JOSEPH TERAN

PROFILE

EXCLUSIVE

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Jo Lee Talks To: A Symbol Of Genius The Adeste Laureate 2010

By Josephina Lea Mascioli-Mansell

It was one of those nominated reads that instinctively said, 'THIS is rare'! And, equally fascinating? Was my gut telling me this candidate will become The ADESTE Laureate 2010!

Over the course of each year, we are reminded through the Nominees of The ADESTE Gold Medal just how many wonderful people are doing amazing things from corner to corner in this chaotic world. We, too, are reminded that the most important aspect, the heart of ADESTE is to discover Unsung Heroes who "outperform" in a globe of billions.

So many Nominees are submitted within our five categories of Humanities, Social Justice, Technology, Arts and Medicine and this year became a point of intensification for ADESTE – the reason being: the world is in chaos. Many, many variables came into play.

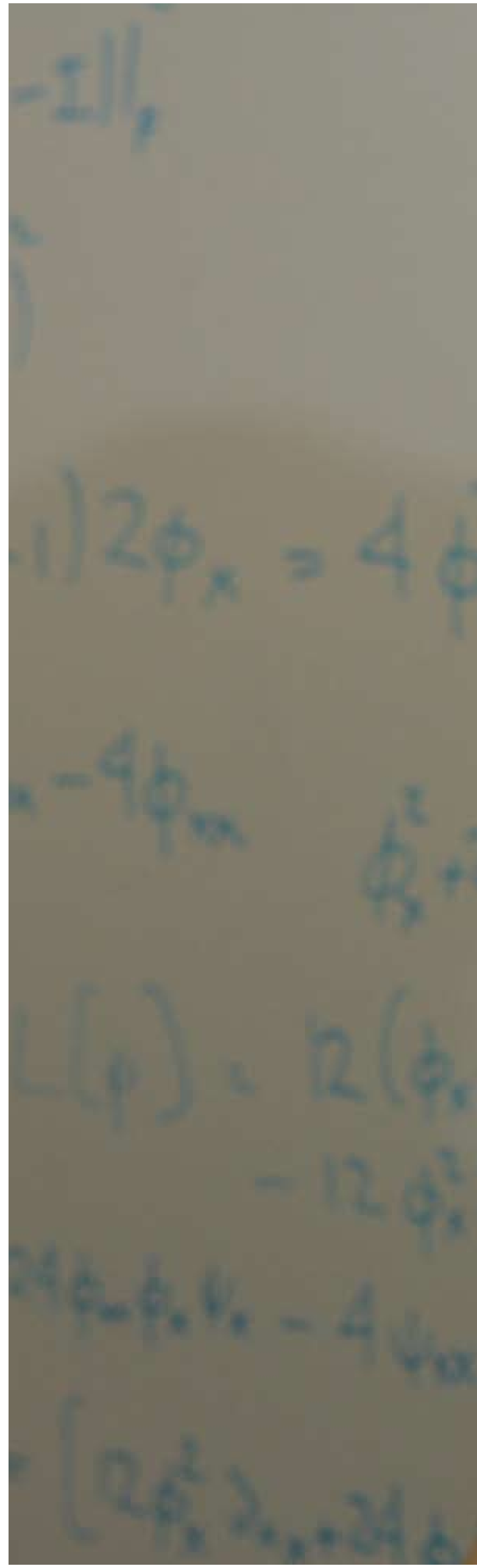
Yet, for the first time in ADESTE's history, the 21 World Voting Members of ADESTE unanimously chose the Nominee who, more than at any time in the past, was a candidate from a category that is particularly timely: the field of medicine. An inventive genius whose creative gift would push the surgical field of medicine into dreams of reality that youth, as little kids, would sit and dream of.

