Beauty is skin deep

You're standing in a swanky hotel ballroom next to a ten-foot Oscar statue, chatting with computer scientists, who seem a little uneasy in their tuxedos. TV crews and reporters gather behind velvet ropes waiting for the chance to get a sound bite from a famous guest. Cameras flash. It's two weeks before the Academy Awards, and you are at the presentation ceremony for the Academy's Scientific and Technical Awards, which honor the people who work magic behind the scenes. These people have revolutionized their particular niches of the film industry, devising new methods for cinematography, optical engineering, electronics, and film production. In recent years, a growing cohort of computer scientists have joined them, as computer graphics becomes fundamental to moviemaking.

CS professor Steve Marschner knows just how this feels. He accepted a Technical Achievement Award from the Academy of Motion Picture Arts and Sciences in 2004 for his research in simulating subsurface scattering of light in translucent materials. "Winning the academy award was an amazing experience," says Marschner. "To see our ideas picked up by industry and put to use in mainstream movies to solve real artistic problems is exciting and gratifying." The mathematical model devised by Marschner and his colleagues led to the realistic skin of characters like Gollum in *The Lord of the Rings* trilogy and Dobby in *Harry Potter and the Chamber of Secrets*; it also permitted computer-generated versions of characters to stand in for The Terminator in *Terminator 3: Rise of the Machines* and Agent Smith in *The Matrix Reloaded*.

According to Richard Edlund, chair of the Academy of Motion Picture Arts and Sciences' Scientific and Technical Awards Committee, "this is one of the holy grails of computer graphics. One of the difficulties of creating lifelike characters in the computer world is the problem that skin is not opaque. If you render a faithfully scanned or created character and the skin is opaque, it doesn't look real."

In 2001 at Stanford, Marschner (then a postdoc at the Computer Graphics Laboratory) and his colleagues, Henrik Wann Jensen, Marc Levoy (a Cornell PCG alumnus), and Pat Hanrahan, developed a model for how light penetrates a translucent material like skin and scatters through the material below the surface before re-emerging. Because skin is translucent, this subsurface scattering model simulates the soft appearance of skin very successfully. Previous models, which tacitly assumed that skin was entirely opaque, resulted in characters with a plastic appearance. The new model was so important in bringing digital characters to life that, within two years after their paper appeared, all the major special-effects studios had incorporated it into their rendering systems.

The subsurface scattering model is based on mathematics that goes back many decades. "The basic math behind our model was originally developed in the 1940s and 1950s for astrophysics; more recently, it was extended by people working in medical physics and doing simulations of laser light in skin and other tissues," says Marschner. "We extended it again to make it work for graphics; now translucency is part of the basic toolkit everyone uses for representing materials."

At Cornell, Marschner has continued his work on realistic rendering of natural materials. Research on rendering human hair led to a model that is based on the realization that hairs are basically thin transparent cylinders. The model, which matches measurements of light scattering from individual hair fibers, is being used in the movie industry to create believable hair for computer-generated characters. In looking at the appearance of wood, Marschner considered its translucent, fibrous structure and implemented a rendering model to replace the old model that assumed wood was opaque.

Marschner is a member of Cornell's Program of Computer Graphics (PCG), a leader in research in synthesizing realistic images.

Top right, Marschner (right) and colleague Pat Hanrahan enjoy the Oscar awards ceremony. Below, Gollum, of *The Lord of the Rings*, as created using the award-winning realistic skin model.

"It's simply a pleasure to be part of such a strong lab," says Marschner. "I feel lucky to be working in this niche. I'm a visual person, and to be able to spend my time scrutinizing the world around me, trying to understand why it looks the way it does, is very rewarding. And to find myself in front of an audience accepting an Oscar —well, that's like something out of a movie."

Don Greenberg (Director of the PCG, center), Kavita Bala (right), and Steve Marschner work on synthesizing realistic images.

Program of Computer Graphics

The Program of Computer Graphics (PCG) is an interdisciplinary center dedicated to the development of interactive computer modeling and rendering techniques and their applications. It enjoys close connections with the CS Department, making it easy for CS graduate students to do research in graphics. CS faculty involved in the PCG are Director Don Greenberg, Kavita Bala, and Stephen Marschner.

