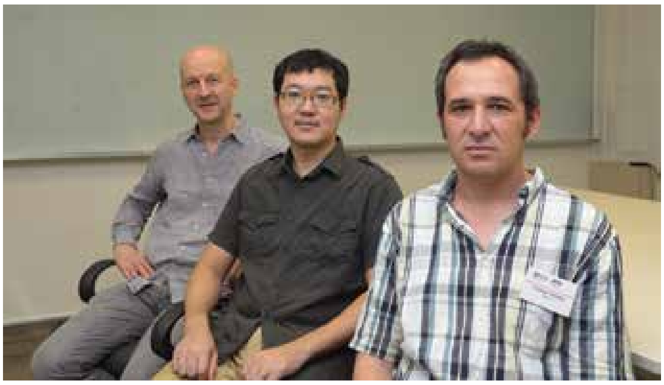
IMPRINTS
INSTITUTE FOR MATHEMATICAL SCIENCES
January – June 2016
ISSUE 27

Stochastic Methods in Game Theory >>>


Marco Scarsini, Satoru Takahashi and Tristan Tomala

Editor's note: In November/December 2015, the Institute hosted the program "Stochastic Methods in Game Theory (16 November - 25 December 2015)". Members of the organizing committee, Marco Scarsini (Libera Università Internazionale degli Studi Sociali Guido Carli), Satoru Takahashi (NUS) and Tristan Tomala (HEC Paris) contributed this invited article to Imprints.*]*

When making a decision an individual often has to consider two crucial factors: uncertainty and the decisions of other individuals. The interaction between these two aspects, that is, the interaction between randomness and strategy has been at the core of game theory in the past few decades. Three areas have been particularly active in the study of this interaction: online learning, stochastic games, and congestion games.

In online learning (and online convex optimization), data is acquired and treated on the fly; for instance, one might think of automatic recognition of hand-written digits. One possible objective is to minimize the overall number of mistakes. Originally, the assumption on the data was that it was generated from some external, unknown, and independently and identically distributed (i.i.d.) process. However, this assumption is too restrictive as the generating process evolves with time. One solution was to remove all stationary and/or stochastic assumption, leading to the so-called "adversarial setting".

The latter can be seen as a game between the learner (or decision maker, algorithm, etc.) and nature that generates data, without any assumption on its behavior. This gives the first connection between game theory and online learning. Reciprocally, one might ask what happens if several players use online learning in a concurrent world; the questions that arise are whether their behaviors will converge to some 'game-theoretic equilibria' and, if it is the case, at which speed.

Finally, data that is available is often induced by the behavior of users (think, for instance, of repeated auctions, or simultaneous connections to broadcasting devices that interfere with each other). Studying and applying this strategic, game-theoretic data-generating process which lies between the stochastic and adversarial ones, is most probably one of the new challenges of online learning.

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A general repeated game goes as follows. In each round, the game is in one specific state and each player chooses an action; the rules of the game then specify the next state of the game together with a (possibly private) signal, and a payoff, to each player. The information available to a player along the play is the sequence of his/her own past actions and past private signals. This flexible framework includes as special cases repeated games with incomplete information, stochastic games, repeated games with imperfect monitoring, partially observed Markov decision processes, repeated games with information lags, and many others.

In one of the most studied cases, state, signal, and action sets are all finite. The general theory of these games has seen recent exciting mathematical developments on the asymptotic analysis when players become increasingly patient.

Continuous-time versions of the game emphasize the link to optimal stochastic control and partial differential equations, and to games with general action and state spaces, whose analysis calls for tools from functional analysis. The applications of this theory focus on strategic experimentation, career concerns with ratings, repeated games with multimarket contact, and implementation theory in repeated environments, computational methods and their complexity.

Congestion games are the most prominent mathematical tool for modeling the interaction of agents who use common facilities and are negatively impacted by the use of others. An important application area is routing where mass has to transit over a network from an origin to a destination. A congestion network is then determined by a directed graph endowed with origin-destination (o-d) pairs and with cost functions attached to edges. This model is flexible enough to study various specification: non-atomic flows representing a large number of players, finite number of players i.e. atomic flows, identical agents or player-specific o-d pairs or cost functions. An early study is by Wardrop (1952) in the context of non-atomic flows. The model of congestion game was introduced by Rosenthal (1973).

In the case of symmetric agents with a single o-d pair, congestion games are potential games and have good properties: existence of pure Nash equilibria, iterative procedures converging to an equilibrium. If this simple case is well understood, many open problems remain in the general case with multiple o-d pairs: existence and uniqueness of equilibrium flows, computational complexity, efficiency of equilibria. One part of the workshop was dedicated to recent advances on the theory of congestion games (e.g. potential and harmonic games, uniqueness with multiple o-d pairs, weighted congestion games, price of anarchy in sequential instances).

The other part of the workshop was devoted to dynamic aspects. Indeed, most of the congestion models are actually static and thought of as steady states of a stationary dynamical system. Precursor dynamic congestion models are found in Vickrey (1969) in the economic literature and in Yagar (1971) in the transportation literature. More recently, Koch and Skutella (2011) have studied dynamic Nash flows over networks which are actual steady states of dynamical systems with constant inflow. The existence of steady states, how the system reaches it, the impact of the inflow process is new and challenging problems in the theory of dynamic congestion games.

Random arrival to a congestion system are studied by the works on strategic queueing models (e.g. Hassin and Haviv, 2003), which can be seen as specific congestion games.

Marco Scarsini *(Libera Università Internazionale degli Studi Sociali Guido Carli)*, Satoru Takahashi *(NUS)*, and Tristan Tomala *(HEC Paris)*

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New Management Board Chairman and member of the Scientific Advisory Board >>>


Choy Heng LAI

The Institute is pleased to welcome Professor Choy Heng LAI (National University of Singapore (NUS)) to chair the IMS Management Board (MB). He was a member of the MB from 2001 – 2005. He will also join the Scientific Advisory Board as an ex-officio member.

Professor Lai is currently Deputy Director of the Center for Quantum Technologies and Professor at the Department of Physics at NUS. He began his career with NUS in 1980, and has since taken on many important administrative appointments at NUS: Head of the Department of Computational Science from 1993 – 1997, Head of the Department of Physics from 1998 – 2000, Dean of the Faculty of Science from 2000 – 2003, Vice Provost (Academic Personnel) from 2003 – 2012, and Executive Vice President (Academic affairs) at the Yale-NUS College from 2012 – 2014.

Professor Lai's current areas of research are in complex networks and their applications, as well as quantum information and computation. He has authored more than 150 publications in internationally refereed journals, and serves as reviewers for many respected physics and computational science journals. He is a member of the SEATPA Committee of the Asia Pacific Physics Newsletter and the Editorial Board for the International Journal of Modern Physics C.

Professor Lai was awarded the Public Administration Medal (Silver) in 2003 in recognition of his service to Singapore. He was conferred the Chevalier of the Ordre des Palmes Academiques by the French Government in 2002. He is a Fellow of the Institute of Physics, Singapore (IPS), and the Singapore National Academy of Science, and he received the 2015 IPS President's Award for outstanding contribution to Physics and university education in Singapore.

Kwok Pui Choi
National University of Singapore

People in the News >>>

Professor Teck Hua HO is appointed Deputy President (Research and Technology) at NUS from 1 June 2015.

The Institute would like to congratulate Professor Teck Hua Ho, our former MB Chairman, for his appointment as Deputy President (Research and Technology). We also would like to express our gratitude to Professor Ho for his guidance and helpful advice and suggestions in strengthening the institute's scientific programs from 2013 – 2015.


Teck Hua HO

Programs & Activities >>>

Networks in Biological Sciences (1 June - 31 July 2015)

— *Jointly organized with Department of Mathematics, NUS*

Website: http://www2.ims.nus.edu.sg/Programs/015bio/index.php

Chair:
Louxin Zhang, *National University of Singapore*

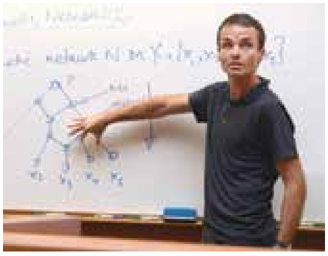
This program focused on the multi-disciplinary research on network models in biological sciences. It involved mathematicians, statisticians, computer scientists, physicists and biologists. One objective of the program was to enable knowledge transfer in the study of cellular networks among a community working in systems biology. Another objective was to work on the systematic methods for phylogenetic networks. In Singapore, good progress has been made in biomedical research in the past decade. Network approach is often seen in local research projects in cancer studies, genomics, and translational medicine.

The program focused on two main themes, and each theme was planned with a tutorial and a five-day workshop. The first theme on protein networks started with Jun Zhu (Icahn School of Medicine at Mount Sinai, USA) giving a six-hour tutorial on network approach for complex diseases. This was followed with a five-day workshop which had 29 talks. The second theme of the program focused on Phylogenetic networks, an emerging field in the research on systems biology. Charles Semple (University of Canterbury, New Zealand) conducted four hours of tutorial lectures on the mathematical aspects of phylogenetic networks. Céline Scornavacca (Université Montpellier II, France) lectured on computer tools for phylogenetic analysis. The following five-day workshop had 31 talks.

Discussion sessions were organized at each workshop to facilitate the dialogue between mathematicians and biologists and discuss the limitations of the existing computer tools in network biology. In 2010, van Iersel, Semple, and Steel posed an open problem by asking if a reticulation visible network displayed by a phylogenetic tree is polynomial time solvable or not. During the program, Andreas Gunawan and Louxin Zhang solved this open problem by collaborating with Bhaskar DasGupta (University of Illinois at Chicago),

In between the two workshops, Chaolong Wang (Genome Institute of Singapore) and Hyungwon Choi (NUS) delivered a seminar talk on 7 and 24 July 2015 respectively on their work related to network models.

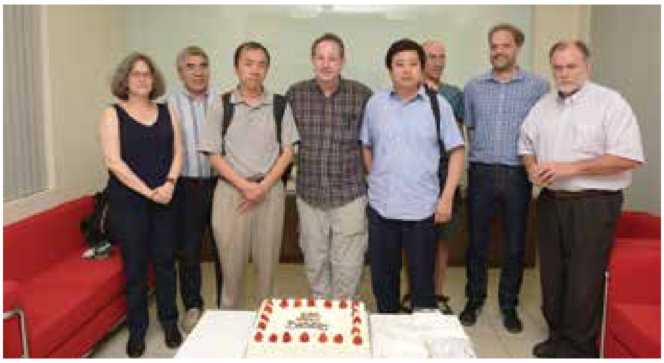
There were a total of 140 participants and among them were 40 graduate students.


