IMPRINTS

INSTITUTE FOR MATHEMATICAL SCIENCES

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John Templeton Foundation Endows a Gift of S$1.4 million to IMS >>>

The John Templeton Foundation has endowed a gift of about S$1.4 million (approximately US$1 million) to establish the Asian Initiative for Infinity (AII) at the Institute for Mathematical Sciences. The gift is expected to be eligible for a dollar-for-dollar matching fund from the Singapore Government.

The AII will focus its activities on areas related to promoting and facilitating research and training in the field of mathematical logic. The idea of an AII was initiated and conceived by Theodore A. Slaman and W. Hugh Woodin of the University of California at Berkeley. Both Slaman and Woodin have been visiting the National University of Singapore since 1997 at regular intervals conducting seminars and participating in workshops and conferences organized by the Department of Mathematics and the IMS. During my visit to Berkeley in October 2006, the AII idea was firmed up and a plan mapped out. In the ensuing three years, a project proposal was prepared, revised and submitted to the Foundation, which awarded the grant in late 2009.

The three-year AII program has a three fold purpose: produce innovative research specifically on Infinity, create a community of researchers on Infinity in Asia, and stimulate the discussion of Infinity among leading scholars. Coincident with the increasing interest in Asia in the study of Infinity in Asia, there are equally exciting opportunities for research in this area. The subject is ripe for major breakthroughs on a variety of fronts. Here the situation in Logic is reminiscent of the situation in the early 1960's just before the breakthroughs of Paul Cohen, Robert Solovay, and others. The vision of AII, located in Singapore, is to provide an incubator to establish broadly in Asia a robust and self-sustaining program in Mathematical Logic with an emphasis on Infinity. During the initial phase, the Initiative will have a major focus on creating a critical mass of researchers on Infinity in Asia. This means educating and supervising a generation of gifted graduate students. The Asian Institute for Infinity will host three summer sessions involving research and training. Each summer, AII will invite three senior participant Lecturers to deliver series of lectures. These lectures are to be accessible to students poised to begin research and lead to the research frontier. The senior participants in the summer programs, including the Lecturers, will be immersed in research. The anticipated breakthroughs will create a unique climate for all of the participants.

There is a discernible trend very recently in organizing summer schools in logic for mathematics students at both the undergraduate and graduate level, for example at the University of California in Los Angeles, Carnegie Mellon University, as well as the tutorials held every year at the European summer meetings of the Association for Symbolic Logic. The logic summer schools at IMS began in 2006 and are a collaboration of Berkeley, the Chinese Academy of Sciences and National University of Singapore. With the gift from the John Templeton Foundation, the Singapore summer school in logic is expected to expand in both size and scope. It is envisaged that participants of the AII summer school will have wider international representation and greater diversity than it has had thus far.

The AII also aims to create an Asian platform for a community of researchers to get together working on some of the most challenging problems, with the common goal to discover truth about the Infinite, and a shared vision that this goal is meaningful. To complement the daily lectures and problem sessions at the summer school, there will also be two to four postdoctoral fellows resident for one to two months, to provide wide opportunities for students attending the summer school to interact with young and senior researchers. In addition, a select workshop on

Continued on page 2

contents

- John Templeton Foundation Endows a Gift of S$1.4 million to IMS 1
- Mathematics of Fat Bouncy Humans 2
- Charles Stein honored on his 90th Birthday 5
- People in the News 6
- Programs & Activities 7
- Mathematical Conversations – Interview with: Larry Shepp 11
- Publications 16
- IMS Staff 16

Mathematics of Fat Bouncy Humans >>>

Jiayi Chong is a Singaporean and works as a Technical Director at Pixar Animation Studios. He graduated with a Bachelors and Masters in Computer Science from Stanford University. Jiayi has worked on the movies Wall-e, Up! and the soon to be released Toy Story 3. In his spare time, he dabbles with graphics programming on mobile devices. He was invited to submit this article showing the use of mathematics and physics in the field of computer graphics.

A fat over-sized human on Wall-e

This article is about the movie Wall-e and the mathematics and science behind the creation of a bunch of fat, over-sized humans. The director Andrew Stanton had a vision of the future where the earth was filled with rubbish and the planet became inhospitable. In this post apocalyptic vision of the future, the remaining members of our human species have fled from earth in giant spaceships. On those spaceships, thousands of robots serve their human overlords, resulting in the humans becoming fat and lazy. The design of these humans on the film went through several iterations. The initial idea was of them being rather jelly like (they even had semi-translucent bodies at some point). Eventually, the art direction settled on over-sized humans with a basic bone structure This meant that the resulting effect on screen was fat, fleshy bodies that jiggled about as they collided with the ground and each other. That image was a topic of several hilarious conversations but it soon turned out to be a big technical challenge. I will be describing to you the step by step process of how we tackled this challenge. Hopefully, this will provide some valuable insight into the world of digital animation and effects.

Traditionally, computer animation is done by human animators plotting values into the software. Those values in turn drive the digital character to act out various set of poses for the shot. This works if you are animating stiff characters with little flesh on them. However, doing just that for a fat, fleshy character results in a rather unappealing and dead looking character. The issue is that in real life, fleshy material will jiggle and bounce about under motion. It is very difficult for human animators to manually animate the secondary ballistic jiggles and bounces on a digital character. Getting the general motion right is already hard enough, getting the secondary motion correct is even harder. Even to an untrained eye, an animated character that lacks secondary motion (it could be a piece of hair that flops as the head turns or a wobbly part on a moving arm) looks dead. Audiences will say, "The animation looks weird and artificial for some reason.. feels rather uncanny" when presented with a piece of animation lacking any sort of secondary motion. In real life, secondary motion is everywhere. Our eyes are very quick to pick out something weird in a scene if there is a lack of secondary motion. In order to bring our characters to life by instilling some secondary ballistics, we turn to the field in computer graphics called computer simulation.

Computer simulation is the simulation of phenomena (both real and non-physical) virtually on a computer. We typically create a model based on the laws of physics to achieve this goal. If you have seen any of the big budget special effects movies in the past few years (Avatar, Harry Potter, Star Trek and of course Wall-e), you would have seen the results of computer simulation. A lot of computer simulation is used in visual effects heavy sequences. Examples of these include crashing waves, the clothing on characters, wavy hair of strange creatures and big explosions. We use computer simulations for such cases because it is repeatable (you cannot blow up model buildings with real explosives too many times, it might get dangerous) and sometimes downright impossible to do in real life (how do you film hair on a unicorn?) In the case of Wall-e, we came up with a physical model for simulating flesh on our human characters.

