total delivered by speakers from Academia Sinica, Taiwan, Harvard University, Indian Statistical Institute and NUS.

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

... Jointly organized with Bioinformatics Institute, Singapore

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*
Members of Organizing Committee:
Danail Bonchev, *Virginia Commonwealth University*
Frank Eisenhaber, *Bioinformatics Institute*
Alessandro Giuliani, *Istituto Superiore di Sanità*
Jun Liu, *Harvard University*
Limsoon Wong, *National University of Singapore*
Michael Zhang, *Cold Spring Harbor Laboratory*

This 5-day workshop will discuss recent progress and facilitate the exchange of new ideas and methods, focusing on the integrative approaches for understanding of different types of regulatory sequences and their structural and functional roles in biological diversity and complexity of genomes, networks and pathways at the genome, transcriptome and proteome and cellular levels. It will also promote communication and collaboration among mathematical, computational and biological scientists in examining essential and unsolved problems of systems biology and biomedicine. The mission of the workshop is to bring together researchers from computational genomics, computational systems biology and bioinformatics to share and develop new ideas, integrate and synergize the strengths of mathematics and computer sciences with molecular biology, biotechnology and clinical studies in the post-genomics era.

Next Program

Algebraic Topology, Braids and Mapping Class Groups (4-20 December 2008)

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

Chair
Jie Wu, *National University of Singapore*
Members
Jon Berrick, *National University of Singapore*
Fedor Duzhin, *Nanyang Technological University*
Liz Hanbury, *National University of Singapore*
Ser Peow Tan, *National University of Singapore*
Yan-Loi Wong, *National University of Singapore*

The recent progress in topology has shed light on many deep connections between algebraic topology and the theory of braids. A successful program on Braids was organized in May-July, 2007. This program will explore further the connections between algebraic topology and braids, and to establish further research collaborations in algebraic topology in Asia.

Activities

1. Workshop on Homotopy, Braids and Mapping Class Groups, 4 - 14 December 2008.

   This workshop will focus on homotopy theory, braids, mapping class groups and 3-manifolds. Participants will explore the mapping class groups with its 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). Besides research discussion among participants, some introductory talks on selected topics will be given to graduate students.

2. The Second East Asia Conference on Algebraic Topology, 15 - 19 December 2008.

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Programs & Activities in the Pipeline

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

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

Organizing Committee
Andrew Barbour, *University of Zurich, Chair*
Louis Chen, *National University of Singapore*
Kwok Pui Choi, *National University of Singapore*

The original application by Charles Stein of the method named after him was in the context of central limit approximation to partial sums of random variables having a stationary dependence structure, a problem involving the normal distribution and the real line. However, its uses have proliferated, with approximations not only to the normal distribution, but also to the Poisson distribution, to multivariate normal distributions, to diffusions, to Poisson processes, to the Ewens sampling formula, to the Wigner semi-circle law, and more. The proceedings of a workshop in the program 'Stein's method and applications: a program in honor of Charles Stein', held at the Institute for Mathematical Sciences of the National University of Singapore in August 2003, illustrate the variety and richness of the field.

In the five years since that program was held, and stimulated to a considerable degree by the impulse that it provided, there have been a number of significant new developments. In view of the breadth and diversity of recent advances, the time is now ripe to hold a further program, with the aim of bringing together the people actively involved in the area, and of cementing and further promoting the development of the field. In addition to the general scientific aim, the program is also designed to develop research in Stein's method in Southeast Asia, where there is a growing interest in the method. It also aims, by way of a series of tutorial lectures, to encourage more young mathematicians to undertake research in the field.

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

Co-chairs of Organizing Committee
Louis Chen, *National University of Singapore*
Takeshi Yamada, *National University of Singapore*

The objective of this conference is to promote research in quantitative finance by providing a platform for researchers in Singapore to interact and share their research findings in this field.

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

International Scientific Committee
Keith Moffatt, *University of Cambridge, UK, Chair*
Hassan Aref, *Virginia Tech.,USA*
Paul Linden, *UCSD, USA*
K.Takeuchi, *Tsukuba, Japan*
Gerd Tetzlaff, *Universität Leipzig, Germany*

Organizing Committee
Keith Moffatt, *University of Cambridge, UK, Chair*
Boo Cheong Khoo, *Department of Mech. Eng., NUS, Co-Chair*
Pavel Tkalich, *Tropical Marine Science Institute, NUS, Co-Chair*
Tieh Yong Koh, *School of Physical and Mathematical Sciences, NTU*
Wei Zhu Bao, *National University of Singapore*
Shie-Yui Liong, *National University of Singapore*

Invited Lecturers
Eddie Bernard, *Pacific Marine Environmental Laboratory, USA*
Kerry Emanuel, *MIT, USA*
Peter Haynes, *University of Cambridge, UK*
A.W. Jayawardena, *International Centre for Water Hazard and Risk Management, Japan*
Paul Linden, *UCSD, USA*
Emily Shuckburgh, *British Antarctic Survey, UK*
Gerd Tetzlaff, *Universität Leipzig, Germany*
Toshio Yamagata, *Tokyo University, Japan*

This School is intended to focus on fluid mechanical aspects, and is aimed at students who have already graduated in mathematics, physics or engineering, and who wish to undertake research in this broad area. It is intended to bring students rapidly to current research frontiers in the fluid mechanics of environmental hazards. The School will start with introductory and motivational lectures on the fundamentals of geophysical fluid dynamics, and on geophysical hazard and risk in atmosphere and ocean contexts, and will then focus on four specific environmental hazards:

i. typhoons and tropical cyclones;
ii. monsoons and flooding;
iii. tsunamis;
iv. pollution of atmosphere, ocean and the urban environment.

