Improvisational Animation

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Abstract

It has long been a goal of the animated agent community to bring embodied agent technologies out of the research labs and into the hands of authors and designers who may put them to practical use. *Improv* is a set of tools and techniques developed at NYU which make it possible to create applications involving animated agents that behave, interact and respond to user input in ways that convey mood and emotion. These tools can be used without prior experience in computer programming, cognitive science or ergonomic simulation, while still allowing creation of animated agents who exhibit behavior which has the lifelike, somewhat unpredictable feel of human behavior, yet remains consistent with a character's personality and defined goals.

The goal of the Improv project is to make improvisational animation accessible to experts with minimal expertise in animation and dramatic performance, and to enable researchers and educators to exploit these technologies without relying on expensive production efforts. These are clearly two of the most important steps toward the wide-scale acceptance and use of animated agents for education and training, social simulation and collaborative environments.

Introduction

The use of interactive animated agents - lifelike representations of real and imaginary entities - in virtual environments has become an interesting and important field of research as the technologies for creating these environments have become progressively more inexpensive and widespread. Until recently, the computer graphics hardware necessary for producing real-time 3D simulations was so expensive as to prohibit its use outside of military and industrial applications. Now, as consumer level PC's become increasingly powerful, and off-the-shelf 3D graphics support becomes more readily available, the application of these technologies to educational and other purposes has become feasible. With this comes a new set of demands. Military and industrial simulations have often viewed the use of animated agents in purely functional terms. The use of animated agents for human factors research in vehicle and factory design has become widespread, but these applications have generally focused on the mechanics of human movement [Badler91]. The military has made extensive use of animated agents in battlefield simulations, but in this case agent behavior has more often than not been restricted to troop movement and general infantry behavior (run, shoot, etc.). The requirements for display of social and emotional behavior of animated agents in these simulations have been relatively limited.

Animated agents are now finding their way into numerous other development efforts and applications. Cognitive scientists and artificial intelligence researchers are using animated agents to expand their investigations into the physical expression of human behavior as it relates to the workings of the human mind [Hayes-Roth96]. Educators, struggling with the limitations of overcrowded classrooms and limited teacher time and resources, are looking to animated agents and virtual environments as a means for providing personalized guidance and tutoring to students. Historians and social scientists now have many of the tools needed to create lifelike, interactive simulations of situations and events which once could only be conveyed through static presentations of collected research and data. Beyond the realm of research and education, animated agents can put a human face on digital assistants and proxies in collaborative virtual environments, for such tasks as communication and negotiation in the absence of, and in support of the human participants. In such contexts, participants must be able to interact with agents in meaningful ways, and must feel that the agent with which they are interacting adequately represents the agent's principal.

Related Work

Two basic approaches are currently combined for creation of animated agents: physical and bio-mechanical simulation and machine learning/artificial intelligence systems. Physical and bio-mechanical simulation systems are used to construct accurate models of human movement and constraints and apply them to situations involving physical activities. These systems use these models to represent a range of physical tasks, from walking, to operating machinery, to negotiating complex terrain in a manner consistent with the capabilities and limitations of human movement. Machine learning and artificial intelligence systems generally seek to simulate human problem solving, in order to create agents who, at some level, think like human beings. They use means ranging from language parsing systems which apply rules for interpreting user entered text (or speech) in order to determine explicit and implicit meaning, to neural nets and fuzzy systems which attempt to develop behavioral rules based on analysis of changing situations and data over time.

Each of these approaches addresses a significant aspect of the animated agent problem. Physical and bio-mechanical models provide realistic and believable representations of human movement through a wide range of changing physical conditions within the virtual environment, while artificial intelligence systems can allow the system to analyze and interpret complex user input and data. Together they address a large part of the animated agent problem, but there is still one significant piece of the puzzle missing. Neither of these approaches makes it easy enough to model agent `mood' or `personality,' or the effect of these internal parameters on the way that an agent responds to events. However, it is just these complex and subtle aspects of human character that define what we perceive as individuality. Without this, the most sophisticated physical models and machine learning tools can only produce simulations which, though they may represent certain relatively mechanical aspects of human capability adequately, are, ultimately, devoid of life. Our work addresses this aspect of the interactive simulation of human behavior.

Goals

Conveying mood and personality is crucial to many new applications in which animated agents are used to express emotional messages or portray specific characters rather than just to solve an abstract problem. In such applications, the *way* in which the agent presents information can be as important as the information being presented.

The focus of the Improv project at NYU has been to provide tools which make it possible to create applications involving animated agents that behave, interact and respond to user input in ways that convey mood and emotion. These tools can be used without prior experience in computer programming, cognitive science or ergonomic simulation, while still allowing creation of animated agents who exhibit behavior which has the lifelike, somewhat unpredictable feel of human behavior, yet remains consistent with a character's personality and defined goals.