The input data for representing digital characters is typically a surface composed of basic shapes like triangles. A surface mesh is useful for the purposes of sculpting and modeling. However, it is less useful for the simulation of a fat human. Creatures are composed of flesh, bone and other internal

Continued on page 3

Continued from page 1

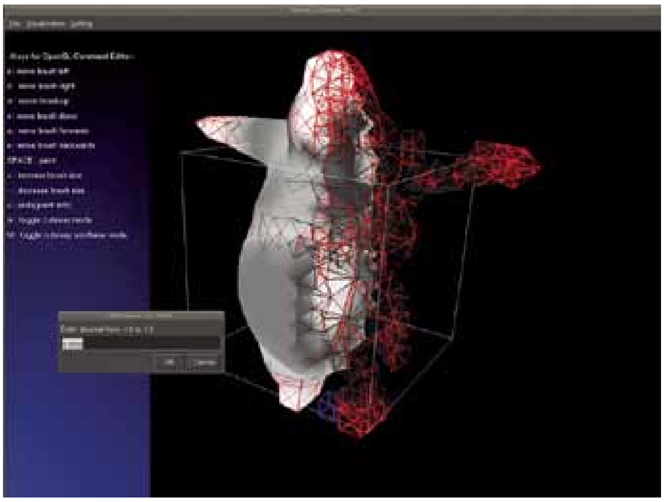
"Infinity and Truth" with leading experts as participants, as well as a research workshop that is a sequel to the Workshop on Computational Prospects of Infinity held in 2005 are also being planned for 2011. The first Computational Prospects took place in July/August 2005 and was attended by more than 50 researchers in the field. It resulted in two published volumes in the IMS Lecture Notes Series that contain both lecture notes and original research papers. It was the success of the first workshop that injected the idea of a second workshop and a meeting on "Infinity and Truth" that will involve mathematicians beyond the field of logic. The John Templeton Fund came at an opportune time for this idea to be realized.

Chi-tat Chong
National University of Singapore

Continued from page 2

structures. The motion of the surface is mostly driven by how those internal structures (muscles, flesh, bone) move. Hence, we will need some way to convert the surface of the character into one that is volumetric in nature. A volumetric representation of a surface will allow us to capture a more accurate form of motion for our human characters. The first thing we will need to do is to be able to answer the following question: Given a point anywhere in 3D space, am I inside or outside the surface? There are various ways to accomplish this and one of them involves using level set methods. You can read more about this topic in various reference books and material. It is a rather involved topic so I will just say that we can represent the volume in an implicit form to answer the above question. An implicit surface is one defined by a function where it returns a zero value when you are on the surface itself. A level set is then such a surface whose implicit function is represented by values sampled on a discretized grid. This makes it convenient to use on a computer because computers are digital in nature and work well with discrete values. We still need to pick a convenient function to represent our surface. The function we choose is called a signed distance function. The idea is rather simple: the signed distance function of a closed surface is simply the distance to the closest point on the surface. If you are outside the surface, it will return a positive value. If you are inside, a negative value is returned. This means we can answer the question of whether we are inside or outside (or on the surface in which case the value will be zero) the surface as well as tell how far we are from the actual surface. To generate a signed distance function, we run the fast marching algorithm on the original surface mesh. Now that we have an implicit volumetric representation of our character, we will next need to decide what to fill this volume up with.

If you are given just a surface mesh on a computer, you will notice that we construct the surface out of basic shapes. The most basic shape one can think of is a triangle. Unfortunately, we cannot fill up the volume with triangles because triangles have no volume. We can however, use a basic shape that is analogous to a triangle in volumetric form. That shape is the tetrahedron. In geometry, a tetrahedron is a polyhedron composed of four triangular faces, three of which meet at each vertex. It is this basic 3D shape that we will use to fill up the volumetric human character. So given that we have the signed distance function of the character, we overlay a rectangular box composed of tetrahedra on top of the character. The box of tetrahedra are sized in such a way that its volume contains the character within it (basically the bounding box of the character). Next, we cull away the tetrahedra that are outside the character. Remember we can do this easily because we have the handy signed distance function already generated. For each tetrahedra in the box, we query to see if it is outside the character by using the signed distance function. We only keep the ones which are on or inside the surface of the character. The result will be a rather blocky looking character made up of tetrahedra. This is not yet good enough for our simulation purposes. The next step involves pushing the blocky tetrahedra close to the surface of the character into the surface itself to try to match the contours of the character. We can use the signed distance function as a guide in this optimization process. After that final step, we have a a volumetric character composed of tetrahedra ready for our simulation purposes!



Cross sectional display of a volumetric character composed of Tetrahedra

At this point, it helps to take a step back to see the bigger picture. What do we exactly want to accomplish with the data that we have generated? The goal is to eventually make characters that have a fleshy, bouncy feel to them. They should respond to collisions and interactions with the outside world. Right now, our character is composed of thousands of tetrahedra. When the character moves, the tetrahedra move along with it. When the character stretches his or her arm for instance, the tetrahedra in the arm also stretch. Flesh as we all know has some kind of elastic feel to it. It will tend to resist changes in its shape when stretched out too much. It will try to recover to its original rest shape when stretching happens. Since we are representing flesh as tetrahedra, the tetrahedra themselves will need to have this property. They should be able to resist compression or stretching under external stress. There are various physical models to accomplish this and the method we choose is called the Finite Element Method or FEM. A variety of specializations under the umbrella of the mechanical engineering discipline (such as aeronautical, biomechanical, and automotive industries) commonly use integrated FEM in design and development of their products. In a structural simulation, FEM helps tremendously in producing stiffness and strength visualizations for objects made up of different materials. You can see why we chose this method now. FEM is used in our simulation to model the stress-strain relationships for the flesh on the characters. We use a biphasic material to represent the flesh. A biphasic material implies that the material itself has 2 different range of stiffness values. This means that the material will tend to resist motion a little if it is stretched out slightly. When it undergoes large amounts of stretching, it will resist motion

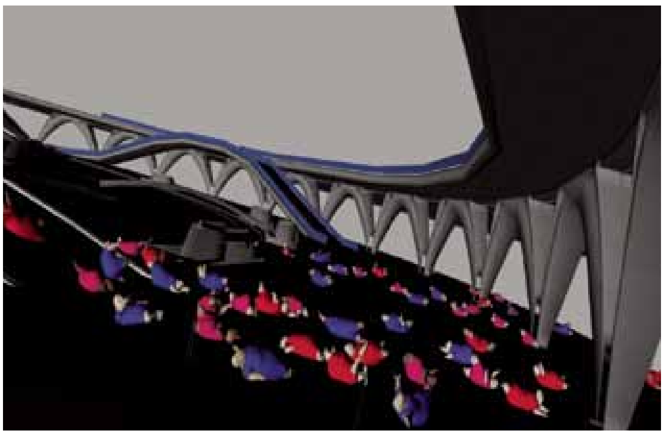
Continued on page 4

Continued from page 3

with a much greater force in an attempt to recover back to its original shape. Of course, the characters are not just composed of flesh. Internally, they have some kind of bone structure which we will need to represent using our model. In order to do this, I wrote software tools that allowed us to paint stiffness values volumetrically on the tetrahedra of the character. We ended painting very high stiffness values for the interior regions of the character to represent the bone structure. Thus, tetrahdra inside the character will resist all kinds of stretching just like real bone. During actual simulation, the soft, fleshy tetrahedra closer to the surface will move about in a less unobstructed way. They will end up colliding with the stiff interior «bone» tetrahedra and react accordingly. The end result is a wave ripple effect on flesh when the character encounters any sort of collision or impact with itself or some external object. That means you can see the flesh rippling about as the character sits down on a chair or slams an arm on a table.

