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Interview: Stanley Osher, 2014 Gauss Prize Winner

'Usefulness makes the beauty of math more fun'

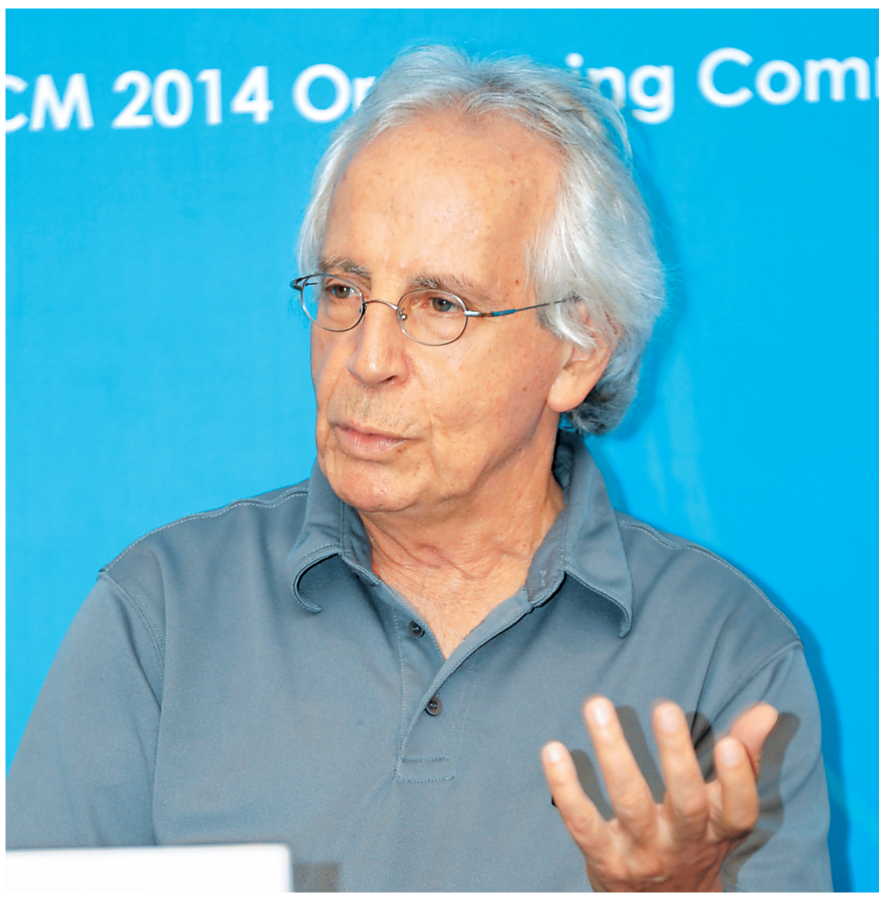
The winner of the 2014 Carl Friedrich Gauss Prize, Stanley Osher, is known for his fundamental contributions to applied mathematics. His pioneering work on level set methods as applied to video image enhancement resulted in the conviction of a rioter in Los Angeles in 1992 through the enhancement of photos showing a distinctive tattoo on his arm.

He founded three companies to commercialize his discoveries, including Cognitech, which commercialized the image enhancement that was crucial in the Los Angeles case. According to Osher, the program is widely used by police forces around the world.

Osher sat down with reporters on Thursday at COEX during SEOUL ICM 2014 to talk about his work in bridging advanced theoretical work and practical uses of that work.

Q. Your work has had an enormous impact in many areas of science and life. Is it potential applications that draw you to problems?

I am very happy when my stuff gets used. I love the beauty of mathematics, but it makes it even more fun when it turns out to be useful, which is not typical. Even people who do applied mathematics often say that they just love the beauty of math much more, but I like both of them. Very often you have no idea what it's going to be used for. This level set business I did with James Sethian – we didn't know that was going to take the universe by storm and get applied to so many different things.



