IMPRINTS

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NEWSLETTER OF THE INSTITUTE FOR MATHEMATICAL SCIENCES, NATIONAL UNIVERSITY OF SINGAPORE

Machine Learning and its Applications

From 10 to 28 October 2022, the Institute hosted a program on "Machine Learning and its Applications". The organizers contributed this invited article to Imprints.

BY QIANXIAO LI *(National University of Singapore)*

In recent years, we have seen a marked increase in the interest in machine learning from both theoretical and practical research communities. On the mathematical side, the success of machine learning, especially deep learning, has presented new problems in learning theory, approximation theory, numerical analysis and high-dimensional statistics. In practical domains, the application of machine learning has evolved outside of classical domains such as image and language processing, into new frontiers in the physical and biological sciences.

In view of the rapid progress in the field, the institute hosted a 3-week long workshop on Machine Learning and its Applications from 10 to 28 October 2022. The aim of this workshop is to bring together researchers in theoretical and applied machine learning, to share their work and to explore collaborative opportunities. A secondary aim is also to promote more interactions within the Singapore research community in machine learning. Thus, this workshop engaged various local research entities and industry research laboratories. The workshop is designed to be diverse, covering a range of topics including deep learning theory, machine learning in the sciences, Bayesian methods, interpretability/fairness in machine learning, and reinforcement learning.

The first part of the workshop consists of a series of pedagogical tutorials on current topics in machine learning and took place in the week of 10 October 2022. Each tutorial was conducted by an expert in the respective fields. Theoretical topics include introductions to Bayesian machine learning by Emtiyaz Khan (Riken), reinforcement learning theory by Nan Jiang (UIUC) and scaling analysis for deep learning by Greg Yang (Microsoft). Introduction to novel applications of machine learning consist of machine learning for partial differential equations by Jiequn Han (Flatiron), AI-augmented human evaluations by Nihar Shah (CMU), and time-series analysis methods and their applications in physics by Andrey Ustyuzhanin (NUS). The tutorials were well-attended by researchers and graduate students, not only from various departments in NUS but also from the broader research community in Singapore (NTU, A*STAR). These tutorials served as useful introductions to the topics to be presented and discussed at the scientific sessions of the next two weeks.

The weeks of 17 and 24 October consisted of scientific sessions, where leading researchers in various aspects of machine learning were invited to present their work. A mix of online and physical talks were arranged.

The practical talks focused on new exciting applications of machine learning in science and engineering. Some notable topics included machine learning for robotics (Anca Dragan, Berkeley; Cornelia Fermuller, Maryland), with an interesting interplay of computer vision, control and AI. Another highlight are topics in data-driven methods in physical sciences, including accelerating computational chemistry computations using deep learning (Min Lin, SEA; Nikita Kazeev, NUS) and large-scale, operational weather prediction (Jesper Dramsch, ECMWF; Jeffrey Adie, NVIDIA). These topics are of critical importance in computational modelling and forecasting, and it was interesting to see how the frontiers are being reshaped by data science and artificial intelligence.

The theoretical portion of the workshop contained invited talks on a range of current topics in theoretical machine learning. Despite the tremendous progress in machine learning applications, our understanding of its working principles remain quite limited. This is especially the case for deep learning with deep neural networks. Talks on this topic included approximation and generalization theory for deep neural networks by Weinan E (PKU) and Gitta Kutyniok (LMU). Beyond deep learning, highlights included developments in kernel methods by Mikhail Belkin (UCSD) and Francis Bach (INRIA, ENS), stochastic optimization by Ohad Shamir (Weizmann Institute), reinforcement learning theory by Jianqing Fan (Princeton) and interpretable machine learning by Rene Vidal (JHU).

Overall, the workshop offered a broad perspective of the current research activities on theoretical and applied machine learning. The tea breaks and student poster sessions also facilitated discussion amongst workshop participants and formed a number of new collaborations. Moreover, it was a rare opportunity for the local research community in machine learning both in academia and industry to gather and exchange ideas.

