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Computer Theater

Computer Theater refers to live theatrical performances[2] involving active use of computers in the artistic process. The concept groups diverse ideas, methods, and levels of integration between theatrical and electronic elements.[3]

The use of computers in theater can be roughly subdivided in four categories. Computers can be used as *electronic puppets*[4], where a human puppeteer controls a computer graphics character displayed on a stage screen. More novel is what I call a *computer-actor*,[5] where the computer automatically controls a character establishing a true interplay between man and machine. A third possibility is expanding the body of an actor on stage, enabling the actor to produce sound, images, or music as expansions of his voice and body – a *hyper-artor*.[6] Finally, the most common example of the use of computers in theater has been *computerized stages*, where the space as an element of the performance (set, lights, and ambient music) is controlled by a computer.[7]

Recent developments in image processing and speech recognition now permit that basic aspects of

the live action performed on a stage to be recognized in real time by a computational system. Also, computer graphics and multimedia technology are achieving a state where live control of graphics and video on a stage screen is possible. These technological breakthroughs are opening the stage for artistic experiences involving computer-synthesized characters and environments that were virtually impossible less than half a decade ago.8

Although input/output possibilities have dramatically increased, a big piece is still missing from the picture: a language for communication between computers and actors, directors,and play-writers.9 While MIDI commands capture electronically the concept of musical notes, the action elements of theater have no established correspondence in the computer realm. Theatrical performances with computers have been quite less common due, in my view, to this lack of appropriate technology to deal with artion, the structural element of theater.

My current work is focused on both to the development of solid foundations for computer theater technology and on the exploration of the artistic possibilities enabled by inserting electronics and computers into the world of theater and interactive art. This paper summarizes some of my views and research, and introduces two projects in computer theater produced in 1996 and 1997.10

Computer Technology for Theater

The relative ease of automatic translation of musical scores to a computational representation (MIDI, for example) seems to have played a major role in the development of computer music. Theater scripts capture many aspects of theater by describing the action and interaction among the characters but there is no method to translate characters'lines and stage directions written in natural language into something useful for a computer engaged in performance. On the other hand, the low-level descriptions of body and joint movements used in computer graphics are hardly the convenient way to describe the long, subtle, and delicate interaction among characters in a play.

Computer representations for human action have recently attracted the attention of the computer vision research community. Representation and recognition of human action constitutes the major component of my scientific research at the MIT Media Laboratory (advised by Prof. Aaron Bobick) The goal is to develop technology to represent to the computer both the individual actions and the interaction among human and computerized characters in a play or story-based interactive environments.

Representing Action and Interaction

Representing actions has been object of research of linguistics,[11] computer graphics,[12] and computer vision.13 However, the research is hindered by unsolved, difficult Al problems like representation and *use* of context, time, and common-sense.

At the MIT Media Laboratory, Aaron Bobick and I are developing a language for action representation, called ActScript,[14] which uses a small number of primitive elements according to principles first proposed by Roger Schank [20]. The basic idea is to decompose an action into smaller component sub-actions and to codify the temporal constraints between them using elements from Allen's temporal algebra [1]. The goal is to have a language that enables the computer to represent most common actions without relying on a large and complex action dictionary. We employ Schank-like primitive actions – PROPEL, MOVE. INGEST, GRASP, EXPEL, PTRANS, ATRAriS, PRODUCE, ATTEND, MTRANS, MBUILD – in tree-like structures representing concepts like physical change, transfer of ownership, goals, and conditional belief.

The existence of an explicit representation for actions allows the construction of computer systems able to reason symbolically about the behavior of the participants in the performance.A computer-actor,for example, can infer how to act towards a goal set by the story or play. Also, if multiple computer- and hyper-actors are engaged in the same performance, they can exchange information using *Act5aipt.* In such a situation, all the sub-systems "speak" a common, high-level language that can also be understood by human beings involved in the process (like it is possible to understand MIOI commands by referring to their musical meaning).

To describe stories and plays, it is necessary to represent not only action but also interaction. Theater plays involve sequential and parallel actions, coincidences, and the notions of development and di-max. That involves complex temporal structures that most of current technology for interaction can not handle.15 For *example,event-based* game and multi-media engines are good when representing what happens when a determined condition is met, but they are dumsy describing events that are pre-requisites for other events, or mutually exclusive actions.

In work started at the ATR-MIC Research Laboratory with Kenji Mase and later Aaron Bobick [14], we developed a method for representing interaction based on the concept of time intervals. Each action is conceptually encapsulated in an interval, and the interaction is described by imposing temporal constraints among the action intervals. In this paradigm – called *interval saipts*- sequencing is achieved by telling the computer that an interval is immediately followed by another. Temporal constraints are also used to describe concepts like preemption, cause, and containment. Currently, Babick and I have been incorporating some of the structures of event-based languages, like conditional execution and loops, into the interval script framework.

Two Projects

Beginning in the summer of 1996, I started to apply the technology described above in real theater projects. In the first one, ***Singsong***,the primary intention was to experiment with the technoloqical and aesthetic limitations of theater with computer-actors. The project currently in development, ***It I I***, explores both the artistic and the technological directions by examining the relation between people and technology through the creation of an environment dominated by a truly computerized creature.

First *Experiment: "SingSongp*

Singsong is a short computer theater play produced in the summer of 1996, at the ATR Laboratories in Kyoto, Japan. The piece is a comical sketch portraying a down trying to conduct a chorus of computer-controlled singers. The story is centered on gags between the down and a troublemaker singer. initially, thissinger complains when *the* maestro requests silence;later. it refuses to get in tune unless the conductor kneels down and pleads; and, after singing, during the applause, it rebels again [Fig. 1).

