Mixing Dance Realities: Collaborative Development of Live-Motion Capture In a Performing Arts Environment

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An experimental dance performance featuring live-motion capture, real-time computer graphics, and multi-image projection was produced by a cross-departmental team of faculty and students at Purdue University. Dancers occupied and traversed performance mediums or “frames,” including a virtual performance frame occupied by a 3D character, driven by a dancer in motion-capture equipment. Developing and facilitating the relationships between the dancers in various performance frames became a primary focus for the project, but other areas, e.g., creating an artistically sound and technologically seamless performance, helping the various team members collaborate, and exploring the nature of the technology, were important focus points as well.

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1. INTRODUCTION

Previous experimentation with motion-capture equipment and contemporary dance inspired the authors to build a theatrical production that would emphasize interaction between dancers who occupy a variety of spaces both virtual and real. The resulting production centered on incorporating or "nesting” a variety of real-time performance elements such as dance, video, and live motion-capture-driven computer graphics.

The team's overriding goal for all work was that each production present a live, professional-level performance to an audience of peers and the local community. In order to present a complete and entertaining work of art, production quality and aesthetic needs always had precedence over technology or research. The precedence of production quality over research or technology often forced the team to be conservative in choices that might lead to unpredictable or aesthetically undesirable results.

The role of technology in any space is to serve the project. In the case of art, technology can serve to communication, change the message, and in many other ways enhance the performance and performance space. More often than not, incorporating technology into an artistic venture becomes a challenge for what designers can do with the technology instead of what the technology can do for the performance.

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This article features the work of a team of dance and computer-graphics artists and technologists. The team’s previous work is mentioned to put this project in context as well as to outline related projects at other institutions, with an emphasis on universities or groups that produced live public performances. We detail the project’s collaborative process; we also present a discussion on nesting performance frames and the technology, a critique of the project, and plans for future work.

2. PREVIOUS WORK

Though several entities have used motion-capture in dance, the cases that stood out as relevant to the team came from the Interactive Performance Laboratory at University of Georgia at Athens, the Troika Ranch, the art of Merce Cunningham, and the Beckman Institute at the University of Illinois at Urbana-Champaign.

The first large-scale production by the Interactive Performance Laboratory was Shakespeare’s *The Tempest*, in which Ariel was projected as a virtual character, but driven in real-time by motion-capture technology. David Z. Saltz, the director of production, said “the character of the spirit Ariel will appear on stage as a large-scale computer animation, but one that varies with each performance because its movements and voice are controlled by a live actor. As a result, the production will retain all the spontaneity of live theater, while exploiting the unique capabilities of digital technology to convey Ariel’s magic nature.” [University of Georgia at Athens 2000]. *The Tempest* was performed in April 2000; the Interactive Performance Lab used a Polhemus Ultra-track motion capture system [http://www.drama.uga.edu/production/archive/1999-2000/tempest/].

The Troika Ranch Dance theatre company was founded in 1993, and since 1994 has been working with motion-capture technology [http://www.troikaranch.org/company.html]. Its first production using live-motion capture was *The Plane*, a duet with a dancer and her projected image [http://www.troikaranch.org/wrk/inplane.html]. This performance took advantage of the company’s custom-built motion-capture system, called MidiDancer, which uses flex sensors to capture the performer’s motions [http://www.troikaranch.org/mididancer2.html].

Merce Cunningham is an innovator in dance and technology. His collaboration with Paul Kaiser, Shelley Eshkar, and Unreal Pictures, called *Hand-drawn Spaces*, is a milestone in motion-capture for dance performance. It was featured in the 1998 SIGGRAPH Conference’s Animation Theatre, and later installed in the Wexner Center for the Arts, as well as traveling to Spain, Italy, Austria, and England [http://www.kaiserworks.com/artworks/handdrawn/handmain.htm]. While this production was not performed live, it did take advantage of multiple screens and abstract character shapes, which were two elements that the team incorporated into the spring production.