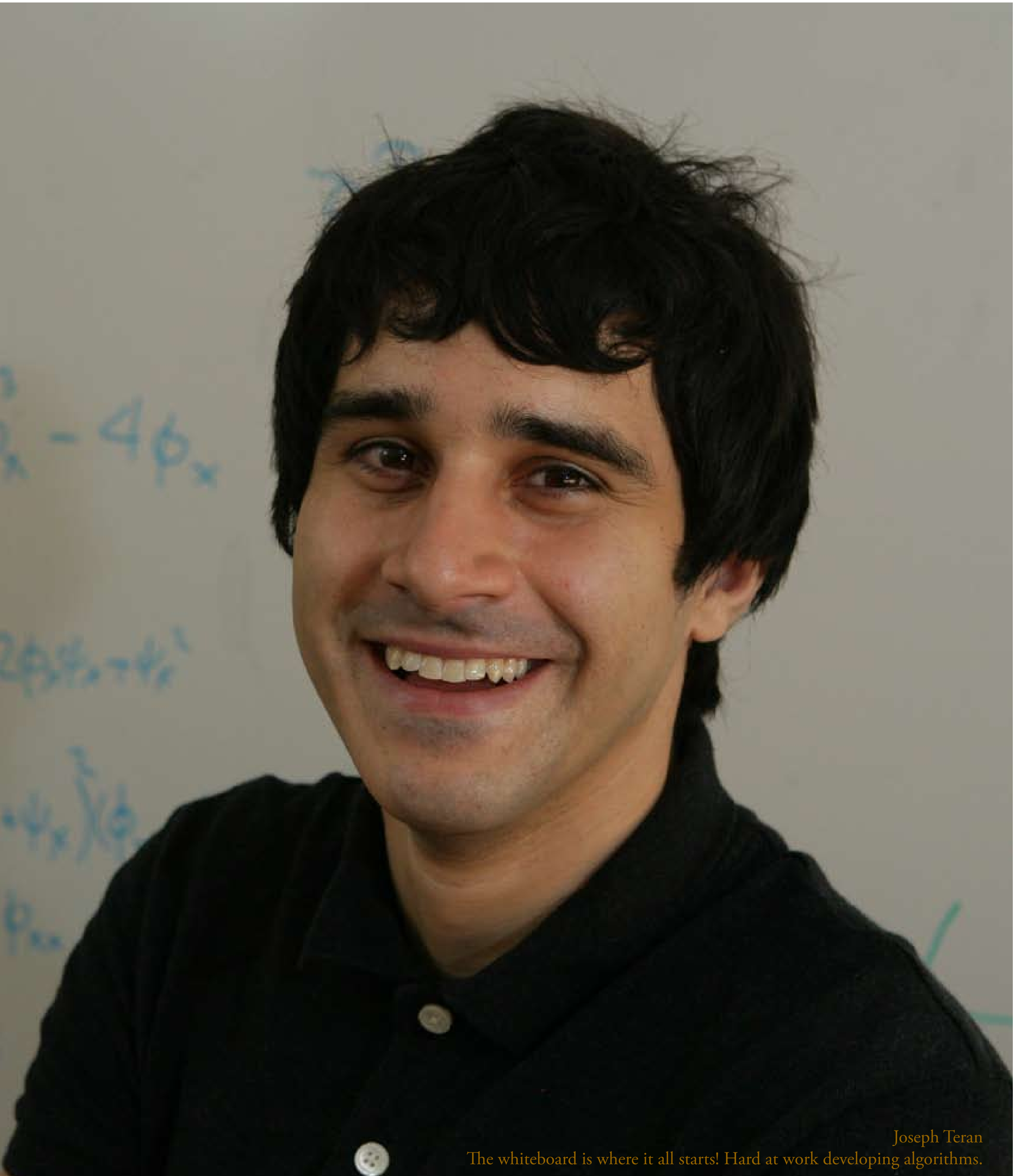
And the Laureate indeed, became Joseph Teran – that 33-year-old who rose above phenomenal plights, seeing the future before it arrived!

Joseph is a University of California at Los Angeles mathematician devoted to making virtual surgery a reality.

A surgeon accidently kills a patient, undoes the error and starts over again. Can mathematics make such science fiction a reality? There's no question about it says Joseph, surgical simulation is coming. It's a cheaper alternative to cadavers and a safer alternative to patients: the global advantages? Saving lives!

Imagine! You are a surgeon practicing on your digital double – a virtual you – before performing the actual surgery on you!





Joseph Teran
The whiteboard is where it all starts! Hard at work developing algorithms.

opposite: I also work on simulating other aspects of virtual characters. Here we see an algorithm used for resolving collision between thin elastic representations of individual strands of hair.

JO LEE: Joseph, here we are, you having risen beyond the multitudes of nominations worldwide, a tough feat! And as strong as my convictions were that you would be the Gold Medal Laureate, one never takes for granted how our 21 World Voting Members of ADESTE will cast their vote. By gosh, as Business 2.0 would have said "it's all in that gut-reaction". My immediate vote? YOU. What a pleasure!

JOSEPH TERAN: Thank you very much, Jo Lee, and the Voting Members of ADESTE. I am honored to have been chosen.

JL: Your passion for mathematics is fascinatingly described. Can you explain "I appreciate mathematical elegance"? I never would have thought of math as being elegant. Would this have anything to do with the idea of visual orientation (design) vs. linear thought and the consequences of the predominance of one over the other?

JT: Mathematics is elegant in its efficiency in my opinion. The most complex behaviors can arise from seemingly simplistic mathematical descriptions.

JL: So what do you mean when you say, "I enjoy the necessary analysis in determining the mathematically correct behavior". Correct behavior? A finance mind would definitely find that 1+1=2. In my business, it could =7. However, would careful analysis in your mind rise into another sphere?

JT: I suppose this would be true of any discipline lending itself naturally to mathematical description: although, obviously this is not always an easy or natural thing to do, Jo Lee.

JL: Joseph, can you then tell me how math will tell you how the world is?

JT: Physics can be used to accurately predict many everyday phenomena. The language of physics is mathematics. That is, many phenomena can be described in terms of mathematical governing equations; unfortunately these equations can be very difficult to solve. Fortunately, computational approaches to solving such equations have proven incredibly effective at allowing us to harness the power of physics to describe complex phenomena. This ability can be used to create artificial scenarios on the computer that can be used in place of real world scenarios that would be too costly, too dangerous or otherwise impossible.

Jo Lee, 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. It's intellectually stimulating, it's fun and it really pays off.

Think of this: you can fail spectacularly with no consequences when you use a simulator and then learn from your mistakes. 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.

