UCLA mathematician works to make virtual surgery a reality

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A surgeon accidently kills a patient, undoes the error and starts over again. Can mathematics make such science fiction a reality?

The day is rapidly approaching when your surgeon can practice on your "digital double" — a virtual you — before performing an actual surgery, according to UCLA mathematician Joseph Teran, who is helping to make virtual surgery a viable technology. The advantages will save lives, he believes.

"You can fail spectacularly with no consequences when you use a simulator and then learn from your mistakes," said Teran, 30, who joined UCLA's mathematics department in July. "If you make errors, you can undo them — just as if you're typing in a Word document and you make a mistake, you undo it. Starting over is a big benefit of the simulation.

"Surgical simulation is coming, there is no question about it," he said. "It's a cheaper alternative to cadavers and a safer alternative to patients."

How would virtual surgery work?

"The ideal situation would be when patients come in for a procedure, they get scanned and a three-dimensional digital double is generated; I mean a digital double — you on the computer, including your internal organs," Teran said. "The surgeon first does surgery on the virtual you.

With a simulator, a surgeon can practice a procedure tens or hundreds of times. You could have a patient in a small town scanned while a surgeon hundreds or thousands of miles away practices the surgery. The patient then flies out for the surgery. We have to solve mathematical algorithms so what the surgeon does on the computer mimics real life."

How far off is this virtual surgery?

"A three-dimensional double of you can be made, but it would now take 20 people six to nine months," Teran said. "In the future, one person will be able to do it in minutes. It's going to happen, and it will allow surgeons to make fewer mistakes on actual patients. The only limiting factor is the complexity of the geometry involved. We're working on that. Our job as applied mathematicians is to make these technologies increasingly viable."

The technology will be especially helpful with new kinds of surgeries, he said.

"A virtual surgery cannot be a cartoon," said Teran, who works with a surgeon. "It has to be biologically accurate. A virtual double needs to be really you."

Teran is organizing a virtual surgery workshop that will take place at UCLA from Jan. 7 to 11 as part of UCLA's Institute for Pure and Applied Mathematics. For information, visit www.ipam.ucla.edu/programs/vs2008/vs2008_poster.pdf.

Making virtual surgery a reality will require solving mathematical equations, as well as making progress in computational geometry and computer science. An applied mathematician, Teran works in these fields; he develops algorithms to solve equations. Advances by Teran and other scientists in computational geometry, partial differential equations and large-scale computing are accelerating virtual surgery.

How human tissue responds to a surgeon, Teran said, is based on partial differential equations. Teran solves on a computer the mathematical equations that govern physical phenomena relevant to everyday life. He has studied the biomechanical simulation of soft tissues.

"Most of the behavior of everyday life can be described with mathematical equations," he said. "It's very difficult to reproduce natural phenomena without math."

Tissue, muscle and skin are elastic and behave like a spring, Teran said. Their behavior can be accounted for by a classical mathematical theory.

Progress in his field is already rapid, Teran said, noting that "things in geometry that used to take days and days start to take hours and minutes."

Teran believes medical schools will increasingly train physicians using computer surgical simulation.

Teran's applied mathematics can also be used to design more durable bridges, freeways, cars and aircraft.

"I would like people who design bridges to be able to use a virtual model — I'm interested in making that a reality and in creating numerical algorithmic tools that let people who design bridges have more computational machinery at their fingertips," he said.

As an undergraduate, Teran realized "you can use math problems to solve real problems and can help people in ways that seem totally unrelated to math." He earned his doctorate at Stanford University, where he took graduate classes in partial differential equations and worked on new ways of solving the governing equations of elastic biological tissues. He was a postdoctoral scholar at New York University before joining UCLA's faculty.

"I started with math because I like problem-solving, and I like how elegant math is," Teran said. "I like how much careful analysis is required, and that there's a right answer. Now I'm completely fascinated by what you get from a simulation, the kinds of complex behavior you can reproduce on a computer and the kinds of questions you can answer. Math will tell you how the world is. It will give you an answer, and it's intellectually stimulating and fun. It really pays off."

Teran, who is teaching a course on scientific computing for the visual effects industry, said he came to UCLA because it is one of the country's best universities for applied mathematics, because its medical school is among the country's best and because it is near Hollywood, where he helps to make movie special effects.

Teran, who works with UCLA's Center for Advanced Surgical and Interventional Technology, spoke this fall as part of Intel Chief Technology Officer Justin Rattner's keynote address at the Intel Developer Forum on the rise of the "3-D Internet." Teran demonstrated virtual surgery applications.

The future 3-D Internet will include an "avatar" — a virtual representation of you — that could look "just like you, or better than you," Teran said.

The graphics will be astonishingly realistic and three-dimensional, he said, but the simulation needs to be much more accurate, a goal Teran is working to achieve.

"As virtual words get more realistic, modern applied mathematics and scientific computing are required," he said.

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