In the fall of 2002, the team began to explore motion-capture, with a student dancer in a motion-capture suit driving a rudimentary bipedal virtual character. After learning the true limitations of the suit, the first live performance was featured in a student-produced dance showcase in November 2002. Like Troika Ranch’s *The Plane*, this performance had only one dancer wearing the suit, choreographed to interact with her live virtual counterpart. The team achieved interaction by using camera moves that changed the scale of the virtual character compared to the real dancer, reversing the direction of the virtual character. Though the virtual character made the same moves as the real dancer, it took on its own personality through camera changes and by changing its shape. Shape changes were done by swapping out the bipedal model with an abstract model, with no
direct relationships between the dancer's body and the virtual model, using keyboard-driven triggers in the software. One of the most important lessons of this performance was that the choreographer could give direction to the computer operator during the performance. Due to the improvisational nature of the dancer’s moves and decisions, the choreographer could quickly react and “communicate” with the dancer by telling the computer operator to change the presentation of the virtual character.

In the early stages in the design and experimentation of the 2003 spring show, the team saw a production choreographed by Luc Vanier, with the collaboration of the University of Illinois Beckman Institute, called Bob’s Palace [http://www.isl.uiuc.edu/Events/festival_2003.htm]. It shared a common goal with the team: that is, the real-time motion-capture of the performance. The Beckman Institute used a Motion Analysis optical motion-capture system that was hung on battens over the stage. The performer who drove the motion of the virtual character was on stage with several other real dancers. A single upstage projection screen was used and there was no interaction between the real dancers and the virtual character. At no time did the live dancers on stage look at the screen; the screen was hung high above the dancers so they could not get close to the projected image.

By using the experiences of the fall show, reviewing related work, and watching the work of the Beckman Institute, the team was able to solidify its goals for the spring show. The goals included the integration of live-motion capture, real-time graphics, actual dancers, who consciously interact with the virtual character, and the use of multiple screens so that the characters could move between them on stage instead of using a single screen.

3. COLLABORATION
Dance performance and computer graphics projects have fundamentally different production life-cycles. One of the team’s goals in a collaborative effort was to merge the separate points of view on production in order to expand the options for the two disciplines. The production’s collaboration and workflow helped create an effective, professional performance that communicated the story of the dance in the desired manner.
in a better, more managed, production. Exploring and applying Laban dance theories to a virtual character increased awareness of the motion-capture system’s capacity, and, in creating the piece, helped to focus on the strengths of motion-capture. Finally, the overall theatrical presentation developed a much more focused and complete performance of the piece.

3.1 Combining Workflows

The team worked to match the production styles of both the computer graphics (CG) and dance disciplines. Integrating a production pipeline with discipline-specific communication between the collaborators was key in developing the project.

After producing the dance, the team realized that it must integrate more time for preproduction. The CG artists learned to accommodate the production style of the dancers, and the dancers learned to work in a more linear fashion. The CG artists developed ways to change the graphics quickly allowing the choreographer to promptly change the aesthetics of the graphics. The dancers learned to map their movements to storyboards to create a library of movements earlier in the production process.

The CG artists needed to find a way to speed up their approach to creating art. Due to short preproduction time and the “stream of consciousness” style of dance improvisation, frequent aesthetic changes had to be made to the graphics. To overcome this problem, the CG artists created a more flexible character setup that allowed the choreographer to gain the interactivity and exploratory possibilities that she was accustomed to; the setup is detailed in the Technology section.

The dancers dealt with working in a much more linear fashion by using storyboards to layout and visualize what the dance would be and where the overall artistic vision was leading the dance. This allowed for ease in communication between the choreographer and the CG artists. But at the same time it constrained the choreographer’s creative process by defining the limits of the dance earlier in the process.

Another issue dealt with while working within a collaborative effort was the constrained window for improvisation. The motion-capture system allowed the dancer to improvise to the music with a CG character in real time, but a lot of the movement was constrained due to the inherent limitations of the motion-capture suit.

The overall collaborative effort helped to create a new working solution for integrating live-motion-capture performances. Overcoming the discipline-specific communication needs and the development of the production pipeline created a new style of working for both sides of the production, allowing it to evolve quickly and produce a higher-quality performance in the end.