The method treats the hair as an incompressible fluid and as a means to prevent interpenetration in an efficient manner.

JL: Ah yes, the cadaver! Is this not how undergraduates learn the intricacies of the human body? How does a simulator, a so-called digital dummy, compare to the real thing?

JT: In the ideal situation, a three-dimensional, digital double would be generated from MRI or CT scan data; I mean a digital double – you on the computer, including your internal organs!

The surgeon would first perform the surgery on the virtual you. With a simulator, a surgeon can practice a procedure tens or hundreds of times. We have to create mathematical algorithms so that the surgeon's results on the computer mimic real life. You could have a patient scanned in a small town while a surgeon thousands of miles away practices the surgery. The patient then flies out for the surgery. There are so many more examples of the potential benefits of such technology. The need is clear. We must now perform the necessary mathematical and computational research needed to provide this level of functionality.

JL: And how close in time might reality be, Joseph?

JT: It is already happening, albeit on a limited scale. Currently, the primary limiting factor is the complexity of the geometry involved for a given region of the anatomy. My research is primarily geared towards improving this ability. Progress in this regard is already very rapid. Many problems that would have taken days have been reduced to sub-second computation times with the benefit of modern hardware and algorithm design. Our job as applied mathematicians is to make these technologies increasingly viable so that we may one day perform all surgeries with full confidence that the computationally determined results accurately reflect the real patient.

JL: Most of us now think of such computer-manipulated movies as Avatar when we think virtual reality. Would we be wrong to put virtual surgery in this category?

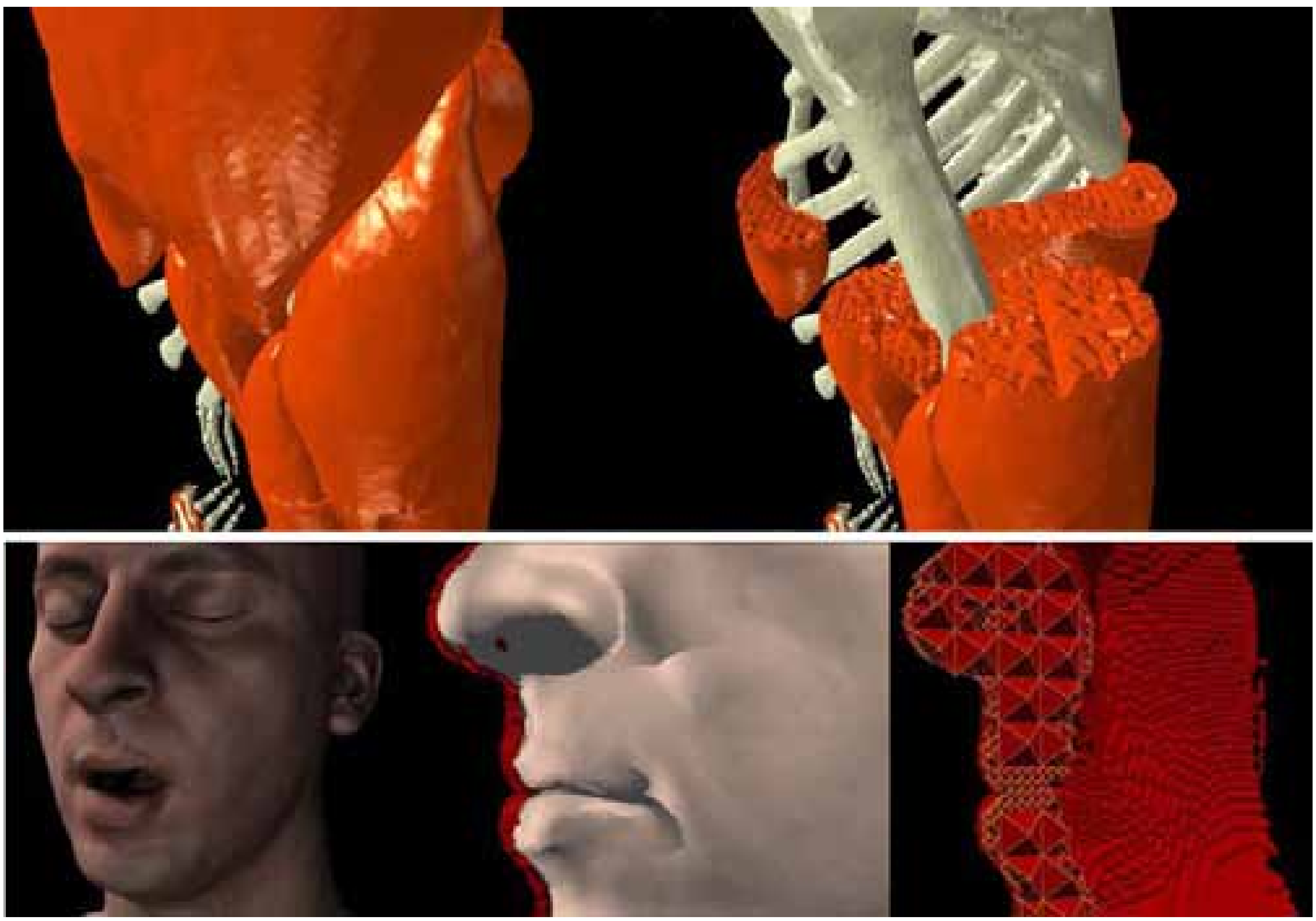
JT: Wrong, yes! A virtual surgery cannot be a cartoon. It has to be biologically accurate and must be interactive. Jo Lee, a virtual double needs to be an accurate predictor of the real you. A three-dimensional double can be made now, but only with great time and expense. In the future, these times must be reduced to the order of minutes. This can be achieved only with significant research and development.