Charles Semple: Counting phylogenetic networks


Daniel Huson: Phylogenetic networks and software


Jun ZHU: Network biology for complex human diseases


Mona Singh: Uncovering variation in protein interaction networks


Sharing a special birthday with Daniel Gusfield


Long-standing interactions of different networks

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IMS Graduate Summer School in Logic (15 June - 3 July 2015)

— Jointly organized with Department of Mathematics, NUS

Website: http://www2.ims.nus.edu.sg/Programs/015logicss/index.php

The IMS Graduate Summer School in Logic is jointly organized and funded by the Institute for Mathematical Sciences (IMS) and the Department of Mathematics of the National University of Singapore. The Summer School aimed to bridge the gap between a general graduate education in mathematical logic and the specific preparation necessary to do research on problems of current interest in the subject.


Andrew Marks: Descriptive graph combinatorics


Jun Le GOH: ADS does not imply SCAC


Participants would gather for discussion sessions in the afternoon sessions, with some students giving talks

The summer school consisted of 12.5 hours of lectures each week by three speakers, namely Hugh Woodin (Harvard University), Andrew Marks (California Institute of Technology) and Theodore A. Slaman (The University of California, Berkeley). Afternoon sessions were planned for group discussions and four student participants also gave talks. These additional research activities complement the main courses and foster interaction among the participants of the summer school. There were 48 participants and among them were 33 graduate students.


Communicating, relating and knowing logic

Note: The institute will be hosting another summer school in Logic from 27 June - 15 July 2016. Interested participants could visit our webpage for more details.

Combinatorial and Toric Homotopy (1 - 31 August 2015)

— on the occasion of Professor Frederick Cohen's 70th Birthday

— Jointly organized with Department of Mathematics, NUS

Website: http://www2.ims.nus.edu.sg/Programs/015homo/index.php

Co-chairs:
Jelena Grbic, *University of Southampton*
Zhi Lu, *Fudan University*
Jie Wu, *National University of Singapore*

This program aimed to explore toric homotopy theory and combinatorial homotopy theory as well as their connections with other areas of mathematics. Apart from discussing on the latest developments in algebraic topology while focusing on the applications of algebraic topology towards high technology and sciences, this program also had introductory lectures, on the subject of topology, lined up for young researchers and graduate students to nurture future development in the area of topology.

This program was organized to honor Professor Frederick R. Cohen (University of Rochester, USA), who has made major contributions in homotopy theory, particularly in the study of loop spaces, and configuration spaces, with connections to braid groups, modular forms and cohomology of groups. Although he was not able to attend the program at IMS, the program participants connected with him through a half-hour Skype session on 27 August 2015.

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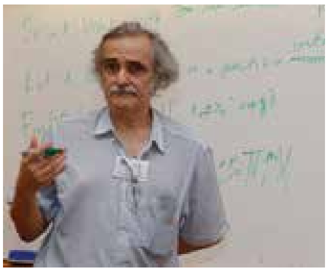

Daciberg Lima Gonçalves: Inclusion of configuration spaces on various surfaces

Vladimir Voevodsky: Univalent morphisms

Michael Farber: Topology of large random spaces

Skype session with Frederick Cohen

Enriching the development of combinatorial and toric homotopy

The program involved researchers from many disciplines, including low dimensional topologists, geometric topologists, algebraic topologists, applied topologists, braid group theorists and combinatorial group theorists. There were 11 contributed talks and five six-part tutorial lectures delivered by Vladimir Vershinin (University of Montpellier II, France), Victor Buchstaber (Moscow State University, Moscow), Stephen Theriault (University of Southampton, UK), Sergei Ivanov (St. Petersburg State University, Russia) and Michael Farber (Queen Mary University of London, UK) in the Young Topologist Seminar held from 11 – 19 August 2015. The lectures and problem discussion sessions covered many areas in topology from pure mathematics to its applications. This seminar gave young researchers an opportunity to present their work in a formal conference setting and discuss their future development with prominent mathematicians established in the area of the homotopy theory. Stephen Theriault (University of Southampton, UK), who is a top researcher in the area of homotopy theory and toric topology, introduced the notion of toric homotopy theory to the program participants. Victor Buchstaber (Moscow State University, Moscow) is a creator and leader in the area of toric topology. Michael Farber (Queen Mary University of London, UK) is a highly recognized, world eminent researcher in the area of applied topology. The Young Topologist Seminar is believed to be the first of its kind in the Asia region. Following the seminar was a two-day workshop which had ten invited talks, and a five-day conference from 24 – 28 August 2015, which had 22 invited talks.

There were a total of 90 participants and among them 25 were graduate students.

Stochastic Methods in Game Theory (16 November - 25 December 2015)

Website: http://www2.ims.nus.edu.sg/Programs/015game/index.php

Chair
Satoru Takahashi, *National University of Singapore*

The program aimed at showing the role of stochastic methods in strategic situations. Three workshops focused on different aspects of the interaction between strategy and stochastics from a mathematical viewpoint.

The Learning session started with a five-part tutorial by Sylvain Sorin (Université Pierre et Marie Curie, France), followed by a four-day workshop with 21 invited talks. The second session on Stochastic Games had six hours of tutorial lectures by Jérôme Renault (Toulouse School of Economics, France) and Johannes Hörner (Yale University, USA), and a total of 22 invited talks. The third session on Congestion Games began with Roberto Cominetti (Universidad de Chile, Chile) delivering six hours of lectures, and followed by a four-day workshop with 20 invited talks.

All these sessions adhered to the original plan, especially in terms of promoting interaction among participants

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working in different fields. The program involved scholars in mathematics, computer science, economics, operations research, probability, statistics and game theory of different denominations. There were a total of 146 participants and among them 39 were students. Results from a feedback survey showed that eight research papers/projects were initiated and/or worked on during or after the program.

Catherine Rainer: A probabilistic representation for continuous-time games

Learning procedures from a game theoretic viewpoint (From left: Johannes Hörner, Jan-Henrik Steg, Yeneng SUN and Sylvain Sorin)

Jim DAI: Stein's method and queueing systems

Obtaining an explicit expression from side observations (From left: Peter Bartlett, Csaba Szepesvári and Nicolo Cesa-Bianchi)

Strong payoff from onsite learning and game theory

New Challenges in Reverse Mathematics (3 - 16 January 2016)

Website: http://www2.ims.nus.edu.sg/Programs/016reverse/index.php

Organizing Committee

Denis Hirschfeldt, *University of Chicago*
Richard Shore, *Cornell University*
Stephen Simpson, *Pennsylvania State University*
Theodore Slaman, *The University of California, Berkeley*
Frank Stephan, *National University of Singapore*
Yue Yang, *National University of Singapore*

Reverse Mathematics is a very active research area that investigates many topics in classical mathematics and involves all major branches of modern mathematics. Over the years, many new axiom systems and techniques from other areas in mathematical logic as well as combinatorics have been introduced and fruitfully explored to study problems in Reverse Mathematics. These investigations have presented important new challenges and opened several new frontiers for research in the field.

There were a total of 19 invited talks for participants to share the latest research results. A three-part tutorial by Vasco Brattka (UniBW Munich, Germany) introduced the participants to the field of Weihrauch reducibilities which is related to reverse mathematics but not identical to it. Participants were updated on the latest research results by the speakers, and the informal collaboration between the participants have been fruitful. The connections to Weihrauch degrees gave the researchers of the program new insights. One topic arising from these discussions is the study of the Weak Ramsey Theorem by Steffen Lempp (University of Wisconsin-Madison, USA) and Henry Towsner (University of Pennsylvania, USA). Yuliya Zelenyuk (University of Witwatersrand, South Africa), who works on group theory and colourings, gave some new impulses for applying the methods of the field to a new area.

Talks were arranged only in the mornings in order to free up the afternoons for discussions. Nine research papers/projects were initiated and/or worked on during or after the program. Among the group of junior participants, there was a PhD student, Ludovic Patey (Université Paris Diderot Paris 7, France) who is very active in research and made key contributions to a paper "Closure of wqos under products" which was initiated during the program.

There were a total of 48 participants and among them six were graduate PhD students.

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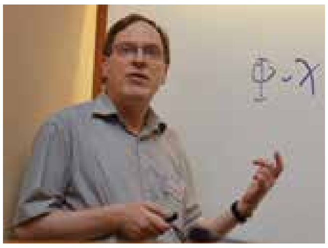
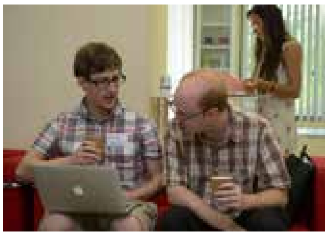


Ulrich Kohlenbach: Logical analysis of proofs in convex optimization and nonlinear semigroup theory

Vasco Brattka: A tutorial on Weihrauch complexity



How do you prove your choice? (From left: Noah Schweber and Henry Towsner)

Mathematical status remains as an open question (From left: Lu LIU, Takeshi Yamazaki, Sam Sanders and Makoto Fujiwara)

Calibrating the strength of reverse mathematics takes a combined effort!

IMS-JSPS Joint Workshop on Mathematical Logic and the Foundations of Mathematics (15 - 16 January 2016)

Website: http://www2.ims.nus.edu.sg/Programs/016wjsps/index.php

Organizing Committee

Chi Tat Chong, *National University of Singapore*
Frank Stephan, *National University of Singapore*
Kazuyuki Tanaka, *Tohoku University*
Yue Yang, *National University of Singapore*

This workshop was jointly sponsored by the Japan Society for the Promotion of Science and the National University of Singapore. In recent years, interaction among researchers in East Asia, particularly in Japan, China and Singapore in foundations and other areas of mathematical logic has increased significantly. This workshop brought together researchers from different areas in mathematical logic, in particular, proof theorists who are currently working on reverse mathematics. The first day of the two-day workshop was jointly organized with the program on New Challenges in Reverse Mathematics (3 – 16 January 2016). The second day of the workshop shifts its attention to set theory and general topics in recursion theory.

This workshop contributed to the research program in mathematical logic, in particular reverse mathematics and cardinal invariants, subjects that are of interest to researchers in both Japan and Singapore. The two-day workshop had a total of 13 invited talks. During the workshop, Keita Yokoyama reported on his recent work on the conservation results of Ramsey's Theorem for Pairs, based on joint work with Ludovic Patey, which is considered an exciting breakthrough in this area.