Harold Soh

Qianxiao Li

Guillaume Sartoretti

Sebastian Goldt

The Statistical Physics of Continuum Particle Systems with Strong Interactions

29 AUG–9 SEP 2022

CO-CHAIRS:
David Dereudre | Université de Lille
Subhroshekhar Ghosh | National University of Singapore
Adrien Hardy | Université de Lille
Mylène Maïda | Université de Lille

Mathematicians and physicists gathered to discuss on the statistical physics of particle systems which exhibit strong correlation and long range dependence. These particle systems include Gibbs point processes such as Coulomb gases, determinantal point process, eigenvalues of random matrices. There were four tutorial sessions and 19 invited talks. The tutorial lectures were given by Alexander Bufetov (Aix-Marseille University, France), Thomas Leblé (CNRS - Université Paris Cité, France), Mathieu Lewin (Université Paris Dauphine, France) and Balint Virag (University of Toronto, Canada). The topics of the lectures were on determinantal point processes and random entire functions, Coulomb and Riesz gases and random plane geometry. There were more than 30 participants.

From Left: Balint Virag, Simona Rota Nodari

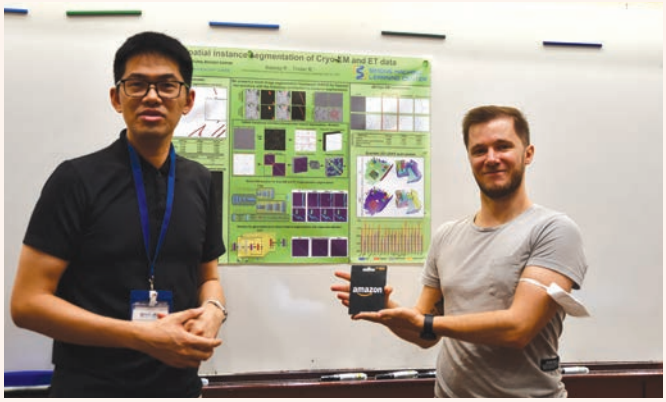
Workshop on Machine Learning for cryoEM

16–23 SEP 2022

ORGANIZING COMMITTEE
Hui Ji | National University of Singapore
Duane Loh | National University of Singapore
Steven J Ludtke | Baylor College of Medicine
Paul Matsudaira | National University of Singapore
Ardan Patwardhan | EMBL-EBI
Yong Zi Tan | National University of Singapore

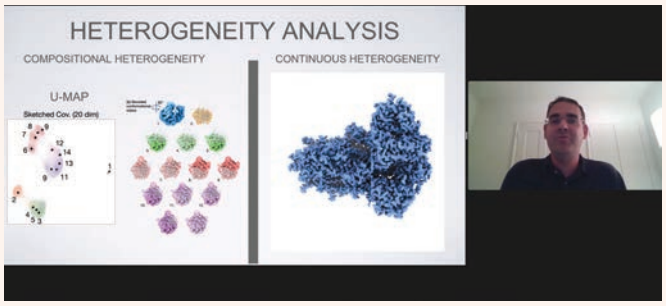
Dr Dari Kimanius (MRC Laboratory of Molecular Biology, UK), Kun Qu and Yong Zi Tan (National University of Singapore) started with a 2-hour tutorial on Single particle imaging on 16 September 2022. They later gave 2.5 hours of tutorial lectures on RELION, a popular statistical and machine learning framework for cryoEM, that afternoon. Jonathan Bouvette (National Institutes of Health, USA) and Anchi Cheng (New York Structural Biology Center, USA) each gave two hours of lectures on 23 September 2022 on SmartScope and Smart Leginon respectively. There were a total of 8.5 hours of lectures. There were 17

Poster discussion



Congratulations to Robert Kiewisz!

talks in total from 19–22 September 2022, of which eight were delivered via Zoom. A few participants presented their poster, and the best poster award was presented to Robert Kiewisz (New York Structural Biology Center, USA) on 22 September 2022. There were more than 100 participants and over 30 graduate students.



Zoom session with Amit Singer

Group photo

Dari Kimanius

Machine Learning and Its Applications

10–28 OCT 2022

CO-CHAIRS
Peter Bartlett | Simons Institute for the Theory of Computing, UC Berkeley
Soufiane Hayou | National University of Singapore
Hui Ji | National University of Singapore
Qianxiao Li | National University of Singapore
Gianmarco Mengaldo (National University of Singapore)
Anqi Qiu | National University of Singapore
Jonathan Scarlett | National University of Singapore
Yong Sheng Soh | National University of Singapore
Csaba Szepesvari | Simons Institute for the Theory of Computing, University of Alberta
Vincent Y. F. Tan | National University of Singapore
Alexandre Hoang Thiery | National University of Singapore
Xin Tong | National University of Singapore
Wanjie Wang | National University of Singapore
Angela Yao | National University of Singapore

This program has enabled researchers to learn the latest developments from different areas in the theoretical and applied aspects of machine learning, and to cross-pollinate ideas. Mathematical problems which arose from machine learning include deep learning and reinforcement learning.