Making virtual surgery a reality will require solving mathematical equations, as well as making progress in computational geometry and computer science. As an applied mathematician I work in these fields, and I work with the surgeons as well. I develop the algorithms to solve equations. Along with other scientists in computational geometry, partial differential equations and large-scale computing, we are accelerating the concept of virtual surgery and it's exciting, Jo Lee!

JL: What is a mathematical algorithm?

JT: An algorithm is just a series of instructions for someone or something to carry out. For example, on the computer it is just a series of instructions given to the computer. With a given sequence of primitive steps, we can solve a larger problem with the aid of the massive computational ability of modern computers.

The dynamics of the musculo-skeletal system are determined by the complex interactions of articulated rigid bodies in the skeleton and elastic muscles. Here, a computer simulation is done to predict the dynamics of the many contacts and collisions coupled with elastic tissues in the upper limb during a simple motion of the arm.



The digital anatomy must be represented by discrete, lego-like, geometric primitives on the computer. The primitive of choice below is a tetrahedron. These simple building blocks must be assembled to represent each individual anatomic structure. Here we see various muscles in the upper-limb and head.

JL: Still, we who are mathematically challenged, to say nothing of barely computer literate, can hardly grasp the concept. How can a mathematically created computer model of a living person equate the real thing?

JT: Well, Jo Lee, I have studied the biomechanical simulation of soft tissues. How human tissue responds to a surgeon is based on partial differential equations. My job is to solve, on a computer, the mathematical equations that govern physical phenomena relevant to everyday life. Tissue, muscle and skin are elastic and behave like a spring. Their behavior can be accounted for by a classical mathematical theory. Most of the behavior of everyday life can be described with mathematical equations. It's very difficult to reproduce natural phenomena without math.

JL: How is medical science keeping up with these advances?

JT: Good question: I believe medical schools will increasingly train physicians by using computer surgical simulation. However, first we must prove to them that these technologies are viable. This is the primary focus of my research.

JL: And are there any other applications for such genius?

JT: Applied mathematics can also be used to design more durable bridges, freeways, cars and aircraft. Jo Lee, I would like people who design anything 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 such devices have more computational machinery at their fingertips.

JL: As an undergraduate, you realized that one could use math problems to solve real problems and help people in ways that seem totally unrelated to math.

Did you ever think when you chose mathematics as a major that it would lead to such heady futuristic endeavors?

JT: Honestly, I had no idea what was possible when I first started out. I just enjoyed my mathematics classes more than the other subjects in my first few years of undergraduate work.

JL: Joseph, how old would you have been when your family suddenly realized that: your intelligence was far beyond the norm?

JT: I don't know. I wasn't incredibly dedicated to science or research until I was about 22.

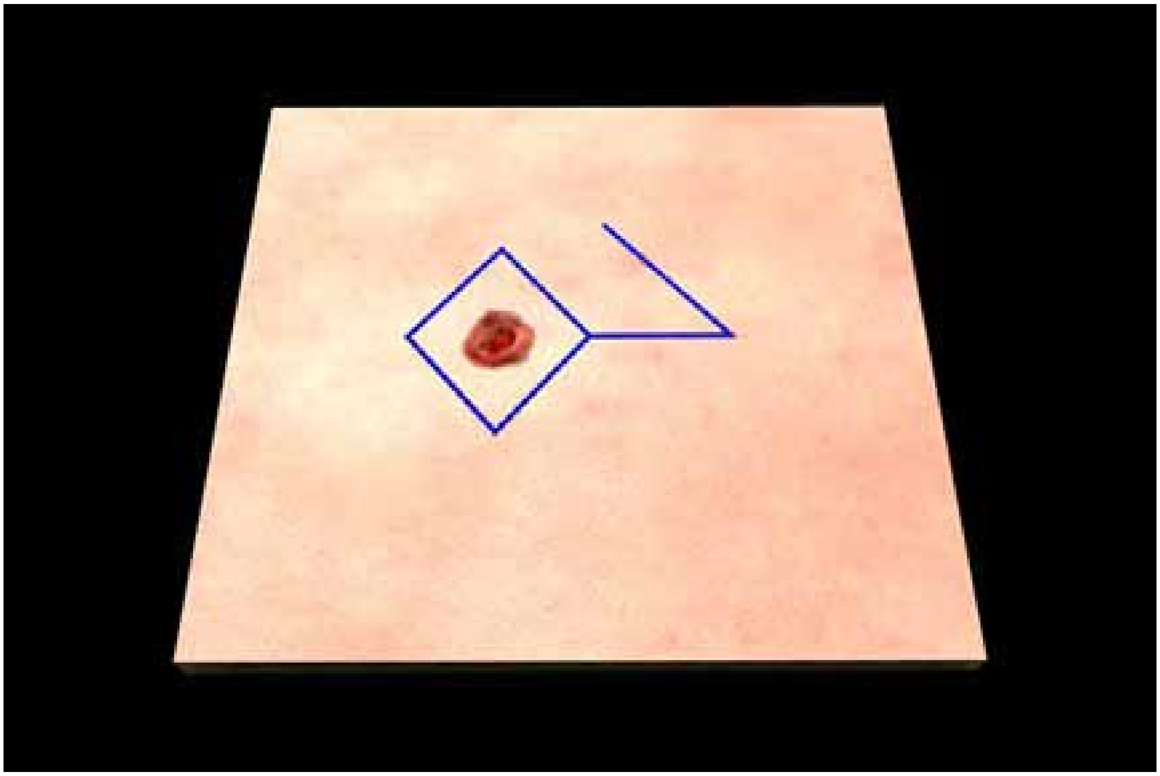
JL: You earned your doctorate at Stanford, where you took graduate classes in partial differential equations and worked on new ways of solving the governing equations of elastic biological tissues. And you were a postdoctoral scholar at New York University before joining UCLA's faculty.

