The Theatre of the Twenty-first Century May Well be Virtual and Online

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***Abstract*—** The idea of combining virtual reality technology and theatrical tradition to create virtual plays has captured artists' imaginations for some time. Using conventional technology, the use of virtual characters in a theatrical performance often integrates the predefined animations of virtual actors into the theater scene, resulting in a performance that can feel stilted and unresponsive due to its preprogrammed nature. Recently new systems allow actors to animate virtual characters in real time, resulting in a more flexible and interactive theatrical performance experience. Actors are sequestered at a remote site, invisible to the audience, and are digitized by a motion capture system. Using camera feeds to provide the remote actors with information about the behavior of the live actors and audience in the theater, the remote actors can adapt their virtual counterparts' behavior to react to live events in real-time, giving the illusion to the audience that the virtual characters are responsive to their actions. In this paper, we will present various concepts of virtual theater and an example of a virtual theatrical performance called Trickster at the Intersection that was presented during Smart Graphics 2010 at Canada's Banff Centre.

I. Introduction

Over the past decade, Virtual Reality (VR) has been used in a wide range of artistic applications including virtual theater. Virtual theater preserves the theatrical performance form through direct mediated interaction of avatars and objects, and it is known for its flexibility of interaction [1], and its potential to create novel theatrical elements [19] that would be impossible to do in the real-world. However, performances in virtual theater are often prerecorded which make them pre-programmed, difficult to use, and lifeless compared to the spontaneity and improvisation of a real performance. Theatre, by its very nature, is a collaborative art. Traditional theater story telling involves a number of artists who create a space and action viewed by an audience. The various artists involved are:

- **Playwright** – describes space, sound, movement, and defines the blueprint for the characters and the story.
- **Director** – interprets playwright's plans and applies them to the space.
- **Designers / Technicians** – design and create and control the actual physical and audio elements placed into the space.
- **Actors** – execute the actions within the space; create the motion and action of the characters.
- **Audience** – reacts and sometimes interacts to the actions.

In virtual theater, the role of the team change as it is offers more possibilities. For example:

- The **playwright** work is very similar to traditional theater but there are much less limits on his thinking such as no need to respect the laws of physics and an almost infinite ability for magic and special effects. In many ways, the playwright has the same freedom as its counterpart in cinema.
- The **director** defines the behavior of actors, the virtual set, and as with traditional theater must interpret the playwright's intentions but must also re-interpret the play with the virtual capabilities in mind.
- The **designers / technicians** have the ability to define, set, and trigger lighting and various staging cues such as: 3D sounds, robotics props, holographic projections, etc. Contrary to standard theatrical practice they are also responsible for programming virtual effects and key elements of the virtual play.
- The **actor** is able to define his/her position and orientation within virtual space as well as how the stage must react to its presence. In many ways the law of physics does not have to be respected. The actor may also be remote to the actual stage and may also be a computerized avatar with some form of artificial intelligence.
- The **audience** has the ability to set their own view as well as to respond to the performance. It can also be present at the theater or tele-present using the internet.

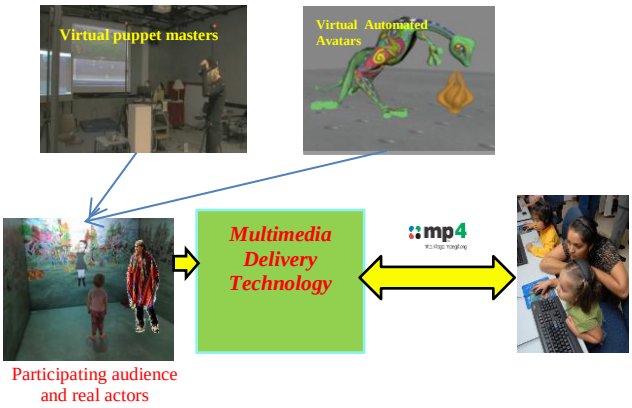


Figure 1: Technologies for a Virtual Theater System.

In many ways virtual theater systems open the door to new forms of theatrical expression as well as standard theatrical plays. For example, plays that require imaginary characters, such as Shakespeare's Macbeth, The Tempest, and Midsummer Night's Dream, could use this technology to add realistic personifications of magic characters like the witches in Macbeth. The key technologies (see Figure 1) that are required to create such a true virtual theater experience are complex and not easy to implement. They include:

- The ability for puppet masters to embody virtual creatures in a simple and expressive way;
- The ability for puppet masters to connect to the system using the internet and animate multiple avatars participating to the play;
- The ability to integrate simple automated virtual creatures or mechatronic robots that respond to the presence of the audience, the avatars, and the real actors;
- The ability of real actor and the audience to be localized by the computer relative to the set and the virtual world: multi-targets motion tracking;
- Reconfigurable display technologies that can be integrated into normal sets or be totally immersive;
- The ability to localize sound and voices in specific locations on the set and the participating audience;
- The ability to steam over the internet performances using MPEG technology;
- The ability for the director and the designers to rapidly create virtual sets and activate actions based on the playwright story.

