Behavioral Modeling and Animation: Past, Present, and Future

Organizers

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Panelists

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Craig Reynolds
DreamWorks Animation

Toby Simpson
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Would computer animators rather be graphical model puppeteers who keyframe the detailed actions of their characters, or would they prefer to direct intelligent, self-animating virtual actors? On the one hand, the animator has complete control over all aspects of the character's low-level motions. On the other hand, control is relinquished to gain greater convenience in the higher-level specification of a character's behavior.

Behavioral modeling was introduced about a decade ago in Reynold's "Boids" model, as a means of producing animated scenes containing many more characters than could practically be animated by hand. The behavioral modeling approach has today expanded to include sophisticated functional modeling of animals and humans, resulting in realistic, self-animating graphical characters.

This panel discusses the fundamentals of behavioral modeling and animation arising from knowledge of living systems and their environments. Artificial life models have evolved a long way from the comparatively primitive geometric models of traditional computer graphics. The panel reviews the state of the art and debates the promises and limitations of behavioral modeling and animation from multiple perspectives, including production animation, the interactive games industry, and the research community.

The Design of Characters with Complex Behavior

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Behavioral control allows animated scenes to contain more characters than would be practical otherwise. The most exciting aspect of behaviorally driven animation, however, is the way these multi-agent systems form an environment in which complex global behavior can emerge from the interaction of relatively simple local rules. A well-tuned behavioral simulation amplifies an animator's effort. When everything goes well, the result is an engaging and visually rich scene full of unexpected details of motion. Poised on the boundary between chaotic dynamics and rigid control, the most enjoyable behavioral simulations operate in the life-like regime Langton called "the edge of chaos."

The crux of behavioral design is the art of tuning the dozens of parameters in a typical behavioral model. I advocate a toolkit approach to building autonomous characters: Starting with a library of simple general-purpose, reusable behavior modules, a character requires only some custom control structure to switch or blend between behavioral modules.

While crowd scenes for animated films are a significant application of behavioral animation, a more compelling argument can be made for its importance in interactive applications. Behavioral characters are reactive agents, and so are uniquely suited to provide believable interaction between human users and autonomous characters. A behavioral character designed to react to others of its kind can just as well react to the avatar of a human participant.

Behavioral Animation in Disney Feature Films

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Over the years, Disney has evolved from traditional hand-drawn crowd scenes where only a few characters are animated to scenes of epic scale involving thousands of animated characters. From the herding system developed for "The Lion King" to the crowd animation packages used for "The Hunchback of Notre Dame," "Mulan," and "Dinosaur" features, we have refined the process of crowd animation. In a production environment such as ours, it is absolutely crucial that an artist, at all times, have absolute control over the visual outcome of a shot. The issue I address is how to gain control over the result of a procedural animation, i.e., the crowd.

While physics, dynamics and artificial intelligence may carry you 90 percent of the way, we need to achieve that final 10 percent. We therefore implemented a hybrid system, where a simulation can be post-edited to achieve a better-looking result. The system provides the means for both macro and micro control. In general, the simulator is used to obtain results as close as possible, which are then fine tuned in an editor. At the macro control level (i.e. the simulation dynamics), we can often provide more explicit control through "image maps," which map from pixels to state parameters. These maps can simply be drawn by an artist, and they provide an input parameter-set to the simulation that would be hard or impossible to achieve only programatically.

Afterwards, at the micro level, an editor can change virtually any parameter of any entity, pertaining to position and velocity, appearance, and behavior timing, thereby providing a mechanism to stage an entity against any visual requirements.

I show how we go from a layout drawing to the final animation and give the artist the control to achieve the final look.

Wildebeest stempede in "The Lion King."

AI Modeling for Behavioral Animation

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The distinguishing feature of behavioral animation is that each animated character is governed by a model of how it should behave. Although the model can be as simple as a few behavioral rules, the interaction between the characters can generate elaborate emergent behavior. The "Flocking Boids" is a landmark example.

A good topic for discussion is the future or extension of behavioral animation models. On the one hand, it is interesting to investigate the realm of emergent behavior from the complex interactions of simpler behavioral entities. On the other hand, a natural extension to current models of reactive behavior is the modeling of cognition. I consider it the ultimate challenge to animation modeling that we may someday model a fully functional human. Imagine how differently an animated feature would be produced when the characters can react and reason like real human actors. The animator's role then will be like that of a director, and the virtual characters will improvise their parts based on the direction they receive.

