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# "Biped": A Dance with Virtual and Company Dancers, Part 1

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Those of us with the luck to attend the debut of Merce Cunningham's "Biped" performance (on 23 April 1999 at the University of California at Berkeley's Zellerbach Theatre) left knowing we'd witnessed something new and unique in modern dance. Cunningham's choreography integrated computer-captured virtual dance movement so directly and naturally as to root the entire piece in today's time and space. We expect this from our upcoming generations of artists, not from a revered icon of American contemporary dance who charted the path over the last half century. Yet "Biped" reveals an openness and curiosity applied to computer technology that makes us anticipate new possibilities rather than honor the past. This was a dance conceived entirely for performance as much within a computer as on stage, yet executed without sacrificing any of the human emotion and movement that makes dance survive as a fine-art form.

Cunningham designed, edited, supervised, and had final cut over all choreography for the real and virtual dancers. The Merce Cunningham Dance Company performed the piece with their customary grace. While Cunningham and his team deserve the reviewers' critical acclaim as to the dance, credit for the entire work must be shared among the principal collaborators, in particular those who created the software, those who took the software and motion-capture data and interpreted it with hand-drawn graphics, and those responsible for the score, costumes, and lighting.



***Figure 1. Animated real and abstracted dance characters are projected onto the scrim separating stage and audience in "Biped."***

## What we see

The stage decor is minimalist, with dark side and back curtains and a few vertical reflective materials placed against the back curtain. Between the front of the stage and the audience lies a transparent, reflective scrim. Animated real and abstracted dance characters projected onto the scrim create the illusion of the animation(s) moving with and among the real dancers—they become part of the set (see Figure 1). In fact, each element—choreography, music, and decor (in this case, projections)—is created separately and united at the dress rehearsal for the first time (usually the day before the opening). This follows a time-honored Cunningham tradition—Cunnigham and composer John Cage collaborated this way starting in the late forties. And, true to tradition, there's a feeling of randomness, although the final mix is quite deliberate and reproducible. The animated projections vary from simple dots or straight lines driven by distinctly human movement to very specific, ghostly human forms appearing to dance with the dancers on stage.

## What takes place

The animations derive from a complex process, beginning with computerized motion-capture sessions. These took place at the Modern Uprising Motion Capture Studios in New York on 6 February 1999, using Motion Analysis' optical motion-capture technology. (See Figure 2.) Wearing a collection of strategically placed optical sensors, two of the Merce Cunningham Dance Company dancers, Jeannie Steele and Robert Winston, performed a series of short choreographed move-



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ments—sometimes alone, sometimes together. The 10-camera system tracks the position transforms for each sensor at the rate of 60 frames per second, recording and reproducing the position of each sensor at any given moment within the computer.

Keith Robinson and Chuck Mongelli own and operate the studio (http://www.modernuprising.com). Before opening up this space in October 1998 at the Brooklyn Navy Yard, they worked at Acclaim Entertainment doing motion capture work for video games. They believe motion-capture technology will become the accepted archival process for dance. Traditional notation systems, such as Laban, are subject to interpretation both by dancers and those trying to imagine the dance, while film and video provide unsatisfactory records of both the performance and choreography. The motion-capture process accommodates permanent, 3D recording at high sampling rates, with results that can be examined from any vantage point, at any speed, and at any degree of accuracy.

The entire motion-capture session for "Biped" took one afternoon. Robinson noted that with the exception of some minor problems encountered when affixing the sensors to the dancers' skin, the capture session went easily. It's not just that the clients knew what they wanted; the dance contained few movements that could cause problems, such as falling or wrestling movements that could occlude or knock sensors loose.

Using technology invented by Michael Girard and Susan Amkraut, the raw motion data is filtered, simplified, and mapped onto a virtual skeleton, or biped. This results in a translation of physical dance movements onto the biped, but we don't see the biped in the final animations.

Two distinct methods generate the animations based on the biped's movements. Earlier efforts used 2D animation. Artists Paul Kaiser and Shelly Eshkar rotoscoped (that is, traced frame by frame) a series of highly gestural, nonsolid 2D hand drawings intended to capture the expression and emotion in the virtual choreography. These looked like an expressive chalk skeleton against a black background. Playing the animation, we see fluid line drawings moving loosely in sync with the invisible biped (see Figure 3).