3.2 Using Laban’s Movement Analysis

The choreographer’s process for choosing the appropriate movement vocabulary for the virtual character started by exploring the natural tendencies of the motion-capture suit the group was using. The choreographer utilized Laban’s effort/shape theories, a dynamic system that describes the qualitative aspects of movement in communicating emotions like fright, apprehension, cheer, and security [Dell 1971]. Through dance improvisation exercises based on Laban’s effort/shape orientations, the choreographer selected those that communicated the thematic ideas of the project and produced the strongest visuals on the screen. The theme of the dance was the precarious relationship between humans and machines, a journey to find a balanced coexistence in the same environment.
Effort may be seen as made up of four factors: weight, time, space, and flow. The team explored the weight elements of light and strong movements. The suit tended to yield very positive results for a strong weight effort. These movement types communicated the idea of aggression better and were easier to implement. Strong movement suited the more rigid and constrained motion that the suit tends to provide. Light movements became very difficult to communicate through the suit, since it did not give quite the resolution and clarity of data needed to portray this information accurately.

Next, the team explored the time elements of sustained and quick movements. Sustained movements, such as the smooth and slow spiraling of the torso to the extended line of the legs and arms, worked. However, contrasting quick body part isolations, such as shaking the hands, were the most dynamic and interesting actions for visual communication.

The choreographer then explored the flow elements of free and bound motion. Free elements did not communicate as well through the motion-capture suit because the small articulate gestures or light graceful paths usually associated with these movements could not be created. It tended to work better when associated with bound movements, which were much more robotic and influenced the virtual character’s role in the performance. These attributes influenced the design of the character as well, lending themselves to more abstract and simplistic shapes and figures and enhancing the robotic and bound nature of the character’s structure.

The shape elements were examined in looking for strong visuals to match the effort shapes, including the opening and closing shapes, spoke-like directional movements, and rising and sinking carving shapes. Due to their robotic nature, spoke-like movements, and those suggesting strong visual geometric patterns, helped to create the desired visuals for the piece.

Exploration of the effort/shape theories helped provide a working set of movement definitions, which became the movement library for the dance. The library helped to determine the kind of production the system lent itself to and defined the role it would play in the overall performance. The Laban analysis became invaluable to the performance, as it helped to limit confusion in movement and in the message to the audience.

3.3 Theatrical Presentation

The theatrical side of the performance is another important aspect of the collaboration. Stage lighting and the design of the space are important parts of the piece, and help tie it together. By primarily using the side and top lights, the lighting designer was able to illuminate the live dancers to accentuate their forms and costumes. Though most of the time it is the designer’s duty to keep light off the projection screens, in this piece textured light shining on the screens at glancing angles added another layer of visual interest without overpowering the video-projected image. A cyclorama upstage of the performance space provided a backdrop of color for the dance. By using color, direction, texture, and intensity, the lighting designer was able to add another dimension to the dance, as well as provide cues to mood changes in the performance.

The three projection screens were a major aspect of the project. The screens provided the space that the virtual character and video elements inhabit. There were two objectives in using multiple screens. One is that, to keep the projections bright, the images had to remain small. By using several smaller screens the stage could be filled appropriately.
with imagery, but without an extremely high lumen output projector or stacked projectors. The second goal was to get away from single-image projection. It is not uncommon to see dance works, plays, and concerts with one screen centered on the stage behind the action. By using multiple screens the team was able to get its virtual character to travel across the entire stage and at different heights. This tied in closely to the ability to create a mood. Various emotions were evoked by the virtual dancer, depending on the placement of the screens.

Use of multiple screens can also develop relationships between the dancers and virtual character. While the virtual character was on the screens that were flat to the floor, the audience was given a sense of the dancer’s relationship to the virtual character. While the virtual character remained at approximately the height of the human dancers, human-like qualities were portrayed by the virtual character. The moment the scale of the virtual character was enlarged to twice the size of the dancers, a structure of control between the dancers and the virtual character emerged. When the virtual character was displayed on the middle screen, a feeling of dominance was evoked; the character was high up in the air, looking down on the dancers.

The lighting and screens were very important to the presentation, helping to bring the meaning of the piece to the audience. These elements also helped give the piece a much more professional finish.

4. NESTING PERFORMANCE FRAMES
The team thought in terms of mixing or “nesting” performance frames as an approach to developing a live dance performance that included multimedia elements such as real-time 3D computer graphics, shadow play, live and prerendered video, and of course, dance.