You are probably wondering at this point how useful the character composed of tetrahedra is. I mean, sure it will wobble about if you drop it on the ground like a rag doll. It does seem kind of pointless since we are not making a movie full of lifeless rag dolls! Indeed you are correct about that. The simulation is only useful if we can combine it with human driven animation,. That is, we want animators to «act» with our simulated digital human characters. This means that the simulated character will have to receive input from the animators and act out the animation while still performing the cool secondary ballistic simulation effects on flesh. The first thing to do is to get the animators to animate the surface mesh just like how they would normally without simulation. The animators move and pose the character over a period of time. The output from such a process is a set of points at each frame in the animation. These points represent the pose of the character at a specific time in the shot. With the input set of points, we will next need to figure out a way to make those points drive the simulated character. Using the idea of a spring from basic physics, we can accomplish this goal. Remember from your physics lessons back in school that a simple spring particle experiences a force that is inversely proportional to the displacement of the particle from its rest position. The further the particle is away from its rest position, the greater the force. This will tend to make the particle attracted to its rest position. Imagine if you wanted a particle to track the position of another. Intuitively, you could attach a spring between that particle and the particle you want to track. The rest position in this case will be the position of the target particle. Now imagine doing that for an entire set of particles. That is exactly what our input animation data is. We will attach springs between the animation points and the simulated points. As the animated points move over time, they will attract and pull the simulated points towards them, thus animating the simulated character. To solve the actual spring equation so that we can make the springs work, we will end up solving an ODE (Ordinary Differential Equation). There are various numerical techniques to solve such equations which you can read up in other reference books or material. Implementing numerical techniques in code to solve the ODE, we end up with a fully simulated flesh character that acts with human driven animation. As the character moves, the tetrahedra push or pull one another, causing waves and vibrations to propagate through the character. The audience will see secondary dynamics like fat jiggles as the character acts out the input poses over time. The general production pipeline animators go through in making their characters come alive on screen thus involves first animating the character on computer and then running the flesh simulation on top of the character to get the secondary ballistics.

The above process describes the animation of a single character. Animating dozens or hundreds of characters poses different problems requiring different solutions. Simulation was the chosen tool to alleviate the misery of manual labor intensive animation. The first thing we did was to get the animators to animate a basic set of motions. These involved the characters going through motions like flailing, kicking their legs about or bobbing their heads in a funny way. Those animations were captured and stored in an animation library. We next created a bunch of simulated characters from the process described above. We applied the animation tracking method locally to the characters mentioned in the previous paragraphs, threw in gravity and ran the simulation. We applied different animations from the animation library onto those characters as the simulation ran. The result was fat humans bumping and reacting with each other. As the flailing animation kicked in for various characters, they pushed each other away (or rolled over) from each other. We got some nice natural rolling motion just by simulation alone as the characters fell from one side of the ship to another. The nice, natural (and hilarious) motion was all obtained for “free” without any additional input from human animators. This saved the team a great deal of time and allowed us to finish those difficult shots. Even then, the simulations were extremely computationally intensive so we ended up writing code to run those simulations on up to 8 processors. I want to stress again that the ship tilting sequence was mainly possible because of the use of the simulation approach. Such a problem would have required a much larger team and many more man hours otherwise.



A test shot of human crowds simulation

Continued on page 5

Charles Stein honored on his 90th Birthday >>>

A symposium in honor of Charles Stein took place at Stanford University on his 90th birthday, March 22, 2010. It was jointly organized by the Department of Statistics, Stanford University, and the Institute for Mathematical Sciences, National University of Singapore.

Charles Stein is considered to be one of the most original thinkers who made fundamental contributions to probability and statistics. He has received many honors and awards and is a member of the National Academy of Sciences (USA). He has given many invited lectures, notably as plenary speaker of the International Congress of Mathematicians, and as the Institute of Mathematical Statistics Wald Lecturer, Rietz Lecturer and Neyman Lecturer. He is currently Emeritus Professor of Statistics at Stanford University.

There were over 100 registered symposium participants who came from at least three continents. Also present were Charles' family members: his wife Margaret, his son Charles Jr., his daughter Sarah and his grandson. In accordance with Margaret's and Charles' wishes, the symposium was a half-day event.

Monday, March 22 was a beautiful sunny day and the symposium began at 1:30 pm with the welcome and opening addresses by Wing Wong, the Chairman of the Stanford Statistics Department, and Louis Chen, the Organizing Committee Chair.

Louis Chen presented Charles with a pewter plate as a birthday gift from his institute. Inscribed on the plate was a poem written jointly by Louis and his colleague Y.K.Leong:

A thinker original and independent,

In search of perfection invariant,

Found admissible wisdom's counterexample,

Made (fame, humility) exchangeable.

This was followed by eight 25-minute talks presented in two consecutive sessions. The speakers and titles of the talks (in chronological order of presentation) were:

Rapt audience at the Stein symposium

Persi Diaconis on Stein's method

Dining with the Steins

Continued on page 6

Continued from page 4

To me, computer graphics is a very exciting field to be in. People in my field get to blow up buildings, make monsters and stretch our imaginations in our everyday work. You can see the results of our work in movies, games and advertisements on television. One should also realize that making cool stuff happen on screen requires an understanding of basic mathematics and physics. The foundation of computer graphics is built on these 2 fields. I find it amazing that we can produce big dinosaurs or flying castles based off knowledge of linear algebra, numerical analysis and probability. Computer graphics is the application of science to create art in a rather fascinating way. As the field continues to evolve, we will most definitely see more amazing things appearing in the theaters, on your gaming consoles and your mobile devices. More complex and involved mathematics/and or physics will also be used to solve these increasingly hard computational problems. As audiences and consumers worldwide demand more compelling and believable digital worlds, the nature of the medium will also demand smarter and more technical people to make such experiences come true. I think we have an exciting road ahead in the coming years.

Jiayi Chong
Pixar Animation Studios

People in the News >>>

KK Phua elected 2009 Fellow of American Physical Society (APS)

Our heartiest congratulations to Professor KK Phua for his election as a Fellow of American Physical Society. Professor Phua is a serving member of the IMS Management Board.

Louis Chen appointed a member of the Advisory Committee of the Beijing International Center for Mathematical Research

IMS Director Louis Chen has been appointed a member of the Advisory Committee of the Beijing International Center for Mathematical Research, May 2010 – April 2013.

CHONG Tow Chong appointed as Provost of Singapore University of Technology and Design (SUTD)

Professor Chong Tow Chong has been appointed as Provost of Singapore University of Technology and Design (SUTD), Singapore's fourth university, with effect from 1 June 2010. Professor Chong is a serving member of the IMS Management Board.