Six speakers gave two hours of tutorial lectures each from 10–14 October 2022. The speakers were Mohammad Emtiyaz Khan (RIKEN, Japan), Jiequn Han (Flatiron Institute, USA), Nan Jiang (University of Illinois Urbana-Champaign, USA), Nihar Shah (Carnegie Mellon University, USA), Andrey Ustyuzhanin (National University of Singapore, Singapore) and Greg Yang (Microsoft Research, USA).

There were 44 talks over the scientific sessions from 17 to 28 October 2022. Examples of presentations included operational weather prediction using machine learning from the ECMWF and NVIDIA, and topics in theoretical deep learning, Bayesian statistics and optimization.

There was active participation from local research entities (Nanyang Technological University, A*STAR) and industrial labs (NVIDIA, SEA). There were more than 250 participants, which included more than 100 graduate students.

Upcoming Activities

Representation Theory, Combinatorics and Geometry

12 DEC 2022–07 JAN 2023

Information Theory and Data Science Workshop

16 JAN–27 JAN 2023

Multiscale Analysis and Methods for Quantum and Kinetic Problems

30 JAN–10 MAR 2023

Games, Learning, and Networks

03 APR–21 APR 2023

International Workshop on Reduced Order Methods

22 MAY–26 MAY 2023

Research in Industrial Projects for Students (RIPS) 2023 – Singapore

22 MAY–21 JUL 2023

From omega to Omega

12 JUN–07 JUL 2023

Emerging New Topics in Functional Data Analysis

10 JUL–21 JUL 2023

Recent Developments in Algebraic Geometry, Arithmetic and Dynamics Part 2

14 AUG–01 SEP 2023

Mathematics of Evolution-Phylogenetic Trees and Networks

04 SEP–29 SEP 2023

Random Interacting Systems, Scaling Limits, and Universality

04 DEC–22 DEC 2023

Random Interacting Systems, Scaling Limits, and Universality

04 DEC–22 DEC 2023

The Mathematics of Data

02 JAN–26 JAN 2024

Mathemusical Encounters in Singapore: a Diderot Legacy

19 FEB–23 FEB 2024

Index Theory and Complex Geometry Part 2

29 APR–10 MAY 2024

Statistical Machine Learning for High Dimensional Data

13 MAY–31 MAY 2024

Computational Aspects of Thin Groups

03 JUN–14 JUN 2024

Biomolecular Topology: Modelling and Data Analysis

24 JUN–28 JUN 2024

Interpretable Inference via Principled BNP Approaches in Biomedical Research and Beyond

08 JUL–02 AUG 2024

Intertwining between Probability, Analysis and Statistical Physics

05 AUG–15 AUG 2024

Frontiers of Functional Data Analysis: Challenges and Opportunities in the Era of AI

19 AUG–13 SEP 2024

Applied Geometry for Data Sciences Part I

30 SEP–12 OCT 2024

Interactions of Statistics and Geometry (ISAG) II

14 OCT–26 OCT 2024

For more information on these and other upcoming events, visit the Events section on our website at ims.nus.edu.sg

SUSAN ALLBRITTON MURPHY:

A PASSION FOR MATHEMATICS AND STATISTICS, SMART[1]

Interview of Susan Allbritton Murphy by Y.K. Leong

Susan Allbritton Murphy is internationally well known for her work applying statistical methods to clinical trials of treatments for chronic and relapsing medical conditions.

More than four decades ago, in a rural town of Louisiana in the southern part of the United States, a young girl by the name of Susan Allbritton, driven by a passion for mathematics, found herself to be the only female in a class of students majoring in mathematics. She then went on a special program to study mathematics in Heidelberg in Germany, where she became attracted to statistics. On her return to the United States, she worked as a biostatistician for a year at Louisiana State University Medical School at New Orleans. However, her interest in mathematical statistics brought her to the Statistics department at University of North Carolina at Chapel Hill. Her original passion for mathematics made her choose the more mathematical parts of the statistics courses in her graduate studies. In fact, her 1989 doctoral dissertation on "Time-Dependent Coefficients in a Cox-Type Regression Model", written under the supervision of Pranab Kuma Sen, is a mathematical study on methods for nonparametric modeling. After her PhD, she won grants to do post-doctoral research in Utrecht, Netherlands, and at MSRI (Mathematical Sciences Research Institute) at Berkeley in California.