The School will include workshop activity in which groups of students will study key papers cited by the lecturers, and

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will be encouraged to identify and formulate new model problems that need to be solved in each of the above four areas. In this way, it is envisaged that the students will be fully involved in active and collaborative research activity.

Student Registration
Online student registration is now invited. Grants to cover travel and local subsistence costs will be awarded on a competitive basis. Applications from students resident in Bangladesh, China, India, Indonesia, Korea, Malaysia, Philippines, Sri Lanka, Thailand and Vietnam, as well as Singapore, are particularly encouraged. Limited places may be available for applicants from Australia, New Zealand, Japan, or further afield.

The deadline for registration and application for grants is 30 January 2009. Please visit our website http://www.ims.nus.edu.sg for more details.

Statistical Genomics (1 - 28 June 2009)

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

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

Members
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, statistics becomes even more indispensable. The success in understanding the data generated from genomic studies becomes more and more dependent on the concerted effort among 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 authorities of the field and to get inspired for their further research.

Activities
The program will consist of two workshops, one on Gene Mapping and the other on Genomic Profiling, and a graduate summer school.

The workshop on Gene Mapping 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.

The workshop on Genomic Profiling 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.

The summer school is intended for graduate students from Singapore as well as overseas universities. It will provide the students with basic training in statistical genetics as well as in topics related to the workshops. It will engage them in research through seminar talks and discussions with the participants of the program. The summer school will be conducted through tutorials, lectures and special seminars as well as other activities.

Eleventh Asian Logic Conference (22 - 27 June 2009)

... Jointly organized with Faculty of Science, NUS

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 Local 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 logics. It also aims at promoting activities of mathematical logic in the Asia-Pacific region and bringing logicians both from within Asia and elsewhere together to exchange information and ideas. Singapore is 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. The program will cover a wide range of topics and will feature plenary lectures presented by leading specialists in every major area of mathematical logic. In addition there will be many contributed talks.

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

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

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

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

Members
Weinan E, *Princeton University*
Jian-Guo Liu, *University of Maryland*
Jie Shen, *Purdue University*
Chang Shu, *National University of Singapore*
David Srovolitz, *Princeton University (to be confirmed)*
John Wang, *National University of Singapore*
Ping Wu, *Institute of High Performance Computing*
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 multi-scale 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 bring leading international applied and pure mathematicians, physicists, materials scientists and computational scientists together to review, develop and promote interdisciplinary researches on problems at the interface between mathematics and materials sciences.

Activities
The program activities will consist of two workshops, tutorials and public lectures, a series of seminars and collaborative research.

1. Collaborative Research: 1 July – 31 August, 2009
2. Summer School: 27 July – 7 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 Lectures
   Distinguished researchers will give public lectures on topics in physical modeling, mathematical theory, computational methods and applications related to computational materials simulation and design.

Financial Mathematics
(1 November - 31 December 2009)
…Jointly organized by Risk Management Institute, NUS
Website: http://www.ims.nus.edu.sg/Programs/financialm09/index.htm

Chair
Paul Embrechts, *Swiss Federal Institute of Technology (ETH) Zurich, Switzerland*

Members
Min Dai, *National University of Singapore*
Hanqing Jin, *National University of Singapore*
Hinz Juri, *National University of Singapore*
Kian-Guan Lim, *Singapore Management University*
Defeng Sun, *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. Based on results from probability theory and stochastic calculus, problems of portfolio selection and fair contract valuation have been solved within a sound mathematical framework. The insights gained broke new grounds and the resulting concepts have been successfully extended both mathematically and in practice.

This program will focus on, but is not limited to, the following three areas:
1. the pricing and hedging of environmental and energy-related financial derivatives;
2. risk and robust optimization;
3. optimal stopping and singular stochastic control problems in finance.

These areas form the substance of 3 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.

Highlights of Other Activities

Workshop on Stein's Method (31 March - 4 April 2008)
Website: http://www.ims.nus.edu.sg/Programs/stein08/index.htm

Chair
Andrew Barbour, *University of Zurich*

Members
Kwok-Pui Choi, *National University of Singapore*
Aihua Xia, *University of Melbourne*

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Stein's method in action

Andrew Barbour: Matrix correlation statistics

Since Stein's pioneering work, much has been done to refine and develop his method, but it remains a highly active field of research, with many outstanding problems, both theoretical and in applications. This five-day workshop brought together mathematicians from Australia, France, India, Philippines, Singapore, Switzerland, Thailand, USA, UK and Vietnam at the forefront of this effort, to report on the newest developments and to initiate further joint projects. At the same time, it attracted 19 young mathematicians to participate in the meeting, and to share in our enthusiasm for the field.

