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COURSE NOTES C20

ADVANCED TECHNIQUES IN HUMAN MODELING, ANIMATION AND RENDERING

Chair
Daniel Thalmann
Swiss Federal Institute of Technology

Lecturers
Norman Badler
University of Pennsylvania
Demetri Terzopoulos
University of Toronto/Schlumberger Laboratory
Nadia Magnent-Thallmann
University of Geneva

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.

For synthesized images containing humans 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.

Another problem in the generation of realistic human beings is the problem of texture. The specification of texture maps has been done manually for many years. We describe ways to automatically construct texture maps with certain properties to represent, in particular, "dirty" natural textures. The specification is stated in language and a rule-based system figures out the appropriate placement and parameters for texture generation based on fractal subdivision and distribution models. 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.

address: MIRALab, CUI, University of Geneva, 12 rue du Lac
CH 1207 Geneva, Switzerland, tel: +41 (22) 787-6581
fax: +41 (22) 735-3905, E-mail: thalmann@uni2a.unige.ch

Daniel Thalmann is currently full Professor and Director of the Computer Graphics Laboratory at the Swiss Federal Institute of Technology in Lausanne, Switzerland. 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

Address: Computer Graphics Lab, Swiss Federal Institute of Technology
CH 1015 Lausanne, Switzerland, tel: +41 (21) 693-5214,
fax: +41 (21) 693-3909, E-mail: thalmann@eldi.epfl.ch

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 *theVisual Computer*.

Dr. **Norman I. Badler** is the Cecilia Fitler 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.

Address: Computer and Information Science, University of Pennsylvania
200 South 33rd Street, Philadelphia PA 19104-6389, tel: (215) 898 5862,
fax: (215) 898 0587, E-mail: badler@central.cs.upenn.edu

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 massively 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.

Address: Department of Computer Science, University of Toronto,
10 King's College Road, Toronto, ON, Canada M5S 1A4,
tel: (416) 978-7777, fax: (416) 978-1455, E-mail: dt@orasis.vis.toronto.edu

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 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.

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.

3. Human Rendering

Texture Synthesis (Badler, 15 min)
- Texture generation models
- Interaction between texture and geometry
- Determining textures from rules
- Interfacing to the texture generator through natural language

Skin Texture, Hair Modelling and Rendering (Thalmann, 30 minutes)
- Skin Texture
- Fur models
- Earlier hair models
- Pixel-blending techniques
- An anisotropic light model
- Shadow Buffers

Composition stage
Use with conventional renderers
Hairstyle generation
HAIRDRESSER an animator-interface

4. Cloth Modelling and Animation

Dynamic cloth models (Terzopoulos 15 min)
Basic physics of cloth.
Deformable models of clothing.
External forces.
Draping effects.
Constraints from impenetrable obstacles.

Wrinkles, Collision and Self-Collision Problem (Magnenat Thalmann, 30 min)
Wrinkles
Self-collision avoidance
Wind model
Force field model
Case-study: Marilyn's skirt in the film Flashback

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. Emotions, individualized models and Behavioral Human Animation (Thalmann, 30 min)

Emotion, Generation and Synchronization with Speech
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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