In 1989, she joined Pennsylvania State University as an assistant professor and rose through the ranks to associate professorship in 1996. In her early years in Penn State, she was invited as visiting professor to the Netherlands, France, and Sweden to work on problems in theoretical statistics, some of them arising from concrete problems in real life. It was around 1996 while she was at Penn State that Murphy became interested in the applications of statistics to medicine. Then in 1998 she moved to the University of Michigan, where she held joint positions in the Department of Statistics, and the Institute for Social Research. In 2002, she was awarded an Independent Scientist Mid-Career Award, from the National Institute on Drug Abuse on ``Reducing Drug Abuse with Individually Tailored Treatments.'' This award was "to enhance the transition from primarily theoretical research to both applied and theoretical work on sequential decision making in health". This transition marked the beginning of a life dedicated to developing "new methodologies to evaluate courses of treatment for individuals coping with chronic or relapsing disorders".

In 2004 Murphy was appointed H.E. Robbins[2] Professor of Statistics in the University of Michigan and Research Professor in its Institute for Social Research, and in 2005, Research Professor of Psychiatry. In 2017 she moved to Harvard University as Professor of Statistics, Professor of

[1] Sequential Multiple Assignment Randomized Trial
[2] Herbert Ellis Robbins (1915-2001)

Computer Science at Harvard's John A. Paulson School of Engineering and Applied Sciences, and Radcliffe Alumnae Professor at Harvard's Radcliffe Institute for Advanced Study. In 2021 she was named Mallinckrodt Professor of Statistics and of Computer Science and Radcliffe Alumnae Professor at Harvard University. She is currently spending a year as a Fellow at the Radcliffe Institute.

Since 1998, when Murphy was invited to give an IMS (Institute of Mathematical Statistics) Special Invited Lecture at the joint statistical meetings of ASA, IMS, ENAR, and WNAR[3] in Dallas, Texas, she has given numerous plenary talks, presentations, prestigious lectures, and keynote addresses at major scientific and medical meetings on the use of statistics, AI (artificial intelligence) and data science in medicine. An early achievement in the application of statistics to real-world medical needs was the Sequential Multiple Assignment Randomized Trials (SMART), which helps clinicians assess and modify treatments of patients for a range of chronic and relapsing diseases such as ADHD, alcoholism, drug addiction, HIV/AIDS, and cardiovascular disease. For this work, she was awarded a McArthur Fellowship in 2013.

Her current research interests include experimental design and causal inference concerning dynamic or individually tailored treatment regimes, sequential decision problems in digital health intervention development. These methods and algorithms are implemented on wearable devices to provide individually tailored treatments to each individual. Her capacity for collaborative research with statisticians, data scientists, AI researchers and medical specialists is extensive and tremendous. The impact of her contributions to medical knowledge and health care may be gauged by awards such as the Leo Breiman Senior Award, the Van Wijngaarden Award, the Royal Statistical Society's Guy Medal in Silver, the R.A. Fisher Award, and the Precision Medicine World Conference 2018 Luminary Award.

She is an elected member of the following scientific bodies: the (US) National Academy of Sciences, the (US) National Academy of Medicine, the International Statistical Institute, and the College on Problems in Drug Dependence. She is a Fellow of the American Statistical Association and the Institute of Mathematical Statistics. She is a former editor of *The Annals of Statistics* and a past-president of the Bernoulli Society and a past-president of the Institute for Mathematical Statistics.

Murphy finds beauty in the precision and clarity of mathematics when it is applied to statistics. Not surprisingly, she finds a similar beauty in the game of ice hockey, about which she is passionate. She plays five times a week,[4] which may perhaps explain her athletic figure (with a shock of white hair on her head).

The achievements of Susan Allbritton Murphy exemplify the success that comes from a single-mindedness of purpose in pursuit of a passion motivated by a desire to create a greater impact in society. She is a role model for all beginning multidisciplinary researchers, not just for women mathematical scientists.