Continued from page 5

- Larry Brown (University of Pennsylvania) — "Stein's research on fixed sample optimality, apart from multivariate normal minimax shrinkage".
- Morris Eaton (University of Minnesota) — "On some contributions of Charles Stein to applications of invariance in statistics".
- Carl Morris (Harvard University) — "Shrinkage estimation".
- Brad Efron (Stanford University) — "Stein's unbiased risk estimate".
- Peter Bickel (University of California, Berkeley) — "Charles Stein: Semiparametric models and nonparametric methods".
- David Siegmund (Stanford University) — "Charles Stein and fixed precision sequential estimation".
- Andrew Barbour (University of Zurich) — "Stein's (magic) method".
- Persi Diaconis (Stanford University) — "Few but ripe: 35 years of following Charles Stein".

A special brochure was printed and distributed during the symposium to mark the occasion. The brochure contained pictures of Charles and statements about him from his colleagues:

Persi Diaconis — *Charles Stein is a quiet man but when he talks, we listen. When Markov chains started to become popular (about 1980), he seemed interested as well. I asked him why and he answered as if it is obvious: "Of course, a reversible Markov chain is the same thing as an exchangeable pair." I knew that exchangeable pairs were a mainstay of Stein's Method. His statement changed my research direction. Twenty five years later, he added another sentence: "I always thought it would be a good idea to go through Feller's Volume One using the method of exchangeable pairs". Susan Holmes and I had been going through Feller with Bayesian eyes (I doubt Charles approves). That extra statement should keep me going for another twenty five years.*

Brad Efron — *Gustav Elfving once told me "After I met Doob I wondered why anyone else would do probability, and after I met Charles I wondered why anyone else did mathematical statistics".*

Wing Wong — *Among the great mathematical statisticians of the 20th century, some left their mark by developing new theories and techniques, and others by discovering surprising results that shattered long-held beliefs. Charles Stein is unique in his ability to do both. He is truly a giant among giants.*

The symposium ended with a dinner held at the Schwab Residential Center (Stanford University). During the dinner, a mathematics genealogy chart of Charles Stein was presented to Charles by Wing Wong. A number of people (including Persi Diaconis, Ted Anderson, Ken Arrow, Brad Efron, Margaret Stein, Charles Stein Jr., Susan Holmes) shared their reminiscences about Charles Stein. It was indeed a happy and memorable occasion for Charles, his family and his friends.

More details of the symposium (including the slides of each of the eight talks) can be found at:

http://www-stat.stanford.edu/~ckirby/charles/Symposium2010.html.

Pictures taken during the symposium and the dinner at:

http://www2.ims.nus.edu.sg/Programs/010CharlesStein90/visualbox/index.htm.

Louis Chen and Wei-Liem Loh
National University of Singapore

Programs & Activities >>>

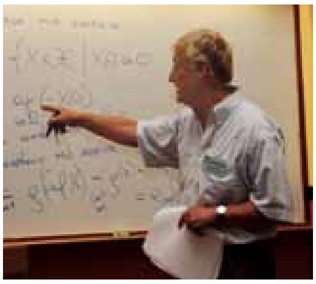
Past Programs in Brief

Financial Mathematics (2 November – 23 December 2009)

Website: http://www2.ims.nus.edu.sg/Programs/financialm09/index.php

Chair

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



Hans Föllmer: How to choose your portfolio

Shige Peng: On managing financial risk

A break from financial crisis

The program brought together leading experts in financial mathematics from around the world to the IMS and provided a platform for participants to interact and work together in this interdisciplinary research field. The Singapore scientific community and NUS researchers were given valuable insights into the three main areas of emphasis of the program: (1) Risk measures and robust optimization in Finance, (2) Pricing and hedging of environmental and energy-related financial derivatives, and (3) Optimal stopping and singular stochastic control problems in finance Both mathematical methodology and practical applications were highlighted in the program. The program enhanced the interaction and collaboration between local participants and prominent international researchers.

Two series of tutorial lectures on risk measures and stochastic control problems in finance were delivered to train graduate students and young scientists. A total of 71 graduate students from NUS, NTU and SMU attended the lectures. Through these lectures, they learned some elementary and advanced topics in this fast-growing interdisciplinary field and also got the opportunity to interact with the world leading experts.

Complex Quantum Systems (17 February – 27 March 2010)

... Jointly organized with Centre for Quantum Technologies

Website: http://www2.ims.nus.edu.sg/Programs/010quantum/index.php

Chair

Heinz Siedentop, *Ludwig-Maximilians-Universität München*

The program was organized in two related sections, but with different emphasis, namely "Large Coulomb Systems" and "Quantum Information and N-Representability". The topics included in the program marked an area of considerable current research activity. The goal of the program was not only to communicate recent research results and initiate collaboration between the mathematicians and physicists, it was also intended to initiate collaboration between participants of the many-particle community and the quantum information community. The program, which featured two introductory courses, aimed to introduce interested graduate students and non-specialists from both mathematics and chemistry to the research area. It has delivered new opportunities for research and collaborations to research groups in mathematics, physics and chemistry.

Matthias Christandl, Jens Eisert and Christina Kraus: Conversing on the quantum

Complex Quantum Systems: An active informal seminar

A quantum group

Continued on page 8

Continued from page 7

Next Program

Geometry, Topology and Dynamics of Character Varieties (18 June – 15 August 2010)

... Co-sponsored by Global COE (Center of Excellence) of the Tokyo Institute of Technology, Compview and the National Science Foundation (USA)

Website: http://www2.ims.nus.edu.sg/Programs/010geometry/index.php

Co-chairs:
William Goldman, *University of Maryland*
Caroline Series, *University of Warwick*
Ser Peow Tan, *National University of Singapore*

Character varieties lie at the confluence of many important areas of mathematics including algebraic geometry, hyperbolic geometry, Kleinian groups, Teichmueller theory and three dimensional topology, dynamical systems, gauge theory, and number theory. Their study reveals many deep and rich connections between these fields. The program will bring together some of the leading experts from these different backgrounds to explain their subjects and explore connections between them, to report on the latest developments and to chart out new directions. It also aims to introduce various aspects of this important subject to graduate students and young researchers, discussing open problems and fostering future research in this area. In particular, it will give students and researchers from the Australasian region a chance to interact with experts and researchers from Europe and the United States. An important aspect which will be emphasized in the program is the role of computer simulations and experiments in the field, and it is hoped that participants will profit from the opportunity to interact and experiment with computer experts during the program.

The main activities of the program consist of a three week summer school, a two week workshop and a one week conference. Both the workshop and the conference are designated ICM satellite conferences.

Upcoming Activities

From Markov Processes to Brownian Motion and Beyond: An International Conference in Memory of Kai Lai Chung (13 – 16 June 2010)

... Sponsored and financially supported by Peking University, Nankai University, Institute for Mathematical Sciences, NUS and Institute of Advanced Studies, NTU
... Co-sponsored by Institute of Mathematical Statistics and IMS-China

Website: http://www2.ims.nus.edu.sg/Programs/010KaiLaiChung/index.php

Chair
Zhiming Ma, *Chinese Academy of Sciences*

The conference will be held at Peking University, Beijing. For more information, please refer to the website.