Figure 1

Two pieces of technology were fundamental in the development of ***Singsong***.The computer vision program *pfinder16* was employed to process the images taken from a camera and to extract the position of the hands and the head of the performer. In the dosed context of ***Singsong***,this tracking information could be safely translated into actions like pointing, a request to stop, and conducting. To represent the interaction between the virtual and real characters, the paradigm of ***interval****scripts* mentioned before was developed and implemented, making possible easy story-dependent specification of character behavior.

A Computer Pantomime:"It ***I*** *JP*

It/I is a computer pantomime for a human and a computer actor about living in a world incrrasmgly populated by technology. In this allegory of the contemporary world, freely inspired by Samurl Beckett's *"Act Without Words 1:·waiting* for Godot",and *"Ghost Trio",* a human character,'I~inhabits a space dominated by an omnipresent computer creature,"It"."It" is never actually seen, but its existence is felt through virtual objects projected on two large stage screens. By manipulating the human character's desire of information and entertainment, "It" leads"!" into a perpetual cycle of despair, resignation, and death.

It I I employs state-of-the-art computer vision technology able to track the actor and props in spite of lighting changes and rear-projection screens.17 The different modules that control the physical devices, the characters, and the play communicate among themselves using *ActScript.* We use an improved version ofinterval scripts to describe and control both the characters'behavior and the overall structure of the play, enabling flexible rehearsal and greater interactivity between human and computer actors. The concepts of actions, conditional events, and negative constraints between characters are fully implemented and used in ***It I I***.

Another new aspect of ***It I I*** is audience interaction with the computer character. As part of the play, members of the public are invited to join the performance and inhabit temporarily"I"'s little world. The computer character automatically controls the performance while the non-actor is on stage, leading him/her to experiences similar to those lived by "I." After the actor's performance, the public is invited again to the stage, this time to a more private experience of living in the universe controlled by"It:

Making Theater with Computers

The concept of action is essential to the vitality of theatrical performance and must be incorporated, implicitly or explicitly, into any computer theater system. I do not foresee widespread use of comput-

ers in theater until a language paradigm is established which is expressive enough for computer manipulation, and simple enough to be used by performers, directors, and play-writers.

Bringing computers to theatrical performances has the potential to move theater into new directions. With computer- and hyper-actors the stage is open to characters that are legitimate representatives of the electronic realm that surrounds us, although computer theater certainly goes beyond the representation of its own electronic substrate. Computers can create new characters and bodies to be explored creatively by play-writers and directors as much as computers have expanded the frontiers of the musical experience.

However, I am particularly fascinated by the possibility of using computerized environments and characters to make plays where a member of the audience is able to experience the feeling of living a character in the play. This excitement drives me towards the development of autonomous computer-actors and stages that are able to both integrate perfonners and audience and also control an interactive re-enacting of the play with non-actors playing the main characters.

Computerized characters and plays is a personal path to explore the frontier between real and virtual worlds that is increasingly blurred by technology. *Singsong* and *It/ I* are simple, first experiments about designing, scripting. rehearsing, and performing with characters - and"actors" - which are born virtual, truly inhabit a non-physical world, interact with human performers, and tragically disappear with the click of a switch.

Admowledgmaits

Many of the ideas of this paper were elaborated and refined during conversations with Prof. Aaron Bobick. The MIT Media Laboratory and the Digital Life Consortium are supporting the research on action understanding and computer theater and the play *It/ I*. The ATR-MIC Research Laboratory, the MIT Japan Program, and the Starr Foundation supported me during the development of *Singsong* in Japan.

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1. The term "computer theater" has been previously used to describe adventure games with complex stories (see[2]). One of the reasons for reshaping the term computer theater as described in the text is to highlight the similarities with computer music and the development of inter-relations between music and computers in the last three decades (for current perspectives, see[191).
2. Using here Schechner's definition of performance as• ... an activity done by an individual or a group (performers) in the presence of and for another individual or group (audience).' (21].
3. It is not the goal of this paper to review the work done in computer theater. The works referenced here were selected solely to illustrate different approaches. A larger compilation of ref erences is available at http://www.media.mit.edu/-pinhanez/ctrefs/ctrefs.html.
4. Examples of use of electronic puppets are more common in the context of performance animation. See Protozoa's work [http://protozoa.protozoa.com/) and RiGBy, which appears in performances by D'Cuckoo (http://www.dcuckoo.com!).
5. For example, the creatures designed by Naoko Tosa [24], Bruce Blumberg [12], and Joseph Bates [3].
6. For example, the works of George Coates (http://www.georgecoates.org/), Troika Ranch [http://www.art.net/Studios/Performance/Dance/Troika_Ranch!TroikaHome.htrnl), Mark Reaney (18].The tenn hyper-actor is suggested as an analogy with Tod Machover's hyperinstruments [11).
7. A typical example is Robb 1.ovell's•Intelligent 5tage'[10].
8. Some examples are Tod Machover's Brain Opera {http://brainop.media.mit.edu/), and Gloriana Davenport and Larry Friedlander's Wheel of Life [4].
9. A similar situation is faced by dancers and choreographers who, notwithstanding being more active in exploring the new technologies, also lack a language to describe body movement and shape to electronic partners.
10. For a more detailed paper on the technological aspects of the research, see [16].
11. Examples are the works of Jackendoff [7], Schank [20], and Pinker (17].
12. See Kalila [8].
13. See Siskind [22].
14. ActScript is a development of a paradigm previously developed called action frames (see [15]).
15. Interesting exceptions are the works of Galyean [5] and Strassman [23].
16. *See* [25].
17. Using three cameras in a fast triangulation system [6].