Physically Based Modeling

Course Organizer

Andrew Witkin
Pixar Animation Studios

Physically based modeling has become an important new approach to computer animation and computer graphics modeling. Although physically based modeling is inherently a mathematical subject, the math involved needn't be any more difficult nor esoteric than the math that underlies many other areas of computer graphics, such as ray tracing or surface modeling. Many papers on the subject have presupposed a specialized mathematical background that many members of the computer graphics community lack. Consequently, many capable computer graphics practitioners, despite their interest in the subject, have simply been put off by the density of the math.

This course addresses the need to make the principles and methods of physically based modeling accessible to a broader computer graphics audience—those who are familiar with mainstream computer graphics and have the usual basic computer graphics math, such as vector/matrix manipulations, but whose first year calculus course may be only dimly remem-bered.

Course topics include modeling the dynamics of particle systems and rigid bodies, basic numerical methods for differential equations, simulation of deformable surfaces, collision detection, modeling energy functions and hard constraints, and the dynamics of collision and contact.

Additional material/updates can be found at:

`http://www.pixar.com/aboutpixar/research/pbm2001`

Course Schedule

8:30 am **Introduction**

8:45 am **Differential Equation Basics** **Witkin**

Vector fields and integral curves; initial value problems; basic numerical methods; modular implementation of differential equation solvers.

9:30 am **Particle Dynamics** **Witkin**

F=ma; phase space; basic forces: gravity, drag, springs, etc. Simple particle collisions; structured implementation of interactive mass-and-spring systems.

10:00 am **Break**

10:15 am **Particle Dynamics (Cont'd)** **Witkin**

10:30 am **Implicit Methods** **Baraff**

Penalty methods and the problem of stiffness: visualizing the problem; how to avoid it; what to do if you can't; Simulating large systems.

11:15 am **Cloth and Fur Energy Functions** **Kass**

Point-volume comparisons, convex and nonconvex polyhedra, coherence based methods, curved surfaces.

12:00 pm **Lunch**

1:30 pm **Rigid Body Dynamics** **Baraff**

Center of mass and inertia tensor; orientation and angular velocity; force, torque, and Newton's laws; rigid body equations of motion: how to simulate rigid bodies.

2:15 pm **Constrained Dynamics** **Witkin**

"Tinkertoy" systems: rigid rods instead of springs. Using constraint forces to avoid stiffness. Lagrange multipliers: solving for constraint forces. basics of collision and contact.

3:00 pm **Break**

3:15 pm **Collision and Contact** **Baraff**

Impulses; one-sided constraints; multiple constraint; discontinuities.

4:00 pm **Dynamics in *Monsters, Inc.*** **Witkin/Baraff/Kass**

Course Speakers

Andrew Witkin joined Pixar Animation Studios in 1998 as a Senior Animation Scientist. He was previously on the faculty of Carnegie Mellon University, from 1988 through 1998. Prior to joining the faculty at Carnegie Mellon, Andrew Witkin was director of the Perception and Graphics groups at Schlumberger's Palo Alto Research Lab. He received a BA in Psychology from Columbia College in 1975 and a PhD in Psychology from MIT in 1980. Dr. Witkin has published extensively in the areas of Computer Vision and Computer Graphics. He serves as an associate editor for ACM Transactions on Graphics, has served on numerous conference program committees, and is a fellow of the American Association for Artifical Intellgience. His awards include Best Paper prizes at the National Conference on Artifical Intellegence and the International Joint conference on Artifical Intellgence, the Grand Prix for Animation at the 1987 Parigraph competition in Paris, France, and the Grand Prix for Computer Graphics, Prix Ars Electronica 1992, Linz, Austria. He is the recipient of this year's ACM SIGGRAPH Computer Graphics Achievement Award.

David Baraff joined Pixar Animation Studios in 1998 as a Senior Animation Scientist. Prior to his arrival at Pixar, he was an Associate Professor of Robotics, and Computer Science at Carnegie Mellon University. David Baraff received his Ph.D. from Cornell University in 1992, where he was a graduate student in Cornell's Department of Computer Science, and Program of Computer Graphics. Before and during his graduate studies, he also worked at Bell Laboratories' Computer Technology Research Laboratory doing computer graphics research, including real-time 3D interactive animation and games. After receiving his Ph.D., he joined the faculty of Carnegie Mellon University. In 1995, he was named an ONR Young Investigator. His research interests include physical simulation and modeling for computer graphics, robotics, and animation.

Michael Kass is a Senior Scientist at Pixar Animation Studios where he developed the tools for physically-based clothing animation that were used on Pixar's Academy Award winning short film "Geri's game." He received his B.A. from Princeton in 1982, his M.S. from M.I.T in 1984, and his Ph. D. from Stanford in 1988. Dr. Kass has received numerous awards for his research on physically-based methods in computer graphics and computer vision including several conference best paper awards, the Prix Ars Electronica for the image "Reaction Diffusion Texture Buttons" and the Imagina Grand Prix for the animation "Splash Dance." Before joining Pixar in 1995, Dr. Kass held research positions at Schlumberger Palo Alto Research, Apple Computer, and was Director of Technology at Live Picture Inc.

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