Tenth Anniversary of IMS: Celebrating 10 years of Mathematical Synergy (24 June 2010)

Website: http://www2.ims.nus.edu.sg/Programs/010ims10/index.php

The IMS will be celebrating its 10th anniversary with a one day event to be held at the IMS auditorium on 24 June 2010. The theme of the program is "Celebrating 10 years of mathematical synergy". The Guest of Honor for the event will be the President of NUS, Professor TAN Chorh Chuan, and highlights of the activities include a video clip presentation of the activities of the IMS over the last decade, a musical performance of an original piece for flute and harp composed by Professor Bernard Tan for the occasion, as well as talks by Professor Tony Chan from the Hong Kong University of Science and Technology, Professor Hugh Woodin from the University of California at Berkeley and Professor Yeneng Sun from NUS. In addition, as part of the celebrations, World Scientific will also be publishing a book "Creative Minds, Charmed Lives" of interviews of 38 eminent scientists and mathematicians conducted at the IMS by the former editor of *Imprints* Y.K. Leong. These interviews first appeared in *Imprints*, and have formed a staple and much anticipated part of the newsletter. A commemorative booklet for the event featuring articles by the Chairman of the Management Board Professor Chi-tat Chong and the chairman of the Scientific Advisory Board Professor Roger Howe, contributed thoughts of various program organizers and participants, and interviews by Y.K. Leong of the director as well as the deputy directors (past and present) will also be published. As we look forward to more activities and programs contributing to a more vibrant and exciting research environment in the mathematical sciences at IMS and Singapore in the future, we take this chance to celebrate and show our appreciation to all who have contributed in one way or another to the success of the IMS.

Asian Initiative for Infinity (AII) Graduate Summer School (28 June – 23 July 2010)

... Jointly organized with Department of Mathematics, National University of Singapore, funded by the John Templeton Foundation

Website: http://www2.ims.nus.edu.sg/Programs/010aiiss/index.php

The Graduate Summer School aims 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.

The main activity of the AII Graduate Summer School will be a set of three intensive short courses offered by leaders in the field, designed to introduce students to exciting current research topics. These lectures will not duplicate standard courses available elsewhere. Each course will consist of lectures with problem sessions. On average, the participants of the AII Graduate Summer School will meet twice each day for lectures and then again for a problem session.

Continued on page 9

Continued from page 8

Programs & Activities in the Pipeline

Workshop on Recent Advances in Bayesian Computation (20 – 22 September 2010)

Website: http://www2.ims.nus.edu.sg/Programs/010bayc/index.php

Chair
David Nott, *National University of Singapore*

Over the last 15 years there has been an explosion in the use of Bayesian methods in applied statistics. Due to advances in technology for data collection in many fields of science, engineering and the social sciences, applied statisticians increasingly have to deal with problems of combining data and information from different sources. This leads naturally to the use of richly structured hierarchical models, and advances in Bayesian computational methods have meant that a Bayesian approach is often the most easily implemented one for inference in such models. The purpose of this workshop is to bring together leading researchers in the area of Bayesian computational methods to discuss challenges and opportunities in the area, with a focus on dealing with large data sets.

Hyperbolic Conservation Laws and Kinetic Equations: Theory, Computation, and Applications (1 November – 19 December 2010)

Website: http://www2.ims.nus.edu.sg/Programs/010hyperbolic/index.php

Organizing Committee:
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This program will provide a forum for people working in hyperbolic conservation laws, kinetic equations, mathematical physics, scientific computation, and engineering to jointly promote research on the kinetic equations for the rarefied gas dynamics. This program will offer a series of comprehensive tutorial lectures by senior scientists from rarefied gas theory, semi-conductor industry and nonlinear hyperbolic PDE to train PhD students and people who are interested in these topics.

Workshop on Recent Advances in Nonlinear Time Series Analysis (7 – 18 February 2011)

Website: http://www2.ims.nus.edu.sg/Programs/011wnlinear/index.php

Probability and Discrete Mathematics in Mathematical Biology (mid-March – early June 2011)

Coding, Cryptology and Combinatoric Designs (15 May –11 June 2011)

... *Jointly organized with Nanyang Technological University*

Computational Prospects of Infinity II, incorporating a Summer School and a Workshop on Infinity and Truth (mid-June – mid-August 2011)

Highlights of Other Activities

Workshop on Epidemiology of Infectious Diseases: Emerging Challenges (4 – 8 January 2010)

Website: http://www2.ims.nus.edu.sg/Programs/010wkepid/index.php

Paul Ananth Tambyah: A clinician's perspective

An emerging group of infectious researchers

Infectious diseases abound in Singapore, and tropical diseases are not as well understood as those affecting higher latitudes: for instance, influenza occurs year-round on the equator, not just mainly in a winter season as in Europe, and there are many unknowns relating to the mosquitoes that act as vectors for diseases such as dengue and Chikungunya. Thus, the workshop was very relevant to Singapore, to her scientific community, and to the university. Infectious disease modeling work is of a multidisciplinary nature. This means that the various parties are distributed across many different organizations – universities, research institutes, government and hospitals – which reduce the potential for

Continued on page 10

Continued from page 9

cross-fertilisation of ideas. The workshop served a valuable service by bringing together people from these disparate areas to meaningful discussions which could lead to possible collaborations.

The participants of the workshop came from a variety of backgrounds, both from Singapore and overseas. Local participants include those in the area on medicine, statistics, economics, engineering and computing. A total of 70 people attended the workshop.

2nd Singapore Conference on Quantitative Finance (5 March 2010)

... Jointly organized with Saw Centre for Quantitative Finance and Department of Mathematics

Website: http://www2.ims.nus.edu.sg/Programs/010cqfinance/index.php

Ying Chen: A question on financial bubbles

The idea of using mathematics to model financial products was conceived more than a hundred years ago. However, it was only in the past 30 years, with the rapid development of computer and communications technology together with globalization and banking liberalization that mathematics and statistics have been extensively used in the finance industry. A new subject, Quantitative Finance, grew out from these applications and the growth was so phenomenal that the indiscriminate use of mathematics and statistics has been blamed partly for the 2008 financial crisis. Therefore, there was a need to further develop the mathematical theory to provide a better understanding of the scope and limitations of the financial models. The Second Conference, with talks delivered by nine local and overseas speakers, served to further promote Quantitative Finance and provide a platform for researchers and practitioners to interact and share their experiences and findings.

Symposium in Probability and Statistics in honor of Charles Stein on his 90th Birthday (22 March 2010)

Website: http://www2.ims.nus.edu.sg/Programs/010CharlesStein90/index.php

An article on Charles Stein honored on his 90th birthday is found in this issue of *Imprints*.