Stanley Osher, the 2014 Gauss Prize winner, speaking at a press conference at COEX on Thursday. The UCLA mathematician's research has found applications in areas as diverse as animated motion pictures and law enforcement.

What would you say is the most exciting application of your work?

It's time dependent, but compressive sensing, or sparse reconstruction, can be used to do an MRI scan in one-eighth the normal time. It turns out that it's also useful in physics in a whole new way. So I'm really motivated by trying to understand quantum physics and material science because this stuff turns out to be very useful there. So I'm led by algorithms to new applications and these applications take on a life of their own.

Mathematicians don't work on just one thing at a time, and they often make transitions into different work. What triggers such transitions?

A lot of it is luck, amazing luck. I run in to people who have interesting thoughts and ideas.

For example, I ran into Leonid Rudin at a meeting and he said that images have something to do with shock capturing. At that time I was doing shock capturing, and I didn't even know what image analysis was.

But I went crazy when I heard that. So I dug up all the information I could find. I grabbed the thesis and I went out of my mind. It was a fantastic observation. So a lot of it is meeting the right people. Connections we made between sparsity and materials science were just mentioned by one of my colleagues in material science. It's just talking to the right people. It's good to get out there and talk to scientists and be willing to listen to what they have to say.

Achievements

Stanley Osher has been a leader in developing mathematical algorithms, including essentially non-oscillatory methods for hyperbolic conservation laws, level set methods for front tracking, and L1 and TVD methods for image processing, tomography, and optimization. Those algorithms are used by scientists and engineers the world over.

His research includes the development of innovative numerical methods to solve partial differential equations, analysis of these algorithms and the underlying PDEs, and their application to many areas of engineering, physics and image processing.

In his early research career, he was involved in the development of high resolution numerical schemes to compute flows having shocks and steep gradients, including essentially non-oscillatory schemes, with Harten, Chakravarthy, Engquist, and Shu; weighted ENO schemes with Liu and Chan; the Osher scheme; the Engquist-Osher scheme; and the Hamilton-Jacobi versions of these methods. These methods have been widely used in computational fluid dynamics and related fields.

In the late 1980s, he developed total variation-based image restoration with Rudin and Fatemi and shock filters with Rudin. These are pioneering and widely used methods for PDE-based image processing and have also been used for inverse problems.

His pioneering paper on level set methods, "Fronts Propagating with Curvature Dependent Speed: Algorithms Based on Hamilton-Jacobi Formulations" (JCP, 1988, with Sethian), has been cited more than 10,000 times in other scholarly work. The method captures moving interfaces, and has been phenomenally successful as a tool in PDE-based image processing and computer vision, as well as applications in differential geometry, image segmentation, inverse problems, optimal design, two-phase flow, crystal growth, deposition and etching.

This relatively simple idea also turns out to be extremely powerful in solving problems in multi-phase flows and animate fluids, and is used by animated film studios such as Pixar, Disney, Industrial Light & Magic, and Dreamworks. One of Osher's students, Ron Fedkiw of Stanford University, won an Academy Award for film animation techniques he devised using these methods.

Compiled by
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Interview with Shigefumi Mori, president-elect of the IMU

New leader sees himself as a servant of the union

Shigefumi Mori, who has contributed to the advancement of mathematics with his theory on algebraic three-folds, will take on another, challenge to contribute to the discipline as the leader of the global mathematical society.

The 1990 Fields Medalist was elected the next president of the International Mathematical Union during the 17th IMU General Assembly in Gyeongju on Monday. Although he said he was daunted by the size of the job ahead, the calm, genial mathematician has already demonstrated his administrative skills as the director of the Research Institute for Mathematical Sciences at Kyoto University, his alma mater. The IMU also gave him an early vote of confidence; he was the only nominee for the presidency and was elected unanimously by the GA in Gyeongju. He will succeed Ingrid Daubechies in the job in January, 2015.