Symposium on Pure and Applied Analysis (21 April 2008)

Jointly organized with Department of Mathematics

Website: http://www.ims.nus.edu.sg/Programs/pure_sym08/index.htm

The Symposium marked the initiation of academic exchange between IMS and the Liu Bie Ju Centre for Mathematical Sciences at the City University of Hong Kong. The speakers included Professors Roderick Wong and Philippe G. Ciarlet, Director and Deputy Director of the Liu Bie Ju Centre and Professors Zuowei Shen and Xingwang Xu of the National University of Singapore.

Symposium in Honor of Kiyosi Itô: Stochastic Analysis and Its Impact in Mathematics and Science (10 - 11 July 2008)

Jointly organized with Research Institute for Mathematical Sciences, Kyoto

Website: http://www.ims.nus.edu.sg/Programs/kiyosi08/index.htm

Co-Chairs

Hans Föllmer, *Humboldt-University of Berlin*
Masatoshi Fukushima, *Osaka University*

Members

Edwin Perkins, *University of British Columbia*
Yoichiro Takahashi, *Research Institute for Mathematical Sciences, Kyoto*

See the article in this issue of *Imprints* for a report on the Symposium.

7th World Congress in Probability and Statistics (14 – 19 July 2008)

Jointly sponsored by the Bernoulli Society and the Institute of Mathematical Statistics
Jointly organized by the Department of Statistics and Applied Probability, Department of Mathematics and Institute for Mathematical Sciences of the National University of Singapore

Website: http://www.ims.nus.edu.sg/Programs/wc2008/index.htm

Chair of Scientific Program Committee:

Ruth Williams, *University of California, San Diego*

Chair of Local Organizing Committee:

Louis Chen, *National University of Singapore*

See the cover article of the present issue of *Imprints* for a perspective on the 7th World Congress in Probability and Statistics.

Public Lectures

The Institute organized three public lectures in April and August 2008.

Larry Schepp: Mining data to manage diabetes

Larry Shepp of Rutgers University gave a public lecture on "Data Mining with Modeling: Managing Diabetes" in April 2008. In the '60's, John Tukey and his followers brought exploratory data analysis into statistics. In this talk, the speaker argued that Tukey's approach, as he stated it, does not permit the solution to a problem to depend on the problem; and thereby inhibits statistics to grow and

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Mathematical Conversations

LUI Pao Chuen: Of Science in Defense >>>

LUI Pao Chuen

Interview of LUI Pao Chuen by Y.K. Leong

LUI Pao Chuen played a pioneering and pivotal role in the establishment and development of the scientific and engineering capabilities of the Singapore Armed Forces (SAF) and the Ministry of Defense (Mindef).

Leaving behind his original dream of becoming a university lecturer after getting his bachelor's degree in physics from the then University of Singapore in 1965, he had a short stint at a radio and space research station before becoming one of the first scientists to join Mindef in 1966. Starting as a captain in the Logistics Division, he rose to the rank of colonel in 1978 in the course of a long and illustrious career in helping to build up, practically from scratch, the defense capability of a small nation that had to fend for itself economically, politically and militarily overnight. When he officially retired from SAF in 1986, he became the country's first Chief Defense Scientist. He went on in his typical tireless and visionary way to promote and coordinate research in science, engineering and technology in Mindef and SAF and to tap the resources of the universities and national research institutes in areas such as information and signal processing, remote sensing, experimental hydrodynamic studies, high performance computing, computational mechanics and biomedical research.

In 1973 he obtained a Masters degree in operations research and systems analysis from the US Naval Postgraduate School (NPS). While contributing much to defense science, he came back, in a full circle, to his original aim of teaching in the university when National University of Singapore appointed him as Adjunct Professor in Industrial and Systems Engineering in 1990. His contributions earned him professional recognition as Fellow of the Institution of Electrical Engineers (UK), Chartered Electrical Engineer of the UK Engineering Council and Senior Fellow of NPS. He was awarded the Commander of the Royal Order of the Polar Star by Sweden, NPS's Distinguished Alumni Award, induction into NPS Hall of Fame and the 2002 Singapore National Science and Technology Award. In addition to being appointed to leading positions in many national bodies such as Defense Science Organization, Defense Science and Technology Agency, National Research Foundation and Temasek Laboratories, he has been a member of the IMS Scientific Advisory Board that chartered the Institute's direction right from the beginning in 2000. Though he has recently relinquished his post of Chief Defense Scientist in 2008, he continues as a consultant to Mindef.

On 3 January 2007, he was interviewed by Y.K. Leong on behalf of Imprints. The following is an edited and vetted version of the interview in which he gave us an insight into an unusual and distinguished career in defense science and how his scientific team questioned conventional wisdom encapsulated in the safety codes of the US Department of Defense and introduced new codes that are now scientifically accepted.

Imprints: You started schooling in Singapore at a rather late age after your family moved from China and Hong Kong. What is your most memorable impression of education (whether in school or university) in those days?