This paper presents a prototype system developed in our laboratory that demonstrates some of the capabilities of virtual theater technologies. The system features immersive display peripherals used as part of the theatrical set, networked cameras, real-time motion capture and gesture recognition, integrated into a virtual environment development suite (Virtools). The system allows natural interaction between the audience and the virtual characters without the aid of tethered input devices. In the current system, the audience can view the virtual actor in an immersive four-wall CAVE (see Figure 2(a)) to interact with a remote actor digitized in real-time by a motion capture system (Figure 2(b)) allowing the actor to control an avatar (see Figure 2(c)) and to create actions in the virtual world using gesture. While the audience does not know that the virtual character is controlled by a remote actor, the remote actor can see and listen in real time to the audience and other actors located on the real theater set by using networked cameras and microphones.

One of the key components of the system is the use of gesture recognition technology to create actions in the virtual world. For example, as the actor performs his/her gestures, one can create actions that materialize objects, stretch objects, turn them transparent or appear/disappear, and emit sparkles etc. In many ways, many gesture-triggered special effects can be created depending on the scenario of the play. By using gesture recognition based only on the actor's motion, one can smoothly integrate actions into the performance, making each performance a unique experience that can be controlled by the subtlety of the human actor and the reaction of the audience. In addition, remote cameras on the audience side can be used by the actors to observe the participant and to give them the illusion of responsiveness. Two key issues are addressed in this paper. First, by using full- body tracking and gesture recognition, manipulation of the virtual characters and virtual world is intuitive and natural. The system is fully automatic and trivial to experience. The actors are not required to have specialized training and can animate the virtual characters or create the virtual world by simply moving naturally. Second, the system is truly interactive and fluid as the motion capture, the gesture recognition, and the rendering are performed in real-time (100 FPS).

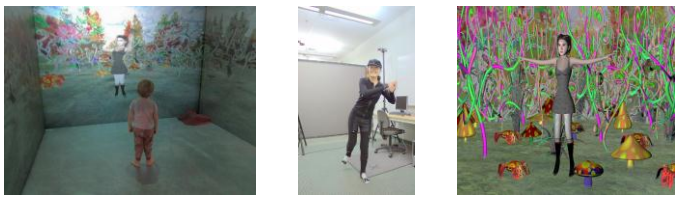
In Section 2, we will review the pertinent literature. In Section 3, we will describe a virtual theatrical performance called *Trickster at the Intersection* that was presented during Smart Graphics 2010 conference at Canada's Banff Centre. We will then conclude and discuss future work.

II. Related Work

Virtual plays have been around for decades. However, it has never been thought as a replacement of real theatrical performance. Reeve [15] pointed that key features of a typical theatrical rehearsal process can significantly improve the sense of presence for participants within a shared virtual environment. In [15], it is demonstrated that traditional shared Virtual Environments (VEs) for the production of theater has specific requirements to create a sense of presence. The level of presence is dependent on the actor avatar, actor-space, and actor-actor relationships. Current virtual theater environments cannot achieve this sense of presence. The difficulty of changing normal theater to its virtual form, and to retain the original narrative is immediately evident. There has been extensive research and literature on increasing spectator's commitment to the virtual environment and increasing user's feeling of "presence" by having user involved at different levels of interaction. The most naive interactions include the use of limited input resources, such as a simple mouse [21], a keyboard [10], video cameras [2], Nintendo Wiimotes [17], or a pressure sensor [20] etc, and the use of AI agents to interpret inputs. In these systems, once the input is interpreted, a pre-defined animation is played, during which a user has no control over its execution. Other systems use speech and gesture inputs instead. For example, Dow et al.[4] proposes to use remote human operators to play "behind- the-scenes" roles (type player's spoken utterances) to control a live embodied character, so that it is able to recognize user speech and gesture inputs. In such systems, users still passively play the pre- scripted narratives, and specifying interactions remains in the do- main of programmers. Higher level of interactions allows characters in a virtual theater to be treated as virtual actors and the novice user can construct narratives in which they appear [8]. For example, the "Virtual Theater" project of Barbara Hayes-Roth [7] and the IMPROV virtual actors system [14]. These systems allow users who would normally be excluded from the creation of play to be involved at

different levels ranging from choosing their viewpoint to defining dynamic behavior of virtual actors using various tools, such as simple scripts, so that authoring virtual environments maybe performed by novice user. At a certain level, these systems simulate the improvisation characteristic of theater performance. Recently Taylor [22] demonstrates how one can improve audience participation and sense of presence by creating a technology that allows them to become a collaborators and co-creators of the shared experience. The two performances *humanaquarium* and *neightingallery* developed by her team are excellent examples of how by design one can engage the audience by allowing them to be participant to the creation.