The discussions that took place outside formal talks allowed participants to share ideas and report on the latest progress made in their work. Three research papers/projects were initiated and/or worked on during or after the program. There were a total of 43 participants together with seven PhD students.

Frank Stephan: Semiautomatic groups and semigroups

Yiqun LIU: Another algebraic decomposition of R

Thoughts on the formalization of logic (From left: Yue YANG, Kazuyuki Tanaka and Guohua WU)

Pointing out theorems in pairs and two colors (From left: Ludovic Patey and Keita Yokoyama)

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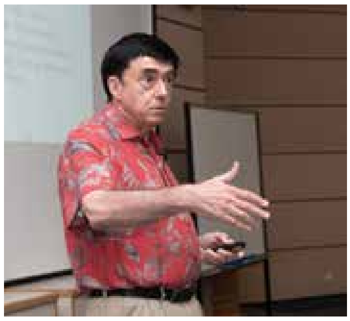
Participants of the second joint workshop with JSPS at IMS

Public lectures:

Assaf Zeevi: Turning (big) Data into (even better) Decisions

Professor Assaf Zeevi of Columbia University, USA delivered a public lecture on "Turning (big) Data into (even better) Decisions" in NUS on 17 November 2015. In the lecture, Professor Zeevi demonstrated ably how the vast amounts of accessible data are fueling new developments in statistics, computer science and decision sciences and at the same time generating fundamentally new business models as well as market disruptions. He sketched some key ideas that were driving these developments, and explained why and how machine learning ideas were playing an increasingly important role in the newly emergent field of data science. He concluded his lecture with many interesting examples from several recent application domains. A total of 102 people attended the lecture.



Stephen G. Simpson: Foundations of Mathematics: An Optimistic Message

Professor Stephen G. Simpson of Pennsylvania State University, USA delivered a public lecture on "Foundations of Mathematics: An Optimistic Message" in NUS on 6 January 2016. Professor Simpson began with the remark that mathematics had often been regarded as a role model for all of science -- a paragon of abstraction, logical precision, and objectivity. In the 19th and early 20th centuries, many areas of mathematics made tremendous progress in the rigor and logical framework. The great mathematician Hilbert proposed a sweeping program whereby the entire panorama of higher mathematical abstractions would be justified objectively and logically, in terms of finite processes. However, the publication of Gödel's famous incompleteness theorems triggered an era of confusion and skepticism. The lecture, however, ended with a high note of optimism as he gave us a glimpse of how modern foundational research had opened a new path toward objectivity and optimism in mathematics. A total of 90 people attended the lecture.

Current Program

Semidefinite and Matrix Methods for Optimization and Communication (18 January - 28 February 2016)

Website: http://www2.ims.nus.edu.sg/Programs/016semi/index.php

Organizing Committee

Rahul Jain, *National University of Singapore*
Hartmut Klauck, *Nanyang Technological University and National University of Singapore*
Troy Lee, *Nanyang Technological University*
Miklos Santha, *Université Paris Diderot - Paris 7 and National University of Singapore*

Activities

- Tutorial on Learning: 16 November 2015
- Workshop 1 on Log Rank Conjecture: 18 - 22 January 2016
- Workshop 2 on Positive Semidefinite Rank: 1 - 5 February 2016
- Workshop 3 on Approximation Algorithms: 15 - 19 February 2016

The program will cover topics in combinatorial optimization, approximation algorithms, and communication complexity and links connecting these areas. A common approach to hard combinatorial optimizations is to look at relaxations of

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these problems as linear or semidefinite programs. On the algorithmic side, one hopes to show that these relaxations can provide good approximations to the optimal value. On the hardness side, one hopes to show that (ever more complicated) relaxations are still far from the true value.

Next Program

New Developments in Representation Theory (6 - 31 March 2016)

Website: http://www2.ims.nus.edu.sg/Programs/016theory/index.php

Co-chairs
Wee Teck Gan, *National University of Singapore*
Chen-Bo Zhu, *National University of Singapore*

The program will focus on the representation theory of reductive groups over local fields and their related Hecke algebras. It covers the following three aspects of the subject:

- Classification of irreducible representations in terms of L-parameters
- Understanding and computation of invariants of representations
- Explicit constructions of representations

The program will examine recent developments in each of the three areas and highlight fruitful interactions among them. For example, there has been much work on how various harmonic analytic invariants behave under Langlands functorial lifting or theta lifting. Moreover, the generalisation of automorphic descent requires one to have a good understanding of the possible Fourier coefficients or the wavefront set of representations. Uncovering such interactions, especially unexpected ones, will be a main goal of this program.

Activities

- Collaborative Research: 6-31 March 2016
- Tutorial on Hecke Algebras by Dan Ciubotaru, University of Oxford
- Tutorial on Automorphic Descent by Lei Zhang, National University of Singapore
- Tutorials and Workshop on New Developments in Representation Theory: 8-28 March 2016
- An Afternoon of Activities, 23 March 2016
  Jointly organized with Department of Mathematics, NUS
  - Colloquium Lecture by Roger Howe, Yale University
  - Young Mathematician Lecture by Raphael Beuzart-Plessis, National University of Singapore

Oppenheim Lecture 2016 (16 – 17 March 2016)

— *Jointly organized with Department of Mathematics, NUS*

Website: http://ww1.math.nus.edu.sg/events/oppenheimlecture2016.html

Wednesday, 16 March 2016, 2:00pm - 3.30pm
LT31, Block S16, Level 3, Faculty of Science, NUS
Around the Reproducibility of Scientific Research in the Big Data Era: What Statistics Can Offer
Emmanuel Candes, Stanford University, USA

Activities held in conjunction with Oppenheim Lecture
Thursday, 17 March 2016, 3:00pm - 4.00pm
Block S17, #04-06, Seminar Room 1, Department of Mathematics, NUS
Modern Optimization Meets Physics: Recent Progress on the Phase Retrieval Problem
Emmanuel Candes, Stanford University, USA

Programs & Activities in the Pipeline

New Directions in Combinatorics (9 - 27 May 2016)

Website: http://www2.ims.nus.edu.sg/Programs/016combin/index.php

Co-chairs
Ka Hin Leung, *National University of Singapore*
Bernhard Schmidt, *Nanyang Technological University*
Qing Xiang, *University of Delaware*

The aim of the program is to bring together academic researchers in Design Theory and Additive Combinatorics to explore new techniques and problems that related these two areas. Design Theory originally deals with problems of arranging objects according to certain rules. In recent years, it has found important applications in Computer Science, Statistics, and Digital Communication. Additive Combinatorics is an area connecting Additive Number Theory and Combinatorics, which has experienced

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tremendous growth over the past decade. In particular, methods from Combinatorics have been used successfully to attack deep problems in Number Theory.

Activities

- Weeks 1 - 2, Informal Discussion
- Week 3, Workshop, Mini-Courses on Designs and Additive Combinatorics, 23 - 27 May 2016

International Workshop on Fluid-Structure Interaction Problems (30 May - 3 June 2016)

Website: http://www2.ims.nus.edu.sg/Programs/016wfluid/index.php

Co-Chairs

Boo Cheong Khoo, *National University of Singapore*
Zhilin Li, *North Carolina State University*
Jie Liu, *National University of Singapore*

Many problems in applied sciences and engineering involve the motion of geometric objects such as interfaces or filaments interacting with surrounding fluids. These problems are generally called fluid-structure interaction problems. This workshop aims to bring together mathematicians, computational scientists, and engineers having a common interest in solving fluid-structure interaction problems. The ultimate goal is to initiate new research collaborations that improve on existing techniques and generate ideas for new approaches.

Empirical Likelihood Based Methods in Statistics (6 June - 1 July 2016)

Website: http://www2.ims.nus.edu.sg/Programs/016emp/index.php

Organizing Committee

Sanjay Chaudhuri, *National University of Singapore*
Song Xi Chen, *Peking University and Iowa State University*
Malay Ghosh, *University of Florida*
Ian McKeague, *Columbia University*
Art B. Owen, *Stanford University*
Cheng Yong Tang, *Temple University*

Empirical likelihood based methods are becoming more and more popular in current statistics and econometrics. It is a semi-parametric method which allows the user to specify a parameter based model through estimating equations. However, there is no need to specify any distribution for data generation. This distribution is estimated from the data by a constrained empirical estimate. Information about the parameter is included through the constraints imposed by the estimating equations.

There are several advantages of using empirical likelihood based methods. It is usually easier to specify and handle estimating equations than a full fledged parametric model. Empirical likelihood is easy to compute. Under the true model the empirical likelihood based estimates are almost as efficient to their parametric counterparts. However, if the parametric distribution for data generation is misspecified empirical likelihood based estimates are often more efficient. These properties have lead to an increased popularity of empirical likelihood based methods in severely constrained problems.

Activities

- Tutorial on Empirical Likelihood: 6 – 10 June 2016
- Workshop on Recent Developments in Empirical Likelihood Methodology: 13 – 17 June 2016
- Workshop on New Applications of Empirical Likelihood: 20 – 24 June 2016
- Collaborative Research: 27 June - 1 July 2016

Mathematics of Shapes and Application (4 - 31 July 2016)

Website: http://www2.ims.nus.edu.sg/Programs/016shape/index.php

Co-Chairs

Ji Hui, *National University of Singapore*
Sergey Kushnarev, *Singapore University of Technology and Design* Laurent Younes, *Johns Hopkins University*

Understanding how a single shape can incur a complex range of transformations, while defining the same perceptually obvious figure, entails a rich and challenging collection of problems, at the interface between applied mathematics, statistics and computer science.

The topic "Mathematics of Shape and Applications" has traditionally been a highly interdisciplinary research area, and typically involves mathematicians, statisticians, engineers, computer scientists as well as a wide variety of clinical researchers such as neuroscientists, psychiatrists and radiologists. This is only possible due to the interaction

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and collaboration among the aforementioned different fields that has resulted in this common interest and the proposed IMS program will further strengthen such a beneficial arrangement. In addition, the proposed IMS program includes a series of tutorials that will allow local participants to quickly grasp the fundamentals of this topic before going into the deeper and more exciting open research questions.