Joseph, today along with your research, you are teaching a course on scientific computing for the visual effects industry. Is that one of the reasons that brought you to UCLA?

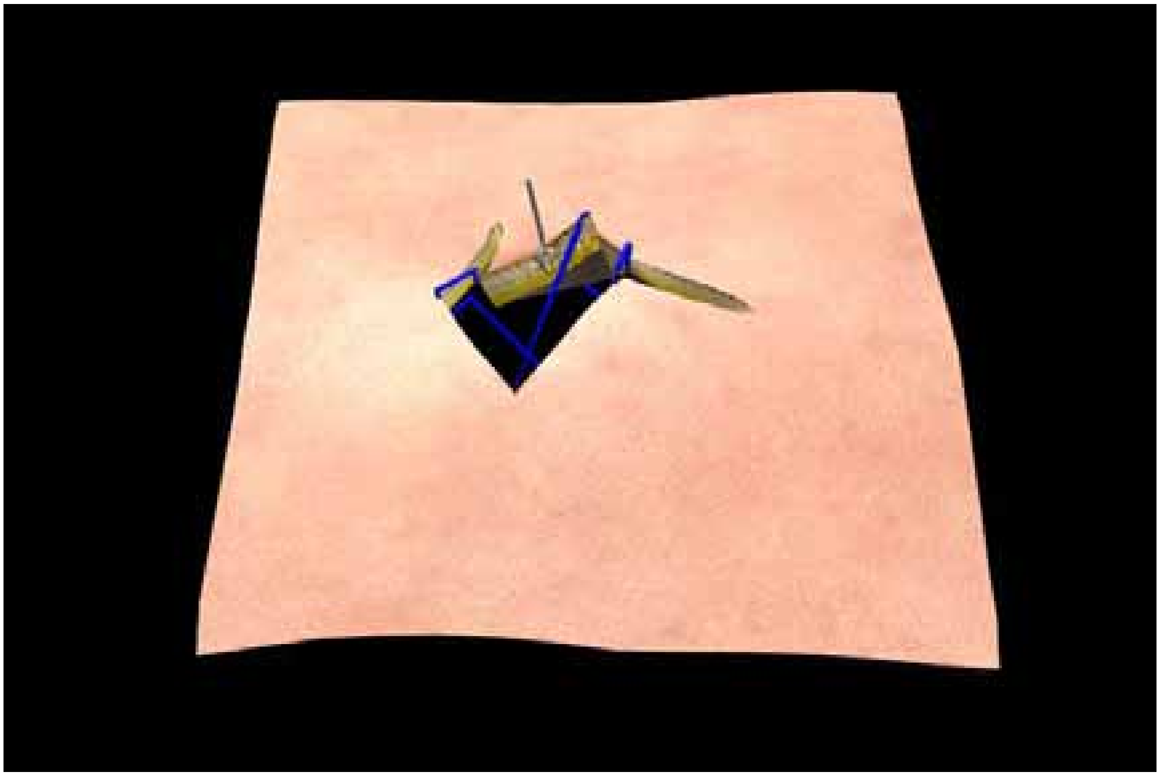
JT: Jo Lee, UCLA is California's largest university, with an enrollment of nearly 37,000 undergraduate and graduate students. I came to UCLA because it is one of the country's best universities for applied mathematics (currently ranked second overall), because its medical school is among the country's best and because it is near Hollywood, where I help to make movie special effects.

JL: Hollywood and special effects! It sounds like the play side of virtual reality! I read that, demonstrating virtual surgery applications, you spoke a few years ago at a prestigious event about the rise of the 3-D Internet. How on earth did you make the connection?