LUI Pao Chuen: I moved to Singapore in 1954 when I was 8 eight years old. In school I had to catch up with the rest of my cohort. I needed to move much faster and the school was very kind to me. My first school was Balestier Road Boys' School (for a year) and after a double promotion, I went to St Patrick's .The school was quite different in those days. In 1962, I was a boarder in St Patrick's and had a chance to be away from my family. We were boys of 8 years old staying together in a very disciplined type of environment. Every morning we attended classes and after studies, we played games in the afternoon. We had a lot of freedom and I enjoyed doing things in the Scout Movement. I also spent a lot of time in the library reading mathematics. When I entered university [University of Singapore] I had one clear objective – to graduate, get a scholarship and come back with a PhD. Unfortunately I didn't do well enough in my final exams. I didn't get a First Class Honors and I could not get a scholarship to go to Cambridge. That was when I decided to start working.

I: You could have gone to some other university for graduate studies.

L: I set my mind to do something. When I couldn't get it, I would do something else.

I: What did you do after that?

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L: The UK Science Research Council had a Radio and Space Research Station in Singapore. It had two sets of facilities, one at the Bukit Timah campus, next to the Students' Union House, with equipment to measure the ionosphere and the other was at the Sembawang Air Base where they were tracking the UK1 and UK2 satellites and gathering data from satellites passing over Singapore. I was employed by the UK Science Research Council to work at both facilities. After one year, I found that the Singapore Armed Forces had opportunities for me to contribute to Singapore, and so I switched.

I: Your initial training was in physics, but your career was more in engineering or at least technology. Did you ever consider doing an engineering degree in the first place?

L: Our family finances did not allow me to study engineering. At that time you had to go to KL [Kuala Lumpur] to do engineering. The engineering faculty was in MU [University of Malaya]. At that time, SU [University of Singapore] was part of MU, and they [MU] did not have a medical faculty while SU did not have an engineering faculty. To do engineering, you had to go to KL or do it at the polytechnic [Singapore Polytechnic], but it was only a diploma course, not a degree course. Reason number two is that engineering was a four-year course, whereas for physics, you could do it in 3 years by going directly into the second year as a "super-fresh" student.

I: After you were appointed as the Chief Defense Scientist in 1986, your work seems to move more towards research capabilities in science and technology.

L: Before that, I was running special projects. My last assignment was as a project director for Mindef and SAF. One major capability development is in science and technology capability in SAF and Mindef and to develop international relations.

I: Do the research capabilities have to be connected to defense?

L: Most of the capabilities we do must add value to our defense capability, including the R&D [research and development].

I: What is your latest research initiative?

L: I'm more involved in the management of research and development rather than doing research myself. For example, we have a problem of space in storing a large amount of ammunition in Singapore. Can you find a way where you require less land? There is so much land required if you store it on the surface. If you were to go underground, below the rocks, the current codes say that you require 240 hectares. But we looked deeper into it and found that actually those codes were not based on science but on empirical considerations. We did research and development on the ground shock behavior of explosives when they explode and we came out with a code that requires much less land than that. We embarked on a very large technology development program. Firstly, you must understand the physics, do the modeling of how explosives detonate and study their detonation patterns. Originally, we assume that explosives detonate as point masses, but we realize that's not the case in real life. They cannot be point masses, they are distributed in storage. When they explode in storage, they can go off together provided they detonate together. But would the peak pressure be the same as a point mass? We then did some computer simulations and found that the pressure is very slow if you assume that they are distributed and you have a very simple assumption that they detonate at the same time, which is a contradictory type of assumption. So then what else are there? We know that the ammunition is axially distributed. We looked at a number of critical parameters. First, the ground shock: will the buildings nearby collapse? You also need to know the structural behavior through soil, through layers of rock and so on. We thought that there must have been some research done in those things. The very interesting thing is that in the US Department of Defense, for safety codes, there were two formulas used to determine ground shock. So we put in the amount of explosives that we intended to store into the formula. One formula came up with an answer of 60 meters and our formula came up with something else. We went back to the Department of Defense and there was a big meeting. We had two sets of formulas and two different answers; so one of them must be wrong. Unless we have the scientific basis, we cannot persuade you to accept our findings. So we went back to the mathematical formulation, computer simulation, small scale testing and finally large scale testing. We built a tunnel in Sweden to verify our model. After that, the results were presented to the experts in NATO. They looked at our results and found that there was a scientific basis for us to write a new code based on our findings. What does that mean?

The normal way of storing ammunition above ground requires 1000 hectares of land. If you were to go below the rocks, in the caverns, making use of the present safety codes, the land required is 240 hectares. We found that these are empirical codes without any scientific basis to it. We went back to the scientific basis of the effects of the explosions – the theory, modeling, small-scale testing and large-scale testing – and found that the amount of land required is 100 hectares. This new code is now embodied into the safety codes of the US and NATO.

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I: Is it implemented in Singapore?

L: Yes, of course. Why would we want to spend 12 million [Singapore] dollars on R&D to find that out?

I: In some countries, there is a perception among some academics that research sponsored by defense agencies tends to be geared towards military objectives and therefore not "peaceful" in nature. What is your view about this?

L: In Singapore it is very clear. If there is no defense, there will be no Singapore. The economic well being of the country depends on the perception of investors that Singapore is a safe place to invest their money in. In order to convince investors that Singapore is a safe place, national security must be given top priority by the Government. With national security comes development, next economic development, then social development. National security is fundamental to the well being of Singapore. NUS defense technology is a strategic thrust of the university and is important for our defense.