The first Asian elected to the IMU presidency, Mori said he would foster diversity and balance within the union and pay due attention to mathematicians in every continent.

Mori, 63, was born in Nagoya, Japan, and received his bachelor's and master's degrees at Kyoto University; he also earned his Ph.D. there in 1978. He has held teaching positions at his alma mater, Harvard University, Columbia University and the University of Utah in the United States, among others. Since 1990 he has been associated with the Research Institute for Mathematical Sciences, and was director of the Institute from 2011 until last March.

In 1990, the year he received his Fields Medal, he also was awarded the Cole Prize of the American Mathematical Society.

Mori sat down with Myung-Hwan Kim, president of the Korean Mathematical Society, on Tuesday. Excerpts from their conversation follow.

Kim: First of all, let me congratulate you on being elected as president of the IMU.
Mori: Frankly, I am not sure whether I should be congratulated, but thank you. The job seems to be much heavier than I thought, so I have to be prepared. Before getting excited, I should think about what to do. I have been told by my family that if I have stress, I should channel it in a positive direction. I am sure that the presidency is a very difficult task to take on. To do that, I must get cooperation, and maybe that way I can become wiser just a little bit.

Kim: What do you want to do as president of the IMU?
Mori: Well, I think that it is not the right question, because my kind of leadership is not to pull other people in the direction that I have in mind. I would rather listen to other people, understand what is best for the situation, and go together. But if there is one thing on my mind right now that I would like to do, it is that we mathematicians need to secure very patient, long-term support for our research activities. I don't know that I will be able to achieve it, but that will be an important thing.

Kim: How different will Mori's IMU be from the previous IMUs?
Mori: I attended the IMU General Assembly under the management of Ingrid. I adore her. It's not something that I can even try to do. It is totally different. My command of English is just so-so. It's not something that I can compete with, so I should do it in my style. That is also what I am supposed to do as an Asian.

Kim: You are quite moderate. But I heard that you were a very good leader as a director at RIMS. Your kind of leadership is also very good.
Mori: I wasn't the boss of the institute. I was a servant, listening to other people. That's my style, I think.

Kim: So, you will be the president but act like a servant.
Mori: I think so. I will listen to other people. Of course, I cannot follow everyone's suggestion.

Kim: The NANUM program at the Seoul ICM 2014 invited about 1,000 mathematicians from developing countries. The IMU also introduced the MENAO symposium with the slogan "The spirit of sharing." What is your personal view on this movement?
Mori: Certainly, it is a very important direction to be taken. I was told that in many emerging countries, many mathematical societies are being formed. Inviting younger mathematicians to the congress is very much appropriate and I admire Korea's decision to invite as many as 1,000 people. In Brazil they will maybe not have as many guests as in Korea, but they are doing something similar. So, it was a very important initiative by Korea.

Shigefumi Mori speaking to Myung-Hwan Kim on Tuesday at COEX. Mori was elected as the next head of the International Mathematical Union at the IMU's General Assembly in Gyeongju on Monday.

Kim: A Mathematical Union of Asia (the tentative name) probably cannot be established this year. What is your opinion on this idea and if you like it, what would be the ideal relationship between the IMU and this regional union?
Mori: The relationship, I think, is clear. This Asian union will be an affiliate member of the IMU.

Kim: You will be the first Asian president of the IMU. How significant is that?
Mori: I don't think I was chosen because I am an Asian. But, if my becoming the president encourages my Asian colleagues, I will be happy. And also it will be good for Japan.

Interlocutor
Myung-Hwan Kim
President of the Korean Mathematical Society

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Meaning of "Math&Presso" A compound word joining "math" and "press" with a slight alteration and pronounced similar to "espresso," this newsletter is distributed to participants every morning and will, we hope, serve our readers like a hot cup of coffee. Math + Press = Math&Presso ≈ Espresso

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The Organizing Committee of the International Congress of Mathematicians has commissioned the Korea JoongAng Daily, the leading English-language newspaper in Korea, to publish an official daily newspaper for the congress. The editors and the organizers are not responsible for the opinions expressed by the interviewees and published here or for any consequences arising from the accuracy of the information herein.