Public Lectures

Jakob Yngvason: Cold atoms, warm smile

The public lecture on "Cold Atoms and Quantized Vortices" delivered by Professor Jakob Yngvason, Universität Wien, Austria on 23 February 2010 attracted about 90 people, including many students from the junior colleges. The experimental realization of Bose-Einstein Condensation (BEC) in ultracold atomic gases in 1995 has created lasting interest in the strange quantum properties exhibited by such systems. These include superfluidity and the appearance of quantized vortices in rotating gases. BEC was predicted by Albert Einstein in 1924 but its full theoretical understanding still poses highly challenging problems. In the lecture, Professor Yngvason gave a highly engaging and nontechnical introduction to BEC and some of the phenomena associated with it. The lecture piqued the interests of the students so much that there was a long and spirited question and answer session following it.

Paul Embrechts: Poise at a time of crisis

Professor Paul Embrechts from the Swiss Federal Institute of Technology (ETH) delivered a public lecture on "Mathematics and the Financial Crisis" on 16 November 2009. This timely talk, in the wake of the recent financial crisis, and given by a world leading expert on financial mathematics was extremely well received and attracted an audience of about 150 people. In the talk, Professor Embrechts put into perspective how

Continued on page 11

Mathematical Conversations

Larry Shepp: From Putnam to CAT Scan

Larry Shepp

Interview of Larry Shepp by Y.K. Leong

Lawrence Shepp is world-renown for pioneering and fundamental contributions to computed tomography and for extensive work on applications of probability, statistics and mathematics to physics, engineering, communications, mathematical finance and genetics. His work in tomography has a great influence on biomedical imaging which has important applications in medical X-ray and nuclear magnetic resonance (NMR) technology.

He was a winner of the William Lowell Putnam Intercollegiate Mathematics Competition in 1958 and obtained his PhD from Princeton University in 1961. From 1962 to 1996, he was a Distinguished Member of Technical Staff at Bell Laboratories, and concurrently held joint appointments at Columbia Presbyterian Hospital, Columbia University and Stanford University. From 1996 onwards, he returned to academia full-time, first at Columbia University and then at Rutgers University. He is Board of Governor's Professor at the Statistics Department, Rutgers University since 2004. From June 2010, he will be emeritus professor at Rutgers University and professor of statistics at Wharton School, University of Pennsylvania.

His work in stochastic processes and computer tomography has earned him numerous honors and awards, among them membership of the National Academy of Science, Institute of Medicine, Academy of Arts and Science, fellowship of the American Institute for Medical and Biological Engineering, Paul Lévy Prize and the IEEE Distinguished Scientist Award.

He has been invited for visiting positions by many countries throughout the world. After returning to academia, he continues to offer his services to the medical and engineering industries. He also serves on the editorial boards of leading journals in probability, imaging sciences and computer tomography.

Shepp was invited by the Institute to give a public lecture on *Data mining with modeling: Managing diabetes* on 24 April 2008. On the same day, he was interviewed by Y.K. Leong on behalf of *Imprints*. The following is an edited and enhanced version of the interview, in which Shepp traces a distinguished and colorful career from his first success in mathematics in the Putnam Mathematics Competition to the deep impact and influence that his work on computed tomography has exerted in the medical sciences. Brimming with the energy and passion of an avid problem solver, he also gives us a glimpse of a halcyon period of multidisciplinary research in Bell Laboratories.

Imprints: You were a winner of the Putnam Mathematics Competition in 1958. Could you tell us something about it?

Larry Shepp: The remarkable thing about that was that I was trained by my mentors, Don Newman and Murray Klamkin in the problems of the exam. I am sure that I would not have won without their help. We went over the old exams very

Continued on page 12

Continued from page 10

financial mathematics has contributed substantially to a better methodological understanding of the fundamentals of modern finance, and also the role of mathematics in the current financial crisis. He also touched on the consequences that will be drawn with respect to teaching and research from this development - but not only in (financial) mathematics.

Crisis management – learning about the dos and don'ts

Continued from page 11

thoroughly and this helped me enormously. I would never win the Putnam today. The problems are hard, but after awhile they are very much like crossword puzzles. At that time I was at a very small engineering school, Brooklyn Poly [Polytechnic], and it was amazing that we beat Harvard. In the next 5 years, Brooklyn Poly continued to dominate because I trained them. They were smart people but it was the training that did it.

I: Did you get a scholarship because of that?

S: No, the scholarship came before that. I was not that strong a student in high school because it was not only mathematics and I was not good at anything except mathematics. I got a scholarship with Brooklyn Poly. They paid 300 dollars out of 600 dollars tuition. Then I won the Putnam and I got a scholarship to go to Harvard. That's what the Putnam winners get. But I turned that down. I didn't go to Harvard. I went to Princeton because of [William] Feller. He came to give a talk at Brooklyn Poly and I couldn't understand a word he said. For one thing, he spoke English with a very heavy accent. The mathematics was way above my head even though I had won the Putnam, but I knew I wanted to work with him. That was the time of Sputnik and the money was flowing from the government. So I went to Princeton instead and I never regretted it. Princeton had a wonderful impact on me. I was helped by Feller and other people. He was much older than me. I had the ideas of a young man and he had the ideas of somebody who had been around for a long time and went through many difficulties. He was from Yugoslavia and may have had some Jewishness in his past, but he never thought of himself as Jewish. He decided to leave [Yugoslavia] because he could see what was coming at that time. He and I were not on the same wavelength politically because I was not so interested in politics at that time, but we talked about mathematics and he was very helpful to me.

I: After your PhD you were at the University of California at Berkeley for only a short period and then you joined Bell Laboratories for quite a long period of time. What made you join Bell Laboratories?

S: My first job was at Berkeley and Feller helped me get that job. I was there for only a year. What happened there was interesting. Several things happened. One was that my father became ill. I knew I would have to go back to New York in the east. I wanted to get a tenure position at Berkeley, but I thought I would go back to the east for a year and then I would go back to Berkeley, but it didn't work out well. I was very busy studying the Russian language for my own interest. They gave me two very big courses to teach, you know, hundreds of people. It was very hard for me. And then, Jerzy Neyman asked me to run a seminar. It was a lot more than I thought I could handle, but he said, "You don't have to do it if you don't want to do it." So I said, "Well, in that case, I don't want to do it because I'm too busy writing papers, teaching so much and I have all these responsibilities and learning Russian." And then he said, "But the youngest person in the department runs the seminar. That's the tradition." By this time, I was fed up with him. I didn't respect him that much anyway, and I said, "The tradition is over." He just left and I didn't know he was angry. Then a few years later, I applied to be an exchange scholar in Russia and I lived in Russia for 6 months. But when I got the letter, I saw the level of anti-Semitism in Russia and I began to work against the Russian regime in any way I could. There were some laws that I broke while I was there in 1966. As a result, the KGB [state and intelligence agency of the Soviet Union] threatened me with 15 years in prison if I didn't become a Soviet agent. In January of 1967, I lived in the US embassy for a week and made an application for an exit permit.