4.1 The Performance Frame
The unique relationship between audience and stage constructs a conceptual performance frame that endows the stage with a special property which may generate a “willing suspension of disbelief,” a concept originated by Samuel Coleridge in the early 19th century [Coleridge 1907]. The concept refers to the heightened experience of a poem (or performance) when an audience temporarily believe that the events and characters are “real.” This notion has migrated across many entertainment media including film, television, video, computer games, and real-time virtual environments [Laurel 1993]. (In virtual environments, the concept has been renamed “presence,” and has been studied scientifically [Ijsselsteijn et al. 2001]).

The framing of performances in theatrical space has taken many forms throughout history [Mielziner 1970]. With the introduction of film, video, and television, framing a performance, e.g., a theatrical one, becomes a function of its media. Many technological innovations and special effects associated with media were a direct response to the creative license offered by the flexibility of the performance frame and its technological potential [Bates 1992; Hellig 1992; Laurel 1993]. Innovators have sought to expand their media to create comprehensive experiences that approach those of the imagination. Recent developments in mixed-reality technologies and their various applications in live performance settings have opened up many new avenues for framing, communicating, and exploring imagination [Benford et al. 2002; Koleva et al. 1999; 2001; Sparacino et al. 1999].
4.2 A Framework for Nesting Performance Frames
Thinking in terms of performance frames, the team sought to build a multiframed dance production and to observe the relationships between dancers occupying the spaces in different frames. Since some of these frames would be located inside other frames, i.e.,
be “nested,” properties and trade-offs associated with relationships between frames were observed.

To create a conceptual framework for the project, the overall production was divided into discrete performance spaces, or “frames,” based on the specific properties inherent in each medium, i.e., stage, silhouette, video, virtual, feedback, and mocap. There were a total of seven performers, including the virtual character, driven by the mocap dancer, who at any given time occupied one or more conceptual spaces.

4.2.1 The Stage Frame
The primary performance frame was labeled the “stage frame.” It contained all the elements of the proscenium stage, including five live dancers and three projection screens situated mid-to-upstage. The screens on stage left and right were positioned on the ground and the screen at center stage floated above the heads of the dancers. The dancers interacted with one another and with the live content projected onto the screens.

4.2.2 The Silhouette Frame
At various points in the piece, one or more of the dancers would travel upstage and enter behind a projection screen. The light from the projectors created a well-defined layer of shadow movement (the silhouette frame) for the stage dancers and the virtual character to interact with. The problem with this frame was that the silhouette dancers could not see the stage dancers in front of the screen, which limited the levels of interaction for the silhouette dancers. But it was possible for silhouette dancers to see the virtual character if it was projected onto the same screen.

4.2.3 The Video Frame
The video frame only occupied the center projection screen and just played prerendered video footage. The video was a recording of the four primary stage dancers who moved their heads as if observing the events on the stage. In this frame, interaction could be simulated by the stage dancers by pretending that the video was live.

4.2.4 The Virtual Frame
The virtual frame was a central element of the production and was occupied by a virtual character driven, in real time, by an offstage dancer in a motion-capture suit. The virtual character was designed to traverse the entire stage by crossing from one projection screen to another (see Section 5 for details).

Because the virtual character was presented in real time, active positioning of the character as well as modification of the properties of the virtual camera could be done to adjust to changes made during the performance.

While experimenting with scaling and positioning the virtual character in rehearsals, it was observed that a live virtual character acquires unique characteristics when it is scaled to human-size and positioned on the ground next to a performer. In the final performance the unique relationship between real and virtual dancers was further explored by slowly adjusting their relative sizes. At one point, the virtual dancer could fit into the hand of a stage dancer; at another point the virtual dancer was larger than the entire projection screen.

Creating effective communication between the virtual character and onstage dancers was a challenge. In the rehearsal space, the dancer in the motion-capture suit could always see the interaction between her character and the stage dancers; but during the performance the mocap system driving the virtual character would be located remotely in
a room behind the stage. The dancers in the stage frame could see and respond to the virtual character, but creating a communication channel for the virtual character became a challenge that was solved by a live video feedback frame of the live performance.