In 2019 Susan Murphy visited the Institute for Mathematical Sciences, National University of Singapore (IMS, NUS) from 16 February-1 March 2019 as Distinguished Visitor for the program "Statistical Methods for Developing Personalized Mobile Health Interventions" (4 February–1 March 2019), for which she also co-chaired the organizing committee. She gave two talks under the Distinguished Visitor Lecture Series: (i) "Stratified Micro-randomized Trials with Applications in Mobile Health" on 18 February 2019, and (ii) "Challenges in Developing Learning Algorithms to Personalize Treatment in Real Time" at the workshop "Analysis of Data from mHealth Intervention Studies" on 25 February 2019. She also gave a public lecture titled "Mobile Health Intervention Optimization" on 21 February 2019.

As early as 2007 Murphy had research collaborations with Augustus John Rush, an emeritus professor of psychiatry in the Duke NUS Medical School in Singapore. A more recent connection is the fact that one of the local co-chairs of the IMS program, Bibhas Chakraborty of the NUS Department of Statistics and Data Science, was her PhD student and collaborator. It was during Murphy's visit to IMS (NUS) that Y.K. Leong took the opportunity to interview her on 22 Feb 2019 on behalf of imprints. The following is an edited and vetted version of the transcript of the interview, in which she traces her trajectory from her original interest in mathematics to statistics and from Louisiana State University to Harvard University. She also gives us some insight into her work applying statistics to real-world needs and the role of technology like mobile phones and wearables in providing medical treatment.

Acknowledgement. Y.K. Leong would like to thank Von Bing Yap and Bibhas Chakraborty, both of the Department of Statistics and Data Science for respectively preparing a raw draft of the transcript of the interview and for information about Susan Murphy's connection with NUS.

[3] American Statistical Association, Institute of Mathematical Statistics, Eastern North American Region, Western North American Region

[4] https://college.harvard.edu/academics/faculty/faculty-spotlights/susan-murphy

IMPRINTS I **You graduated with BS from Louisiana State University, then went to do a PhD at the University of North Carolina at Chapel Hill. Was there any special reason for doing so?**

SUSAN MURPHY M I went to Louisiana State University because I lived near this university. If you went to any university at all, you would go to Louisiana State University! And then I went to do a PhD at the University of North Carolina at Chapel Hill. It remains in the southern part of the United States and was not far from Louisiana. At that time of my life, I pretty much stayed in the southern part of the United States.

I **At which stage of your education did you decide to specialize in statistics?**

M I chose statistics after college. I was a mathematics major in Louisiana State University. After college, I was fortunate enough to go to Germany to study mathematics and there I took a statistics course and realized that I really liked statistics. Statistics is an area of mathematics that had a little bit more immediate impact on society and I found that very attractive. So I chose statistics.

I **That was before you did your PhD?**

M Yeah, this was way before I did a PhD.

I **Was it some kind of an exchange program?**

M No, it was a special program. It was after college and I would go and study mathematics in Germany.

I **Where did you go to study mathematics in Germany?**

M I studied in Heidelberg.

I **Why didn't you continue to do a PhD in Germany?**

M I wanted to go into statistics. There were more opportunities at that time in statistics in the [United] States as opposed to Europe. It's a little different now.

I **You were at the University of Michigan from 1998 to 2017. That's a period of 19 years, before moving to Harvard University as Professor of Statistics and Computer Science. Does this indicate a shift of emphasis in your research direction?**

M No, it doesn't indicate a shift in the research direction. It indicates a shift in how I'm organizing my research. At Harvard, I seek to have an increased involvement by undergraduates in that research. Harvard has excellent undergraduates, so it's a great opportunity for me to involve undergraduates. And at Harvard I won't have to spend quite as much time writing grants.

I **I notice you are also in the computer science department. It's a little unusual.**

M It's great. I'm very fortunate. The Computer Science department at Harvard is exceptionally good and exceptionally collegial. I'm very fortunate to be part of that department.

I **Harvard University used to have a women's wing, so to speak, in Radcliffe College. Is the Radcliffe Institute, of which you are also a professor, related to Radcliffe College?**

M So, Radcliffe College was integrated completely into Harvard in 1999. And what happened after that integration was the Radcliffe campus became home to the Radcliffe Institute for Advanced Study as well as some housing for undergraduates. And so my affiliation is with the Radcliffe Institute for Advanced Study. That Institute now is located where the former Radcliffe College used to be, but Radcliffe College has been completely integrated into Harvard.