I: It sounds like fiction.

S: It's all true. I can prove it. You can check the *New York Times*. What happened was that they gave me an exit visa. I had anticipated that they would. They would not risk the exchange program which was very beneficial to the Soviets 'cause they could send spies to America while we were sending naïve people. I wasn't naïve and they threw me out. When I got back to the United States, the FBI [Federal Bureau of Investigation] thought that because they threw me out, I was a Soviet agent and that they threw me out as a cover. So they would not let me go back to Bell Laboratories. That was the only place I could go to at that time, I could have gone to University of Kansas or Bell Laboratories. Bell Laboratories was like manna from heaven. I had a wonderful time there.

I: Did you do any classified work at Bell Labs?

S: I never did any classified work directly though I often spoke with engineers who did classified work, but they always hid details from me. The FBI thought that having a KGB agent inside the Bell Laboratories would not be so good and they refused to let me return to my position. But Bill Baker, who was Vice-President of Bell Labs (I didn't know him), came to me and asked me in a roundabout way whether I was a spy. I said, "No". I worked against the Soviets; the FBI was safe in the United States and they were accusing me of being a traitor. I told him, "I am a loyal American and I hate communism." He believed me and he told me later on that he argued with the FBI in Washington

Continued on page 13

Continued from page 12

for a whole day and they finally let me back into Bell Labs. Many years later, I made a freedom of information act request – we have this wonderful freedom of information act in the United States. As a citizen, you can get access into government files about you. The law enabled me to get what Neyman said about me. Neyman said, "Never put this person in a position of trust." The FBI went to interview everybody who knew me and Neyman was in that category. Everybody else said, "No, he's fine. He's a loyal American." But Neyman said, "Don't trust him." You know why? Because I wouldn't run his seminars. But I like Berkeley and I go back to Berkeley a lot, and they made me a Miller Fellow.

I: But you were at Bell Labs for a long time.

S: Only for 34 years! In 1996, Bell Laboratories broke up – the mathematicians went one way and the engineers went the other. I was always working with both of them, and I didn't really want to make that choice. I thought that 34 years was enough, so I went to academia at that point – one very nice year at Columbia and then I went to Rutgers.

I: You also went to Stanford?

S: I went to Stanford over the years frequently. They made me an adjunct professor in statistics for about 15 years. Then they decided that they didn't want to have any more adjunct professors, they wanted me to go there full-time. I couldn't do it because of my children and my wife and my son. Bell Labs is on the east coast and Stanford is on the west coast. I have a very long-standing relationship with Stanford but it was never full-time

I: Could you tell us how you came to work in computed tomography?

S: I happened to be in Columbia Presbyterian Hospital when the great English engineer Godfrey Hounsfield [Nobel laureate in Physiology/ Medicine 1979] was trying to sell Columbia Presbyterian Hospital a CAT scanner in 1976. I happened to be there that day. I saw his demonstration, I asked him, "Are you using a formula based algorithm or are you doing it by some iterative procedure?" He said, "We're doing an iterative procedure, which we believe is optimal". I didn't believe that was optimal. So I switched from probability to engineering for a while, and that was perhaps the smartest thing I ever did. The most important, interesting and motivating thing that I have ever done was in experimental tomography.

I: Did you get into the experimental part?

S: I did. The key ideas in the design were due to my colleagues, not me, but I played a big role in the electronic design of the 4th generation CAT scanner. I was in pretty much every aspect. That was in 1972 through the 1980s. Now the CAT scan is dominated by magnetic resonance imaging; technology moves very fast.

I: What were the mathematical aspects?

S: The mathematical aspects from the mathematician's point of view are very clear. Radon's theorem had to be involved and that was very exciting. If it had not been for Radon's theorem, I never would have got into it because it gave me the feeling that I could make some contribution. I suspected that Hounsfield didn't know Radon's theorem and I did, and that was a good thing. The contribution that I made was not so much in the algorithmic development (although everybody talks about the Shepp-Logan algorithm) but it was more in the understanding of how to judge and how to read rather than the development of the algorithm. I did very well on that but that was largely pretty well understood from the work of all the people like [Ronald] Bracewell and [A.V.] Lakshminarayanan and [G.N.] Ramachandran and other people. The probabilists, [Harald] Cramér and [Herman] Wold wrote a paper in 1927 – they were not aware of Radon's theorem but they re-derived it via the Fourier transform. All that stuff was pretty well understood by the time I came along. I made a contribution to the numerical aspects of the algorithm. I made a very clever step that speeds up the algorithm and that was an important thing.

I: That wasn't really probability, wasn't it?

S: I like to think it's probability, a little bit. Computed tomography is based on reconstructing a function from its marginal distributions, and a marginal is certainly a basic concept in probability. I do not think of CAT scanning as all that far from probability because of this. Even more so, emission tomography is driven by statistics in an even stronger way since the major limitation is statistical noise due to low counts.

I: There seems to be two types of tomography, one is continuous and the other is discrete, isn't it?

S: Yes. There is a discrete tomography and there are many types of tomography, i.e. many inverse problems that can be called tomography. What is usually called discrete tomography is a very special one and is still very much in a research mode. It refers to trying to find a fault in the crystals used in integrated circuitry. Most other problems of inverse type are, as you say, continuous, including emission tomography.

Continued on page 14

Continued from page 13

I: Are the problems solved by a combination of algorithmic and statistical methods?

S: The problems in computed tomography – projection, Radon inversion – that's Fourier transform. Emission tomography seeks a maximum likelihood estimate which has a statistical basis. NMR, magnetic resonance imaging, is tomography also; that's pure Fourier transform based.

I: Have advances in computed tomography contributed to non-invasive methods of detection and treatment in medical science?

S: Yes, extremely so. Nobody is going to get to old age anymore without being screened by CAT, MRI scanners and maybe emission scanners (PET [positron emission tomography] or SPECT [single photon emission computed tomography]) as well.

I: Are advances in the hardware comparable with the advances in the theoretical aspects?

S: Yes. Every one of these tomographies depends very much on the advances in hardware as well as software. But I would say that in the CAT scanner (Hounsfield's invention) the main role is played by mathematics. In emission tomography, the main role is played by statistics. The algorithm in each case can be set up by using ray processes and things like that. This is a secondary issue. NMR is very strongly driven by Fourier transform and the use of gradient field. The advances in a rapidly growing field depend a lot on the hardware, but you really cannot separate the two.

I: Do you see yourself as a problem solver?

S: Yes. It's really funny that you've pointed this out in the interview where you go back to the Putnam. It's true that I see myself as a problem solver. I really urge people to think of themselves as problem solvers and apply whatever methods that they can dream up to solve them. I learned that from Don Newman who was a mentor of mine. Rather than being driven by trying to develop a theory, you are driven by problems you are working on. This is a very important philosophy. Sometimes people forget this and fall back on the methods they know to solve the problem that just appeared. This rarely works well.

I: After all, mathematics is about solving problems.

