Interview with Dr Stanley Osher

Rochelle Kronzek

The Carl Friederich Gauss Prize *was premiered in 2006 and is awarded every four years at the International Conference of Mathematics. Presented jointly by the International Mathematics Union and the German Mathematical Society, Stanley Osher became just the third individual to be honored.*

The Gauss prize, which many now consider the most important award in applied mathematics, was established to give recognition to mathematicians who have impacted the world outside of their field through contributions to the business world, technology and everyday life.

Previous recipients of this new but prestigious honor include ***Kiyoshi Itō*** *in 2006 who pioneered* ***the theory of stochastic integration and stochastic differential equations now known as Itō Calculus****. Itō Calculus is an important mathematical tool in the study of random events and is important to mathematical finance.* ***Yves Meyer****, won the Gauss Prize in 2010 for contributions to several areas of mathematics: (a) In 1970, he developed* ***the theory of model sets in number theory****, which has become an important tool in the mathematical study of quasi-crystals; (b) together with Coifman and MacIntosh he proved the continuity of the Cauchy integral operator on all Lipschitz curves, a long-standing problem in analysis; (c) Meyer played a leading role in the modern development of* ***wavelet theory****, which has had a spectacular impact in information sciences, statistics and technology. Fourier analysis is a universal tool in applied mathematics, and due in a large measure to Meyer's work, wavelet theory has become the new name for Fourier analysis.*

The IMU posted this notice during the ICM 2014 in Seoul in honoring Dr. Osher:

"Stanley Osher is awarded the Gauss Prize for his influential contributions to several fields in applied mathematics, and his far-ranging inventions have changed our conception of physical, perceptual, and mathematical concepts, giving us new tools to apprehend the world.

Dr. Osher has made influential contributions in a broad variety of fields in applied mathematics. These include high resolution shock capturing methods for hyperbolic equations, level set methods, PDE based methods in computer vision and image processing, and optimisation. His numerical analysis contributions, including the Engquist–Osher scheme, TVD schemes, entropy conditions, ENO and WENO schemes and numerical schemes for Hamilton–Jacobi type equations have revolutionised the field. His level set contributions include new level set calculus, novel numerical techniques, fluids and materials modelling, variational approaches, high co-dimension motion analysis, geometric optics, and the computation of discontinuous solutions to Hamilton–Jacobi equations; level set methods have been extremely influential in computer vision, image processing, and computer graphics. In addition, such new methods have motivated some of the most fundamental studies in the theory of PDEs in recent years, completing the picture of applied mathematics inspiring pure mathematics.

Trained as an applied mathematician and an applied mathematician all his life, Osher continues to surprise the mathematical and numerical community with the invention of simple and clever schemes and formulas. His far-ranging inventions have changed our conception of physical, perceptual, and mathematical concepts, and have given us new tools to apprehend the world."

Stanley Osher

Stanley Osher has made many important contributions to applied mathematics, scientific computing and

Stanley Osher was given the Gauss Prize by South Korean president Park Geun-Hye

computational science, and he's not finished yet! He has applied his pioneering work on level set methods and other numerical methods for partial differential equations to the field of image processing and, in particular, to video image enhancing and movie animation. According to Dr. Osher's brief bio at the UCLA Institute for Pure and Applied Mathematics:

"Dr. Osher has co-invented and developed: the level set methods for computing moving fronts involving topological changes; essentially non-oscillatory high order methods for approximating hyperbolic conservation laws and Hamilton–Jacobi equations; total variation and other partial differential equation based image processing techniques; fast optimisation algorithms for ℓ^1-based regularisation, and diffusion generated geometric motion."

Elected in 2005 to the National Academy of Sciences, and in 2009 to the American Academy of Arts and Sciences. Dr. Osher has been an Alfred P. Sloan Fellow and a Fulbright Fellow, and was selected to give a plenary address at the 2010 International Conference of Mathematicians and the John von Neumann Lecture at the 2013 meeting of the Society for Industrial and Applied Mathematics.

A UCLA Professor since 1977, Stan has been the Director of Special Projects at the Institute for Pure and Applied Mathematics (IPAM) at the University of California at Los Angeles for 15 years and was formerly the Director of Applied Mathematics.

The Thomson Reuters Corporation has compiled a 2014 list of "Highly Cited Researchers". Individuals earned this distinction by authoring the greatest number of publications officially designated by Essential Science Indicators as "Highly Cited Papers" — that is, among the top 1% most cited for subject field, year of publication, and exceptional impact. Osher was among the most highly cited in both Mathematics and Computer Science.

I had the opportunity to meet one of Dr. Osher's 50 former PhD students in Seoul, Korea last summer and met with Dr. Osher himself at IPAM seven months later in February 2015. He is a likeable, humble and funny guy....

Candid Moments with a Talented Man!

Rochelle Kronzek: Stan, thanks for agreeing to talk with me about your background and career.