I: Has NUS been given any grants by Mindef?

L: Mindef identifies some research which can be done by researchers in the universities and accordingly funds the researchers to do this research. In order for results to be able to be fed into DSO [Defense Science Organization] they must create systems that are of high mutual value.

I: Does Mindef approach individual academics to do the research?

L: It started more than ten years ago with road shows that we conduct every year with briefings of what we are doing to academics to see whether they have any interest. Therefore it is a two-way thing.

I: Could you tell us what is defense systems engineering? What is the role of mathematics in this discipline?

L: Systems engineering ensures that all the components of an enterprise are blocked together in such a way that they will achieve the objective of that enterprise, by looking at the topologies and components of the subsystems, and in particular, defense systems engineering as it pertains to defense systems. The role of mathematics is fundamental. In anything that we do, it provides the tools for a scientific basis.

I: Is any of the research done by scientists in DSO considered to be "classified" and hence not published in the public domain? If so, would that be contrary to the spirit of free inquiry that is so dearly cherished by creative scientists?

L: There is protected work done by DSO. One is the development of capability that is normally systems specific and that is classified. They are creating capability that is of high value and that you cannot buy. These are the things that are classified and we will not tell people what we are doing until we know that the value of that information is no more relevant. But in the case of research, like lasers and mathematics, it is publishable. Some of the researchers are adjunct professors in the universities. There are research intensive type of publications. There is work on developing capabilities and we don't publish them. There are two parts of DSO: the open part dealing with more fundamental and basic research, and the second systems part of DSO.

I: Do you have people working on both types?

L: Yes, they can work on both.

I: Has "biological warfare" been seriously considered a potentially lethal option to be countered in defense science and are there any effective measures against such options?

L: More than 10 years ago, we established a biomedical initiative and one of the areas of focus was to study how biological agents could be spread in a densely populated place like Singapore and how we can respond. Biological activity has been a threat and continues to be a threat. Therefore the defense, medical and environmental research institutes play a part in total defense and have a responsibility to do research in the solution of this problem.

I: Is there any collaboration between DSO and biological scientists?

L: Our capacity is very limited. That is the reason why the billing in the BMRI [Biomedical Research Institute] in the medical faculty is for scientists in DSO to clap hands with the medical faculty.

I: Is there some kind of biological initiative initiated by DSO or Mindef?

L: I wouldn't say biological initiative. Perhaps research in defenses against biological agents.

I: You mentioned that there are people in DSO who do more publishable research. Are they free to choose their kind of research problems?

L: Most of their research is in common areas of interest

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rather than in the areas of interest of the investigators. The investigators know the ultimate areas of interest to defense science and therefore, if they want to publish in astrophysics say, then probably they are not going to get much financial support from Mindef or DSO.

I: What are some of the "pure" areas relevant to DSO?

L: Electromagnetics. There was one book on electromagnetics. What I mean is information theory – or rather information security, especially with computer systems. We have a number of mathematicians working on how to protect information and how to understand information that could be extracted from noise.

I: Are computer scientists involved?

L: We have a sizable group of computer scientists working in defense.

I: Are there many of our graduates working in DSO?

L: One thousand something.

I: What are some of the achievements that you would like to be remembered for?

L: The things that are very interesting I can't tell you because they are classified, and the things that I can tell you are quite mundane. One thing I would like to be associated with is the build up of the core of engineering capability in SAF. When I joined the Logistics Division, there were only a handful of us with some science background. Now we have up to 3,000 science and engineering graduates. It takes a considerable effort to build, equip and train first rate engineers and then develop them into an organization. I'm quite proud to be associated with the people and organization that will be able to provide that depth in science and technology that allows them to have the confidence in pressing beyond world class caliber.

I: Do you think of retiring?

L: I'll be retiring in March 2008.

I: In spite of your heavy administrative involvement in many companies and committees, you have found time to teach in the engineering faculty of NUS for about ten years. What is the greatest satisfaction that this has given you?

L: More than 10 years. I started teaching in 1990 because the engineering faculty thought a minor in development systems would add value to the faculty. I teach one module a year on large scale systems engineering. I feel that it is important for the older generation to share their knowledge with the younger generation through teaching. The way I teach is through story-telling and case studies and to relate it back to some of the theory that are all there. I find that when the students meet me after 10 years, they still remember. It's not the theory but the stories and the lessons learnt.

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interact with the rest of science. The point was illustrated with data-mining examples, in particular discussing a new large data set composed of glucose levels of blood of a large number of diabetics at 5 minute intervals over a period of a year to study the important problem of how to make algorithmic use of these readings for closed-loop control of an insulin pump.

Burkhard Kümmerer of Technische Universität Darmstadt gave a public lecture on "Knot or not Knot?" in August 2008. The talk started with a look at the origins of knot theory. A method for distinguishing different knots, discovered by V. Jones, by attributing to them certain polynomials is one of the great recent achievements in mathematics. Essential features of this discovery can be understood with only elementary mathematics. The talk used the example of knot theory as an angle for exploring question: "What is mathematics?" Mathematics is about more than just numbers, mathematics requires lots of imagination, and, last but not least: mathematics is fun.

