SIGGRAPH 98

22

Artificial Life for Graphics, Animation, Multimedia, and Virtual Reality

Organizer

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University of Toronto/Intel Corporation

Lecturers

Bruce Blumberg

Massachusetts Institute of Technology

Przemyslaw Prusinkiewicz

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Craig Reynolds

DreamWorks SKG

Karl Sims

Genetic Arts

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Daniel Thalmann

Swiss Federal Institute of Technology

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course notes

Artificial Life for Graphics, Animation, Multimedia, and Virtual Reality

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Abstract

This course investigates the increasingly important role that concepts from the field of artificial life are playing across the breadth of computer graphics, including image synthesis, modeling, animation, multimedia, and virtual reality. Attendees will be systematically introduced to techniques for realistically modeling and animating objects that are alive. They will also explore graphics techniques that emulate phenomena fundamental to biological organisms, such as biomechanics, behavior, growth, and evolution. The challenge is to develop sophisticated graphics models that are self-creating, self-evolving, self-controlling, and/or self-animating, by simulating the natural mechanisms of life.

Topics include modeling and animation of plants, animals, and humans, behavioral animation, communication and interaction with synthetic characters in virtual worlds, and artificial evolution for graphics and animation.

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Lecturer Biographies

Bruce Blumberg is an Assistant Professor at the MIT Media Lab, where he has founded a new research group, "Synthetic Characters". The group focuses on the problem of building interactive animated characters for use in virtual environments such as immersive story-telling systems, games, and web-based worlds. His research is on the development of an ethologically-inspired architecture for building autonomous animated creatures which live in 3D virtual worlds. Blumberg did his doctoral work at the MIT Media Lab in the Autonomous Agents group under the direction of Professor Pattie Maes and received his PhD in 1996. He is one of the chief architects of the ALIVE project at the Media Lab. Previously he worked at Apple, Inc., as product manager for the LaserWriter, and at NeXT, Inc., where he was the first employee after the founders. He has presented papers at SIGGRAPH and at AI and ALife conferences.

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). Prusinkiewicz received SIGGRAPH's *1997 Computer Graphics Achievement Award* for his work on modeling and visualizing biological structures.

Craig Reynolds (SM '78 MIT; SB '75 EECS, MIT) recently joined the Feature Animation Division at DreamWorks SKG where he does R&D primarily in behavioral animation. Previously he was a Member of the Technical Staff at the Silicon Studio division at Silicon Graphics, where he designed behavioral systems for autonomous agents in animation and interactive multimedia. His project at Silicon Studio was 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 is Professor of Computer Science and Electrical and Computer Engineering at the University of Toronto, where he leads the Visual Modeling Group and is an NSERC Steacie Fellow and a Killam Fellow of the Canada Council for the Arts. He also heads the Computer Graphics Animation research group at Intel Corporation in Santa Clara, CA. After earning his PhD in Computer Science (AI) from MIT in 1984, he was a research scientist at the MIT Artificial Intelligence Lab through 1985. Prior to joining the UofT in 1989, he was a program leader at Schlumberger Corporation research centers in California and Texas. His published works comprise more than 200 research articles, primarily in computer graphics and vision, and also in medical imaging, CAD, artificial intelligence, and artificial life, including 8 SIGGRAPH papers and the recent edited volumes "Animation and Simulation" (Springer '95) and "Real-Time Computer Vision" (Cambridge Univ. Press '94). He has given hundreds of invited talks around the world, including several distinguished lectures and keynote addresses. A former Fellow of the Canadian Institute for Advanced Research, his contributions have been recognized with awards from the IEEE, the American Association for Artificial Intelligence, the Canadian Image Processing and Pattern Recognition Society, the International Digital Media Foundation, Ars Electronica, NICOGRAPH, and the University of Toronto. He serves on the editorial boards of *Graphical Models and Image Processing*, the *Journal of Visualization and Computer Animation*, *Medical Image Analysis*, and *Videre: Journal of Computer Vision Research*. He has served on ARPA, NIH, and NSF advisory committees and is program chair of the 1998 Computer Vision and Pattern Recognition Conference (CVPR'98).

Daniel Thalmann is 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 shown on many TV channels all over the world.

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Course Introduction and Overview
Demetri Terzopoulos

Computer graphics modeling for animation, multimedia, and virtual reality has made significant advances in the last decade. The field has witnessed the transition from an earlier generation of purely geometric models to more elaborate physics-based models. We can now simulate and animate a variety of real-world objects with stunning realism. Where do we go from here?

Graphics researchers have begun to explore a new frontier—a world of objects of enormously greater complexity than is typically accessible through physical modeling alone—objects that are *alive*. The modeling and simulation of living systems for computer graphics resonates with the burgeoning field of scientific inquiry called *Artificial Life*. Conceptually, artificial life transcends the traditional boundaries of computer science and biological science. The natural synergy between computer graphics and artificial life can be potentially beneficial to both disciplines. As this course will demonstrate, potential is becoming fulfillment.