Contrary to cinema character animation cannot be performed using traditional computer graphics techniques as one needs to be able to animate virtual characters in real-time and be responsive to other actors, avatars, and the audience. Recently, there have been several efforts to build virtual characters in a more expressive way that responds to actor's directions [18, 12], in 2D multi-media environments as well as in virtual environments. Intuitive and expressive control of virtual character requires high degrees of freedom (DOFs) input in order to be as expressive as real human actors. Ninomyia [13] allows actor to control virtual marionette characters based on computer graphics using their hand and finger movements as if they were controlling marionettes in a theatrical play. The system recognizes hand gesture of the marionette manipulator and transforms it into motion of a marionette character. Using network, the system allows multiple marionettes to be included by allowing multiple users to join the networked virtual marionette theater. This system is excellent for Marionette Theater but would not allow actors or dancers to naturally interact with their virtual counterpart. To solve some of those issues, Cheok [3] describes an interactive virtual theater system based on embodied mixed reality space and wearable computers. Here again, there is no direct link between the actor's normal gesture and the virtual character expression. Other systems are capable of live performances, such as puppetry [5], where human actors directly control some features of the virtual character using hand movement. The ability to animate virtual characters realistically using real actors truly creates a sense of reality and presence that no AI agents have ever been able to match so far.



(a) (b) (c)

Figure 2: Virtual theatrical performance of the Trickster at the Intersection: (a) The Banff Centre four wall display system; (b) A performer in a motion capture suit who is responsible to drive the embodied trickster and to create his magic world using gesture recognition; A video camera located in the CAVE allows the performer to monitor the audience reaction and to improvise ways to surprise and trick them; (c) The trickster in his magic forest.

Application of real-time motion capture data in live performance has also been explored to create more direct link between the virtual character and live dancer/actor by several researchers [11, 6, 16]. However, they do not consider virtual environments and narratives driven by performance as our system does. Actors also usually need specialized knowledge to use real-time motion capture in actual performances [6]. By using automated data processing and gesture recognition, we will demonstrate that it is possible for actors with limited technical knowledge to deliver high-quality performance and also drive actions in narrative by triggering computer-generated animations based on gesture recognition.

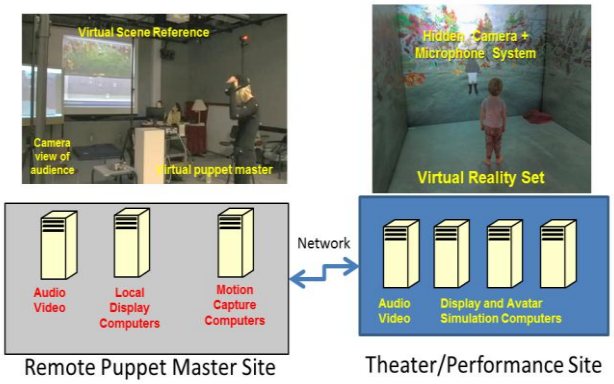


Figure 3: System architecture for the virtual performance: Trickster at the Intersection

III. Trickster at the Intersection

We demonstrated a prototype application of our system at Smart Graphics 2010 held at Canada's Banff Center. The immersive and interactive play called *Trickster at the Intersection* explores the relationship between the real and the virtual world where a mythological creature called the Trickster plays with the audience uneasiness with the virtual world. Visitors to the performance can interact with the Trickster which at first gives the illusion of been a simple virtual character dancing around and creating his own world but occasionally surprises the audience by truly interacting with them creating a sense of uneasiness that this Trickster may be real in some way. As the Trickster plays in his magical forest he is able to create whimsical trees, mushrooms, and plants. For example, when the visitor points to an area of the virtual world, the Trickster correspondingly points to the same area and commands flowers to grow in that area to welcome them. The experience brings the audience and the character together at the intersection between the physical and the virtual world. Contrary to the work by Mateas' and Stern's 2005 called "interactive drama" [9], in our system we replace the need for standard input devices (desktop, mouse and keyboard) for a much more expressive and intuitive tool that truly allows the performer

to create a sense of presence of a real-virtual entity. The gesture recognition system can be personalized to fit with the performer style. Only notable, recognizable and definable gestures are coded in our system, so that the behaviors of objects are not trigged by some random motion during the transition of different motion. An action script describing the specified gesture and corresponding behavior is present to the dancer before the show. Figure 3 shows the action script of our current system. Figure 4 shows the virtual play driven by the actor's performance. As shown in Figure 4, the movement of the virtual character is a mirrored motion from the real actor's motion. This is not a problem for the actor as it simulates how he would see himself in front of a mirror. A dancer who has never worked with the motion capture system before can easily understand his task and his role in the performance.