I **Previously the women were in Radcliffe [College].**

M Yeah, that was a very long time ago. But even before 1999, this was completely over.

I **Is the [Radcliffe] Institute modeled after the Princeton Institute for Advanced Study?**

M I wouldn't say that [it is]. It reminds me a little bit more of the Stanford institute for Social and Behavioral Sciences.

I **Harvard University has an emeritus professor in theoretical statistics. The term "theoretical statistics" does not seem to fit into the usual picture of statistics as an applied area. What does that term mean?**

M It turns out that only some areas of statistics are applied. There's a whole area of statistics that is very theoretical, in particular the study on the foundations of statistics. That's a very theoretical area. And so, one might spend most of one's career on the foundations of statistics and then you would say that they are doing theoretical statistics. So, it really depends on which area of statistics one works in. There are broad areas of statistics that are not very applied at all.

I **Would theoretical statistics be more like probability theory?**

M It might use probability theory, but it might have a lot of philosophy as well. Statistics is a data science,

so the philosophy of how you collect data, how you extract evidence, causal inference – these are all parts of statistics. And they may or may not involve a great deal of probability. It just depends on what area in the foundations of statistics that one works on. So, it's not necessarily mathematical; it may be more philosophical.

I **In the Singapore educational system, statistics used to be only an optional topic at the 'O' level, which almost all schools will not choose. Most people think of statistics as the computation of things like averages, medians or standard deviations and pictures of histograms and pie charts. Do you think that statistics should be made a compulsory component of mathematical teaching, and done more conceptually?**

M Well, statistics, if it's taught properly, is about critical thinking and being able to judge evidence, and how data is used to contribute to evidence or provide evidence. The more our citizens can judge evidence and how it accrues from data, the better citizens they will be as part of the nation. So for example, when you read the newspaper and a new drug has been developed, you can be much more critical of the evidence that led to that adoption of the drug. And that's a really important thing. And in today's world, because artificial intelligence is being used to mine big data (to attempt to extract information), statistics helps people to be more thoughtful and critical and be able to understand the quality of such information when it's extracted from big data. So, statistics is really important in terms of being a good citizen (the educated citizen).

I **Unfortunately, I think most people do not really appreciate the finer points of statistics.**

M Yeah. The word "statistics" is sometimes intended to mean averages, medians and standard deviations, but that's not the area of statistics. Those are different things. The way we use English conflates those two issues, and so, you end up with this misunderstanding.

I **Has the position of women's career advancement in the United States improved significantly since the early years of affirmative action for women in academia in the '70s?**

M Well, nowadays, most statistics departments as well as mathematics departments have multiple female faculty. There was a woman[5] who won the Fields Medal. Top awards are being won by women, and you see women in leadership positions in scientific societies. So, certainly things are greatly improved.

I **In your Sequential Multiple Assignment Randomized Trial (SMART) model of treatment, in which treatments are administered according to past outcomes, is there some kind of machine learning strategy involved? If so, will AI make an important impact in the coming future?**

M Certainly, if one is interested in learning how to adapt treatments delivered by technology over time, it is useful to utilize machine learning algorithms. So, artificial intelligence plays a much bigger role in the work I do. Currently, I work on how we can provide support via mobile health. This involves sequential decision making. It turns out sequential decision making has an incredibly long history in statistics, going back to [Herbert Ellis] Robbin and [Barbara Hazard] Munro decades and decades ago. This is a modern area of control theory. Some of your listeners may be familiar with control theory. So, the role AI plays in mobile health is that here we don't have a system dynamics model. We don't have differential equations that involve how states and controls lead to the next state. So, the way you learn a good policy is you have to process data in an appropriate way. And this is an area of artificial intelligence called reinforcement learning. And it's an area in which you are sequentially experimenting so as to learn and optimize how you can provide support to people via their mobile devices.

I **At first I thought the "SM" in SMART is actually "Susan Murphy".**

M No, it's not. It has nothing to do with me. [*Laughs*]

I **Does this [SMRT] depend on the use of modern technological devices?**

M Yeah, everything. I don't work on SMART studies anymore. The work I do now is mainly in mobile health and that depends on technology. Most of it goes along with smart phones. And so. there's a lot of computational issues that are involved.