The goal of the course is to investigate the vital role that concepts from artificial life can play in the construction of advanced graphics models for animation, multimedia, and virtual reality. The course will demonstrate and elucidate new models that realistically emulate a broad variety of living things—both plants and animals—from lower animals all the way up the evolutionary ladder to humans. Typically, these models inhabit virtual worlds in which they are subject to physical laws. Consequently, they often make use of physics-based modeling techniques. More significantly, however, they must also simulate many of the natural processes that uniquely characterize living systems—such as birth and death, growth, natural selection, evolution, perception, locomotion, manipulation, adaptive behavior, intelligence, and learning. The challenge is to develop sophisticated graphics models that are self-creating, self-evolving, self-controlling, and/or self-animating, by simulating the natural mechanisms fundamental to life.

The course shows how artificial life techniques are being exploited in graphics, animation, multimedia, and virtual reality and will progress according to the six sessions summarized below:

1. **Artificial Plants (Przemyslaw Prusinkiewicz):** This segment of the course will show how to use formalisms inspired by biological development processes to grow highly complex and realistic graphics models of plants. We will review Lindenmayer systems, introduced as a theoretical framework for studying the development of simple multicellular organisms and subsequently applied to the study of higher plants. Geometric and stochastic plant models expressed using L-systems have been extended in a manner suitable for simulating the interaction between a developing plant and its environment, including light, nutrients, and mechanical obstacles. We will also explain how to model the response of plants to pruning which yields realistic synthetic images of sculptured plants found in topiary gardens.

2. **Artificial Evolution for Graphics and Animation (Karl Sims):** This segment will show how artifical evolution allows virtual entities to be created without requiring detailed design and assembly. We will show how to evolve complex genetic codes that describe the computational procedures for automatically growing entities useful in graphics and animation. Fortunately, graphics practitioners are not required to understand these codes. Instead, they simply specify which results are more and less desirable as the entities evolve. This is a form of digital Darwinism. We will demonstrate the artificial evolution of several types of graphical entities, including virtual plants, textures, animations, 3D sculptures, and virtual creatures.

3. **Behavioral Animation and Evolution of Behavior (Craig Reynolds):** This segment will demonstrate how complex animations can emerge with minimal effort on the part of the animator from behavioral rules governing the interaction of many autonomous agents within their virtual world. We will review a classic experiment, the flocking of "boids," that convincingly bridged the gap between artificial life and computer animation. We will explain how this behavioral animation technique has been used to create special effects for feature films, such as the animation of flocks of bats in *Batman Returns* and herds of wildebeests in *The Lion King*. We will also explain how to automatically evolve behaviors that allow multiple animate agents to perform useful tasks such as navigation and game playing for multimedia applications.

4. **Artificial Animals (Demetri Terzopoulos):** This segment will show how to build highly realistic models of animals for use in animation and virtual reality. We will present a modeling approach in which we simulate the physics of the animal in its world, the animal's use of physics for locomotion, and its ability to link perception to action through adaptive behavior. As a concrete example, we will explain the details of an autonomous virtual fish model. The artificial fish has (i) a 3D body with internal muscles and functional fins which locomotes in accordance with biomechanic and hydrodynamic principles, (ii) sensors, including eyes that can image the virtual environment, and (iii) a brain with motor, perception, behavior, and learning centers. We will present a general approach to teaching artificial animals to perform complex locomotion tasks. Similar zoomimetic modeling principles are applicable to humans. In particular, we will explore the highly automated construction of anatomically correct, functional models of people's heads from scanned data for facial animation.

5. **Artificial Life of Virtual Humans (Daniel Thalmann):** This segment of the course comprises an in-depth investigation of techniques for modeling and animating the most complex living systems–human beings. In particular, we will explore the increasingly important role of perception in human modeling. Virtual humans are made aware of their virtual world by equipping them with visual, tactile, and auditory sensors. These sensors provide information to support human behavior such as visually directed locomotion, manipulation of objects, and response to sounds and utterances. We will demonstrate sensor-based navigation, game playing, walking on challenging terrain, grasping, etc. We will also explore communication between virtual humans, behavior of crowds of virtual humans, and communication between real and virtual humans. Techniques for real-time virtual humans in real scenes will also be

discussed.

6. **Interactive Synthetic Characters (Bruce Blumberg):** In the final segment of the course, we explore the design and implementation of systems that enable full-body interaction between human participants and graphical worlds inhabited by artificial life forms that people find engaging. Entertaining agents can be modeled as autonomous, behaving entities. These agents have their own goals and can sense and interpret the actions of participants and respond to them in real time. We will explore immersive, nonintrusive interaction techniques requiring no goggles, data-gloves/suits, or tethers. The general approach will be illustrated with the ALIVE (Artificial Life Interactive Video Environment) system, which many participants have experienced at SIGGRAPH exhibitions.

Course Schedule

Time	Topic	Speaker
08:30	Introduction	Terzopoulos
08:45	Artificial Plants	Prusinkiewicz
09:45	Artificial Evolution for Graphics and Animation	Sims
10:00	Break	
10:15	Artificial Evolution, cont'd	Sims
11:00	Behavioral Animation	Reynolds
12:00	Lunch	
13:30	Artificial Animals	Terzopoulos
14:30	Artificial Life of Virtual Humans	Thalmann
15:00	Break	
15:15	Virtual Humans, cont'd	Thalmann
15:45	Interactive Synthetic Characters	Blumberg
16:45	Questions & Answers	
17:00	Adjourn	