Stanley Osher: Pleasure.

RK: Would you please talk a bit about your background and childhood.

SO: I came from a poor family. We lived in East New York, Brooklyn. It was a rough neighbourhood, the one portrayed in "Goodfellas". In fact, Henry Hill was a neighbour of ours! My father held a variety of jobs including delivering laundry on a bicycle. He also taught himself calculus. He had wanted to be a surveyor. Unfortunately, my dad was not very successful in business and died when I was just eight years old.

RK: Who were your "heroes" when you were young?

SO: Jackie Robinson was my hero (baseball) and my sister Sondra was my longtime advisor and mentor. She became my link to having any kind of a future outside of the "hood".

My sister Sondra is seven years older than me. She received a PhD in mathematics at NYU. I was too old for Vietnam and too young for Korea. In 1957, after the Russians launched Sputnik, there was a ton of money available for graduate school education. Sondra encouraged me to follow in her footsteps...as much for economic reasons as anything else. An advanced degree in mathematics was a sure ticket to a good job. Joining the middle class became my motivating factor.

Both Sondra and I went to Brooklyn College for our undergraduate work. My sister encouraged me to apply for an NSF scholarship to go to NYU. I won the award and received free graduate school tuition and $300 per month to live on, tax free. I started at NYU in 1962 and remained there until 1966. I lived in Greenwich Village and my life changed completely. For once, I had some money and I was exposed to a completely different segment of life and experiences in New York with academia, the arts, creative people etc.

RK: Who were your mentors at NYU?

SO: At NYU in the 1960s, all of the big names in applied oriented mathematics were faculty at the Courant Institute including Louis Nirenberg , Jürgen Moser, Joe Keller, and others. Peter Lax eventually became my mentor. The caliber of professors of Mathematics in the 1960s was incredible.

I had other mentors outside of NYU over the years, many related to numerical analysis, including Gil Strang at MIT, and Heinz-Otto Kreiss at Uppsala, Sweden, Cal Tech & UCLA. I have been VERY lucky.

RK: Who was your PhD advisor at NYU?

SO: Jack Schwartz was my advisor. A very nice guy who seemed to know everything. I received my PhD in pure mathematics in functional analysis in 1966.

RK: Where did you spend your early years after your doctoral program?

SO: I spent two years at Brookhaven in a research job from 1966–68. I then went to UC Berkeley from 1968–1970 followed by 1970 to 1976 teaching and doing research at Stony Brook on Long Island. All the while, I was still working in pure mathematics. I thought there was not much happening in applied mathematics at the time. In 1976 I was a visiting professor at UCLA. Andrew Majda recruited me to come to UCLA. I made the move in 1977 and I've been at UCLA ever since. Another important person for me at UCLA was Bjorn Engquist, now at UT Austin, who was with me at UCLA for a long time. Andy and Bjorn were important colleagues and collaborators.

RK: Applied Mathematics at UCLA is very established and prestigious today.

SO: Yes, we are like the "Courant Institute West". Of course, I think that we're better! We only have 10 faculty in applied mathematics but the work of IPAM is year round and attracts top researchers from around the world for extended periods of time. In a time where NSF funding is being scrutinised and often cut, we've been renewed for another five years! We've hosted unique research in applied mathematics in materials science, nanotechnology, biotechnology, information science, etc.

RK: How did you and others build the Applied Mathematics program at UCLA?

SO: We had a very sympathetic UCLA administration and, after overcoming initial suspicion, a very sympathetic bunch of pure math colleagues in our department. We hired great people and everyone gets along with no political undercurrents.

RK: You have said that "The language of applied mathematics is differential equations". Please explain why to our readers.

SO: Actually I am getting more liberal in my old age. There is no doubt that problems in physics, engineering and applied science drove applied math for a long time. Since Newton, the language has indeed been differential equations. However the computer led us to numerical analysis, first of differential equations, but now, with the advent of big data, things like discrete optimisation, numerical linear algebra, statistics, machine learning … are centre stage. And we have moved with the times. Our students get jobs at Google, Facebook, etc. But I still want to comingle these fields with differential equations.

RK: You have also been accused of bringing together Quantum Mechanics, Applied Mathematics and Information Science with your research and practical outcomes. Not many have been able to accomplish that, sir!

SO: I have been very lucky. The products that are the outcomes of my collaborations and research are partially serendipitous. I am able to do the mathematical calculations but many of the people that I've collaborated with have come up with some terrific ideas as well. I write the algorithms while others come up with the applications!

RK: Well, you're being very humble. According to Thomson Reuters Research (listed at the UCLA website) your research papers were in the top 1% of all citations between 2002 and 2012 in both mathematics and computer science! Your research underpinnings have been the basis for lots and lots of work that has been accomplished subsequently, sir!

RK: It seems to me that you have carved a niche of very unique applied mathematics as your mathematics and that of your colleagues and collaborators. How did you ever get involved with movie animation and Hollywood? Please explain the link between your mathematics and the final product.