Activities

- Summer School on Mathematics of Shapes: 4 - 15 July 2016
- Workshop on State-of-the-Art Shape Research and its Applications: 18 - 22 July 2016
- Workshop on Applications: Biomedical Imaging and Computer Vision: 25 - 29 July 2016

IMS Graduate Summer School in Logic (27 June - 15 July 2016)

... *Jointly organized with Department of Mathematics, NUS*

Website: http://www2.ims.nus.edu.sg/Programs/016logicss/index.php

The Summer School bridges the gap between a general graduate education in mathematical logic and the specific preparation necessary to do research on problems of current interest in the subject.

Activities

- Week 1: Lectures by Hugh Woodin, Harvard University
- Week 2: Lectures by Theodore A. Slaman, The University of California, Berkeley
- Week 3: Lectures by Thomas Scanlon, The University of California, Berkeley

Geometry, Topology and Dynamics of Moduli Spaces (1 - 19 August 2016)

Website: http://www2.ims.nus.edu.sg/Programs/016wgeo/index.php

Co-Chairs

Ser Peow Tan, *National University of Singapore*
Graeme Wilkin, *National University of Singapore*

The subject of this program is the topic of moduli spaces and their connections with different areas of mathematics and physics. Moduli spaces arise naturally from the study of one of the most fundamental problems in mathematics: parametrising mathematical objects up to equivalence. Understanding the moduli space and its local and global structure can often give new information about the underlying geometric problem.

The focus in this program will be on the moduli spaces of geometric structures on Riemann surfaces and moduli spaces of Higgs bundles, for which the geometry, topology and dynamics gives new information about geometric and topological problems in low dimensions.

Activities

- Workshop on New Perspectives on Moduli Spaces in Gauge Theory: 1 - 5 August 2016
- Informal discussions, research collaborations and mini-courses: 8 - 12 August 2016
- Workshop on Moduli spaces of geometric structures: 15 - 19 August 2016

Workshop on Mathematics of Information - Theoretic Cryptography (19 - 30 September 2016)

Automata, Logic and Games (22 August - 25 September 2016)

Higher Dimensional Algebraic Geometry, Holomorphic Dynamics and Their Interactions (3 - 28 January 2017)

For a full list of upcoming events, visit our webpage at http://www2.ims.nus.edu.sg/

Mathematical Conversations

Olivier Pironneau: Control theory, Computational Fluid Dynamics, Mathematical Finance >>>

Olivier Pironneau

Interview of Olivier Pironneau by Y.K. Leong

> *"Already now mathematics, in addition to its intrinsic importance, is one of the keys for the development of other sciences and of industry. Everything indicates that this already fundamental role will increase during the next century."*
>
> -- Jacques-Louis Lions (1928-2001), Speech at Opening Ceremony of International Congress of Mathematicians, Zürich, 3 August 1994

Olivier Pironneau made important contributions to control theory, fluid mechanics, scientific computing and mathematical finance.

He had his undergraduate education in *École Polytechnique* and obtained his PhD in control theory at the University of California, Berkeley. He then went to Cambridge University, UK, for a short postdoctoral stint with Sir James Lighthill (1924-1998). There he learned fluid mechanics and applied control theory to problems in fluid dynamics and, in particular, the optimal shape of airplane wings. On his return to France, he had a fortuitous meeting in a train with one of the most influential mathematicians in France in the 20th century, Jacques-Louis Lions. This led to 5 years of research at INRIA (*Institut national de recherche en informatique et en automatique*, French Institute for Research in Computer Science and Automation) and many industrial collaborations, notably with *Dassault Aviation*. In 1979 he moved back to academia, first to the mathematics and computer science department of University of Paris 13 and then to University of Paris 6 *(Université Pierre et Marie Curie, UPMC)* in 1984 and subsequently became the director of its numerical analysis laboratory. He retired in 2011 and is now an emeritus professor in UPMC.

Pironneau's research output is prodigious (more than 300 papers and 8 books). His pioneering contributions to the aviation industry included the first computer simulation of a three-dimensional, high Mach number, transonic flow around a complete aircraft (with three engine air intakes included), the Falcon 50. He did important work on domain decomposition methods with J.-L. Lions and made pioneering contributions in the use of control theory in fluid dynamics; in particular, to the solution methodology of the Navier-Stokes equations using (1) a nonlinear least squares formulation in an appropriate Hilbert space, and (2) a mixed finite element approximation in their stream function-vorticity formulation. In recent years, he has returned to mathematical finance, a subject that first attracted him in his graduate studies, and worked on computational aspects of financial engineering.

An obligation to teach computer science resulted in his development in 1987 of one of the first user-friendly software for solving partial differential equations, which eventually became one of the most widely used freely available software FreeFem++. Some of the well-known books he has written are: *Optimal Shape Design for Elliptic Systems, The finite element methods for fluids, Simulation Numerique en C++* (with Ionut Danaila, Frédéric Hecht), *Computational Methods for Option Pricing* (with Yves Achdou), *Applied Shape Optimization for Fluids* (with Bijan Mohammadi), *Analysis of the k-epsilon Turbulence Model* (with Bijan Mohammadi), *Introduction to Scientific Computing* (with Brigitte Lucquin).

In a manner somewhat similar to that of his charismatic mentor and benefactor J.-L. Lions, Pironneau has shown tremendous energy and interest in contributing to the image and service of mathematics and scientific computing within France and without. He was scientific advisor at INRIA, CNES (*Centre national d'études spatiales*, National

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Centre for Space Studies), CNE (the Commission on nuclear waste disposal) and the Finnish centre for supercomputing CSC (Computer Sciences Corporation). Currently, he is President of the Scientific Council of AMIES (*Agence pour les mathématiques en interaction avec l'entreprise et la société*, Agency for Interaction in Mathematics with Business and Society) and President of CSCI (*Comité stratégique pour le calcul intensif*, National Strategic Committee for Super Computing). He is the UPMC delegate for scientific integrity in the *Directoire de la Recherche*. In addition, he is an associate editor of several journals including the *Comptes Rendus de l'Académie des Sciences (mathématiques)*.

His awards and honors include Blaise Pascal Prize, Marcel Dassault Prize, Member of the French Academy of Sciences, Member of *Institut Universitaire de France*, Associate Member of the Russian Academy of Sciences, *Chevalier de l'Ordre National du Mérite* and *Légion d'honneur*.

On the international front, he helped to establish academic programs of study in computing in India in the late 1990s. He has been a regular visitor to the Institute for Mathematical Sciences (IMS), National University of Singapore, first in December 2003 to give a seminar on *Control of Shock Positions with Application to Sonic Booms* and then in August 2004 as a co-chair of the IMS program *Wall-Bounded and Free-Surface Turbulence and its Computation* (July-December 2004) and was back in January 2012 for the program *Multiscale Modeling, Simulation, Analysis and Applications* (1 November 2011 - 20 January 2012). More importantly, he was a member of the Scientific Advisory Board (SAB) of IMS from 2008 to 2013. It should be mentioned that Pironneau is the second French mathematician who has contributed to the development of IMS after the untimely death of J.-L. Lions, who was an active founding member of the IMS's SAB, barely two months before the official opening ceremony of IMS on 17 July 2001. When Pironneau was in IMS for the regular meeting of the SAB on 25 July 2012, Y.K. Leong interviewed him on behalf of *Imprints*. The following is an edited and vetted version of the transcript of the interview in which he traced the serendipitous journey he travelled from a somewhat aborted start in mathematical economics to the pinnacles of computational fluid dynamics and scientific computing through control theory (optimization) and then back to mathematical finance. The interview gives us a glimpse of the driving force of mathematics and computers in the aviation industry and in the understanding of some basic questions in fluid dynamics.

Imprints: You did a DEA (French Master) in mathematical economics before going to UC Berkeley for your PhD with E. [Elijah Lucien] Polak in the Department of Electrical Engineering and Computer Science. Was it a switch of research interest?

Olivier Pironneau: Yes. I was registered to do mathematical economics with a French professor but it didn't work that well. The French professor did not know the topic because he was learning the topic at the same time as I was, and so we were both at a loss. This was at the time when mathematical economics (the theory of [Gérard] Debreu) was very popular and I wanted to work in that field. But with this French professor it did not work out. So I decided that France was not well-organized for PhDs and I decided to leave and try the US. I went to the US; I wanted to do control theory which was somewhat connected with mathematical economics but only somewhat. This is why I ended up in Berkeley with Polak.

I: I notice that it was in the department of computer science and electrical engineering.

P: Yes, but control theory was taught and research done in this department. In those days, the department of operations research in Berkeley was not doing that and the department of mathematics was very pure. It was done in electrical engineering. Those were the days of systems theory. You know, the days of electronics, much of applied mathematics (in particular, feedback control) came from electronics.

I: But your work was quite mathematical, wasn't it?

P: Yes. Polak was actually specialized in optimization theory. Control theory is a special case of optimization theory in infinite dimensional space. Even though it was theoretical, the applications were very direct. You could use it in many control problems for complex electrodynamic systems or even missiles. It was not far away from applications. I was also dealing with optimization problems.

I: From Berkeley you went to Cambridge as a post-doc with James Lighthill [(1924-1998)] and then you returned to Paris *(Université Paris 6)* to do a *Thèse-d'Etat*. Was this career path planned or did it just happen?

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P: It just happened. This was one of the things (that was my luck) in my scientific career. I wanted to work in California, I wanted to stay in the US, but there was a big crisis. There were no jobs in California in those days in the '70s. I was offered a job by NASA but it was military; I didn't like it. I had heard that James Lighthill wanted to see if control theory was useful for fluid mechanics. So he hired me. I came to Cambridge, UK with absolutely no knowledge of fluids. That was strange because this was the world's best fluid mechanics department. So I had to learn the whole lot of fluids, just by myself. I learnt it by talking to people, by osmosis. This was a great experience.

I: You never did it in university?

P: Oh, just basic undergraduate courses in fluids, very little. I didn't know what a partial differential equation was, in particular.

I: I think James Lighthill did some pioneering work in fluid dynamics.

P: Yes, he is one of the world's most famous fluid dynamicist. I had the chance to work with him on the optimal shape [of wings]. I kept my mathematical specialty for fluids and I did control theory for fluids within the interest of the department which was called DAMTP [Department of Applied Mathematics and Theoretical Physics]. This was a great experience. It was a postdoc. So after two years, I had to go back. I went back to France. I met Jacques-Louis Lions in the train on the way to Paris. This was another [stroke of] luck. He asked me, "What do you do?" I told him he had been my professor when I was at *École Polytechnique*. Of course, he did not remember me. "Ah, you have been in Great Britain," he said, "That's interesting. I need some contacts in Great Britain." I told him everything I knew, and then he offered me a job. Just because we met in a train! I sent him my papers and he was quite excited.

