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COURSE NOTES

17

ADVANCED TECHNIQUES
IN HUMAN MODELING,
ANIMATION, AND RENDERING

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ADVANCED TECHNIQUES IN HUMAN MODELING, ANIMATION, AND RENDERING

SIGGRAPH '92, Chicago

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Abstract

This course will discuss several important problems to be solved to incorporate realistic human characters in computer-generated films. Research in this area implies the development of techniques: for improving the physical aspects of the actors: shapes, colors, textures, for improving the deformation of limbs during motion, for improving facial expressions and deformations, for specifying the tasks to be performed using natural language, for simulating behaviors.

The first problems we will discuss are the problems of shape creation and animation. For the shape creation, we will show the impact of new 3D devices (Spaceball, Polhemus, dataglove) on the design of human body and face. We will then discuss the problem of improving the realism of motion not only in terms of the joints as for robots, but in relation to the deformations of human bodies during animation. Two methods for improving these deformations are described: Joint-dependent Local Deformations and deformations based on finite element theory.

The course will also describe techniques for realistic facial modeling and animation including physically-based techniques and rational free-form deformations. A method of estimating facial muscle contractions from video sequences is also discussed. Finally, we will describe a methodology for specifying facial animation based on a multi-layered approach. Each successive layer defines entities from a more abstract point of view, starting with phonemes, and working up through words, sentences, expressions, and emotions.

For synthesized images containing human beings, realistic hair has long been an unresolved problem and therefore has often been absent from these images. The great number of geometrical primitives involved and the potential diversity of the curvature of each strand of hair makes it a formidable task to manage. In this course, we will review techniques for rendering fur and hair and modeling hairstyle. We will emphasize a method based on pixel-blending for generating images completely free of aliasing artifacts. The problem of skin texture is also discussed.

Clothes in computer-generated films are often simulated as a part of the body with no autonomous motion. In this course, we will present methods for designing and animating clothes. Two separate problems have to be solved for cloth animation: the motion of the cloth without collision detection and the collision detection of the cloth with the body and with itself. Deformable models provide a powerful approach to the first problem. In addition to free-form geometry, the formulation of deformable models involves physical principles that govern rigid and nonrigid dynamics, including elastic, inelastic, and thermoplastic deformations. For the collision and self-collision problem, we present a method of collision detection especially efficient for dynamic models.

The process of interpreting Natural Language instructions shows deep and fascinating connections between language and behavior. When the behavior is to be portrayed by a synthetic human agent, various questions arise regarding the types and roles of planning, geometric reasoning, constraint satisfaction, human capabilities, and human motion strategies. We discuss the realization of a language-to-animation connection through computational models of verb definitions executed by a simulator accessing a Knowledge Base, and animated through a graphical human figure.

Finally, we will discuss an individualized walking model and present an innovative way of animating actors at a high level based on the concept of synthetic vision. The objective is simple: to create an animation involving a synthetic actor automatically moving in a corridor avoiding objects and other synthetic actors. To simulate this behavior, each synthetic actor uses a synthetic vision as its perception of the world and so as the unique input to its behavioral model.

About the lecturers

Nadia Magnenat Thalmann is currently full professor of Computer Science at the University of Geneva, Switzerland and Adjunct Professor at HEC Montreal, Canada. She has served on a variety of government advisory boards and research program committees in Canada. She has received several awards, including the 1985 Communications Award from the Government of Quebec. She is the President of the Computer Graphics Society. Dr. Magnenat Thalmann received a BS in psychology, an MS in biochemistry, and a Ph.D in quantum chemistry and computer graphics from the University of Geneva.

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Daniel Thalmann is currently full professor, head of computer science, and director of the Computer Graphics Laboratory at the Swiss Federal Institute of Technology in Lausanne, Switzerland. He also is an adjunct professor at the University of Montreal. Since 1977, he was Professor at the University of Montreal and codirector of the MIRALab research laboratory. He received his diploma in nuclear physics and Ph.D in Computer Science from the University of Geneva. He was visiting Professor at the University of Nebraska and invited researcher in the Computer Graphics Group at CERN. He cochairs the EUROGRAPHICS Working Group on Computer Simulation and Animation

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Nadia Magnenat-Thalmann's and **Daniel Thalmann's** research interests include 3D computer animation image synthesis, and scientific visualization. They have published more than 100 papers in these areas and are coauthors of several books including: *Computer Animation: Theory and Practice* and *Image Synthesis: Theory and Practice*. They are also codirectors of several computer-generated films *Dream Flight*, *Eglantine*, *Rendez-vous à Montréal*, *Galaxy Sweetheart*, *IAD*, *Flashback*, and *Still Walking*. They cochaired several conferences included Graphics Interface '85, CGI '88, Computer Animation '89, '90, and '91. They are also co-editors-in-chief of the *Journal of Visualization and Computer Animation* and editors of *the Visual Computer*.

