SIGGRAPH 1992

19th International Conference On Computer Graphics and Interactive Techniques

McCormick Place, Chicago
July 26 - 31

COURSE NOTES 16

PARTICLE SYSTEM MODELING, ANIMATION, AND PHYSICALLY BASED TECHNIQUES

Organizer
Donald H. House
Williams College

Lecturers
David E. Breen
Rensselaer Polytechnic Institute

David R. Haumann
IBM T.J. Watson Research Center

William Reeves
Pixar

David Tonnesen
University of Toronto
DEC Cambridge Research

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Donald House
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COURSE ABSTRACT

Particle systems were dramatically introduced to the Computer Graphics community when Bill Reeves used them to portray a planet-engulfing conflagration for the "Genesis Sequence" in the motion picture, *Star Trek II*. Since then, particle systems have proven to be powerful and popular tools for the portrayal of a variety of complex phenomena. Examples are as diverse as waterfalls and snow, grass and drifting leaves, liquid and draping cloth.

This course is designed to provide both a thorough introduction to the fundamentals of particle systems, and a glimpse into their promise for providing powerful modeling tools for the future. We begin with a retrospective introduction to particle systems by Bill Reeves, that includes clips from several memorable films. Bill contrasts particle system modeling and rendering with surface based techniques, and shows the power of the particle-system approach for a large class of problems. Dave Haumann then presents a tutorial-by-example on a hierarchical approach to the use of particle systems in choreographing animations, as done for the film *Leaf Magic*. Dave shows that by using particles to construct physical objects with two or more levels of "physical" detail, it is possible to choose the level of "motion" detail exhibited in the resulting animation. Having laid these foundations, we look at some of the possibilities and challenges inherent in coupling the particles in a system so that they interact with each other. Taking a theoretical approach, Don House introduces this topic by outlining the potential uses of particle systems for the modeling of complex and sometimes ill understood materials. He then addresses the computational pitfalls inherent in solving the many-body problem resulting from particle coupling, and describes algorithms for dealing with these pitfalls. Dave Tonnesen moves from theory to practice, explaining a variety of techniques he has developed using interacting particles, including his use of symmetric energy fields for modeling heat-dependent behavior, and of asymmetric fields in an interactive variable-topology 3D surface modeling tool. He concludes with a discussion of particle-system rendering techniques. Dave Breen completes the coupled-particle story by presenting an interesting application, a particle-based physical model of the draping behavior of woven cloth. His talk serves to amplify and illuminate both theory and technique. On the one hand he emphasizes how the modeling of small scale cloth structure results in emergent, characteristic, cloth-like draping and folding at the large scale. On the other hand he gives a detailed explanation of the computational techniques used to represent and evaluate the cloth model.

SPEAKER BIOGRAPHIES

Donald House is an Associate Professor of Computer Science at Williams College, and a Visiting Research Scientist at the Design Research Center, Rensselaer Polytechnic Institute. He earned a BS in Mathematics from Union College in 1969, an MS in Electrical Engineering from Rensselaer in 1978, and a PhD in Computer Science from the University of Massachusetts in 1984. His current work in computer graphics and animation focuses on particle-based physical models of complex materials. Earlier, Don pursued research in Computational Neuroscience, investigating computational strategies of depth perception in frogs and toads, and had a ten year industrial career with G.E. in process and industrial automation.

David Breen is a Research Engineer and a PhD Candidate in Computer and Systems Engineering at Rensselaer Polytechnic Institute. He received an AB in Physics from Colgate University in 1982, and an MS in Computer and Systems Engineering from Rensselaer in 1985. He has been on the full-time research staff of the Rensselaer Design Research Center since 1985, where he is the co-leader of the Visual Technologies Program. From August 1987 to July 1988 he was a visiting research engineer at the Zentrum für Graphische Datenverarbeitung in Darmstadt, Germany. His research interests include particle-based modeling, computer animation, volume data analysis and object-oriented computer graphics. Dave co-lead the team that developed the object-oriented animation system, The Clockworks, and has been a frequent contributor to the SIGGRAPH Art Show.

David Haumann is currently a Research Staff Member at IBM T. J. Watson Research Center in Yorktown Heights, N.Y. He received his BS in Applied Mathematics from Brown University in 1977, and his PhD in Computer Science from The Ohio State University in 1989. His experience in computer graphics spans the fields of radiation treatment planning, flight simulation and commercial computer animation production. His research interests include computer graphics, animation, and physically-based modeling. Dave's animation techniques have been featured in the award winning SIGGRAPH films "Dynamic Simulations of Flexible Objects", "Balloon Guy" and "Leaf Magic", and he has contributed to several others, including "Broken Heart" and "Dirty Power".

William Reeves is head of Animation Research and Development at Pixar. He received his B. Math. from the University of Waterloo in 1974, a Msc. Computer Science from the University of Toronto in 1976, and a PhD. in 1980. From 1980 to 1986, Bill was a project leader in the systems, and then the graphics groups at Lucas Films. He joined Pixar in 1986. Bill is best known for his invention of the particle-system image synthesis technique. He has also made numerous other research contributions to the field including new inbetweening techniques, a model of ocean waves with Alain Fournier, and an efficient anti-aliased shadow algorithm with David Salesin and Rob Cook. Bill's film credits include: "Star Trek II: The Wrath of Khan", "Return of the Jedi", "The Adventures of Andre and Wally B.", "Young Sherlock Holmes", "Blowin' in the Wind", "Flags and Waves", "Luxo Jr." (1986 Academy Award nominee), "Red's Dream", "Tin Toy" and "Knickknack". In 1988, Bill received an Academy Award for Best Animated Short Film for his work as Technical Director on "Tin Toy".

David Tonnesen is a research assistant and a PhD Candidate in Computer Graphics at the University of Toronto, and is also a consultant for DEC Cambridge Research Laboratory. He earned BS degrees in both Electrical Engineering and Computer Science from Washington University, St. Louis in 1983, and received an MS in Computer Science from Rensselaer Polytechnic Institute in 1989. He has held positions at the Neuroanatomical Image Processing Facility at Washington University's School of Medicine, Rockwell International Space System Division's Space Shuttle Flight Simulation Laboratory, Cray Research, and Lawrence Livermore National Laboratory NMFECC. His research interests include computer graphics, animation, physically based modeling, and surface reconstruction techniques.

SCHEDULE OF SESSIONS

INTRODUCTION

8:45 • House -- Overview of the course and speakers.

SESSION 1 -- FUNDAMENTALS

9:00 • Reeves -- Retrospective introduction to particle systems.

10:15 BREAK

SESSION 2 -- CHOREOGRAPHY

10:30 • Haumann -- A hierarchical approach to physically-based choreography with particles.

SESSION 3 -- COUPLED PARTICLES: THEORY

11:45 • House -- Introduction to modeling complex phenomena using interacting particles.

12:00 LUNCH

1:30 • House -- Computational issues in dealing with coupled particle systems.

SESSION 4 -- COUPLED PARTICLES: TECHNIQUES

2:00 • Tonnesen -- Modeling and rendering with coupled particles.

3:15 BREAK

SESSION 5 -- COUPLED PARTICLES: AN APPLICATION

3:30 • Breen -- A particle-based dynamic model of draping cloth.

4:45 END

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