Improv employs a variety of techniques to accomplish this. Human beings are capable of performing many different activities simultaneously, while internally maintaining long-term goals and motivations. For animated agents to appear lifelike and believable, they must mimic these internal structures. To allow this, Improv is structured around an engine which continuously maintains and updates the state of the animated agent. This provides a behavioral layering mechanism which enables authors to create multiple behaviors that run simultaneously, each of which may activate or influence other behaviors. Layers of motivation can manifest themselves in activities carried out simultaneously, such as walking or running, combined with change in facial expression. These layers are structured hierarchically, so that behaviors on a layer responsible for maintaining long term goals can activate behaviors on layers containing the activities needed to carry out those goals, and so on. Improv provides authors with the ability to create such behaviors within a continuum that ranges from linear sequencing, where each action comprising a behavior is carried out a specific time and in a predetermined order, to stochastic selection according to author-defined rules. Such rules are defined using a set of tools which enable the author to control the way in which user input and environment-derived clues influence on animated agent's apparent mood, personality and behavior. Also, because coordinated action of a group of separate graphical agents is often crucial, Improv allows the author to define layers of behavior and behavioral rules which apply to the activities of entire agent groups, while still providing the individual agent with its own unique personality.

This approach combines concepts adapted from various fields of study. The Improv engine is roughly based on the Subsumption Architecture approach of [Brooks86], which has been used for numerous embodied agent systems including [Blumberg95]. Although most of these systems enforce a strict top down hierarchy of behavior, Improv's model is heterarchical, enabling authors to define their own connections between various layers of behavior and how these layers interrelate. Improv employs statistically controlled randomness to let authors create behavioral tendencies that are unpredictable yet consistent with an agent's character and personality. The methods employed to achieve this are conceptually similar to techniques employed in neural nets and fuzzy systems. However, rather than automatically generating statistics based on an analysis of large quantities of data, authors shape statistical parameters based on their concept of the agent's goals and motivations. Perhaps the most crucial inspiration for this work comes out of improvisational theater, where actors make use of numerous techniques to portray a wide variety of characters and scenarios in an environment in which events are not predetermined and where outcomes are subject to numerous influences including audience response and interaction.

Prior Work

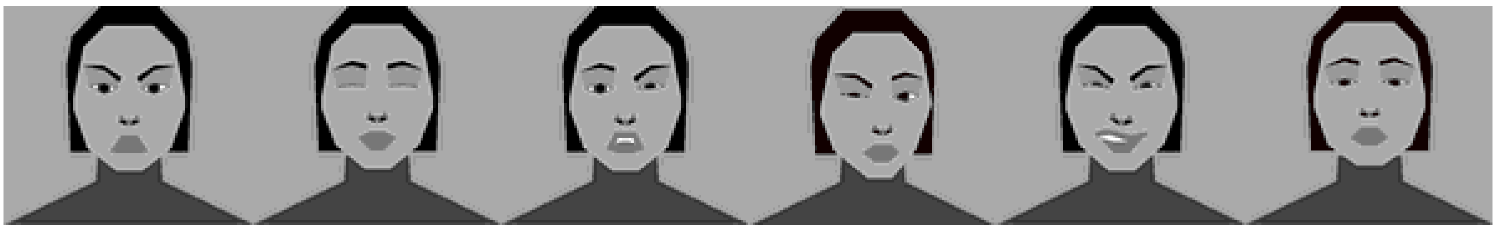
The Improv Project is an ongoing research effort. A layered animation engine based on these principals was first described in [Perlin95] after being demonstrated in "Danse Interactif" [Perlin94] at the SIGGRAPH94 Electronic Theater. Linear and non-linear control over sequences of behavior and of explicit, random and rule based behavior activation was demonstrated at the SIGGRAPH95 Interactive Entertainment exhibit and at SIGGRAPH96 where it was formally presented in [Perlin96] and demonstrated in the *Digital Bayou* exhibit. These demonstrations featured simple examples involving small groups of agents engaged in specific activities for limited periods of time. These examples were developed using a programming interface which, while quite useable, restricted the use of Improv to authors with considerable programming experience and knowledge of the inner workings of the system.

Scenes from "Danse Interactif", SIGGRAPH '94,
"Interacting with Virtual Actors", SIGGRAPH '95,
and "The Botanica Virtùal", SIGGRAPH '96