I: You also did this thesis *[Thèse d'État]*.

P: Yes. I came to INRIA *[Institut national de recherche en informatique et en automatique*, French Institute for Research in Computer Science and Automation] to do research in applied maths and computer science. I was a researcher. He [Lions] told me if I should plan my career as a professor later, I need a *Thèse d'État*. This is compulsory to be professor. I told him, "Isn't my PhD enough?" "In principle, it is," he said. "Look, you have done some research. You just have to translate it into French. So why don't you do it and then we forget about it." It wasn't really very difficult for me.

I: Was Lions the Director of INRIA?

P: No, he was the director of the applied math section of INRIA in those days.

I: You more or less succeeded him at INRIA, isn't it?

P: I had a fast promotion because Lions became the head at INRIA. [Roland] Glowinski left for the US. So I was third in the line. So they gave me the directorship of the applied math section, actually one part of the applied math section.

I: You wrote MacFem/ PCFem in the late 1980s. Was it the precursor of the current freeware FreeFem++ ? If so, how did it develop into the latter?

P: This is again one piece of luck in my career because I got a position at a French university in Paris, called *Université Paris Nord* or Paris 13, on the condition that I teach computer science. So I had to learn computer science; in particular, I learned the theory of compilation and so I had this idea of having a user-friendly language for people who do PDE (partial differential equations). Those were the days of Apple II and then the PC. And I could use it in my teaching as well. I did the first version and I wanted to sell it.

I: It was in Pascal, wasn't it?

P: It was in Pascal and I created a company with a friend of mine and we sold it. I think we sold about 100 copies. The lesson that I learnt is that if you really want to make business in a software company you should devote yourself full-time and you should have a strong sales department. I was not interested in that and so I backed off and I decided to give it away. When I transferred to Paris 6, I had to teach a course on computer science tools for applied mathematicians. The same problem came out and then I had a math colleague, very advanced in computer science. We rewrote together the MacFem, FreeFem in C++ and then we gave it away as open source. This is the first of this type of software which is popular now. You can download it from www.freefem.com and I worked on it for 10 years. I got too busy and my

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colleague Frédéric Hecht took over and made it a marvellous product. It is an incredible product because of him although I started it. He deserves the credit.

I: Is it freely used nowadays?

P: Yes. It's popular all over. We get people from China, people from Philippines, whatever, they all write to us – you know, how do you do that, can you extend it to that? We answer them.

I: Some of your papers dealt with problems in aerodynamic flow. Have you done any consulting with the aerodynamic industry?

P: Yes, there is a French company called *Dassault Aviation*. This company is very open to research. Right from the beginning in the '70s when I came back to France they approached us and asked me to help them in the flow simulation for the airplane. Although I never consulted (because they don't believe in consulting, they can have it for free), they backed me in getting a contract with state agencies for military and commercial research. I got quite a lot of money to develop my team and we did some great work. I think we were the first to compute the flow around a complete airplane. This was in the beginning of the '90s. We were in competition with Anthony Jameson. He was working for Boeing and Grumman. I think we did something that, in those days, they couldn't do. Now he is ahead and some of those things made him famous.

I: Did you have anything to do with the Concorde?

P: Nope. The Concorde is the other French company which is now called *Airbus* but in those days it was *Aérospatiale*. It's a joint program with the British people and a good deal of the aerodynamics was done in the UK. In fact, Lighthill was involved but I was too young for that. The Concorde was 5 years earlier. I was too young to contribute in any case. But to *Airbus*, for example, I did not contribute directly, but our methods have been adopted by them. Now *Airbus* is an European consortium but there are state agencies which contribute to the aerodynamics of the airplane. One is called ONERA *[Office National d'Etudes et de Recherches Aérospatiale]* in France and another DLR *[Deutsches Zentrum für Luft- und Raumfahrt e.V.*, German Aerospace Cente] in Germany. If you want your ideas to be used within the aviation industry it's a long process. You have to give a proof of concept. They will pay for PhD students to test it and then test it in their configuration. Only then can it be used.

I: In the old days, they used to use the wind-tunnel. Do they still use the wind-tunnel?

P: Yes, they use it for certification. It's compulsory, but actually, if you ask me to fly an airplane which has not been tested in the wind-tunnel I would be confident. I would fly it, knowing for sure that it is properly designed. You don't need the wind-tunnel. It's a big revolution.

I: A number of your papers are jointly written with researchers in other countries and often with more than one author in different countries. How is such collaboration conducted?

P: I think there is no rule. It just goes, it's difficult to plan. I'm not particularly a good example for co-operation, actually. Most of my work, I did alone. There are many people who are more talented for co-operation than I am. Although I did work in co-operation, we did in blocks separately. In one case I would be invited for a month and the guy says, "I have this idea." I say, "I think I can help you in there." And we write joint papers, which is usually the case, or else I get a PhD student and then I contribute to his thesis and I write my name on it. As you grow older, you know, you get a young guy and you give him an idea. Maybe it takes you 5 minutes and the young fellow feels obliged to put your name on it because the core idea is yours. I think it's a bit like cheating. Some of my papers are like that.

I: What about email? It's widely used.

P: Yes. In one case I had an interesting paper with a Japanese. We met and discussed five minutes and we decided that we could do it. We did it entirely by email. Yet most of the time I think you need to meet.

I: It appears that the style of research in applied mathematics like computational fluid dynamics and control theory is becoming highly collaborative resulting in many-author papers, very much like research in biology or experimental physics. Does this reflect a fundamental difference between the way of thinking in applied mathematics and that in pure mathematics?

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P: That's a very interesting question. In the scene of applied mathematics, half of the fields are now very difficult to do by one single person. It's team work. Anything to do with big computing using super-computers, you cannot do it alone basically. The people who do it in teams get much better work, you know, better graphics, details and so on. You can be a genius, invent new methods and write a code much better than a team. I totally believe in that. But in the end you have to be within a team. Somebody has to write the software. Some PhD student has to help you. So times have changed.

I: From a physical point of view, is it not fair to say that the Navier-Stokes equations must have a unique solution under a given set of initial conditions for a given fluid even though the solution may not be expressible in closed form? Also, in principle, the equations can be solved computationally using the computer. When then are the equations considered to be "truly" and "finally" solved?

P: You know there is a Clay [Mathematics Institute] Prize for this problem. It's not so much that you want a closed solution of the Navier-Stokes equations – everybody forgets about that. The problem is that the Navier-Stokes equations are not well posed because we don't know how to prove unicity in 3D. Either it is smooth and we do not know how to prove it has a solution or it is not smooth and may have several solutions. The problem is open. It's a mathematical question and this mathematical question is also a physical question. Some people say, "Well, the Navier-Stokes equation is not the correct physical model." People who work in engineering and physics have no philosophical questions of that type. They compute, first of all. They try to simplify the equation and write it in explicit form or they compute. They are never blocked by not finding a solution or not being able to compute a solution. In practice, this is not the problem although it is a very interesting and very hard mathematical problem. The practitioners are much more interested in turbulence. Turbulence is a real mathematical and engineering problem. We know only two things about it – the Kolmogorov scale [Andrei Nikolaevich Kolmogorov (1903-1987)] and the wall log scale. These two facts can be reproduced; anytime you make an experiment you can reproduce these things. We don't know how to prove them. It's an open mathematical problem. And you are concerned with it every day – the weather is controlled by turbulence. Maybe "control" is not the right word.

I: Is turbulence governed by the same equations?

P: Yes, but it's very hard to compute.

I: But in principle, it's possible to compute.

P: In principle, if you give me a big enough computer, I can do it. I don't think I will be stuck by the fact that the solution is not unique, maybe there are more. I would like to be able to compute the mean flow without having to compute all the small eddies which I don't care for. So an understanding of turbulence is necessary.

I: But physically the solution must exist.

P: Yes, but you don't want to have a model which does not have a unique solution. Which one is the correct one? You know, if it is not unique, it bifurcates at some point, or something. We don't know any of these.

I: Any final solution in sight, within say the next ten years?

P: I don't know. You ask the astrologer *[laughs]*. This problem has been around for 100 years and there is very little progress. Kolmogorov is the only one. Wall log layer is an experimental observation, maybe by von Kármán [Theodore von Kármán (1881-1963)].

I: Has the use of computers contributed to any breakthroughs or to the formulation of new concepts in fluid dynamics?

P: Sure. The use of computers in fluid dynamics has revolutionised the field. The field has not recovered from that. Before, you have people who have been doing simplification of the Navier-Stokes equations for special cases and the other guys were testing whether the simplification was okay. After that nothing is left but these two. People just say, "We have this engineering problem. We want to compute it." Then the theoreticians have gone to the most interesting problem of fluid dynamics which is nowadays in astrophysics, understanding the formation of the stars. This is a fluid problem. The process of computing is extremely important. It's a tool. You still have theory and experiments but you also have computing. It's one third of each.

I: Do I understand that the computer actually has given rise to new conceptual ideas?

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P: No. I think it gives new tools to test ideas but it also gives new tools to solve problems. If your problem is to build an efficient car engine where you have combustion chambers to optimize, the theory is one thing but most people who want to optimize the design would just do it by computer.

I: Can the methods of fluid dynamics be applied to problems on a quantum or cosmological scale?

P: For an answer, we can look at astronomy. You know, the discovery that more than 90 percent of the energy is dark, which means that we don't know what it is and we don't know whether it is real or not. I call this real research. This is a major hypothesis in cosmology and fluid mechanics. You know, the only way we can test it is by simulation and the simulation is done by computational fluid mechanics, by vortex methods for compressible fluids. Because it is a plasma, highly compressible, the equations of radiation are written with vorticity theory. Very complicated.

I: You mention dark matter. Is it some kind of medium or gas or something like that?

P: We don't know. You have dark energy and dark matter. If you don't put dark energy in the model for the simulation of the equations of the universe after the Big Bang, you can't explain the expansion of the universe. And then dark matter is also something which computational astrophysicists feel is needed. Dark matter is also necessary to make a correct simulation of the universe. With these two hypotheses, they are able to reproduce the creation of galaxies, which is not bad. This is quite a fantastic discovery.

I: Is it dark because it has not been observed?