I **Is it possible in the future maybe you have a chip that can be implanted into the body?**

M I don't know if we're going to want that. But certainly, having a chip in a T-shirt that you might wear, you would choose to wear that T-shirt when you're exercising so that you could monitor the role the exercises are playing in terms of your physiology. That might be something that many people would be interested in.

I **But if you wear a watch it could be really inconvenient.**

[5] Maryam Mirzakhani (1977-2017), Fields Medal 2014, and more recently, Maryna Viazovska, Fields Medal 2022

M Yeah. Or some sort of chip that's embedded in your clothing – that might be much easier.

I How about the applications in other fields?

M Yeah. Much of my work has been used across a variety of fields – childhood depression, substance use, addiction, smoking, obesity, depression. I have a website I can give you where they list a lot of these projects, but, as a whole, it's across a variety of areas in which we need to make sequential treatment decisions.

I What about Alzheimer's disease?

M No, actually that's one area that I've always wanted to work in, particularly for the caregiver. I think it would be very interesting to work on some sort of mobile app or something that could go on an iPad. It would help caregivers as they care for someone suffering from Alzheimer's. But I haven't had that opportunity, and that would be a natural area for me [to work in].

I What about psychological problems like schizophrenia?

M I don't work on that, but my work has been used in those areas.

I Medical treatment has improved vastly with advances in technology. How much of these technological advances have been influenced by mathematics in general, and statistical theory in particular?

M So, I'll give you an example. You know, many people with diabetes have automated insulin pumps. The insulin pump is attached to them, and it's automated. That is using control theory. So, mathematics plays a big role, right? Because the foundations of control theory come out of mathematics. So, that's one way in which mathematics helps people live more normal lives. Statistics provides the foundations for how we decide whether or not new drugs will be provided in the marketplace. Statistics provides the designs for the clinical trials that are used to collect evidence that regulatory agencies can use. Like any new devices, wearable devices, implants: all of these have to be vetted and they're vetted via the use of both statistical design and experiments as well as statistical methods used to extract information from the data. So, statistics plays an enormous role in our society in protecting us from products that might not be good for us and helping us find products which would help us enhance our life.

I What about in non-medical fields, like sports and athletics?

M I don't know about Singapore. I'm sure it's the same. But in the States, athletes are being outfitted with wearables and they're tracked the whole time they play.

"STATISTICS PLAYS AN ENORMOUS ROLE IN OUR SOCIETY IN PROTECTING US FROM PRODUCTS THAT MIGHT NOT BE GOOD FOR US AND HELPING US FIND PRODUCTS WHICH WOULD HELP US ENHANCE OUR LIFE."

And then a variety of machine learning and statistical analysis are applied to that data to provide advice both for the athlete and his or her coach, to improve their performance. So it plays a big role in sports and I suspect it's going to be an increasing role.

I It's better than taking drugs.

M Much better. I agree, much better.

I Has there been any effort to encourage more mathematicians to look at problems arising in biology and medical science?

M It depends. If you go to many departments in the United States, there's a large number of mathematicians working in biology.

It's relatively common actually. I know some mathematicians in North Carolina who work on models for how the AIDS virus infects the human body. So, there's a lot of mathematics here. I don't know if they're using stochastic differential equations, but they are using PDEs [partial differential equations]. So there's a lot of mathematics that can be done in understanding biology, particularly infectious diseases and so on.

I Is it a problem to encourage mathematicians to actually take some interest in non-mathematical fields?

M Nowadays, the current trend in the States is that more and more mathematicians are becoming interested in real life problems, and they are very eager to do that. Of course, as you know, this is cyclical. So, when I graduated with my PhD, I did mainly mathematics. And at that time, that was what everybody was encouraged to do. So, we were all working on the foundations of statistics. But then with time, now we've returned to trying to have more relevance in real life. But I suspect in 10 years or so, we'll again start working more on the foundations of statistics and move back to the theory. So, it's very cyclical.

I What is the role of placebos in clinical trials?

M I'm not involved in those kinds of studies. There is a lot of interest in placebos in the behavioral sciences. If we could understand why people respond to placebos, like a sugar pill, maybe we could develop better therapies and treatments that have almost no side effects. A really big interest in placebos is to understand why it is that they appear to impact humans. Why do placebos work so well?