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Manjul Bhargava: Fields Medalist

From counting oranges to a $1 million conjecture

For Manjul Bhargava, one of the four Fields Medalists at SEOUL ICM 2014, simply going to the supermarket with his mother as a young boy was full of wonder. He saw mathematics everywhere.

One day, when he was about eight, he followed his mother, Mira Bhargava, a mathematics professor at Hofstra University in New York, to a supermarket and saw oranges stacked in pyramids. The eight-year-old boy wondered how many oranges there were in that pyramid.

"If there are seven oranges on each side of the pyramid, how many oranges are there in total?" young Bhargava wondered. "How do you tell how many oranges there are in a pyramid if there are n oranges on each side?"

Despite his young age, Bhargava had an "aha!" moment after wrestling with the problem for months, finding that the equation was $n(n+1)(2n+1)/6$.

"That was something I was very excited to discover," said Bhargava. "It wasn't a new discovery, but was the first problem that I solved by myself as an eight-year-old and it was the kind of thinking that I would do in the future, understanding the number of objects of given kinds inside certain shapes of space."

Bhargava met with reporters at COEX on Thursday.

Manjul Bhargava answering reporters' questions on Thursday at COEX. He is one of four Fields Medal recipients announced Wednesday at the SEOUL ICM 2014.

Q. You are the first person of Indian origin to receive the Fields Medal. What does that mean for your life and career?

A. I was born in Canada and grew up in the United States, but in a very Indian home because my parents had emigrated from India. Physically, I also spent a lot of time in India, as I took several months off from school every few years to spend time with my grandparents in Japer. I really do identify with all three countries. I still visit India every year as I lecture students there fairly regularly. I also do some volunteer work and teach students who live in the slums in India. I also have many collaborators there and do research work. Since I did grow up in a very Indian way as well with the culture and language, I feel like I'm in a position where I can take a lot of the amazing strides that the United States has made in education and try to spread the word a little bit and help out the Indian educational system.

You have also made progress toward solving the Birch and Swinnerton-Dyer conjecture that's related to elliptic curves. Can you tell us more about that?

Yes, it's one of the Clay Mathematics Institute's seven millennium problems. If you solve one of them, you get a million dollars. It's a conjecture about predicting whether certain equations have solutions. Such equations are called elliptic curves and they take forms such as $y^2=x^3+ax+b$. Here, a and b are fixed whole numbers and x and y are the variables. It's the smallest equation for which we don't in general know whether it has whole number solutions or rational number solutions.

It looks so simple and yet there's no known algorithm to decide whether this has any solutions. But there is a proposed algorithm. Nobody knows whether it works or not, but this proposed algorithm allows whether it has finitely many solutions or infinitely many solutions. So if it was true, it would be amazing as it would tell us how to solve cubic equations, taking us further from the quadratic case that's so classical and would take us into this whole new realm, which comes up throughout mathematics.

So the work I did was not about proving that this method always works. It was about proving that it works most of the time. So if you pick an elliptic curve at random and you apply this procedure, better than 66 percent chance, it will work. Before it wasn't even known if there's a better than zero percent chance. So to know that most of the time it will work is significant but of course it doesn't mean that this conjecture is true.

Achievements

Scientists have discovered and classified systems of numbers for millennia as they gradually realized that the operations of addition and multiplication have characteristic features that strongly constrain the way they occur in different parts of nature.

The ramifications of the concommitant theories have been deep and far-ranging, both for other mathematical structures as well as for our understanding of the physical universe. For example, after the establishment of the basic theory of real numbers underlying algebra and geometry, the discovery of the complex numbers led eventually to the development of group theory, and to their manifestation in quantum mechanics, whose mysterious complex amplitudes are still the subject of interpretation and debate. In tandem with such continuous number systems, the discrete number systems that form their skeleta have been studied by arithmeticians, who have come to realize that their properties and classification are more intricate and difficult than their continuous analogues.