To this end, the topic of artificial intelligence naturally enters the domain of graphics modeling. We are still a (very) long way from achieving this goal. However, this should not intimidate us from making initial steps, nor should this invalidate our early attempts. I advocate exploration of existing AI techniques and ongoing AI research for cognitive modeling in animation. The common goal of modeling human intelligence shared by AI and graphics researchers will surely prove beneficial to both areas.

Crowd in "The Hunchback of Notre Dame."

Artificial Fishes in a Digital Sea

Artificial Life in Home Entertainment

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A critical part of computer gaming in the future will be construction of believable artificial agents and rich, diverse, and self-consistent environments in which they can live – an application for which artificial life techniques are well suited. Artificial life is likely to be a key technology of the future, and many aspects of it are already finding their way into home entertainment in titles such as “Creatures.”

“Creatures” allows users to interact with artificial autonomous agents whose behavior is controlled by genetically specified neural networks and biochemistry, and is currently the only commercial entertainment product to provide this. We believe that the success of “Creatures” demonstrates the value of such technologies in entertainment and the strength of the relationships that users are able to form with such agents.

We expect that by pursuing the process of using computers to model biological systems that can in themselves be intelligent, rather than attempting to make a computer intelligent, we will be able to achieve human-level intelligence in a machine by the year 2020. We believe that “Creatures,” and now “Creatures 2,” represent substantial steps in this direction – plausible artificial organisms whose behavior is emergent rather than programmed – living in rich, detailed eco-systems. It is likely that this approach will yield virtual realities that are so real that it may not be possible to tell the difference any longer.

What are the Limits of Behavioral Modeling and Animation?

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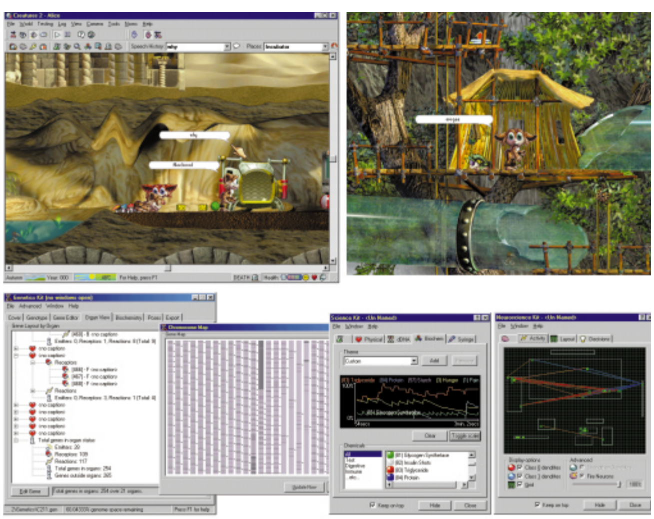
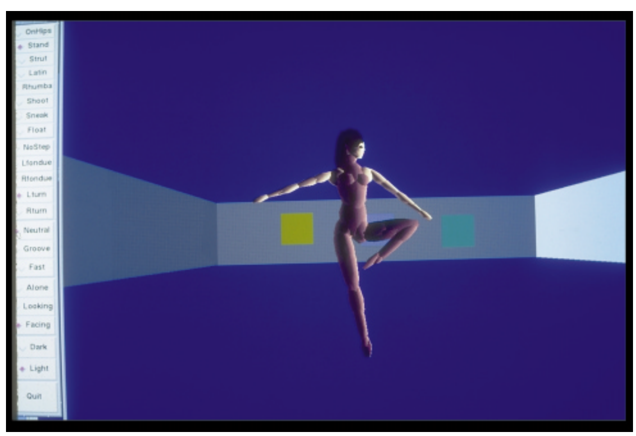
Animators freely tap into many (and often unexamined) intuitions and judgments in order to create their work. Even the most sophisticated behavioral modeling techniques cannot completely replace culturally and psychologically informed authoring techniques that talented animators employ to create linear animation (for example, why did a character raise his eyebrow and hunch his shoulders in just that particular way at that moment?).

Explicitly defined behavioral models will never be able to completely replicate such intuitions and judgments. Such behavioral models will always need to be integrated and leveraged with contributions from more traditional approaches that simply give animators a flexible tool with which to “sculpt” their intuitively based judgements.

So how do we blend behavioral modeling with the sort of hand-tuned work that animators and other skilled craftspeople are so good at? How do we do this in an interactive setting, when the animator is no longer present to modify a character’s response to an evolving story? I think our most important challenge is to work out good ways to integrate behavioral and animation-compositing methods. This challenge is the focus of our Improv project at NYU.



Creatures 2



“Danse Interactif” by Ken Perlin, SIGGRAPH 94 Electronic Theater