Burkhard Kümmerer: Enjoying knotty problems

Reinhard Werner: The promise of quantum computers

Reinhard Werner of Technische Universität Braunschweig delivered a lecture on "Are Quantum Computers the Next Generation of Supercomputers?" in August 2008. The dream of Quantum Computing promises to deliver computing power that would outperform all classical computers, even classical computers of the future. In particular, the standard public key encryption methods could be broken on a quantum computer. In the talk, the speaker described the current state of quantum technology, which still lags far behind the dreams, but had made remarkable progress in recent years. The features of quantum mechanics which enable such feats were discussed.

Michael S. Waterman: Breathing Mathematics into Genes >>>

Michael Waterman

Interview of Michael S. Waterman by Y.K. Leong

Michael Waterman is world acclaimed for pioneering and fundamental work in probability and algorithms that has tremendous impact on molecular biology, genomics and bioinformatics. He was a founding member of the Santa Cruz group that launched the Human Genome Project in 1990, and his work was instrumental in bringing the public and private efforts of mapping the human genome to their completion in 2003, two years ahead of schedule.

After his PhD in statistics and probability from Michigan State University, he taught at Idaho State University and visited Los Alamos National Laboratory for a short period before going to University of Southern California (USC) in 1982 to pursue a long and distinguished career in molecular biology, mathematics and computer science. The well-known "Smith-Waterman algorithm", which he developed with Temple F. Smith in 1981 for determining the degree of similarity (homology) of amino acid sequences from DNA, RNA and proteins, is catalytic in igniting the bioinformatics revolution. The formulae, which he and Eric Lander derived in 1988, are crucial for the so-called shotgun strategy for assembling genome sequences by cutting up the genome into short fragments that are easier and faster to sequence and then fitting them correctly together. In 1995, he published the first textbook Introduction to Computational Biology: Maps, sequences and genomes that laid the foundations of the new field of computational biology, of which he is considered to be the founding father. When he first went to USC, he started one of the world's first cross-disciplinary programs connecting genetics, mathematics and the information and computer sciences. With the setting up of the Center for Computational and Experimental Genomics in 2001, Waterman and his collaborators and students continue to provide a road map for the solution of post-genomic computational problems.

For his scientific contributions he was elected fellow or member of prestigious learned bodies like the American Academy of Arts and Sciences, National Academy of Sciences, American Association for the Advancement of Science, Institute of Mathematical Statistics, Celera Genomics and French Acadèmie des Sciences. He was awarded a Gairdner Foundation International Award and the Senior Scientist Accomplishment Award of the International Society of Computational Biology. He currently holds an Endowed Chair at USC and has held numerous visiting positions in major universities.

In addition to research, he is actively involved in the academic and social activities of students as faculty master of USC's International Residential College at Parkside.

Waterman has served as advisor to NUS on genomic research and was a member of the organizational committee of the Institute's thematic program Post-Genome Knowledge Discovery (Jan – June 2002). On one of his advisory visits to NUS, *Imprints* took the opportunity to interview him on 7 February 2007. The following is an edited and enhanced version of the interview in which he describes the excitement of participating in one of the greatest modern scientific adventures and of unlocking the mystery behind the building blocks of life.

Imprints: Your *PhD* was in probability and statistics. How did you get into biology?

Michael Waterman: My PhD thesis was in probability and I did my initial work in probabilistic modeling and iteration of deterministic functions. I got into biology in connection with Los Alamos. Stan Ulam, who was a mathematician, was interested in what mathematics you might need in the new biology. He brought Temple Smith to Los Alamos for a number of visits. Another scientist at Los Alamos named Bill Beyer had an NSF project for one summer and I came to work with Bill and Temple. That was how I met Temple Smith and what really started me in this area.

I: Ulam was not really a biologist.

W: Not at all. He started as a completely pure mathematician in the Polish school of mathematics famous for its problems begun in a café [Scottish Café]. He came to the US – I forgot who really brought him to Los Alamos – and worked on the Manhattan Project. He actually flowered there and

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contributed to all of the amazing crowd there. He was one of those few great men who was still around many years later.

I: It seems that he had some foresight and could see that biology would be a thing of the future.

W: Yes, but I don't think he knew exactly what it was. He saw that it was intriguing and different, and it was clear to him there was something there.

I: I remember he wrote a book on "What is Life?"

W: That book was by Schrödinger. It's not really a very accurate book about the subject, but it inspired many people to take on the mathematical and other aspects of biology.

I: After Los Alamos, where did you go to?

W: When I started this work, I was a faculty member of Idaho State University. I was just visiting Los Alamos in the summer. Then in 1975 I went there permanently until 1982. In 1982, for most of the year, I had a visiting appointment in the department of biochemistry and biophysics at the University of California in San Francisco – a very biological place. Then I went to USC [University of Southern California].

I: All this while, you were still doing mathematical work?

W: I do mathematical work. At Los Alamos, I was in a statistics group analyzing energy data. Beginning with Temple Smith I also worked on stratigraphics in mathematical geology. I worked on a number of different applied problems, but because of the connections with Bill Beyer and Temple Smith, I was doing some of this work in biology, mostly algorithmic, in biosequence metrics as a hobby until finally, about 1981, 1982, I decided that that was what I would really like to concentrate on.