The possible rules for discrete pairs were classified at the time of Gauss in relation to his remarkable study of arithmetic composition laws on quadratic forms. In the late 19th century, Hermann Minkowski developed the geometry of numbers, a study of the regions of high-dimensional space that are occupied by the discrete number systems. The geometry of numbers became a standard tool of number theory in the subsequent years, but it was only in the 1960s that Harold Davenport and Helmut Hasse put it into a form refined enough for the classification of three-dimensional discrete number systems. There are many ways in which this idea of classification can be made precise. But the one emphasized in this line of work is the counting of discrete number systems of fixed dimension and bounded discriminant, the volume inside Euclidean space taken up by a minimal parallelogram of the number system.

Manjul Bhargava, by building upon his careful study of Gauss's "Disquisituones Arithmeticae" and some remarkable and playful ruminations on Rubik's Cube, succeeded in reinterpreting and unifying the work of Gauss, Minkowski, Davenport, and Hasse into a beautiful theory of integral invariants of arithmetic symmetries, a harmonious amalgam of discrete number systems and geometry in high dimensions.

By utilizing this theory, in a series of works involving a continuous stream of deep insight and technical mastery, he extended the classification of Gauss and Davenport-Hasse to 4- and 5-dimensional discrete number systems.

Recast into a suitable framework, Bhargava and his collaborators' work also applied the enhanced geometry of numbers to Diophantine problems, the study of integral solutions to polynomial equations that that goes back in history to ideas of Pythagoras and Diophantus.

Among the remarkable collection of his results, the key statement of the celebrated conjecture of Birch and Swinnerton-Dyer about cubic equations in two variables has now been shown to be true for a positive proportion of the infinitely many possibilities.

Compiled by
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Imaginary: The beauty and the practical applications of mathematics

Intuition guides viewers to deeper understanding

Mathematics is not just for understanding. It is for experiencing.

Imaginary, an exhibition based on an innovative approach to mathematics education, is helping many parents eager to turn their children into mathematically gifted students. Since its inaugural in Germany in 2008, the traveling exhibition has attracted more than a million visitors in most parts of the world, many of them parents hand in hand with their children.

The Organizing Committee of the Seoul ICM hopes to arouse significant public interest in mathematics by inviting Imaginary to come here. This is the first time the exhibition has been on display at a congress; it is also the largest exhibition in the history of the project.

The exhibition, at COEX Hall C until Wednesday (closed on Sunday), features the most popular Imaginary modules from earlier exhibitions and adds new software, images, films and sculptures. More than 10,000 visitors are expected to visit the exhibition, according to the National Institute of Mathematical Sciences of Korea.

NIMS organized the Korean exhibition in collaboration with the LOC of SEOUL ICM and the Oberwolfach Research Institute for Mathematics, Germany that created the program. Andreas Daniel Matt, a mathematician at the institute, together with Christian Stussak, a software developer, visited NIMS in June to help prepare the exhibition.

Students (and parents) crowd around a display at Imaginary, a traveling exhibition of mathematical concepts and applications that is being shown in Seoul for the first time. The exhibition, which includes dynamic computer-based modules and a strong dose of aesthetics, is open at Hall C at COEX today and Monday through Wednesday.

Promoted with the slogan of "Open Mathematics," Imaginary helps people approach mathematics intuitively. It explains concepts behind mathematical equations by using shapes and forms that those equations create.

In addition to the installations and framed images at the exhibition, visitors can also browse virtual models on computer screens, including the Surfer, a program to visualize real algebraic geometry and developed for the Imaginary.