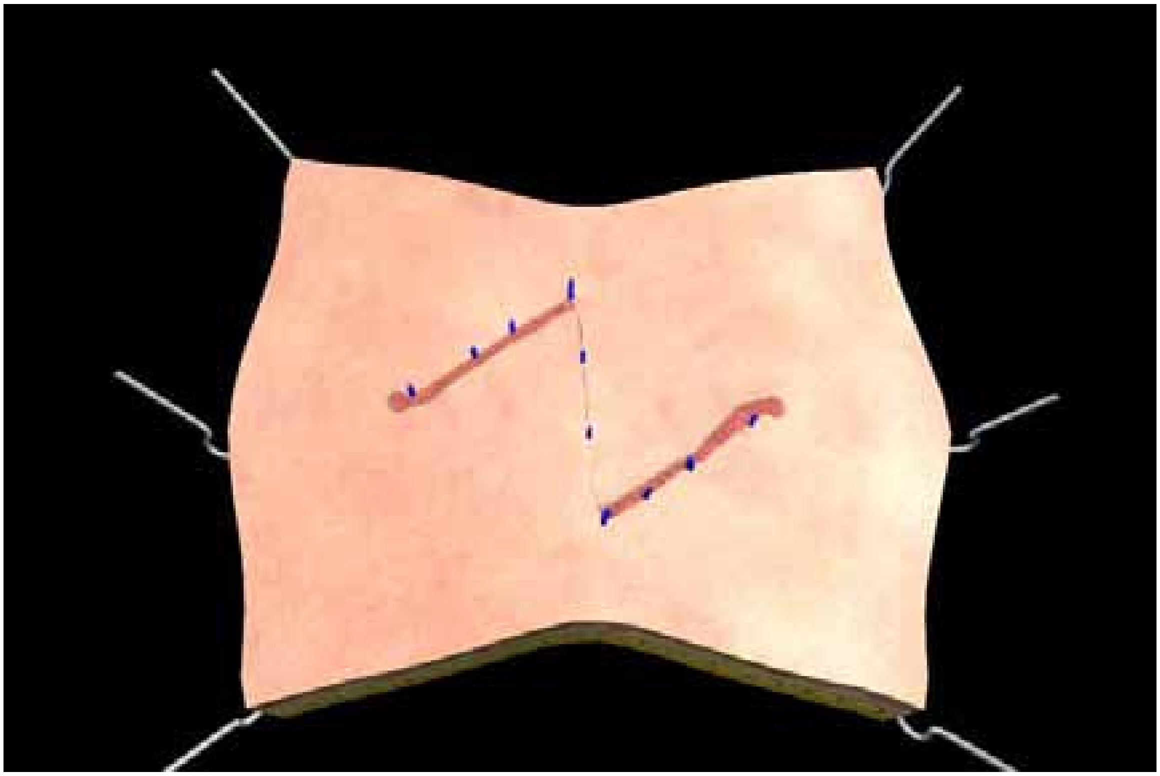
JT: In the fall of 2007, I spoke as part of Intel chief technology officer Justin Rattner's keynote address at the Intel Developer Forum. I was illustrating the idea that the future 3-D Internet will include an "avatar" – a virtual representation of you – that could look just like you, or better than you. I noted that the graphics would be astonishingly realistic and three-dimensional but for surgical simulation they would need to be much more accurate, a goal I am working to achieve. As virtual worlds get more realistic, modern applied mathematics and scientific computing are required.



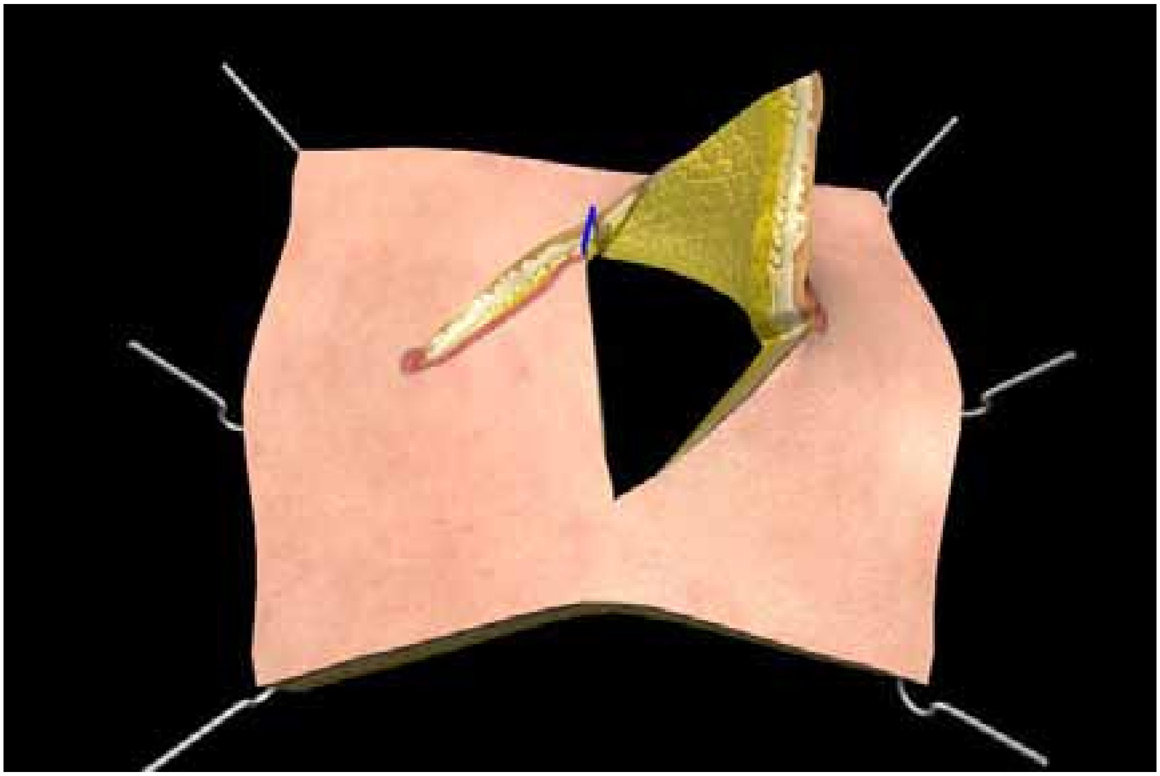
A close-up image of a malignant melanoma before the virtual procedure.