P: It has not been observed. The hypothesis is put and then you see that the consequences are correct. More than half of the astrophysicists don't agree at all. It's not accepted yet but it looks convincing.

I: Does dark matter obey the usual laws of physics?

P: Yes, and with simulation they can tell you where is dark matter. You won't be able to see it with the instruments but someday they will measure it, I don't know. It's like the black holes. In the beginning, you have no way of exploring the black holes because all the light will become invisible but now we have ways to infer that the black hole is there, what is its role and so on.

I: Should computer programming be made compulsory in the undergraduate curriculum?

P: Oh, yeah, it's a big debate. Undergraduate, I would think so. In fact, do you think people need to speak English? So, the answer at the time you ask the question is "No" but later in your career, the answer is "Yes". So you do need to get by with English. If you take somebody who is destined to be an engineer or a scientific career with engineering or otherwise, if he does not know programming, he is crippled in his work. He will rely on other people's work; he will not understand what he does. To me, the question is slightly different. Everybody needs to learn programming but how much do you need to learn, that's the big question. I think everybody needs to know what it is and how it works. Whether everybody needs to be fluent, I don't think so. This is too much to ask. Also, another reason why you should be exposed to programming is that the later you learn it the more difficult it is. It's like natural languages.

I: I think you know that Jacques-Louis Lions was one of the founder members [of the IMS Scientific Advisory Board] before he passed away. How much influence did he have on you?

P: Very strong. I was closely associated with him right from the meeting with him in the train. I have been working in his team and have been his "foreign minister" when he was head of INRIA; I was taking care of foreign relations. When he was consulting with *Dassault* he created a joint centre in my university and I was head of it. So I have been associated very closely with him. In his later work on domain decomposition, he did it essentially with me. I can tell you that Lions is a very influential person because in France mathematics is traditionally very pure and he has shown that you can do good mathematics and really good applied mathematics. He did it himself. Then because he was very charismatic, all those who met him were receiving energy for their tasks. He gave them means to work, he gave them positions, he told them to go and see such and such and get some contract money from such and such organizations. He was extremely influential. His international career is a little bit harder to assess. The world is vast but wherever he went, it's the same thing. He inspired people to do things,

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he gave them confidence in whatever they were doing. He showed them that applied mathematics is not a joke, that it is very good mathematics and has very useful applications.

I: It's quite unfortunate that we didn't have him in the Advisory Board for long.

P: Yes. You know, I met great people in my career. I met Jacques-Louis Lions, James Lighthill and some other people who are equally incredible. Jacques-Louis Lions is certainly the man who is the most charismatic, the most well-rounded in the sense that as a human being he is also incredible.

I: What about James Lighthill? How do you compare him with Lions?

P: James Lighthill was incredibly intelligent. He was also amazing. You know, there was a strike in the post-office in England. Somebody at a dinner said to him (he was criticising), "Why don't you set it right?" and he said, "Okay." And he did. He was head of the research centre at British Aircraft Corporation. There was something in those days like 200 researchers and he would see each one of them once a week or once every two weeks. Incredible power of work. He was very good, very brilliant, impressive but he was not charismatic. It's not like when he went to see you, you would go back with a lot of ideas. He wasn't like that.

I: I suppose Cambridge is a bit more academic.

P: No, he was head of research in England for Concorde. But because he was so brilliant he was a little detached from normal human beings.

I: British style, I guess.

P: Yes, you know, a bit of a gentleman.

I: What advice would you give to students who want to get into computational fluid dynamics or applied mathematics?

P: In these days, I would tell them to be at the interface of something. To be a mathematician in applied mathematics, the computing facilities are very, very good. If you can also add a very good knowledge or understanding of an applied field, then you are safe in two respects. First of all, you will see completely that what you do is useful. Secondly, you will participate in research. We are living at a time when computer science and therefore mathematics as well are invading all fields. And the difficulties that the traditional chemists or geologists have are that they don't know enough mathematics and computer science to participate in the development of the software. They are just software users. But for somebody who is trained in applied math, it's much easier to learn geology, for example, and to be able to talk to people and then by osmosis you learn much more and then you are in a very powerful position. So the future is to be at the interface between an application field and the computer and applied math. Probably, as we said earlier, belong to a good team. This is the kind of advice I would give them. And then select the fields of the hot topics at the moment … you know, everybody wants to lean finance. Finance is okay, it's a good thing, but chemistry, astrophysics and maybe economics, all these fields really need good mathematicians.

I: But you never really went back to economics.

P: No, I do mathematical finance; 60 percent of my current mathematical activity is in mathematical finance. I wrote two books on it.

I: It's your first love.

P: Well, finance is not really economics. I wish I could do economics but economics is in a really weird state.

I: It's not the same as finance?

P: No, in the mathematical theory of Debreu on economics there is price but there is no money and so this is one of the things which are missing as I understand it. Specialists in economics are at a loss because the stock market is an engineering system of money and finance. Yet there is a strong connection with economy but nobody knows how to model both. We know how to model economy, we know how to model finance but we don't know how to mix both.

I: What about students? You had many students before?

P: I had many students. My favourite student is a PhD student. Although I had a lot of interesting interaction with Masters students, I think the professor can give inspiration to a Masters student, but it is difficult for a professor to get

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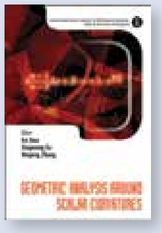
inspiration from a Masters student. But to get inspiration from a PhD student to a professor is the usual thing and there is nothing more joyful in the life of a professor than having seen some genius in a PhD student. This is really the best thing that can happen to you. I have had some very talented PhD students.

I: Such as?

P: Frédéric Hecht who is such a talented computer scientist and mathematician. I had Bijan Mohammadi who is now head of Cerfacs *(Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique)* [from 2010 to 2013] for computing for CFD. He's like a good gardener. You know, if I grow it on my own it will be so small, and a good gardener will grow it so big. When you program, there is a little bit of that too. He can write computer programs that I could never dream of doing. He's from Iran but he left Iran. And then I had Yves Achdou, one of the best French mathematicians at the moment. Who else? You have to be careful because if you put that down, all the others will be offended. There are many others who cannot come up to my mind directly. I had about 30 PhD students.

Publications >>>



Volume 31:
Geometric Analysis around Scalar curvatures
Edited by **Fei Han** *(National University of Singapore, Singapore)*, **Xingwang Xu** *(National University of Singapore, Singapore)*, **Weiping Zhang** *(Nankai University, China)*

Publisher: World Scientific Publishing Co. Pte. Ltd.
Edition: July 2016, 250 pages.

Order direct from publisher at
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Volume 30:
Modular Representation Theory of Finite and *p*-Adic Groups
Edited by **Wee Teck Gan** *(National University of Singapore, Singapore)* and **Kai Meng Tan** *(National University of Singapore, Singapore)*

Publisher: World Scientific Publishing Co. Pte. Ltd.
Edition: April 2015, 260 pages

Order direct from publisher at
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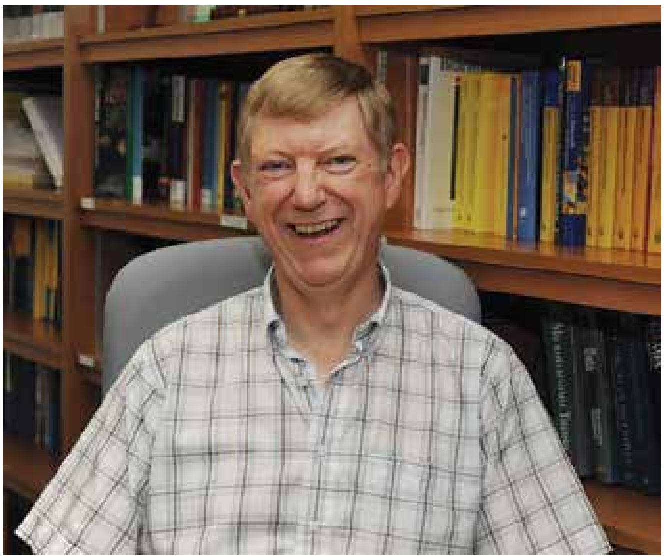
Iain Murray Johnstone: Dealing with High-dimensional Data – Wavelets, PCA, RMT >>>



Iain Johnstone

Interview of Iain Murray Johnstone by Y.K. Leong

> *"The coming century is surely the century of data. . . . Two of the most influential principles in the coming century will be principles originally discovered and cultivated by mathematicians: the blessings of dimensionality and the curse of dimensionality."*
>
> – David L. Donoho

Iain M. Johnstone is one of the world's leading theoreticians in statistical decision theory and has contributed to the theory and application of new methods of analysis of high-dimensional data, and has been a statistical collaborator in medical fields like cardiology and prostate cancer research.

Born in Melbourne, Johnstone grew up in Canberra where he obtained a National Undergraduate Scholarship in 1974 to study at the Australian National University (ANU). After obtaining his BSc (Hons) and MSc, he won an ANU Travelling Scholarship to do his PhD at Cornell University. He then joined the Department of Statistics of Stanford University in 1981 as Assistant Professor and rose through the ranks to become Professor of Statistics and Professor of Health Research & Policy (Biostatistics), a joint appointment in Stanford's School of Medicine, in 1992. He has been the Marjorie Mhoon Fair Professor in Quantitative Science since 2005. He has served as Department Chair, Senior Associate Dean for Natural Sciences and Vice Dean for Academic Planning in the School of Humanities and Sciences.

He has been invited to France as visiting professor at University of Paris VII, XI and Centre Emile Borel. He was SERC Visiting Fellow at the University of Bath, UK and a member of Mathematical Sciences Research Institute, Berkeley. Since 1993 he holds an ANU Adjunct Professorship in the Mathematical Sciences Institute and School of Finance, Actuarial Studies and Applied Statistics.

In the wake of the sensational discoveries of wavelet theory in the late 1980s and early 1990s followed a series of collaboration with his famous Stanford colleague Donald Donoho and French mathematicians Dominique Picard and Gérard Kerkyacharian on the use of wavelets to optimally remove noise from certain kinds of signals and images. Johnstone made important contributions to wavelet-like methods in estimation theory, asymptotics and application areas, simulation methodology, volume tests of significance, hazard rate estimation and maximum entropy methods. One particular off-shoot is the efficient Donoho-Johnstone soft-thresholding algorithm which is widely used in statistical and signal processing applications and which is a beautiful interaction of harmonic analysis and approximation theory with statistical decision theory.