Dr. Norman I. Badler is the Cecilia Fidler Moore Professor and Chair of Computer and Information Science at the University of Pennsylvania and has been on that faculty since 1974. Active in computer graphics since 1968 with more than 80 technical papers, his research focuses on human figure modeling, manipulation, and animation. Badler received the BA degree in Creative Studies Mathematics from the University of California at Santa Barbara in 1970, the MSc in Mathematics in 1971, and the Ph.D. in Computer Science in 1975, both from the University of Toronto. He is Co-Editor of the *Journal of Graphical Models and Image Processing*. He also directs the Computer Graphics Research Facility with two full time staff members and about 40 students.

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Demetri Terzopoulos is an associate professor of computer science at the University of Toronto and a fellow of the Canadian Institute for Advanced Research. For the past five years he has been affiliated with Schlumberger, Inc., serving as a program leader at the Laboratory for Computer Science, Austin, TX, and at the former Palo Alto Research Laboratory. Previously he was a research scientist at the MIT Artificial Intelligence Laboratory, Cambridge, MA. His areas of interest include computer vision, computer animation, visualization, and massivel parallel computation. Terzopoulos received a PhD in artificial intelligence from MIT in 1984. He received an MEng in electrical engineering in 1980 and a BEng in honours electrical engineering in 1978, both from McGill University. He is a member of the editorial boards of *CVGIP: Graphical Models and Image Processing* and the *Journal of Visualization and Computer Animation* and is a member of the IEEE, AAAI, NY Academy of Sciences and Sigma Xi.

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Detailed outline of course and schedule

1. The Complexity of Models in Human Animation: an Overview (Magnenat-Thalmann, 30 min)

2. Human Shape Design and Body Deformations

Human Body Shape Design (Magnenat-Thalmann, 30 min)

- Actor shape modelling
- Human prototyping
- The Use of 3D Input Devices in Human Modeling and Animation
(Space Ball, Polhemus, DataGlove)
- Local deformations
- A Sculptor Approach to Human Modeling

Human Body Deformations (Thalmann, 30 min)

- Joint Local Deformation (JLD) operators for body mapping
- JLD operators for hand covering
- Mapping algorithm
- Deformations based on Finite-Element theory
- Case study: ball grasping and pressing
- Animation control

The physically-based approach (Terzopoulos 10 min)

- Overview of the physically-based approach to human modeling and comparison with geometric techniques.
- Aspects of human character animation that can benefit from physically-based modeling.

Modeling deformable materials in and on the human body (Terzopoulos 20 min)

- Review of deformable models of curves, surfaces, and solids.
- Implementation recipes for dynamic deformable meshes.
- Associated physically-based constraint methods.

3. Human Face Animation and Rendering

Physics-based Facial Modelling and Animation (Terzopoulos, 30 min)

- Biophysics of facial tissue.
- Capturing facial geometry using adaptive deformable meshes.
- Deformable models of facial tissue.
- Anatomical facial muscle models.
- Controlling facial muscles.
- Physically-based approaches to capturing facial expressions from video for realistic facial animation.

High-level Control of Facial Animation (Thalmann, 20 minutes)

- A Multilayer approach
- Simulation of Facial Muscle Actions Based on Rational Free Form Deformations
- Phonemes and Expressions
- Words and Emotions
- Synchronization between speech, emotions and eye motion
- The HLSS language

Skin Texture, Hair Modelling and Rendering (Thalmann, 20 minutes)

- Skin Texture
- Fur models and earlier hair models
- An anisotropic light model

Pixel-blending techniques
Shadow Buffers
Composition stage
HAIRDRESSER an animator-interface

4. Cloth Modelling and Animation

Dynamic cloth models (Terzopoulos 30 min)
Basic physics of cloth.
Deformable models of clothing.
External forces.
Draping effects.
Constraints from impenetrable obstacles.

Dressing animated synthetic actors (Magenat Thalmann, 30 min)
3D garment design
Physical model
Collision and self-collision detection and response
Seaming and attaching forces
Case-studies

5. The Use of Natural Language in Human Animation (Badler, 1h30)

Animation from Instructions
The graphical basis: human figure capability models
 Biomechanical primitives: Torso
Motion primitives: reach, grasp, lift, move, look-at,...
Motion strategies: strength, posture
Simulation of Processes
 Knowledge base
 Control algorithm
 Monitors and interruptions
Motion Verb Semantics
 Component analysis of motion verbs
 Kinematic, dynamic, and constraint types
 Making, breaking, and maintaining constraints
 Spatial prepositions
 Adverbs and manner
Planning Issues
 Reactive and incremental planning
 Coarse versus fine motion planning
Natural Language Understanding
Facial animation from language intonation

6. Individualized models and Behavioral Human Animation (Thalmann, 20 min)

Behavioral animation
Vision-based obstacle avoidance
Displacement local automata
Case study: vision-based walking
 Mechanisms of locomotion
 Locomotion over complex terrains
 An allure-based walking model

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