Once the visual line of communication was established between the dancers and the virtual character, real-time interactions between the two could be explored.

4.2.5 The Mocap Frame
Three performance zones were identified, calibrated, and associated with the screens to create a coherent relationship between the motion-capture dancer, the virtual character driven by her, and the representation of the space occupied by them on the stage. The virtual worlds projected onto the screens suggested that there were spatial “zones” behind the screen which were occupied by the virtual character. The virtual character was to traverse all three projection screens, so this zone had to be conceptually connected. The team accomplished this by establishing a tight relationship between the spatial layout of the projection screens and the coordinate space inside the motion-capture and real-time performance software. This mapping of the stage frame and the virtual frame was essential to create the virtual character’s traversal of the projection screens.

Once this mapping was established, the dancer in the mocap suit had to learn a strange notion: that there were “invisible cameras” in space in front of her, focused on her, and that she had to dance for the cameras to display the appropriate dance perspective for the audience and other dancers. This became a challenge, and without a good reference system the virtual character would wander out of view of the virtual cameras or show up only partially in the wrong camera frame. To address this problem a large paper grid was laid out over the mocap dance space for reference mapping; the mocap dancer would begin in a position that was mapped to the origin of the virtual frame and then a more coherent connection between all three “zones” could be established.

4.2.6 The Feedback Frame
Mapping the spatial zones of the virtual character was not enough. The dancer needed clear visual feedback of events on the stage frame, so a video camera was set up at front of house (FOH) to capture the entire stage frame. The live video frame was projected onto a large gray wall above and in front of the mocap dancer’s mapping zone. Hence the motion-capture dancer had a “big picture” of the performance and experienced the strange sensation of performing onstage while being in the audience, but actually being in a large, isolated, room behind the stage! Unfortunately, this approach had many limitations and posed several performance problems. Due to the distancing and orientation of the camera’s point of view and the dancer’s experience of general disorientation, the dancer had to again make psychological spatial adjustments to effectively and convincingly interact with dancers in the stage frame.

5. TECHNOLOGY
100d11A0N1C00E1 was performed in the Loeb Playhouse, which is a 1,038-seat proscenium theatre. The performance was part of the Spring Works 2003, which is a presentation that combines work from several faculty choreographers and student dancers comprising the Purdue Repertory Dance Company. To accommodate the technical needs of 100d11A0N1C00E1, it was scheduled as the opening dance [Patterson-Neubert. http://www.purdue.edu/UNS/html4ever/030421.Cunningham. vpa.html].

To produce the images on the screen, the pipeline is separated into the motion capture hardware, character construction and setup, computer hardware, and video switching and projection. The technology for the production enabled each of the frames explained previously to co-exist.

5.1 Character Construction and Setup
The virtual character was modeled in Discreet’s 3dsmax 5.1, and then exported using the FBX file format to Kaydara’s FilmBox Online 3.5. In FilmBox, a null object skeleton was “characterized,” which is a process that allows a character to be animated using motion-capture devices, existing motions from a library, or the software’s built-in IK/FK control set. The project’s character was segmented and had no deforming parts. The character’s modeled pieces could be parented or deleted from the null objects as they were updated; this setup was more efficient and didn’t necessitate recharacterizing the character. Characterizing in FilmBox is a tedious process, so having to do it with the choreographer present at design meetings is undesirable at best, since it is quite unproductive for her to wait while each change is made. Being able to swap out parts quickly allowed the team to make design changes promptly and efficiently.

5.2 Motion-Capture Hardware
The motion-capture system for both the fall 2002 and the spring 2003 production was a Gypsy 3.0 wired motion-capture system manufactured by the Analogus Corporation and distributed by Meta-Motion. The Gypsy 3.0 is an electro-mechanical motion-capture suit that utilizes 43 potentiometers to measure rotation data at the wearer’s joints. Since the Gypsy 3.0 is a wired system, its range of motion is limited to a 50-foot radius using batteries and 25 feet using corded A/C power.

