

“Biped”: A Dance with Virtual and Company Dancers, Part 1

Jeffrey Abouaf

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 embraced and integrated computer-captured virtual dance movement so directly and naturally as to root the entire piece in today’s time and space, with today’s sensibility. 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.

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—Cunningham 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, per-

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



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formed a series of short choreographed movements—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. For example, notation (that is, Laban notation) gets you only so close to the source before the dancer must interpret it; film and video are two-dimensional and impermanent. 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, this 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 make 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).

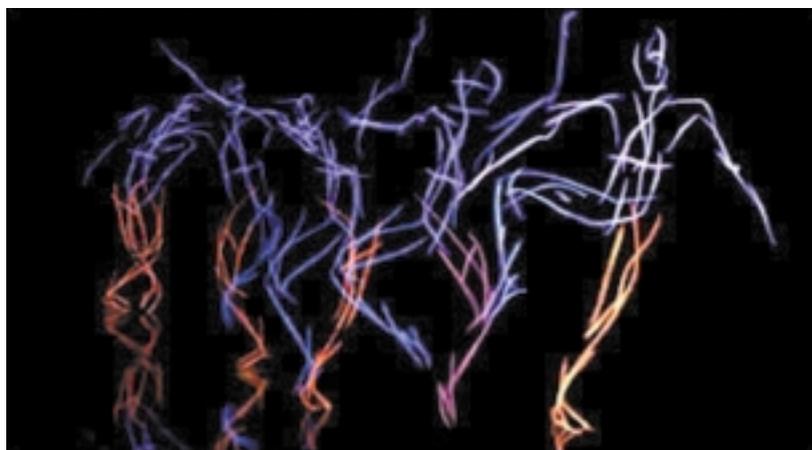
A third variation was to scatter dots along the surface of the invisible spline character (resembling placement of the motion-capture sensors, only without the body). A fourth was to scatter straight lines the same way, pointing away from sections of the “skin.” Notwithstanding the abstract nature of these forms, we immediately recognize this 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-

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



Courtesy of Riverbed



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, and whose overlapping artistic journeys predate that.

Kaiser/Eshkar and Riverbed

The ideas driving Kaiser’s work during the early 90s 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, anticipation, and so on 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 must 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. Alongside George Balanchine and Martha Graham, he’s considered the most important and innovative dance choreographer 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 the 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” sequence.

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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“Biped”: A Dance with Virtual and Company Dancers, Part 2

Jeffrey Abouaf

Part one of this article (see *IEEE MultiMedia*, Vol. 6, No. 3, July-September 1999, pp. 4-7) reported the premiere of Merce Cunningham’s “Biped,” critically acclaimed for its unique mix of physical and virtual choreography. “Biped” employs motion capture to record the physical dance moves of two company dancers and to transfer the movements to the virtual skeleton within the computer via the Character Studio plug-in. Cunningham extensively edited this virtual choreography; Riverbed artists Shelley Eskar and Paul Kaiser created and texture-mapped fluid hand-drawings onto the skeleton. (The skeleton disappears and only the drawings are visible.) In live performance, these abstract apparitions are projected on a scrim (a transparent material separating the dancers from the audience).

In the intervening months, the talents that converged to spawn “Biped” have moved on from the collaboration to resume their original creative paths. The Merce Cunningham Dance Studio has been on European tour with “Biped,” and Riverbed’s Kaiser has debuted a solo work in the San Francisco Bay Area. Discreet and Unreal Pictures continue to refine and adapt the capabilities of the Character Studio software to the latest release of 3D Studio Max. So how did they come together in the first place, and how might they again?

Merce Cunningham

In her July, 1999 review of “Biped” for *The Village Voice*, Deborah Jowitt described the Cunningham style as follows:

His dancers—with legs attenuated, feet as busy, and spines often as lifted as any ballet artist’s—give the illusion of making choices, even when complexities beset them. They can tilt their bodies, slash their arms, circle their heads, while tearing around a space rendered ominously by electronic storms of music and

still look as if this is what they’ve decided to do. This is how they cope with whirlwinds.

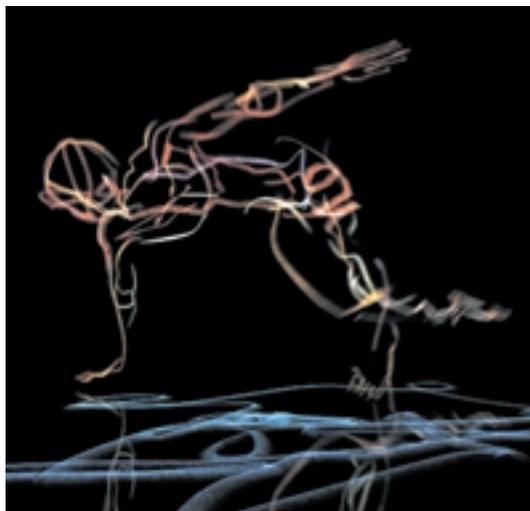
But within Cunningham’s style, “Biped” stakes out new ground. In performance, “Biped” is the third of three pieces, following “Summerspace” (1958) and “Sounddance” (1975). The first two works reflect the time of their creation and their place in contemporary art history. Given Cunningham’s musical collaboration with John Cage and with his art directors during those times—Robert Rauchenberg and Jasper Johns—it’s no surprise these earlier works reflect issues that dominated formalist painting and music when they premiered.