S: Absolutely. I think it was Hermann Weyl who said the mathematics walks on the feet of little problems.

I: Which piece or pieces of work in probability and statistics give you the fondest memories?

S: I'm most happy with my work on probabilistic problems on random covering and zeros of random polynomials. It is amusing that probabilists do not seem to be as interested in solving problems any more. Rick Durrett and I have written a polemic on this in which I point out that a recent paper of mine that solved a problem I worked on for 40 years and finally solved was rejected because the referee did not like the method that was used.

I: When did you become interested in problems in mathematical finance?

S: In 1983 or 1984, ATT [American Telephone & Telegraph] found that they did not have enough expertise in economics to argue effectively for their monopoly position. A new economics department was formed within the math department under Ed Zajac to provide theory for dealing with the FTC (Federal Trade Commission). Ed hired 40 economists and since they were going to be put into the math department, they had better be good mathematicians. He hired some very smart people. That was when I began to get interested, but I didn't get completely interested in it until a little later with when my friend [Albert] Shiryaev and I began to work on problems in Russian options. I had done a lot of stochastic optimization problems before getting into finance per se, but he wanted to work in finance. He helped me bridge that gap. But since I have gone to academia and found that many of our students want to become rich on Wall Street and want somebody to teach them the mathematics behind Wall Street, which is basically Ito calculus, I am more involved in mathematical finance. (This may change with the 2008 stock market disaster.)

I: You collaborated quite a bit with Shiryaev, isn't it?

S: Yes, we have many joint papers and I'm expecting him to visit me in a couple of weeks in New Jersey. In fact, even when I was in Russia at the time when the KGB clamped down on me, I always entertained the idea that he might have been part of it.

I: Although you left industry to join academia full-time in 1978, you have continued to maintain an almost continuous connection with industry. What is the motivating force behind this?

S: That is a very good question. I guess part of the reason was problem-oriented in a sense. Academics often go off the deep end but they lose track of why they are doing it

Continued on page 15

Continued from page 14

because it is so pure. I like to play a role in the world like all applied mathematicians. I like to solve problems and so I do a lot of consulting for industry like electronics, engineering, semiconductors and lots of other companies. I like to stay close to the real problems; it's my training from Bell Laboratories.

I: I think you were once quoted for something about rediscovery.

S: I can tell you what that was about. Gina Kolata [of *New York Times*]called me up one day. She said she lost the quote that I made when somebody said that he knew something I claimed to have discovered and that in fact I simply rediscovered it. I replied, "When I discovered it, it stayed discovered." Now, in fact, I stole that quote. It was said by somebody else, maybe even by many people, but I heard [John] Tukey say it. Tukey in fact said, "When I discovered the fast Fourier transform, it stayed discovered". I believe that I gave him the "credit" for this clever defense when I stole it. Maybe I neglected to do it, but, in any case, I said to Gina, "Don't ascribe the quote to me, ascribe it to Tukey because it's NOT mine." She said, "Okay, I promise to do that." Sure enough she did not do it; I called her to complain that she had promised to do it and did not keep her promise. Her excuse was that the editor cut it out because the article was too long. Aargh!

I: But it's a great problem. There's so much information and knowledge scattered all over the place. It's hard to locate them unless somebody writes a book

S: I'm not going to write a book. I tried that but it's very hard to write a book. There is a big role to play if somebody wants to do that. There is a good book [*Mathematics of medical imaging*] by Charles Epstein on tomography from Larry Shepp's point of view. I am grateful to Charles for doing something I cannot do. Mark Kac was great at writing books too.

I: I notice you are also interested in problems in genetics.

S: Yes. Genetics attracted my interest because it's such an important thing. I tried to contribute and we wrote a paper on entropy and information theory in genetics. You really want to understand the correspondence between the gene and the part of the genome and the function you observe. We made a feeble attempt by trying to use entropy. We did find an interesting conclusion of negative type. We showed that introns have lower entropy (less randomness) than protein producing exons. This contradicted the conventional wisdom that the role of introns is a placekeeper for large scale genetic changes. It is tempting to form this hypothesis because to assume that gradual changes in genes can occur it is necessary that each change has survival advantages but this seems very unlikely say in the development of an entirely new function such as hearing or sight. Placekeeping changes may well take place in the so-called junk DNA, but if introns were placekeepers then they ought to have higher entropy but they certainly do not. Therefore they must have survival functionality. (See M. Farach, M. Noordewier, S. Savari, L. Shepp, A. Wyner and J. Ziv, ``On the entropy of DNA: Algorithms and measurements based on memory and rapid convergence'' *Proceedings of the Sixth Annual ACM-SIAM Symposium on Discrete Algorithms,* (1995).)

I: Do you have any graduate students?

S: I have at the present moment only one or two, but I've been carrying about six along at the same time. It's a lot of fun. I do feel the need to pass on to others what I have learned from Feller, Newman, Klamkin and Slepian, who helped me as mentors.

I: Is Slepian a mathematician?

S: Slepian was trained in physics and he was a great mathematician. He died recently. [David Slepian (1923 – 2007) was head of the Mathematical Studies Department of Bell Labs.]

I: Do you believe one should try hard problems?

S: I never worked on the Riemann Hypothesis or the four-color problem because neither of those problems turned me on and I knew that both were not in the area that I am good at. Those problems did not grab me but tomography grabbed me so much that it was the only thing that I wanted to do. I asked Dick Hamming, "Dick, would you use iterative methods or would you use a formula?"

I: Is it Hamming of "Hamming codes"?

S: Yes, he was a very good engineer, mathematician and computer scientist. He was at Bell Labs. Dick said he would just use iterative solutions. He made wild statements like "The Lebesgue integral is of no practical value in the sense that if the design of a plane required the Lebesgue rather than the Riemann integral then I refuse to fly in it". He is, of course, right in this assertion, but for one who is trained like I was trained to love Lebesgue integrals, one wants to believe that knowing Fourier-Lebesgue integration has utility. That was a big motive for me. I wanted to show Hounsfield and Hamming and myself that one could do

Continued on page 16

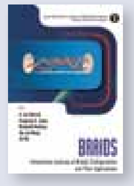
Publications >>>

Continued from page 15

something with Lebesgue's mathematics. At the end of the day, the mathematics that I and Ben Logan created was not exactly Lebesgue integration. The truth seems to be quite on Hamming's side. But, nevertheless, I think there are insights that were obtained from pure mathematics. I'm pleased that I could show that in some way, and even more so that I could I leave it to Charles Epstein to write the book.

I: Any advice for students?

S: I would urge them to, when they see a problem that really turns them on, throw everything at it, don't waver, work hard, don't give up and stick with it until somebody, preferably you, solve it. But you've got to choose the right problem. It's so hard to decide when you've got the right problem. Sometimes you've got to put it on the back burner. You don't want to get hung up on one problem forever. I learned at Bell Labs to work on several problems at the same time. It's a hedge.



Volume 19:
Introductory Lectures on Braids, Configurations and Their Applications

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