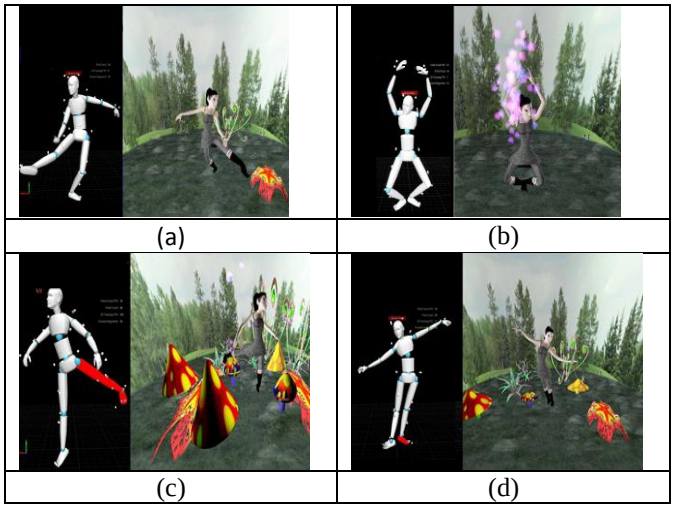


Figure 4: Dynamic virtual world driven by the actor's performance: (a) Hands close-up gesture triggers sparkles. (b) Lifting left hand and left foot triggers plants grow on left-hand side. (c) More plants appear by different gestures. (d) Gestures trigger stretching animation of plants to simulate growing effect.

Our system is basically composed of the following components (see Figure 3). The avatar and scene rendering are performed on two networked high-end graphics PCs, one as a performer's monitor and the second one managing the display at the theater set. At the theater location, a display peripheral can be inserted in the set using trans- parent projection sheet technologies 1 or around the audience using a CAVE 2 like system. At the theater location the set is equipped with web cameras and microphones linked to the remote actor location using a standard network. At the remote location, the actor is tracked using an Optitrack motion tracking system calibrated to transmit skeleton information to the theater computer. The system is integrated using Virtools VR authoring tools from Dassault Systems. The communication between the motion tracking system and the rendering programs is performed using a modified version of the Open Source NATNET client/server utility.

On the performer's monitor, performers are able to see the reactions of the real audience as well as a feed showing a representation of their avatars in the virtual world that is being created during the performance, allowing them to monitor how their actions affect both the physical and the virtual worlds. Because the performance is driven by real-time motion data, this information needs to be transmitted to both location via network (performer's monitor manager and theater manager). The virtual play that the audience sees on the set is always the same as the one performer sees remotely. This implies that the virtual performance must be synchronized in real-time on the performer's monitor as well as on the theater screen. The virtual world in our project is actually a media layer where the interaction between audience and performer can be integrated and manipulated at will. In this way, we are able to have both audience and actor involved in the creation of the virtual world and how it behaves and changes. The need for real-time performance is critical for this application. With motion capture system, high-speed internet, and two PCs each equipped with two high-end graphics cards (NVIDIA GeForce 5800), our system runs in real time at a speed of 100 FPS. By careful integration and system optimization there is no delay between the remote actor performance and the live action on the theater set.

Conclusion and Future Work

In this paper, we present a prototype system that enables true real-time interaction between an audience and a virtual character. The character which is animated through the live performance of a real actor in a remote location can be used in a theater setting to add to the narrative of a play and to interact with the audience or with other actors. The virtual character can "see" and "listen" to the user through net-worked cameras and microphones installed at the theater location. This allows the performer to "respond" in real-time to the reaction of the audience. The short performance Trickster at the Intersection presented at the Banff Center was well received as the audience truly felt that they had a real interaction with the trickster. They really felt that the Tricksters was alive and present on the set. Considering the fact that the connection between the performer and the audience is based on a network connection, one could imagine that the fact that the connection between the performer and the audience is based on a network connection, one could imagine that more than one remote performer could be part of a virtual play and could interact with the real-actor present at the theater and the audience. In such a system, it becomes possible for the audience to immerse themselves and become part of the virtual world as the action takes place, and perhaps even choose to interfere with the action and help shape the narrative themselves, thereby becoming part of the performance and creating a truly interactive and collaborative version of virtual theater. We are currently working on new ways to create virtual avatars based on artistic 2D drawing that can be animated by motion capture system. We are also looking to create a new longer performance with real/virtual actors, improved

audience tele-presence using MPEG technology, and new technologies to improve the transfer of playwright scenario into Virtools scripts, i.e. Theatrical Virtools. We are also looking to include a mechatronics character like the *nightingallery* bird developed at the Culture Laboratory in Newcastle England.

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