

Artificial Life for Graphics, Animation, and Virtual Reality

Organizer
DEMETRI TEBZOPOLLOS
University of Toronto

Lecturers
PATTIE MAES
Massachusetts Institute of Technology

PRZEMYSŁAW PRUSINKIEWICZ
University of Calgary

CRAIG REYNOLDS
Silicon Studios

KARL SMS
Thinking Machines Corporation

DANIEL THALMANN
Swiss Federated Institute of Technology

Course **7** **NOTES**



SIGGRAPH 1995

**22nd International Conference on Computer
Graphics and Interactive Techniques**

**Conference/6-11 August 1995
Exhibition/8-10 August 1995
Los Angeles Convention Center
Los Angeles, California USA**

Artificial Life for Graphics, Animation, and Virtual Reality

Course Notes for SIGGRAPH'95

Course Organizer

Demetri Terzopoulos
Department of Computer Science, University of Toronto

Lecturers

Pattie Maes
Media Laboratory, Massachusetts Institute of Technology

Przemyslaw Prusinkiewicz
Department of Computer Science, University of Calgary

Craig Reynolds
Silicon Studio

Karl Sims
(independent)

Daniel Thalmann
Computer Graphics Lab, Swiss Federal Institute of Technology

Abstract

This course investigates the increasingly important role that concepts from the field of artificial life are playing in the construction of advanced graphics models for animation and virtual reality. Attendees will be exposed to techniques for realistically modeling and animating objects that are alive—both plants and animals—from lower animals all the way up the evolutionary ladder to humans. The methodology presented subsumes physics-based modeling and, more significantly, addresses issues uniquely characteristic of living systems, such as birth and death, growth, evolution, locomotion, manipulation, perception, behavior, intelligence, and learning. The artificial life approach allows graphics practitioners to progress beyond the simulation of non-living physical “objects” to synthesize autonomously self-animating “subjects.” Topics covered include the realistic modeling and animation of plants, animals, and people, adaptive behavior for animation and interactive multimedia, communication and interaction with autonomous agents in virtual worlds, and artificial evolution for graphics and animation.

Contents

Abstract	0-1
Lecturer Biographies	0-4
Lecturer Contact Information	0-6
Course Introduction and Overview — Demetri Terzopoulos	0-7
Session 1 Artificial Plants — Przemyslaw Prusinkiewicz	
Notes “The Artificial Life of Plants,” P Prusinkiewicz, M Hammel, R Měch, J Hanan	1-01
Session 2 Artificial Evolution for Graphics and Animation — Karl Sims	
Paper “Artificial Evolution for Computer Graphics,” K Sims	2-01
Paper “Evolving 3D Morphology and Behavior by Competition,” K Sims	2-11
Session 3 Behavioral Animation and Evolution of Behavior — Craig Reynolds	
Slides “Building Behaviors for Animation and Interactive Multimedia,” C W Reynolds	3-01
Paper “Flocks, Herds, and Schools A Distributed Behavioral Model,” C W Reynolds	3-12
Paper “Evolution of Corridor Following Behavior in a Noisy World,” C W Reynolds	3-27
Paper “Competition, Coevolution and the Game of Tag,” C W Reynolds	3-37
Session 4 Artificial Animals — Demetri Terzopoulos	
Slides “Artificial Fishes,” D Terzopoulos, X Tu, R Grzeszczuk	4-01
Paper “Artificial Fishes Autonomous Locomotion, Perception, Behavior, and Learning in a Simulated Physical World,” D Terzopoulos, X Tu, R Grzeszczuk	4-10
Paper “Realistic Modeling for Facial Animation,” Y Lee, D Terzopoulos, K Waters	4-22
Session 5 Artificial Humans in Virtual Worlds — Daniel Thalmann	
Notes “The Artificial Life of Virtual Humans,” D Thalmann	5-01
Notes “Introduction to the Artificial Life of Virtual Humans,” N Magnenat Thalmann, D Thalmann	5-02
Notes “Virtual Actors Control versus Autonomy,” D Thalmann	5-06
Paper “The Artificial Life of Synthetic Actors,” N Magnenat Thalmann, D Thalmann	5-07