SO: It started with the realisation that the level set method could be used to realistically simulate things like the motion of bubbles in water. Until this observation, films like "Titanic" used very simplified models to do this.

RK: What is Shock Capturing?

SO: Think of the "Sonic Booms" of the 1970s, or hydrodynamics. It is a discontinuity in movement, like jamming on the brakes on the freeway. The late Dr. Ami Harden was an important collaborator with me in shock capturing. Lenny Rudin is the one that made a brilliant link between shock capturing and image processing. Images are characterised largely by discontinuities, like shocks. We then started a company together in 1988 called "Cognitech". Many related ideas came up as a result. In 1989, with Emad Fatemi we developed total variation based image processing. Total variation is a good measure of things which are smooth except for isolated jumps.

RK: How about the Level Set Method. What does that mean?

SO: It's a way of representing surfaces mathematically and has connections with differential geometry. When you have bubbles of air in water you can characterise what's going on by having a single function which is relatively smooth, taking on values less than 0 inside the bubbles, greater than 0 in the water outside and 0 on the interface. Then we just let this function change with time according to the laws of physics or whatever, and watch what happens. It's especially advantageous when bubbles merge or split.

I collaborated with James Sethian at UC Berkeley on that work. It is a method for capturing moving interfaces and has become a very successful tool in other disciplines — partial differential equations based image processing and computer vision, computer graphics, computational fluid dynamics. There are literally millions of references to it on Google.

RK: When did you and Dr. Sethian do that work?

SO: I believe that we first published our work on the Level Set Method in 1988.

Ronald Fedkiw is a professor of Computer Science at Stanford University and was one of my PhD students. He has been awarded two Academy Awards for his work on the Star Wars movies, Harry Potter films and Pirates of the Caribbean series.

RK: What is Forensic Image Processing and what does that have to do with your mathematics?

SO: Do you remember the Reginald Denny incident in LA where he was beat up after the police beating of Rodney King sparked riots in the 1990s?

RK: Of course.

SO: Well, there were videos taken of the bad guys roughing up Mr. Denny. My colleague, Lenny Rudin and I (through Cognitech) were able to use mathematics to clarify the very blurry image of a tattoo on one of the attackers arm. Our technology was used ultimately to help convict that individual. That is an example of image processing. It is all about image processing through partial differential equations or PDES. This all came about in 1989.

The paper I published with Lenny Rudin and Emad Fatemi about image processing and total variation in 1992 is my second most cited paper. We delayed publishing our paper about the technology for three years because of our company business.

RK: What have you been working on since the Level Set Method and Image Processing?

SO: Something called "Threshold Dynamics" which is a clever way of doing complicated motions by breaking them into simple steps and fast optimisation methods for "Compressive Sensing" which is a signal processing technique for acquiring and reconstructing a signal by finding the sparsest solution to an underdetermined linear systems.

RK: I believe that the first thing that you've mentioned is known as the "the Merriman–Bence–Osher (MBO) threshold dynamics scheme"! You don't seem to want to slow down with your research.

SO: Not at all, Rochelle. Receiving the Gauss Prize has been both humbling and inspiring. It has motivated me to do more research to fulfil the tremendous honor that has been bestowed on me.

RK: UCLA's Institute for Pure and Applied Mathematics or IPAM hosts long programs, workshops, public lectures and other programs that connect mathematics and other disciplines and multiple areas of mathematics. I see from your website that these activities bring in thousands of visitors annually from academic, government and industry.

It is amazing to me that IPAMs "long programs" bring together leaders of research, industry and government for three months of work!

Tell me a little more about the accomplishments of IPAM.

SO: It has been a centre for tremendous collaborative research. It has brought Information Science and Applied Mathematics together. The top names from around the globe in machine learning, materials science and different areas of mathematics have collaborated on some exciting new research.

RK: What are a few examples of strong outcomes from the programs held at IPAM.

SO: The most famous and important is certainly the invention of ℓ^1-optimisation for sparse recovery, known as compressive sensing, by Terence Tao and Emmanuel Candes (also David Donoho).

There are lots of others, e.g., machine learning for materials science, fast algorithms, etc.

RK: Back to you, Stan. You have won many awards and received multiple honors. What has meant the most to you?

SO: That's hard, but I'd for certain say the Gauss Prize as it's considered the top prize in applied mathematics. The two researchers that have won before me are two men that I respect immensely.

Being inducted into the National Academy of Sciences was a huge thrill for me as well.

RK: As you know by now, we at World Scientific are eager to work together with you in the future. I hope that my interview with you is just beginning of a growing collaboration. Thanks so much for your time.

SO: I'm busier than ever these days but I hope that we'll work something out! I've enjoyed talking with you, Rochelle.

Rochelle Kronzek

Rochelle Kronzek is Executive Editor for World Scientific based in the United States.