I: Could you tell us how you got into collaboration with Eric Lander that led to those famous formulae in physical mapping?

W: Eric Lander was still in the Business School at Harvard when he became interested in biology. After that he was at MIT and the Whitehead. Eric had written a proposal to a private foundation and that foundation asked me to look at the proposal. I met him in that connection and so I knew him. He became more and more interested in molecular biology; initially it was going to be neurobiology. We had an acquaintance and our joint paper came at the beginning of the genomics revolution. A t that time he had an office at the Whitehead Institute [for Biomedical Research]. I was visiting and a copy of PNAS [Proceedings of National Academy of Science] was on his desk, it had to do with the first papers on physical mapping, including a paper on physical mapping of yeast by Maynard Olsen, and John Sulston had a paper on physical mapping of C. elegans. The progress reported by these papers was slower than what people expected and the C. elegans paper, which used a different method, had a simulation study. Eric and I thought we should be able to do something with it. So we started thinking about the problem and I realized that it was a coverage problem. I remembered a little book I had seen – Geometrical Probability by Herbert Solomon – on coverage. We went to the MIT library in the middle of the night. We found the book but it didn't really pertain to the kind of problems we were looking at. Actually the problem we worked on was about car parking. Of course, you have a long street on which you park cars at random locations, allowing parked cars to overlap. What is the distribution of the coverage of the long street by this process? We found it was easier to work on the problem directly and we published our first paper. And then later on, Eric proposed a problem that was a little bit different and involved using short unique DNAs to anchor the clones (cars!) for the coverage. There was a paper by Arratia, Lander, Tavare and myself. Arratia and Tavare knew that the Poisson process was the right way to look at the problem. I really learned a lot from these guys.

I: I think Eric Lander once mentioned that he left mathematics for economics first and then biology because he thought that mathematics was too "monastic" and cloistered. In contrast, do you think that you are a mathematician at heart?

W: I went to USC holding tenure at the math department with a joint appointment in biology. Now it's the opposite; actually I hold a tenure in the biology department, but in my heart I'm still a mathematician and statistician. To pick up Eric's comment, I think there are certain people in mathematics who will be motivated to work in other fields. I'm certainly one of those. I like working on problems that require different strategies. One of the appealing things about working in biology is that there is more than one person interested in what you are doing. There is a community aspect of it which is very important to me and keeps me going. There is a very wonderful aspect to working in teams. I think at my age I would find it a very hard time continuing to try to prove things in ergodic theory had I stayed in that area.

I: In contrast, pure mathematicians tend to work by themselves.

W: By themselves, with the door closed. I can do that, but I kind of like talking ideas around and even with people telling I am wrong.

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I: When you wrote the first textbook, published in 1995, that laid the foundations of computational biology, did you expect those dramatic developments in the field to occur within the following 5 years?

W: At that time, I didn't think we would have the human genome sequence by the year 2000. I knew there was going to be great progress, but things happened that I didn't expect.

I: When you wrote the book, has the project already started?

W: The first discussion, which I was lucky enough to be part of, was in Santa Cruz in 1985. There were a dozen people and I was the "computer person" in the group. In fact, there was a California magazine which had an article about this. In 1985, it seemed to be feasible, the computations seemed just possible. Someone brought up the cost of a military ship, and that put the cost of the project in perspective. The project started in 1990 and it was planned to take 15 years (or more) to finish it and push it further.

I: Was the book to some extent motivated by the project?

W: In part, by the data. I had been teaching a course since 1983. While teaching it, I was writing the book and correcting the chapters. I was trying to write the book for several years.

I: Was there any book before that?

W: There was a book [edited] by David Sankoff and J.B. Kruskal [Time warps, string edits and macromolecules]. It was a book based dynamic programming with various applications to genome sequences. That was an important predecessor. There was a book, a rather naïve book, looking at information theory approaches by Lila Gatlin, which was published in 1972.

I: Which is more crucial to the theoretical techniques used in gene mapping: the "better" algorithm or the "faster" computer?

W: I think, both, especially with the difficult mapping problems people attack today, not finding a mutation in a single gene but studying a complex phenotype involving multiple genes. It's not clear how far we will get. There are other extremely important computing facilities of which you have to take advantage.

I: Like parallel computing?

W: That's everywhere today, there is no doubt. In fact, students we recruit to our program ask about what computational facilities would be available to them.

I: Is it possible to break up the problem into small parts to work on?

W: Certainly for some problems it is possible to do it that way. Most of this parallel computing activity in biology is not sophisticated, but for problems where the processors have to communicate it is much more difficult.

I: What are the prospects of quantum computers in genome mapping in the future?

W: I have no idea, not a clue.

I: Do you have some guess?

W: No, I honestly don't. I mean, it's cool, but it will be some time before the quantum computers exist. It's counter-intuitive, some of these properties of quantum computers.

I: Your algorithm and other ideas on sequence alignment have also been applied to linguistics, human language development and even consumer purchasing patterns. Are you surprised by this, and do you know whether anyone has tried applying them to imaging or pattern recognition?