Paper "The HUMANOID Environment for Interactive Animation of Multiple Deformable Human Characters,"	
R Boulic, T Capin, Z Huang, P Kalra, B Lintermann, N Magnenat Thalmann, L Moccozet, T Molet, I Pandzic, K Saar, A Schmitt, J Shen, D. Thalmann	5-12
Paper "A Vision-Based Approach to Behavioral Animation,"	
O Renault, N Magnenat Thalmann, D Thalmann	5-18
Paper "Navigation for Digital Actors Based on Synthetic Vision, Memory, and Learning,"	
H Noser, O Renault, D Thalmann	5-23
Paper "Automatic Derivation of Curved Human Walking Trajectories from Synthetic Vision,"	
R. Boulic, H Noser, D Thalmann	5-32
Paper. "Vision-Based Tennis Players,"	
H Noser, D Thalmann	5-40
Paper "L-System-Based Behavioral Animation,"	
H Noser, D Thalmann	5-44
Paper "Synthetic Vision and Audition for Digital Actors,"	
H Noser, D Thalmann	5-52
Paper "A Multi-Sensor Approach for Grasping,"	
Z Huang, R Boulic, N Magnenat Thalmann, D Thalmann	5-59
Paper "A Walking Control of Autonomous Human Actors for the Evaluation of Public Environments,"	
P Bécheiraz, R Boulic, D Thalmann	5-65
Session 6 Interactive Autonomous Agents — Pattie Maes	
Paper "The ALIVE System Full-Body Interaction with Autonomous Agents,"	
P Maes, T Darrell, B Blumberg, A Pentland	6-01
Paper "Artificial Life Meets Entertainment Lifelike Autonomous Agents,"	
P Maes	6-09

Lecturer Biographies

Pattie Maes (PhD '87 University of Brussels, Belgium) is an associate professor at the MIT Media Laboratory. Previously she was visiting professor and research scientist at MIT's Artificial Intelligence Laboratory. From 1983 till 1989 she was a research scientist for the Belgian National Science Foundation. Pattie Maes' interests lie in the areas of Artificial Intelligence, Artificial Life and Human Computer Interaction. In particular she is interested in building autonomous agents that interact with people. She has authored numerous articles in this area and has edited four books, among them "Designing Autonomous Agents: Theory and Practice from Biology to Engineering and Back" (MIT Press, 1990) and the proceedings of the Artificial Life IV conference, 1994. She is one of the project leaders for the ALIVE project (Artificial Life Interactive Video Environment), which was demonstrated at SIGGRAPH '93 in Anaheim and AAAI '94 in Seattle and which won honorary awards at ArcTec '95, Nagoya, Japan and Ars Electronica '94, Linz, Austria. This project allows a user to interact in real-time with 3D animated autonomous characters.

Przemyslaw Prusinkiewicz is a Professor of Computer Science at the University of Calgary. He has been conducting research in computer graphics since the late 1970s. In 1985, he originated a method for visualizing the structure and the development of plants based on L-systems, a mathematical model of development. He is a co-author of three textbooks and two monographs, *Lindenmayer Systems, Fractals and Plants* (Springer-Verlag 1989) and *The Algorithmic Beauty of Plants* (Springer-Verlag 1990), as well as approximately 50 technical papers. His current research includes the mathematical modeling and visualization of various aspects of morphogenesis. Professor Prusinkiewicz holds an M.S. and Ph.D., both in Computer Science, from the Technical University of Warsaw. Before joining the faculty of the University of Calgary, he was Professor at the University of Regina, and Assistant Professor at the University of Science and Technology of Algiers. He was also a Visiting Professor at Yale University (1988), at L'Ecole Polytechnique Fédérale de Lausanne (1990), and an invited researcher at the University of Bremen (1989) and the Centre for Tropical Pest Management in Brisbane (1993, 1994).