Three seniors from Samcheonpo High School in Sacheon, South Gyeongsang Province, Deokhyeong Kang, Pilhyo Jang and Jungwook Lee, visited the exhibition on Thursday. They said they wanted to study the humanities or education in college but that the visit may have changed their minds. "At least this motivates me not to give up mathematics," Jang said.

The modules on display are beautiful to look at, and aesthetics is one of the two key themes of Imaginary. Beautiful images help people accept the algebraic equations behind them more easily, said Chulmin Kang, a NIMS researcher who organized the exhibition here. "It bridges the gap between the arts and mathematics," he said.

But the second theme is a more practical one in popularizing math. The exhibition stresses the diversity of applications that flow from mathematics in an effort to spark more public interest.

Inseon Jang, a housewife from Mokdong, Seoul, came with her 14-year-old son. The visit, she said, was meant to inspire her son to study mathematics harder, but she also learned something.

"For our generation, mathematics was something that we solved in notebooks, but here I saw it on a computer screen and learned how mysterious and fascinating it is," Jang said.

Saturday, August 16

Schedules for plenary lectures have been changed. Please check the new schedules below.

07:30 - 09:00	IMU Circle breakfast	201
09:00 - 12:30	Plenary Lectures	Hall D
	09:00 - 10:00 Maryam Mirzakhani's Plenary Lecture (PL-7) has been MOVED to the Fields Medalist Lecture at 14:00, Tuesday, Aug. 14.	
	10:15 - 11:15 *The great beauty of VEM's* **Franco Brezzi,** Istituto Universitario di Studi Superiori, Pavia, Italy	PL-8
	11:30 - 12:30 *Rational points on elliptic and hyperelliptic curves* **Special Lecture by Manjul Bhargava (2014 Fields Medalist),** Princeton University, USA	PL-9
12:30 - 14:00	Lunch	
14:00 - 15:00	Lecture by Chi-Wang Shu on the work of the Gauss Prize winner, Stanley Osher	Hall D
15:00 - 18:00	Invited Section Lectures	
	2. Algebra	402
	4. Algebraic and Complex Geometry	300
	5. Geometry	Hall E1-4
	8. Analysis and its Applications	Hall E5-6
	9. Dynamical Systems and Ordinary Differential Equations	301AB
	11. Mathematical Physics	307ABC
	12. Probability and Statistics	308ABC
	Invited Section Lecture by Martin Hairer (IL 12.6) has been canceled because of his Fields Medal Lecture on August 14.	
	14. Mathematical Aspects of Computer Science	317ABC
	16. Control Theory and Optimization	318ABC
	17. Mathematics in Science and Technology	327ABC

15:00 - 18:00	Short Communications	
	2. Algebra	309
	3. Number Theory	310AB
	4. Algebraic and Complex Geometry	311AB
	5. Geometry	316
	6. Topology	312
	7. Lie Theory and Generalizations	313
	8. Analysis and its Applications	320AB
	9. Dynamical Systems and Ordinary Differential Equations	324AB
	10. Partial Differential Equations	319
	11. Mathematical Physics	323
	12. Probability and Statistics	322
	13. Combinatorics	321AB
	15. Numerical Analysis and Scientific Computing	325AB
	19. History of Mathematics	326
12:00 - 18:00	Poster Sessions	Hall C1
	9. Dynamical Systems and Ordinary Differential Equations	
	10. Partial Differential Equations	
	11. Mathematical Physics	
	12. Probability and Statistics	

Other Activities

18:00 - 19:00	Casual Performances	
19:00 - 20:30	Conference Dinner Hosted by the mayor of Seoul	Hall D

- The Bridges Seoul Conference will be held at the Gwacheon National Science Museum from Aug. 14 to Aug. 19. The conference theme is the convergence of art and mathematics. Public lectures and workshops related to mathematics will be available for students. Please go to Hall D in order to receive a free pass to the Bridges conference. Please note that Aug. 16 is Family Day and Aug. 17 is Korean Day at the conference.

Answer to Aug. 15 Daily Math Puzzle .... **24 pieces**