In principal components analysis (PCA), he (jointly with Arthur Yu Lu) gave a consistency condition for standard PCA of high-dimensional data. In recent years, he has applied random matrix theory to the study of high-dimensional multivariate statistical methods such as PCA and canonical correlation analysis, and in particular, to the distribution of the largest eigenvalue of random matrices.

His numerous research papers cover both theoretical and methodological aspects of statistical decision theory. According to the November 2003 issue of *AmStat News*, Johnstone was the second most-cited statistician (after David Donoho). In a study by Thomas P. Ryan and W. H. Woodall on the number of citations of papers in statistics and probability published in 1993-2003 by certain leading journals, his two joint papers written with Donoho were ranked within the top 5 and top 15 respectively: *Ideal Spatial Adaptation by Wavelet Shrinkage* and *Adapting to Unknown Smoothness via Wavelet Shrinkage*.

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Since 1980 he has done collaborative work with Stanford's medical researchers in cardiology and prostate cancer and this has resulted in more than 20 joint papers published in refereed medical journals. His consultation work extends to other technological companies outside of Stanford. From the 1990s onwards, he goes back to Australia once or twice each year to renew academic and social links with statisticians in ANU and Melbourne University. During his visit in 2006, he served as an international reviewer in the National Strategic Review of Mathematical Sciences in Australia.

He has received numerous awards and honors for his research contributions, notably the Presidential Young Investigator Award, Royal Statistical Society Guy Medals in Bronze and in Silver, Guggenheim Fellow, Alfred P. Sloan Research Fellow, COPSS (Committee of Presidents of Statistical Societies) Presidents' Award, Membership of American National Academy of Sciences and Academy of Arts and Sciences and International Statistical Institute, and Fellowship of American Association for Advancement of Science, Institute of Mathematical Statistics and American Statistical Association.

He has been invited to give lectures at major scientific meetings throughout the world; in particular, the Le Cam Lecture (Societé Française de Statistique), Wald Lectures (IMS/Bernoulli World Congress) and a plenary lecture at the International Congress of Mathematicians.

He has served on the editorial boards of major statistical journals like *Applied and Computational Harmonic Analysis, Bernoulli, Annals of Statistics, Journal of the American Statistical Association, ESAIM Probability & Statistics* and *Australian Journal of Statistics*. In addition to offering his professional services in advisory and executive committees of scientific organisations like NIH, NRC, NSF, IMS (as President) and Bernoulli Society, he has been actively involved in organising committees of international workshops, conferences and meetings in North America, Europe and Australia.

In 2012, he was invited to Singapore to give talks in the workshops of two IMS programs *Random Matrix Theory and its Applications II* (18 June - 15 August 2012) and *Meeting the Challenges of High Dimension: Statistical Methodology, Theory and Applications* (13 August - 26 October 2012). He also gave an invited seminar at the Division of Mathematical Sciences, Nanyang Technological University. On behalf of *Imprints*, Y.K. Leong interviewed him on 29 August 2012. The following is an edited and vetted transcript of the interview which traces his seamless path from Canberra to Stanford and which gives an extraordinary example of how mathematics can be used to advance theory and methodology in statistics and to contribute to the fight against diseases in medicine.

Imprints: You did your B.Sc. and M.Sc. at Australian National University and then went to Cornell University for your PhD. Why did you choose to go to Cornell?

Iain Johnstone: At that time it was common for Australians to go overseas for doctoral studies. The tradition had been to go to England but at ANU there were several recent graduates from the United States and so I considered both the United States and England. The US system seemed to me to have the advantage that you could choose your supervisor after you arrived rather than having to take a chance on somebody unseen. So my choice eventually came down to Stanford and Cornell. It seemed that at that time if I chose Cornell I would not have to choose between statistics and probability in advance because Cornell was strong in both. In Stanford probability was more in the maths department then although now they have joint appointments for probabilists in both the maths and statistics departments.

I: After Cornell you went to Stanford University and, except for one year, you have been there since 1981. What is it about Stanford that attracts and binds you there for so many years?

J: Stanford has been a special place for statistics ever since the mathematics department chair *Gábor Szegő* [(1895-1985)] famously said to the enterprising young Albert Bowker [(1919-2008)] (who was later to become chancellor at Berkeley), "Young man, what you do is very interesting, but it isn't mathematics." And so the Stanford statistics department was born. Bowker assembled many luminaries including Charles Stein, who wouldn't take the McCarthy era oath of allegiance at Berkeley. Ever since, Stanford has had an inspiring group of department members, post-docs and students. Bowker established an important tradition which was joint appointment of staff between statistics and economics, and geology, and education, and medicine and so on. Since then Stanford has nourished the interplay

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between theory and methodology and applications, to the benefit of all three.

I: Was Bowker a probabilist?

J: He was a statistician. The university has always supported the statistics department. We were given our own building 15 years ago. Its excellent location is near many of the science departments and the medical school. For me personally, Brad Efron and Persi Diaconis were wonderful mentors. I have enjoyed and learnt from many collaborations with colleagues there, especially David Donoho. And again on a personal note, California is in several ways close to my native Australia in climate, landscape and flora -- there are gum trees in both places, for example.

I: It seems to me that Stanford staff are very loyal to the department. Most of them have been there a long time, for example, David Siegmund, Charles Stein, isn't it?

J: Yes, I think this is probably what, in Markov chains, one calls an absorbing state [*laughs*]. Some people have left but many stayed.

I: I notice that you have a kind of permanent position at ANU since 1993. Do you go back to Australia often?

J: I try to go back once or twice a year and keep academic ties in ANU and, to a lesser degree, Melbourne. And my family ties in Canberra play a role, of course. The title of adjunct professor makes it sound a bit more formal than it really is. It gives me a wonderful chance to work and interact with the staff there – Peter Hall [(1951-2016)] at ANU and then Melbourne, and Alan Welsh and Michael Martin in Canberra. It's non-salaried, though from time to time they might ask me to help with ANU matters or occasionally on a broader topic like the 2006 review of mathematical sciences in Australia.

I: You have been honored by leading professional statistical bodies in the US, but in your homepage you are described as a biostatistician. Why not a statistician?

J: The answer is rather prosaic. It mostly shows my incompetence at webpages. The web-page text was written a long time ago perhaps by somebody for another purpose, in a rush for a deadline. I always wanted to make it more accurate and informative. Periodically I would ask people and the answer would always be "Learn html!" or some other user-unfriendly tool. And I didn't want to learn html. Many people manage webpages just fine but somehow I haven't.

I: In the 1990s you achieved a ranking as the third-most-cited mathematician in the world because of your papers on wavelets and noise-reduction methods in signal and image processing. That seemed to be a diversion from statistical problems. How did this come about?

J: It didn't seem like a diversion at that time. In 1988 and 1989 David Donoho and I had been working on a mainline statistical problem – estimation of the mean of a high-dimensional multivariate normal distribution subject to a sparsity-type constraint on the mean vectors. For example, you might require that the sum of the absolute values of the coefficients would be bounded or the number of non-zero coefficients would be relatively small. I remember that David had heard around that time about the explosion of work in wavelets that was beginning and, in particular, that you could characterize many spaces of functions by the properties of their wavelet coefficients. So we were particularly fascinated by the bump algebra which characterizes the class of spatially inhomogeneous signals in terms of the L1-norm of the wavelet coefficients appropriately weighted across the scales of the wavelet transform. This was an "ah-ha" moment because we were able to take our work on minimax risk for L1-balls that we had been doing before and lift it up to function estimation. We both went to Paris at various times and we worked with Dominique Picard and Gérard Kerkyacharian to study many important cases. Wavelets are a wonderful tool for statistical theory and at the same time they are computationally concrete enough for one to develop algorithms, examples and software that have some influence in signal processing.

I: I think, to the untrained layman, wavelets are not that statistical, isn't it? They are not computational.

J: That's true at first sight, but really they provide the orthogonal structure and the localization which are just the right tools for developing some statistical theory about spatially inhomogeneous functions and how to estimate them optimally.

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I: You have recently done some important work in random matrix theory (RMT). I understand that RMT started from some work of Eugene Wigner [(1902-1995)] in nuclear physics and various versions of it seems to have found their way into so many fields. Are they ad-hoc methods or are they manifestations of a deeper underlying theory?

J: A very long answer. While the credit is universally and justifiably given to Wigner for RMT in physics, as a statistician I have to recall that in one sense random matrix theory began in 1928 with the efforts of Sir Ronald Fisher (1890-1962), and John Wishart (1898-1956) who described the distribution of sample covariance matrices and eigenvalues derived from n observations on a *p*-dimensional normal distribution. 1939 was truly a banner year for multivariate statistics because giants like Ted Anderson, Fisher and Abraham Girshick (1908-1955), Alexander Mood (1913-2009) and S. N. Roy (1906-1964) essentially simultaneously, and mostly independently, derived the distribution of the sample eigenvalues under the null hypothesis. The settings were what the random matrix theorists later called the Laguerre and Jacobi Ensembles. Since I am not a physicist I can't speak about the correct place of RMT in physics. In mathematics, in addition to many rigorous results, random matrix theory has also provided fruitful and inspiring analogies such as the similarities between the Gaussian ensemble of unitary matrices and the zeros of the Riemann zeta function. With regard to statistics, maybe I can say a little bit why RMT methods hold some interest. My own interest was kindled by hearing Percy Deift talk about his celebrated work with Jinho Baik and Kurt Johanssen on using RMT for describing the distribution of the longest increasing subsequence of random permutations. As a long-time denizen of Stanford's Sequoia Hall, I had often heard Charles Stein say that the sample eigenvalues of covariance matrices should be shrunk. It seemed that we should be able to borrow from the many advances in RMT to say things about large covariance matrices. And so it turned out, and there is active work by many people now. So one point of view is that RMT is fundamental for multivariate statistics since it studies the eigenstructure of sample covariance matrices, which has been popular ever since the introduction of principal components analysis by Harold Hotelling (1895-1973)] in the 1930s. Now, a more skeptical view may be that truly higher-dimensional data often does not possess the degree of regularity (through independence and homogeneity conditions) that current RMT often assumes. So both views probably have merits. The details of any given problem will be crucial to decide which.

I: So there is an underlying theory behind all the methods?

J: Well, yes. The physicists have talked about ensembles having important invariant properties and the statistics of multivariate normal distributions is a key starting point although we eventually want to know what happens in situations that go beyond that.

I: Why are the eigenvalues of covariance matrices so important?