Craig Reynolds (SM '78 MIT, SB '75 EECS, MIT) is a Member of the Technical Staff at Silicon Studio in Mountain View, California where he designs behavioral systems for autonomous agents in animation and interactive multimedia. His current project at Silicon Studio is the Firewalker multimedia authoring system. He has been previously affiliated with Electronic Arts (1992-94), Symbolics Graphics Division (1982-91), and Information International Inc. ("triple-I" 1979-82). He has screen credits on three feature films including *TRON* (1982) and *Batman Returns* (1992), and several animated shorts such as *Breaking the Ice* (1987) and *Ductile Flow*. He has authored research publications in the fields of computer animation and evolutionary computation. His 1987 *boids* system, a decentralized model of bird flocking, has become a landmark of behavioral animation and Artificial Life research, and has inspired related work in robotics and theoretical biology. Reynolds is a member of ACM and SIGGRAPH.

Karl Sims studied Life Sciences as an undergraduate at MIT and later studied computer graphics at the MIT Media Laboratory. After developing special effects software for Whitney Demos Productions, and co-founding Hollywood based Optomystic, he collaborated with Thinking Machines Corporation for several years as an artist in residence and research scientist. He currently works as an independent in Cambridge, Massachusetts and continues to explore new techniques for creating images with computers. His works of computer animation include "Panspermia," "Liquid Selves," "Primordial Dance," and "Particle Dreams." His interactive installation "Genetic Images" was recently exhibited at the Centre Pompidou in Paris.

Demetri Terzopoulos (Chair) (PhD '84 EECS, MIT, MEng '80 EE, BEng '78 Hons EE, McGill U) is a full professor of Computer Science and Electrical and Computer Engineering at the University of Toronto, where he directs the Visual Modeling Group, and is a Fellow in the Artificial Intelligence and Robotics Program of the Canadian Institute for Advanced Research. From 1985-92 he was affiliated with Schlumberger, Inc., serving as Program Leader at its research labs in Palo Alto, CA, and Austin, TX. During 1984-85 he was a research scientist at the MIT Artificial Intelligence Lab, Cambridge, MA. He has published more than 150 scientific articles primarily in computer vision and graphics but also in computer-aided design, medical imaging, artificial intelligence, and artificial life, including the recent edited volumes "Real-Time Computer Vision" (Cambridge Univ. Press '94) and "Animation and Simulation" (Springer-Verlag '95). He has been a SIGGRAPH course and panel organizer and has produced 7 SIGGRAPH technical papers in his eight years of graphics research. His graphics and vision work has been recognized with several awards, including 3 university Excellence Awards, an award from the American Association for Artificial Intelligence in 1987 for his work on deformable models in vision, an award from the IEEE in 1987 for his work on active contours (snakes), an award from the Canadian Academy of Multimedia Arts and Sciences in 1994 and an award from Ars Electronica in 1995 both for his work on artificial animals. He serves on the editorial boards of *Graphical Models and Image Processing* and the *Journal of Visualization and Computer Animation* and on advisory committees for the Advanced Research Projects Agency and the National Institutes of Health.

Daniel Thalmann is currently full Professor and Director of the Computer Graphics Laboratory at the Swiss Federal Institute of Technology in Lausanne, Switzerland. He is also adjunct Professor at the University of Montreal, Canada. He received his diploma in nuclear physics and Ph.D. in Computer Science from the University of Geneva. He is coeditor-in-chief of the *Journal of Visualization and Computer Animation*, member of the editorial board of the *Visual Computer*, the *CADDM Journal* (China Engineering Society) and *Computer Graphics* (Russia). He is cochair of the EUROGRAPHICS Working Group on Computer Simulation and Animation and member of the Executive Board of the Computer Graphics Society. Daniel Thalmann was member of numerous Program Committees, Program Chair of several conferences and chair of *Computer Graphics International '93* and *Pacific Graphics '95*. He has also organized 4 courses at SIGGRAPH on human animation. Daniel Thalmann's research interests include 3D computer animation, image synthesis, virtual reality, artificial life and multimedia. He has published more than 200 papers in these areas, is coeditor of 20 books, and coauthor of several books including *Computer Animation: Theory and Practice* and *Image Synthesis: Theory and Practice*. He is also codirector of several computer-generated films with synthetic actors including a synthetic Marilyn Monroe shown on many TV channels all over the world.