5.3 Computer Hardware
The spring performance was run from three high-end laptop computers and one backup laptop. The Gypsy suit was connected to a Dell Precision M50, which was used to broadcast the suit’s data over a 100Mb LAN as well as run an instance of FilmBox.
Online 3.5. Two other Sager 5660/5670 laptops ran instances of FilmBox and were connected to the LAN.

5.4 Video Switching and Projection
FilmBox has a full-screen playback mode that removes the user interface from the screen and displays only the virtual camera’s view. To get the FilmBox image out, each computer’s display output was connected to a Sony 1024 scan converter, which transcoded the 1024x768 computer screen signal into an analog composite video signal. The video signal from each scan converter was sent to a Grass Valley 3000 switching desk. The switcher was used to control the video feed of the computers and a Sony DVCAM tape deck and send the signals to three Barco large venue, high-lumen, LCD projectors.

Three screens were used to display the virtual character on stage. Two rear-projected (RP) screens were 7.5’ x 10’ and were located far stage left and right and were hung so that they touched the stage floor at the bottom. The third screen measured 9’ x 12’, was front-projected, and hung upstage from the other two screens at approximately 8 feet above the stage.

The DVCAM footage was taken by a member of the dance team and was composed of digitally manipulated footage of the live dancers on stage; this footage was shown in the last minute of the dance.

5.5 Traversing the Stage
To accomplish one of the most important goals of the production, i.e., allowing the virtual character to traverse the stage via multiple screens, took coordination between the three computers, the switcher, the projectors, and the dancer in the Gypsy suit. Three 8’ x 8’ areas were taped on the floor where the dancer performed. In FilmBox, a scene was constructed that had three cameras that were constrained to each other and the null object character. They stayed a constant distance from the character in the Z-direction and a constant distance from each other along the x axis. These virtual cameras corresponded to the three areas on the floor in which the performer would dance and to the three screens on stage. The virtual cameras had variables in their constraints that allowed the users to adjust the spacing between them to correctly line up with the real capture areas.

After all three instances of FilmBox initialized the Gypsy suit (a process that places the character at the world origin facing the positive Z axis), the dancer could move from one area to the next, which moved the virtual character from one camera’s field of view (FOV) to the next. Each computer kept active a different virtual camera’s view as well as a different background image in full-screen mode. The switcher was configured to send signals from the three laptops to the three corresponding screens on stage. As the dancer moved from one area on the floor to the next, her virtual counterpart moved from one screen to the next. By running these signals through a switcher, the team could fade the screens to black, transition to a DVCAM video deck, or have one computer’s output on all three screens, or any combination of these.

5.6 Communication Between Frames
As mentioned in Section 4.2.6, during actual production the dancer in the motion-capture suit had to be in constant visual contact with the dancers on stage. This communication
allowed for a high level of interaction without the suit and its associated technology actually being on stage with the other dancers. In order to accomplish this, a live video feed from a front-of-house (FOH) camera was projected via a small Sony projector located in an adjacent workspace where the laptops, motion-capture suit, and video equipment were also situated. The standard audio equipment was also in place so that, using Clear-Com closed-circuit headsets, everyone working backstage and the motion-capture crew could communicate.

6. RESPONSE FROM AUDIENCE AND PERFORMERS
Given the nontraditional format of the performance, it was important to get feedback from the audience and performers.

6.1 Audience Response
Many audience members had a positive response to the interaction between the virtual dancer and the live dancers on stage. One response was that “the mocap dance explores tensions between two- and three-dimensional spaces as well as the horizontal and vertical planes of the stage in unexpected ways. By using suspended screens at different heights it allowed the dance to use the vertical space of the stage which is often empty in conventional dance pieces.”

Another audience member, who was attending her first modern dance performance, commented that being able to change the character size added a dimension to the dance that would be difficult to achieve using nondigital means. She thought it had a lot of potential due to its visual style, and that she would like to see similar performances. Additionally, some commented that although the character’s composition was abstract in shape it still conveyed the depth of human personality and that bright colors, bold shapes, and the overall aesthetic gave an uplifting response to the piece. It was suggested, however, that adding another virtual dancer to the performance would have increased the level of interaction.