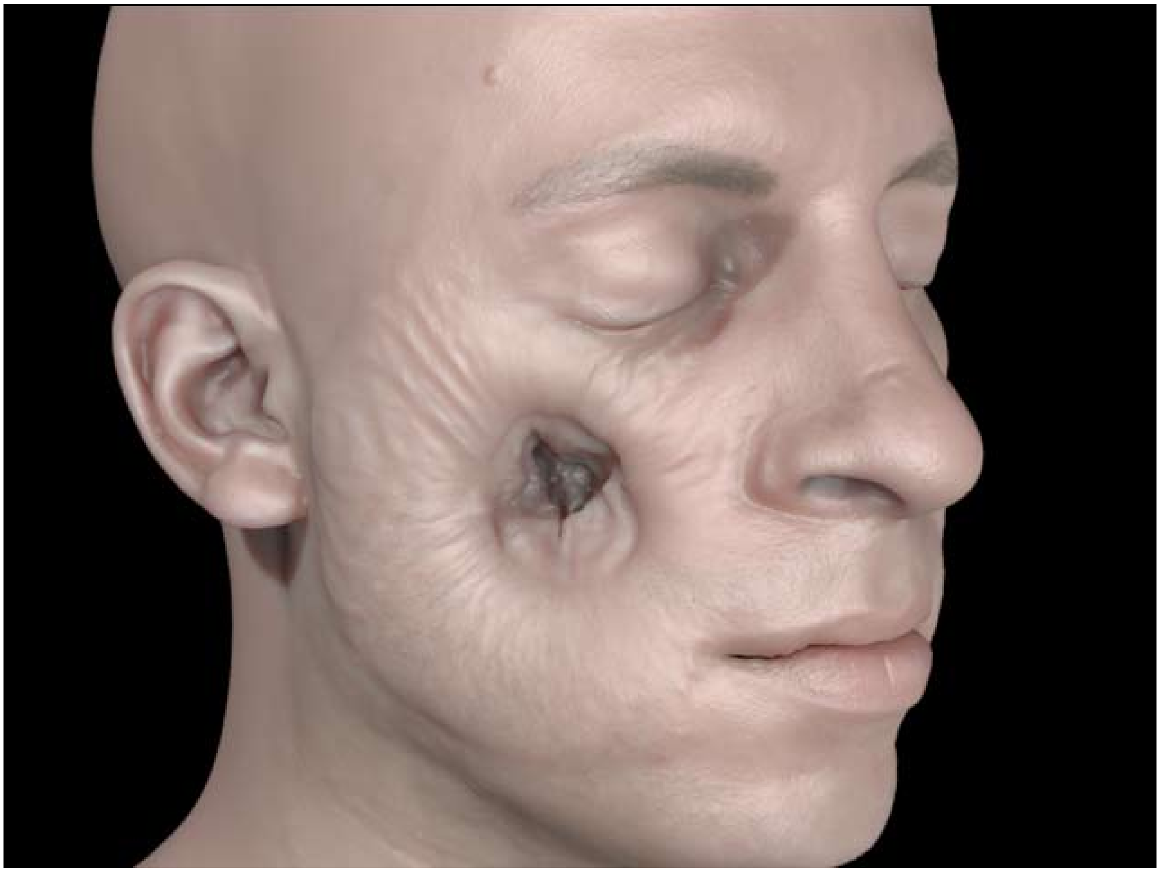
Here, the excision of the melanoma leaves a rhomboidal defect. A simple transposition of a tissue flap is used to repair the tissue.