I It sounds a bit unscientific for placebos to take effect.

M No, I don't think it's unscientific. I think it has to do with brain function. It definitely has to do with brain functioning. I suspect in the cognitive neuroscience field, they may begin to make the early inroads. So it's how we think about the problem, how we frame that problem. Do we have a positive viewpoint on a problem? We know that people who are ill, who have cancer, tend to do better if they have a lot of family support. You know, there's a lot of behavioral aspects to managing a disease or struggling with a disease that lead to better outcomes. And somehow the placebo is touching into some brain function that we don't know. In other words, the brain self-medicates in some way, with the placebos facilitating that. And if one could figure out what that was, that would be a wonderful thing.

I That will be amazing.

M Yeah, because then with someone who's more skeptical, maybe you could help them in another way just by helping them work with their brains. So it would be really, really great to understand how the placebo effect is influencing the brain and the way the neurons communicate with each other and so on.

I What advice would you give to students when they do statistics in the applied field?

M My advice is to pick an area that you're particularly passionate about. If you're a statistician and you want to have a big impact, and you want to do interdisciplinary work, you really need to understand and appreciate that other discipline. Science is not trivial. It takes a lot of work. And you really need to understand the scientific issues in that particular discipline in order to develop the mathematics that will address those issues.

CALL FOR PROPOSALS

The Institute for Mathematical Sciences (IMS) of the National University of Singapore (NUS) invites submissions of proposals from researchers in academia and industry. The proposals are for organizing thematic programs or workshops to be held at IMS.

The IMS is particularly interested in receiving proposals of programs/workshops that focus on exciting new developments in the mathematical sciences. Proposals of interdisciplinary nature in areas that interface mathematics with science, social science or engineering are welcome.

A soft copy of the proposal, for the period of funding from **1 August 2025 to 30 June 2026**, should be sent to the Director of the Institute at imsdir@nus.edu.sg by **31 May 2023.**

The exposition of a proposal should be aimed at the non-specialist and will be evaluated by a scientific panel. Proposals of interdisciplinary programs/workshops should describe how the activity 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 the proposal are available on the IMS website ims.nus.edu.sg. Enquiries may be directed to imssec@nus.edu.sg.

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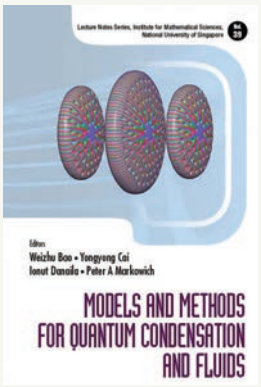

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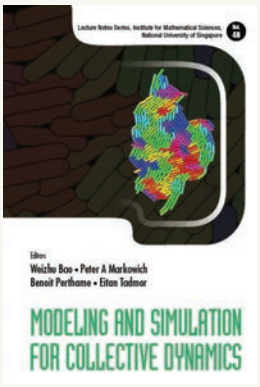

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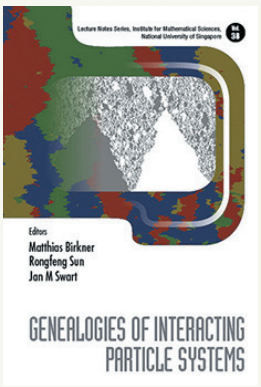

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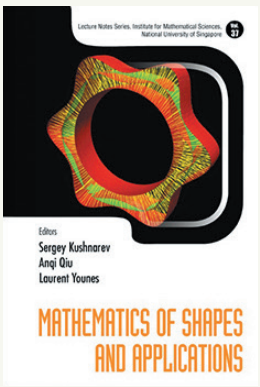

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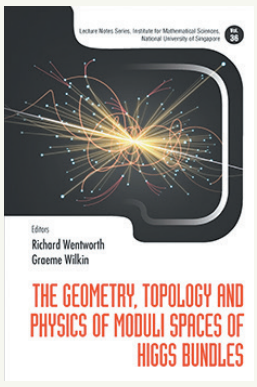

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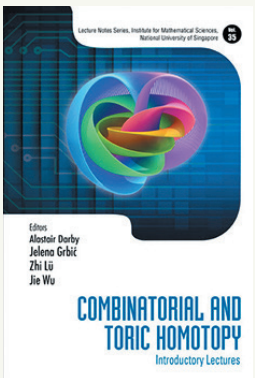

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