6.2 A Dancer’s Experience
“My first reaction to dancing with the suit on was how it changed the way I could move,” said one of the student dancers. “At first, I found it to be extremely restricting and I was
frustrated with what I was not able to do. However, as the process went on, I found myself experimenting more, challenging myself to find new ways of moving. At times it was a strange out of body experience...I would forget that the image on the screen was actually being created that very moment by me” [Padberg 2004].

The dancer reacted to the new environment by saying, “as performers it was as if we had to be as large as that character on the screen, not just in size, but in focus. Dancing beyond our own kinesphere was imperative as we had to be sure to make the live movement of ours and the live movement of the character work together, forming one cohesive choreographic and technological idea.” She added that “On a more environmental level, having the three screens on the stage with us changed the spatial design, thus altering our movement. The presence of that simple technology reminder transferred us to a different world. I sometimes felt I was inside a video game, where my obstacles were not just the character itself but also the screens and the lights and the other dancers” [Padberg 2004].

7. DISCUSSION AND CONCLUSION
The team was able to explore the mixture of motion-capture and dance from two important perspectives. First, the choreographer looked into the constraints of the motion-capture system using techniques from Laban’s effort shape analysis. This allowed the team to see what types of movement could be most effectively enhanced with the technology and helped to drive the final concept of the dance.

Second, from a production standpoint, the creation of multiple performance frames revealed new possibilities for displaying and interacting with digital content with traditional theatrical staging and live video production equipment. After collaborating for nearly a year, the computer graphics artists and technologists and modern dance choreographer achieved a heightened level of respect for each other’s art and way of working. They learned to communicate by speaking each other’s languages as much as possible. The team also learned to adjust its way of working to accommodate the different art forms and constraints, allowing the group to function more effectively.

After completing two projects, the team had reached the technological limits of their resources. The available computers were not powerful enough and the motion-capture suit could not respond to the normal, natural movements of the dancer.

Although the laptop computers had high-end graphics hardware, they were not at the level available for desktop computers. The consequence was that the real-time frame rate was often below acceptable levels; a rate of 30 frames per second (fps) was ideal for this production, but even one as low as 15fps was allowable. The CG artists attempted to create the effect of simultaneous, multiple copies of the virtual character on the screen, but was only able to have three extra copies, as the frame rates would drop below 15fps if there were any more than that.

Although the Gypsy suit has many advantages for motion-capture, e.g., low cost, quick setup for a person who has been calibrated, portability, and ability to work in several different venues including the outdoors, it does suffer from motion data drift, noise, and the limitations of mechanical compared to human motion. In the spring production, drift was a constant problem because it was so important that the character stay in the same relative place in reality and in the virtual world. Noise or jerkiness were often seen in the character’s performance because the mechanical parts were dusty, loose,
or not correctly aligned to the dancer’s body. This drift was due to the InterSense 300 tracker that is part of the Gypsy 3.0, which captures the performer’s body rotation and translation.

There were many problems with the suit during rehearsals due to software glitches and hardware failures. It was not until the technical rehearsals in the theatre for the spring show that the technology began to behave in a predictable manner, most likely because the equipment was no longer being constantly moved between rehearsal spaces.

Along with the character’s simple design, each area or screen in the virtual environment had a unique color. Due to its simple colors and three screens that were almost in the same plane on stage, the production had a very two-dimensional feel to it. There was a lot of motion left and right but very little up and down stage, nor did the screen imagery have any 3D elements other than the character. This simplicity made watching the piece very easy and uncluttered, but artistically it lacked depth in the motion and imagery.

8. FUTURE WORK
After the spring 2003 production, the team began to design a larger, more detailed production for the spring of 2004. The team will focus on a longer preproduction phase and a more complex story and setting for the performance. With the developed story comes the necessity for a virtual environment. The production will have a fully-realized virtual environment along with a virtual character.

Some of the new technology employed for the spring 2004 show is a motion-capture system from Sim Techniques (STT), called the Motion Captor. Since it is a passive optical system, it provides more freedom for the performer and creates less noisy motion, as well as allows for more detailed motion-capture data.

A new character will also be created; it will have more detail, flow with the dancer’s motion, and have a more feminine form.

Faculty and graduate students from the theatre division of the visual and performing arts department will also be involved with the project to add sound and lighting design.

REFERENCES


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