Later Kaiser and Eshkar designed, built, and texture-mapped a very simple spline-based 3D dance character, which they tethered to the skeleton using Biped's companion module, Physique. The Physique technology enables Biped's skeletal moves to properly influence and deform the spline-based character. In this case, the spline

Courtesy of Modern Uprising Studios, New York

***Figure 2. Dancers wearing strategically placed motion-capture sensors.***

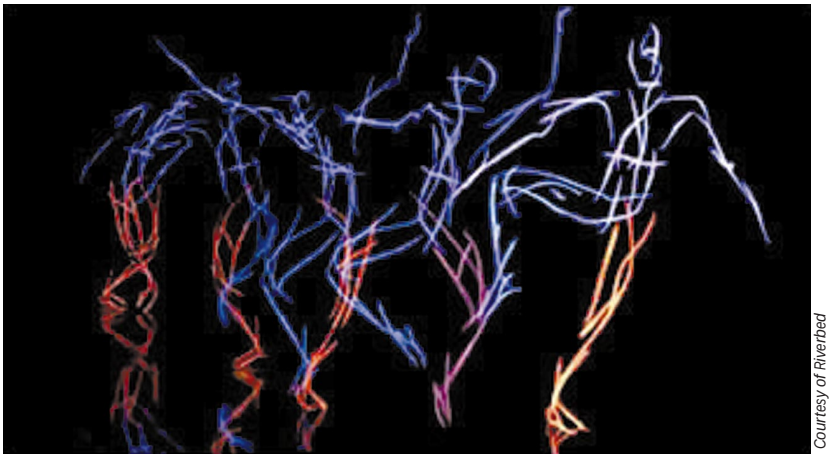
character and the biped skeleton are invisible. Eshkar used the same technique—chalky lines against black—to create the texture map. Because the texture map is transparent (except for gestural hand-drawn effects), these "drawings" wrap around the 3D character. Unlike the 2D approach, this 3D method reveals both the front and back of the character as it moves. To make this work, the line drawings had to be simpler and less expressive (see Figure 4, next page).

A third variation was to scatter dots along the surface of the invisible spline character (resembling placement of the motion-capture sensors, only without the body). A fourth was to scatter straight lines the same way, pointing away from sections of the "skin." Notwithstanding the abstract nature of these forms, we immediately recognize these collections of lines as a dancer once the computer movement is applied.

Using Biped's Motion Flow capability (invented during the course of this project), entire clips and parts of clips could be dissected, combined, and recombined into unique movement se-

Courtesy of Riverbed

***Figure 3. Artists rotoscoped drawings that when animated look like a chalk skeleton on a black ground.***



Courtesy of Riverbed

*Figure 4. Wrapping the texture-mapped drawings around a 3D character required simpler, less expressive drawings than the 2D approach.*

quences. From Cunningham's choreography in the capture session and his motion editing, Kaiser and Eshkar rendered a series of ethereal projections. They categorized these by type and projected them onto the scrim as part of the performance.

## Bringing in the talent

Paul Kaiser, Shelly Eshkar, Michael Girard, and Susan Amkraut are highly trained visual artists whose friendship and association date back to the early 90s. Their overlapping artistic journeys predate that.

### Kaiser/Eshkar and Riverbed

The ideas driving Kaiser's work during the early 80s concerned drawing as performance and mental spaces (exploring the effect or implication of "entering" a drawing like any other 3D space). Several individuals influenced the development of Kaiser's ideas into what became his contributions to the recent works "Hand-Drawn Spaces," "Ghostcatching," and "Biped." In "Biped," Kaiser focuses on the unexpected types of movement that derive from ballet—not the motion of the extremities or the dancer's general movement from one part to another, but the role each part of the body plays in building the complicated, invisible geometry of dance.

Combining the ideas of the motion trails left by a dancer's movements with drawing as performance, and what it might be like to enter and move around a drawing as though it were in someone's mind, Kaiser explored how a hand-drawn space could be spun out of the dance movement rather than stage architecture.

Shelly Eshkar began collaborating with Kaiser at Riverbed around 1996, two years before the Cunningham project (http://www.riverbed.com). Having trained in an environment of sophisticated computer graphics, and with a strong background in drawing, painting, sculpture, and photography, he is adept at making gestural drawings from moving figures. This type of drawing works well when the end result is 2D cell animation. However, a problem arises when the gesture drawing is going to be mapped onto a 3D model—the lines that implied movement are now moving themselves. Eshkar concluded that he had to

> pare down my vocabulary of marks to those that seemed internally motivated by the dancing—some lines felt true, others didn't ... Each hand-drawn dancer was to be a lens for seeing the body in motion differently—to give a sense of bilateral symmetry ...

### Girard/Amkraut and Character Studio

Michael Girard and Susan Amkraut have worked together since the late 70s, when Amkraut was a printmaker and Girard was starting to work in software in the computer arts. They soon realized that what they sought in computer animation was quite different from what had been produced with 2D cell animation. As they pointed out in a 1998 interview, traditional animators use conventions like squash, stretch, exaggeration, and anticipation to convey meaning. "They perfected a type of moving caricature. By contrast, what we've sought in computer animation is to open the door to a new type of animation—one in which we can focus on the subtleties and the micro-structure of motion."

