Computer scientist reveals the math and science behind blockbuster movies

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On Feb. 19 at the annual meeting of the American Association for the Advancement of Science in San Francisco, movie lovers get a behind-the-scenes glimpse at the physics-based simulations that breathe life into fantasy.

"It is an exhaustive task to prescribe the motion of every degree of freedom in a piece of clothing or a crashing wave," says Ron Fedkiw, an assistant professor of computer science at Stanford who will speak about computations used to make solids and fluids more realistic in feature films. "Since these motions are governed by physical processes, it can be difficult to make these phenomena appear natural. Thus, physically based simulation has become quite popular in the special effects industry. The same class of tools useful for computational fluid dynamics is also useful for sinking a ship on the big screen."

Fedkiw's talk is part of a symposium titled "Blockbuster Science: Math and Science Behind Movies and Entertainment," which brings together leaders from industry and academia. The other speakers are Tony DeRose of Pixar in Emeryville, Calif., and Doug Roble of Digital Domain in Venice, Calif. Math Professor Tony Chan of the University of California-Los Angeles will moderate the symposium.

Science at the Oscars

This year, two of the three movies nominated for a special effects

Oscar--Poseidon and Pirates of the Caribbean: Dead Man's Chest, both made by Industrial Light & Magic (ILM)-- required heavy numerical simulation, says Fedkiw, who has consulted for ILM for six years. Most recently, the PhysBAM (for Physics Based Modeling) core math engine he developed helped to create realistic water in Poseidon and Davy Jones' tentacles in Dead Man's Chest.

Computer graphics (CG) experts used to have to make a Catch-22 decision. They could run inferior algorithms on many processors or run the best algorithm on only one processor. The problem is that many algorithms do not scale well to larger numbers of processors. But about a year and a half ago Fedkiw figured out how to run a star algorithm on many processors, resulting in special effects unprecedented in their realism.

He designs new algorithms for diverse applications including computational fluid dynamics and solid mechanics, computer graphics, computer vision and computational biomechanics. The algorithms may rotate objects, simulate textures, generate reflections or mimic collisions. Or they may mathematically stitch together slices of a falling water drop, rising smoke wisp or flickering flame to weave realism into CG images.

Fedkiw received screen credits for his work on Poseidon, on Terminator 3: Rise of the Machines for the liquid terminator and the nuclear explosions and on Star Wars: Episode III--Revenge of the Sith for explosions in space battle scenes.
"My first love is computational physics and most of my career has been dedicated to that," says Fedkiw, who has published more than 75 research papers in computational physics, computer graphics and vision, as well as a book on level set methods with UCLA's Stanley Osher. Recently he has grown interested in applying computational physics to virtual surgery and modeling of the human face.

Fedkiw is the recipient of a National Academy of Sciences award for innovations in the modeling and numerical simulation of flows and pioneering contributions to physically based computer graphics. He also received a David and Lucile Packard Foundation fellowship for simulations of humans and a Presidential Early Career Award for Scientists and Engineers, the nation's highest honor for professionals at the outset of their independent research careers.

Going Hollywood

Research universities like Stanford play big roles in training the next generation of CG specialists and developing the science and technology that gets applied in movies in innovative ways.

"The simulation of gases, liquids and combustion for scientific reasons quickly translates into the ability to make animations of smoke, water and fire," Fedkiw says. "Similar statements hold for soft biological tissues, muscles, fractures and other solid material problems. Once the scientific numerical simulations are worked out, interesting animations can be made shortly thereafter."

Most of Fedkiw's students double-major in math and computer science. "Graphics itself is a bit less important, and many of them don't take their first graphics class until their junior or senior year of college," Fedkiw says. "I started [learning computer graphics] rather late, working in pure mathematics until I was 23 years old, and then switching to applied mathematics after that. I didn't know anything about computer graphics until 1998. And although I did work on engineering-related problems, I didn't do any work in computer science until I started working with a company in 1998 to learn more about graphics."

Fedkiw earned his doctorate in applied mathematics from UCLA in 1996 and did postdoctoral work at UCLA in mathematics and at Caltech

in aeronautics before joining Stanford's Computer Science Department in 2000. He wrote his first two papers for the 2001 SIGGRAPH (short for Special Interest Group for Computer Graphics), an annual CG conference convened by the Association for Computing Machinery (ACM). In 2005, ACM SIGGRAPH honored him with its Significant New Researcher Award for contributions to the computer graphics community.

Getting research experience is important for anyone applying to Stanford's computer science doctoral program. "Connecting with a research group is quite important to do in addition to taking classes," Fedkiw says. He and his students have worked closely with ILM, Pixar, Intel, Honda and Sony Imageworks. "This collaboration with industry is a two-way street and has produced a number of academic papers--as well as some screen credits," he says. "Both the companies and group at Stanford think of this as a highly synergistic relationship."

Fedkiw's favorite movie employing CG is Revenge of the Sith. "When I watched the first [Star Wars movie] at 9 years old, I never dreamed that I'd eventually be helping to make the last one."

Source: Stanford University

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