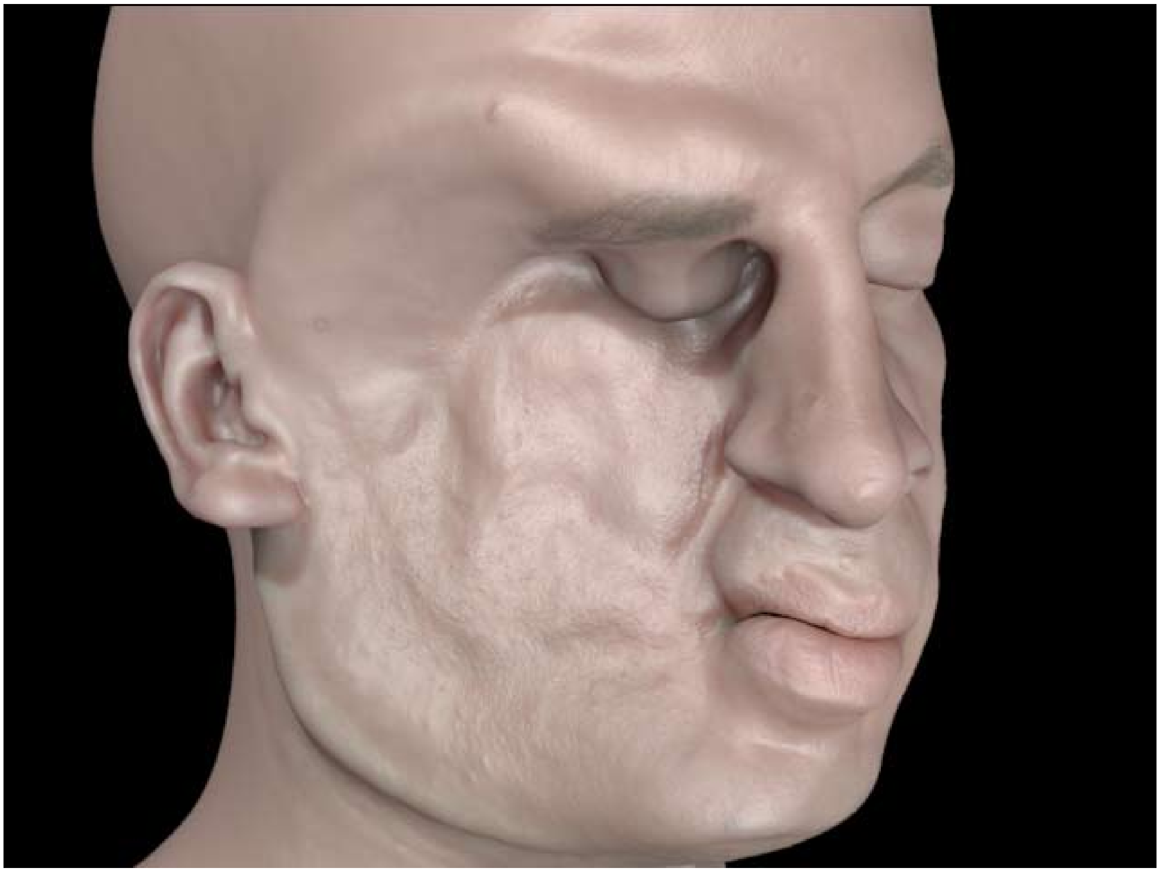


The Z-plasty procedure leaves a scar, but elongates a tissue artificially contracted by scarring.



The virtual surgeon makes a Z-shaped incision (with 60 degree angles) creating two triangular peninsular flaps of tissue. These flaps are transposed to elongate the tissue in the direction of the scar.





opposite top: Modern algorithms allow for incredibly detailed simulations. Here, a recent technique is used to simulate the result of a high-speed projectile impact on a digital double of the head and neck.

opposite bottom: The digital double can be used to predict injuries that would result from traumatic scenarios. This technology will help in the development of surgical approaches for treating such injuries.

JL: Joseph, I bet you're a fun guy! What do you do in your personal time?

We know you are an assistant professor at UCLA, Department of Mathematics, with endless degrees from such prestigious hallowed halls as the Courant Institute of Mathematical Sciences (2005 – 2007), Stanford University (Ph.D., 2005) University of California (B.S., 2000) and a visiting member of Courant Institute of Mathematical Sciences (as a National Science Foundation Mathematical Sciences Postdoctoral Research Fellow).

We know that embracing your stellar career, you've been awarded among many: Discover Magazine – Top 20 Scientists Under 40 (December, 2009) and National Science Foundation Mathematical Sciences Postdoctoral Research Fellowship (2005 – 2007).

What we'd love to know is what excitement do you get into in your fun time?

JT: My only hobby these days is guitar. When I was younger, I enjoyed playing soccer very regularly. These days, I don't have enough time but I would like to get out and play a little more often than I do now.

JL: And inventing! This, too, has got to be tremendous fun! Perhaps it incorporates the highs of soccer into the solitude of music?

JT: I suppose so, yes.

JL: Joseph, earlier on you mentioned that "most of the behaviors of everyday life can be described with mathematical equations." This intrigues me! Can you give me an example of an everyday behavior? Let's say, laughter. What would the equation be?

JT: Laughter is experienced when sound waves created in your throat travel to someone's ears. This process of sound-wave generation is well understood and can be mathematically described in terms of wave transport. The interaction of these waves with the cochlea in your ear enables your experience of hearing laughter. All of these phenomena are naturally described with classical physics and mechanics.

JL: Joseph, what is your most important message for the world to hear?

JT: I guess I would like to encourage people to study math and computer science because it never gets old. You will never be bored because there are always new problems to solve and new things to learn.

JL: You are quite the symbol of genius, Joseph! And how honored ADESTE and JO LEE Magazine are to have you as our Laureate 2010.

JT: Thank you again Jo Lee, I am honored to have been featured!

JL