W: I'm not too surprised by it. I remember years earlier in Idaho trying to use the alignment algorithm to compare two different poems which clearly had a related source. I myself was trying in this direction. One of the earlier persons in this area, David Sankoff, has always had a very serious interest in linguistics, and so this connection was there all the time. For image matching, the alignment algorithm has been generalized to multi-dimensional objects – but it's not so clear how you make this work properly. Alignment has become part of pattern recognition people. Motivated by the problems from biology, people in the area looked at approximate string matching, at the statistical distribution of random strings, and more and more elegant string matching algorithms appeared. This area motivated a lot of work.

I: So much of the DNA in the gene is "junk stuff" without any apparent functionality. It seems hard to believe that Nature is so "wasteful" in her designs. Could it be that there is something we don't understand about this "junk" DNA?

W: I'm sure there is a lot we don't understand about the junk DNA. In very recent years, there are all of these microRNA genes that are around and have important applications such as regulating gene expression which no one knew about

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a few years ago. But by the numbers I've seen, maybe 6 percent of the human genome is under positive selection, and we know maybe about 2 percent of it that is critical to the organism. There is a tremendous amount we don't know.

I: So most of the selection is not in the positive direction.

W: You are asking, "What about that other 94 percent or 90 percent?" You know, it may be like a typical mathematician's office, stacked with papers that you may never have to look at again, that you might use, that you don't throw out. I think that's the difference between the Executive Office where there is hardly clutter and the working mathematician's office.

I: Has there been any progress on this junk DNA?

W: People are all the time looking for patterns in it. Some of the answers may be in how the DNA packs into the cells, the accessibility of the DNA that initiates the copies. It is not clear.

I: Do you think that it is ever possible in the distant future to use extremely powerful computers to simulate how Nature experimented successfully with the nucleotides and other building blocks of life in producing the first primeval life form?

W: It's a question we will probably never know the answer to. They're fascinating questions. Personally, I very much like this idea that the original information molecule was RNA with DNA absent, but there's not too much known for computing the origins of life.

I: Could life have started as a kind of random process?

W: Many people believe that. In the naïve calculations, we take a protein molecule, 100 long and take 20 to the 100-th power, and say that's how it happened. Or that calculation and others like it are used to argue for its impossibility. These arguments are spurious in my opinion. Just how we got the original self-reproducing molecule at the origin of life is a really fascinating question.

I: Can we do some simulation? After all, the rules of combining are known.

W: Maybe. But people also try to figure out what the environment was, of course. That is one of the key ingredients. The complexity is enormous and then there's that billion years of the early earth that you have to catch up.

I: Are there any expectations for the next great conceptual breakthrough in biology?

W: I personally don't have any predictions. I wish I did. I'm still amazed by these small RNA molecules, genes that are so important and we didn't know about them until just a few years ago. And I'm sure there will be something else like that we just haven't thought of.

I: Does it mean that the RNA is more important than the DNA.

W: Well, if first operating molecules in the cell were RNA, that would make RNA very important. One of the key pieces of evidence relates to ribosomes which are assemblies (or machines) made up of sixty some proteins and three structural RNAs. Ribosomes translate messenger RNA into proteins. Harry Noller showed that ribosomes can function without all the proteins, just with the structural RNAs. This is quite surprising and suggests to me that RNA may have been there before proteins.

I: Are there any models for the origin of life? I remember Freeman Dyson once proposed some kind of model.

W: People are always writing about that. But I don't follow it carefully.

I: What advice would you give to someone who wants to study computational biology?

W: I feel that it's important to learn as much basic chemistry, basic physics and basic statistics as the student can. The basic facts are extremely important and some depth in mathematics and biology is also required, of course.

I: Do you have any PhD students?

W: Three PhD students and one post doc at this point. We are attracting students into this area who really come prepared. They know what they want to do and they take some serious courses … 15 years ago, people often had a degree in a different area and then converted to computational biology.

I: Are there any special programs in this area?

W: We have a computational biology PhD program within the biology department. The students take courses in biology, mathematics, statistics and computer science. They work hard!

Publications >>>

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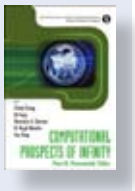

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Obituaries >>>

Kiyosi Itô (1915 – 2008)

Kiyosi Itô, a towering figure in probability theory and pioneer of stochastic calculus and stochastic differential equations, passed away peacefully on November 10, 2008 in Kyoto at the age of 93 after a long illness. The Institute held a celebration of his life and work on July 10 - 11, and he had recently been awarded the Order of Culture by the Government of Japan. (See reports in this issue of *Imprints*). Kiyosi Itô will be sadly missed both as a scholar and as a gentleman.

Oded Schramm (1961—2008)

It is with profound shock and sadness for *Imprints* to report on the untimely death of Oded Schramm in a tragic hiking accident on 1 September 2008. Oded, who was one of the most influential probabilist of his generation, was in Singapore recently to deliver the BS-IMS Special Lecture at the 7th World Congress on Probability and Statistics. He was also a friend, mentor and collaborator to our colleague Wang Zhou in the Department of Statistics and Applied Probability. An online memorial to Oded Schramm may be found at http://research.microsoft.com/schramm/

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