Established in 1973, the PCG has enjoyed NSF support for more than three decades. Prior to its founding, joint research in computer graphics was conducted with GE's Visual Simulation Laboratory in the late 1960s, resulting in the movie *Cornell In Perspective*.

The major long-term goal has been to create simulations that are physically accurate and perceptually indistinguishable from real-world scenes. Currently, the research focus involves three-dimensional modeling and rendering of complex environments for realistic image synthesis. Research is being conducted on light reflection models, methods for rapidly determining the interaction between diffusely reflecting surfaces, parallel processing strategies, micro-geometry surface modeling, perceptual issues in graphics, and a host of other topics related to complex modeling and realistic image displays.

The high scene complexity required for realism makes scalability an important problem. Bala's research addresses this challenge by developing scalable algorithms and representations for illumination, rendering, and modeling. One key insight is that limitations of the human visual system can be exploited to achieve scalability without compromising perceived image quality.

In architecture, research continues on developing methods for interactive computer-aided design, particularly at the preliminary design phase. In medicine, new methods are being developed to display real-time four-dimensional volumetric information and to extract mathematical surface representations of complex body organs.

The PCG serves as the primary focus for computer animation. Two courses are offered, and the PCG is involved in efforts to establish undergrad and graduate majors in digital arts and graphics. Animation research is developing better methods for character modeling and rigging. Many currently used strategies for physically-based motion were developed at the lab.

Close working relationships with industry have resulted in the donation of tens of millions of dollars worth of equipment, making the center one of the most advanced in the United States. The PCG provides a unique opportunity for scientific exploration in computer graphics and parallel processing, as well as interdisciplinary research in computer-aided design.

Throughout its more than three-decade history, the PCG has played a significant role in the computer graphics community. Two articles were published in *Scientific American* (1974, 1991). Greenberg won the prestigious Stephen Coons Award in 1987 and was the founding director of the five-university NSF Science and Technology Center for Computer Graphics and Scientific Visualization. Five faculty and students have won the SIGGRAPH achievement award, and five have received Hollywood's technical Oscars. Many of its hundreds of graduate students are now faculty at the best universities in the world, and others have leadership roles in the software and animation industries.

"Lightcuts" (by Bala, Greenberg, and fellow researchers) enables highly scalable rendering of complex scenes even with millions of lights.

Charlie Van Loan, *Introduction to Scientific Computing: a Matrix Approach Using MATLAB* (Prentice Hall).

Bill Arms, Andrew Myers, Ron Elber join.

1998

With CS providing leadership, Cornell starts the Faculty of Computing and Information Science, to provide a home for interdisciplinary computing work of all kinds. CS, the Program for Computer Graphics, and Digital Libraries are part of it.

David Gries receives an honorary doctorate from Miami University.

Juris Hartmanis receives an honorary doctorate from the University of Missouri.

Pedro Felzenszwalb is the CRA Outstanding Male Undergraduate Awards Runner-up.

David Liben-Nowell receives an Honorable Mention in the CRA Outstanding Male Undergraduate Awards competition.

Bill Arms becomes Chair of the ACM Publications Board and Editor-in-Chief of *D-Lib Magazine*.

Joe Halpern is founder and administrator of CoRR (the ACM-sponsored Computing Research Repository).

Fred Schneider is Associate Editor-in-Chief of the IEEE journal *Security and Privacy*.

Fred Schneider is Chair of the NRC committee that produces the report *Trust in Cyberspace* (National Academy Press). This report assesses the state-of-the-art procedures for constructing trustworthy networked information systems and proposes directions for research in computer and network security, software technology, and system architecture.

Tom Coleman becomes the Director of the Cornell Theory Center.

Jon Kleinberg publishes his Web-search work on using hubs and authorities. The research is credited, together with the Brin-Page work on PageRank, with forming the basis for the current generation of Internet search tools.

Johannes Gehrke, David Schwartz join. Bob Constable becomes Dean of the Faculty of Computing and Information Science. Charlie Van Loan becomes Chair.

1999

Don Greenberg receives an honorary doctorate from the New Jersey Institute of Technology.