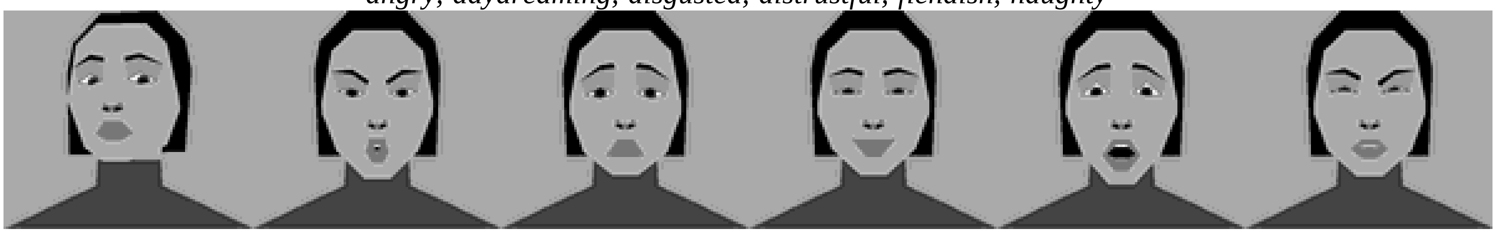
Since then, Improv has been re-implemented in *Java* to allow wide-scale deployment over the World Wide Web. Its architecture has been redesigned to be more object-oriented and to allow for extensibility of the system by independent developers through a common API. This work was demonstrated at SIGGRAPH '97 during the course "Virtual Humans: Behaviors and Physics, Acting and Reacting" In addition to the basic behavior layering and control mechanisms, a set of animation tools has been provided for creating simple animated actions which can be blended together and composited, in much the same way that images are composited in *Photoshop* , along with a set of simple graphic user interface tools for editing these animations. As a result of this effort, running examples and an authoring kit are now freely available to other researchers at *http://mrl.nyu.edu/improv* , runnable within standard Web browsers on either PC or Silicon Graphics clients.

Sid (left) and Wendy (right)
Created using Java version of Improv running within a VRML browser

One particular sub-area in which we made progress was in layered facial expression. For example, how does one make an embodied agent react with appropriate facial expression, without resorting to repetitive prebuilt animations? How does one mix and transition between facial expressions to visually represent shifting moods and attitudes? How can authors of these agents relate lower level facial movements to higher level moods and intentions? We introduce a computational engine which addresses these questions with a stratified approach. We first define a low level movement model having a discrete number of degrees of freedom. Animators can combine and layer these degrees of freedom to create elements of autonomous facial motion. Animators can then recursively build on this movement model to construct higher level models.



angry, daydreaming, disgusted, distrustful, fiendish, haughty



head back, scolding, sad, smiling, surprised, suspicious

Our current goals are to explore the applicability of Improv to implementing an easily authorable *Desktop Theatre* [Strassman91].

Recent Experiments

Several specific procedures were involved in carrying out this experiment. One was a combined Improv Animation/Development Graduate Course. This was a course that we began offering in Spring98. It was a focused projects course open to both Computer Science graduate students and Department of Film and Television animation students. Generally, the CS students worked in Java, creating tools to improve the authorability of Improv. The animation students generally worked mostly in either *Alias PowerAnimator* or *3D Studio Max* , creating vocabularies of short sequences of atomic movements such as "sit", "stand", "scratch head", "walk" "laugh". The tools created by the CS students were used to specify the parameters of a run-time engine which composites and transitions atomic movements together to create rule-based sequences.

This approach allowed the class to separate *character-independent behavior:* behaviors which might be common to any number of characters or situations, such as walking or sitting, from *character-dependent behavior:* behaviors which are specific to an individual character and/or situation such as certain kinds of hand gestures or stances. Character-independent behavior more clearly lends itself to re-usability, so the ratio of character-independent behavior to character-dependent behavior necessary to produce unique and convincing characters is of particular interest.

The final result was "Sid and the Penguins," a live theatrical performance presented at the SIGGRAPH98 Electronic Theatre, in which the "actors" were Improv agents. Each night they were directed to act out a scene together, but each actor had enough intelligence and autonomy to figure out how to play his part, and even to improvise now and then. No two performances were exactly alike. The camera was also an actor. It watched the other actors, and based on what they did during any given performance, it chose shots and decided how to follow the action.

Future Work

The ultimate goal of the Improv project is to enable the creation of large-scale, networked multi-user/multi-agent collaborative environments. These environments may take on many different forms from large-scale historical simulation to shared educational environments in which students in diverse locations around the world can collaborate on projects with the assistance of specialized guides and tutors. In such large scale virtual environments, agents may be used to carry out tasks and to represent human participants. These environments may involve ongoing scenarios that unfold over the course of months or years, or can be applications in which all activities take place in a limited environment within a limited time frame. In either case, the presence of lifelike, believable animated agents can make the difference between rich and complex socially dynamic worlds and lifeless collections of animated geometry.

Several ongoing research efforts at the NYU Media Research Lab are directly or indirectly related to this work. Our laboratory is doing work on miniature direct-drive actuators, which we are using for self-propelling autonomous legged miniature robots. We are using control algorithms from Improv to create a sense of life-like movement to these robots.

Improv is also providing content for our work in active autostereoscopic displays. This research tracks the user's left and right eye positions at interactive rates, and projects a different view onto each eye, using a novel projection masking technique developed in our laboratory. Because Improv characters can dynamically modify body orientation and gaze direction, we are using them as test subjects within responsive virtual autostereoscopic scenes.

We are currently working on the *Pad* multiscale interface. The emerging GUI of Improv provides a context for our work in creating recursive multiscale interface controllers. These allow authors to create arbitrarily nested behavior logic modules. The demands of the Improv GUI design are driving a number of innovations in our research on Pad zoomable GUI design and implementation.

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