J: In principal components analysis one looks for a change of basis for the data in which one can describe the modes of variation, and the eigenvalues describe the degree of variation in the new coordinates. You look for the direction of largest variance and then at the orthogonal direction of next smallest variance and you hope that you might reduce the dimensionality by throwing away most dimensions in which the variance is very small. So you might project your data from 100 dimensions into two. That's the idea of the eigenvalues.

I: You did significant work on the largest eigenvalue of random matrices, isn't it?

J: What I worked on was to develop accurate approximations using the Tracy-Widom distribution, named for Craig Tracy and Harold Widom, which turns out to apply to the largest sample eigenvalue in statistical situations such as principal component analysis. Universality results in random matrix theory would lead one to predict that the result should be true but I was interested in making sure that the approximations were second-order accurate and so applicable to relatively small size matrices.

I: Is your work applied to other fields?

J: The use of the Tracy-Widom distribution for covariance matrices has been taken up in population genetics by people such as [Nick] Patterson, [Alkes L.] Price and [David] Reich in detecting and adjusting for population substructure, for example in genome-wide association studies. So there have been important uses and widely used software in genetics.

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I: Nowadays we are swarmed with so much data that even computers cannot cope with them and the traditional wisdom is that more data means more information. Could recent work on high dimensions – the so-called "curse of dimensionality" – be an indication that there is a fundamental limit on the information that can be extracted from any amount of data, no matter how large it is?

J: One possible answer is a definite "yes" and "no". [*Laughs*] Let me first talk about the "yes" side. Theoretical statisticians and information theorists are often interested in looking into the limits in our ability to estimate an unknown quantity. Careful statements about such limits always require that the hypotheses be laid out. Of course, that's the rub. For example, with a single unknown parameter with n independent observations you can typically not estimate that parameter with precision greater than a constant over the square root of n, and that constant is determined by the distribution of the data. But if you change the assumptions so that the parameter is at the end point of an interval then the rate of estimation improves to $1/n$. When you go to high dimensions, which might be loosely interpreted as many unknown parameters, the role of the assumptions become even larger. If you have n observations on a vector of dimension p when p is comparable to n, which is a popular model for enthusiasts of random matrices, there is no hope to estimate something as basic as the covariance matrix between the p variables without some extra information because you have as many as $p^2/2$ parameters in a general instance. Of course, in many situations we will have extra information that will make the problem accessible. This is a hot topic now and many participants in the IMS [Institute for Mathematical Sciences] program are active. There are many plausible ways to assume sparsity or low dimensional structure and then it is possible to formulate limits to estimation as the data increases under a given model of sparsity. Now let me turn to the "no" side. There is an important mathematical notion of concentration of measure that appears a lot in the study of high-dimensional statistical models. One non-technical way to say this is that if you choose a point at random inside a high-dimensional sphere, this point will be, with overwhelming probability, close to the surface of that sphere. This gives a regularity to some high-dimensional models that makes many theorems possible. So some people talk about the benefits of dimensionality but, of course, there is no free lunch and this brings me back to your question. In many theoretical results about the limits of information there are some assumptions imposed on some kind of homogeneity, full independence or condition of similarity of distribution. The result is often informative and beautiful. However, when you think about some of the different types of data (huge, as you mentioned), one recognizes cascades of genetic data, consumer data, personal genome data and so on. So one slogan you hear is "More data is not just more data, more is different." So there are limits to information derived from homogeneous models, but that is certainly not the end of the story.

I: Is there such a thing as a principle of uncertainty in this kind of high-dimension things?

J: Well, there are many uncertainty principles related to this. Even with one parameter you can express the Cramer-Rao lower bound [Harald Cramér (1893-1985), Calyampudi Radhakrishna Rao] essentially as a form of the uncertainty principle. It's mathematically similar.

I: How did you get into collaborative work in cardiology and prostate cancer? Has it led to any potential treatment for heart diseases or cancer?

J: It was through my joint appointment in the biostatistics department in the medical school of Stanford. One of the roles of the biostatistician is to collaborate with medical investigators, for example, in their clinical research and so we often meet with the physicians to discuss their research and some of those discussions turn into longer term collaborations. For example, I might mention my collaboration with the distinguish urologist and surgeon, Dr Thomas Stamey in the late '80s and '90s. Dr Stamey was one of the first to describe an association between high levels of prostate specific antigen (PSA) and clinical stage in volume of prostate cancer removed by surgery. Now, in subsequent years, screening of PSA levels in asymptomatic men became very common, basically men over 50. I recall that Tom would say, from the early stage of our work, how slowly the tumour grows in many cases so that many men with tumours would normally die of other causes. So he had a growing concern with the automatic use of PSA screening and, to his great credit, as the data on screening accumulated, he added his voice against routine screening. This was a controversial debate, but now discussions between the doctor and the patient are recommended prior to any decision to undergo screening.

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I: What about the treatment of the cancer itself?

J: With cancer treatment – I haven't had so much direct involvement. We were looking more at what one could learn from his accumulated database of surgical cases.

I: Just now you mentioned the prostate screening. Does it mean that a lot of these screening is unnecessary?

J: I haven't kept up with the literature but I believe that's what many informed people would say, namely that PSA, in screening mode, does not discriminate so well between aggressive and slowly growing cancer. But I'm not a doctor.

I: What is your secret for maintaining such a productive interest in such a wide range of fields?

J: Well, I don't know if there is a secret. Statistics is vitally concerned with data and data occurs in virtually every domain in the modern world. So if you like numbers, you are overwhelmed with choice. John Tukey famously said that the best thing about being a statistician is that you get to play in everybody's backyard. The challenge is sometimes really the reverse. How do you stay focused enough and informed enough to make a contribution? Of course, you have to listen carefully to your collaborators and sometimes you have to figure out together with him or her what the real question is rather than what she or he may have said initially.

I: Did you pick up the tools that you need as you go along?

J: In many cases, yes, because if you are discussing a problem with somebody then you have their problem to solve and not necessarily the tools you want to use.

I: Has supervision of graduate students led to any unexpected or surprising breakthroughs?

J: Yes, of course. I thought I would mention two older examples because then I don't have to single out or embarrass more recent and equally excellent students. Many years ago Mark Mathews wanted to do his thesis jointly between statistics and geophysics. Paul Segall was his other advisor. He worked on estimating the depth distribution of slippage on the San Andreas fault (the source of many California earthquakes). I remember being amazed that you could invert surface triangulation measurements across fault in order to estimate what is happening at depth in the fault. Some years later Arthur Lu (on a different subject) came up with a rigorous proof that when the number of dimensions p is proportional to the sample size n in principal components analysis, there is no hope of consistently estimating the population eigenvectors. There had been non-rigorous arguments to that effect in the physics literature, but just out of the blue he really nailed it.

I: There are a lot of models about climate change. Are there any applications to climate change and global warming?

J: That is a whole area in which some statisticians are actively engaged. There is a very significant statistical component to the work on detection and attribution of climate change. I'm not personally very expert in that but it is certainly true that statistical techniques such as principal components analysis -- known as empirical orthogonal functions in the climate community -- play an important role.

I: I think you once gave a talk on your work on the weather, isn't it?

J: Actually, it wasn't my work, so I should explain. This was an after-dinner presidential talk at the IMS [Institute of Mathematical Statistics] annual meeting and I was making a bad pun on the world wide web (www) many years ago, when it was newer. So I used the title "Wishart, Wigner and Weather" and the talk was to illustrate this historical development of ideas in random matrix theory starting with Wishart in statistics and then moving to Wigner's work in random matrix theory in physics and then how some of these ideas have been taken up in statistical applications such as in principal components analysis or empirical orthogonal functions in the climate literature. There is a whole book written in the early 1980s by the climate scientist Rudolf Preisendorfer and it is all about principal component analysis in meteorology. He had looked up all the papers by Charles Stein on properties of covariance matrices. It is an encyclopedic book written entirely about principal components. So I was just telling some of that story in that talk.

I: What advice would you give to a graduate student who wants to do statistics?

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J: Well, advice is a hard thing. Statistics is, if I may use the phrase, a very high-dimensional space. There are many flavors of professional activity available to the young statistician, whether it be working in a solitary way or as a member of a large team, whether it be working mathematically or computationally, whether you are working on research or collaboration in industry, or in academia. If I thought longer I could think of further dimensions. It's just an enormous amount of choice in the statistical space, and perhaps you should do what catches your passion and do it well.

I: I think it is also quite demanding. You have to learn so much mathematics.

J: The mathematics is helpful. Ideally one should identify what you need when you need it. Having a mathematical framework in advance is always helpful.

Thank you for your feedback!

We would like to thank the program organizers for their support and efforts in running the events at IMS! To show our appreciation, here are some of the comments we have received from the participants:

I would like to appreciate you and the entire team for organizing such a workshop and bringing almost all domain experts in this field to the workshop. This is an eye-opener for me.

The workshop was very well organized, with a wise choice of subjects but without becoming too narrow in scope.

Collaboration with other participants provided important research contacts.

By listening to different talks, I got an opportunity to learn new research ideas and discussing them further with fellow mathematicians to apply them on my research.

A very good balance of top level specialists, both senior and junior, from a large variety of mathematical subjects related to the topic of the program.






Call for Pre-Proposals >>>

The Institute for Mathematical Sciences (IMS) of the National University of Singapore (NUS) invites submissions of pre-proposals for April 2018 to March 2019 from researchers in the academia and industry in Singapore or overseas. The pre-proposals are for organizing thematic programs to be held wholly or partly at IMS with funding from the Institute. These programs, each lasting for one to six months, should have a well-defined theme or themes that are at the forefront of current research in an area of mathematical science or its applications, and should be of international interest as well as of interest or relevance to the local scientific community. Typically, a program should involve both international and local organizers. Pre-proposals on interdisciplinary programs in areas that interface with the mathematical sciences are welcome.

A soft copy of the pre-proposal should be sent to the Director of the Institute at imsdir@nus.edu.sg not later than 31 May 2016. The exposition of a pre-proposal should be aimed at the non-specialist and will be evaluated by a panel. Pre-proposals on interdisciplinary programs should indicate how the program would benefit the intended audience with diverse backgrounds and facilitate research collaboration.

Information on the Institute and its activities, as well as a detailed format for pre-proposals are available on the IMS website http://www2.ims.nus.edu.sg. Enquiries may be directed to imssec@nus.edu.sg.

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Printer: World Scientific Publishing Co. Pte Ltd

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