By the fall of 1984 they began collaboration on a new system of character-motion software, out of step with their contemporaries who had been striving for photorealism in computer animation. To model creatures effectively, they had to move beyond the visual and focus on the physical. The software algorithms then existing couldn't accurately interpolate the changes from one physical state to another. They found inspiration in the work at the Ohio State University robotics program, in particular Mark Raibert's work with running machines. Eventually they developed a series of gait pattern algorithms with built-in gravitational dynamics and gait-shifting capabilities. Their gait-shifting algorithm, the most advanced at the time, raised serious questions of optimization: the creature had to be able to move quickly from one gait to another without a jerk. Their efforts at minimizing the jerk gave rise to their notion of "grace" in animation. Girard stated, "... in animation you can take any set of motions

and redefine them so that they satisfy some optimization criteria."

A second problem was how to manage complex motion systems, especially with many characters. They worked on a film, "Eurythmy," containing flocks of birds and moving human and animal characters. They questioned how much of the aesthetic experience depended on the complexity or the organization of the process that created it. Could they isolate patterns of movement and assign controls to have the patterns drive the sequence? They chose to have footsteps-on-a-path drive the animation. Their gravitational dynamics are driven by an inverse-pendulum dynamics algorithm.

Girard and Amkraut's software evolved to become Character Studio, a plug-in published by Kinetix (now Discreet) as part of their 3D Studio Max software (http://www.ktx.com). Character Studio has two modules: Biped, which defines and controls skeletal motion; and Physique, which binds the character mesh to the skeleton and controls how the mesh deforms as the skeleton moves. However, at the time of collaboration with Cunningham, Character Studio lacked two indispensable features:

1. the biped's optimized "graceful" movements lacked the accuracy and subtlety articulated joint by joint by a dancer in real space, and

2. no capability existed to tear apart and recombine motion clips or sequences.

### Cunningham and "Biped"

Cunningham is also famous for his explorations of technology—from film to video to computers. He's among the most important and innovative dance choreographers of the century. He founded the Merce Cunningham Dance Company in 1953. On the Cunningham Dance Foundation site (http://www.merce.org), he's quoted as saying

> There's no thinking involved in my choreography ... I don't work through images or ideas—I work through the body ... if the dancer dances—which is not the same as having theories about dancing or wishing to dance or trying to dance—everything is there. When I dance, it means this is what I am doing.

His collaborating in software development predates this project. For example, he worked with Credo Interactive on Life Forms, to develop a stand-alone Windows/Macintosh-based package for use in virtual choreography, game development, and motion editing.

Kaiser said that when he, Eshkar, Girard, and Amkraut showed Cunningham a hand-drawn test they had made from theater artist Robert Wilson's sketch, he played it through several times, nodded his head, and paused. "Yes, yes," he said, pointing to a small figure lightly sketched in the background, "but can you make that figure move?" Girard, Amkraut, and Eshkar said, "Yes." So, simple as that, he agreed to make a piece with them, a project they were already calling "Hand-Drawn Spaces."

"Hand-Drawn Spaces" was conceived purely for the computer, but the movements of this dance were to be as true to life as possible, with no computerized moves to violate the constraints of human anatomy or the laws of the physical world. The dance was to create a hand-drawn space purely from the movements of digitally recorded dancers, resequenced and recombined by Cunningham. The dance aimed to put viewers right into Cunningham's mind, rendering a mental rather than a pseudo-physical stage space.

That portion, which debuted at Siggraph 98 in Orlando, Florida, had the audience sitting before three screens—a center, and right and left screens angled 45 degrees to the side. A series of figures danced from one screen to another, based on an abstract musical score. The figures appeared to be nothing more than highly gestural line drawings, almost fluorescent against black, apparently the result of hand animation rotoscoped on top of a series of motion-captured, edited, and recombined biped "dance" sequences.

### From "Hand-Drawn Spaces" to "Biped"

The road from "Hand-Drawn Spaces" to "Biped" will be explored in Part 2, appearing in the next issue. Biped represents a substantial step forward: 3D spline-based characters were applied to the biped skeletons, and for the most part, these texture-mapped characters substituted for rotoscoped clips. Second, the animations are integrated with the live dancers as projections, which vary in placement and scale, not just motion. And third, the score by Gavin Bryars, costumes by Suzanne Gallo, lighting design by Aaron Copp, and choreography by Cunningham advanced the state of this art. The next part of this article will also explore future directions for the technology and the artists. MM

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