“Summerspace” reflected frenetic isolation, as dancers appear to scurry about self-absorbed, without regard for each other. It’s raw and abrupt, even violent compared to the second piece: dancers in “Sounddance” appear more fluid. Not only did the dancers interact, but their speed, flexibility, and fluidity revealed more of their classical ballet training.

Described as a “visual artist’s choreographer,” Cunningham has a long record of embracing technologies for what they bring to dance, as well as using them as development and instructional tools. In the 60s and 70s he pioneered choreography for film and video, focusing on what the language of cinematography brings to the mix: how cameras move, cutting from one camera to another, and so on. However, his embracing computer technology in the early 90s derives as much from utility as from adventurousness—motion capture and 3D computer graphics presently offer the most accurate way to record dance.

Working with computers

Cunningham worked with computers in dance for the five years preceding his involvement with Kaiser and Eshkar of Riverbed, and Michael Gerard



Courtesy of Riverbed

Figure 1. Still image from "Ghostcatching." The virtual dancer maintains volume, yet the expressive lines accentuate the dynamics and grace of movement.

and Susan Amkraut of Unreal Pictures. Life Forms was realized in a joint venture between the dance and science departments of Simon Fraser University in British Columbia, with Cunningham and Thomas Calvert of the university involved in the initial development. Subsequently, Life Forms has undergone further development and distribution by Credo Interactive.

Priced under \$500, the recently released Life Forms Pro version 3.5 is a character animation tool for choreography, previsualization, commercial and forensic animation, and movement planning for game developers. Unlike cinematic animation products such as Alias/Wavefront's Maya or Discreet's 3D Max, Life Forms is used primarily to develop motion sequences for export into other 3D modeling, animation, or production environments. In other words, it's a choreographer's notebook. As to his reasons to involving himself in tool development, Cunningham said,

One of its uses is as a memory device. That is, a teacher could put into the memory of the computer exercises that are given in class, and these could be looked at by students for clarification. I have a small number of particular exercises we utilize in our class work already in the memory. But my main interest is, as always, in discovery.

The road from "Hand-Drawn Spaces" to "Biped"

"Hand-Drawn Spaces" was the first effort between Cunningham and Riverbed using the Character Studio software. Motion-captured dance was mapped onto the virtual skeleton, and from still frames of these movements, the artists rotoscoped a sequence of hand drawings that became the final 2D animation. The performance consisted of the animated virtual choreography with the music track.

Thereafter, Kaiser and Eshkar worked with dancer Bill T. Jones to expand the idea of virtual performance at the Arthur A. Houghton Gallery of the Cooper Union School of Art. As skeptical as

he initially was about archiving dance with motion capture, Jones became enthusiastic thanks to the accuracy of the captured results. The goal of their collaboration, "Ghostcatching," was to examine both the dance and space occupied by the virtual dancer.

Eskar revised his drawing style to take advantage of the data's accuracy while maintaining figurative volume. He created line drawings to be texture maps placed on a virtual skeleton: no longer an animated sequence of 2D drawings, each character receives one simple drawing that remains expressive and maintains continuity throughout the sequence. The viewer sees a 3D gestural line drawing in motion that reveals the volume of the character and implies the environment it occupies (see Figure 1). With this bridge from 2D animation to a 3D volumetric motion-capture-driven dancer, the stage was set for the live and virtual dancers to perform together, in what became "Biped."

Working on the Biped

When Riverbed's Kaiser and Eshkar proposed using motion capture with Character Studio as a means of exploring the Cunningham dancers' motions, and 3D spaces as revealed through their motions, the software had not evolved suitably for the task. The Character Studio plug-in for Discreet's 3D Studio Max modeling and animation software (see Figure 2) consists of two modules: a virtual skeleton, or Biped, for which the piece is named, and Physique, used to skin the skeleton with a character mesh. While it already had the advantages of built-in inverse pendulum dynamics to show an accurate, gravity-driven walk cycle and proper anchoring, collision detection, and locomotion through footstep placement, Character Studio could not accommodate raw motion-capture data and afforded no way of joining and editing existing motion files. Unlike Life Forms, 3D Studio Max has a highly evolved tool set for building and texture-mapping characters, whether photorealistic or fantasy based, which made it preferable for generating the final ghost-like images used in the performance. Cunningham's involvement in developing Biped became much of the R&D and primary beta test of what would become Character Studio 2.0.

Dancer Jeannie Steele took part in the motion-capture sessions used to create "Biped" and in all performances of "Biped." I interviewed her for this article just prior to the company's departure on tour with "Biped" in France, Germany, and Italy

this fall. Asked what it was like to see her dance movements in virtual space, Steele answered that at first she was astounded to see the accuracy of the data from the unfiltered sensor patterns—not only could she recognize the distinctive dance movements, she could distinguish her pattern as unique from her fellow dancer. Then there was a secondary feeling of mild humiliation, much like hearing one’s own voice on a tape recorder for the first time.

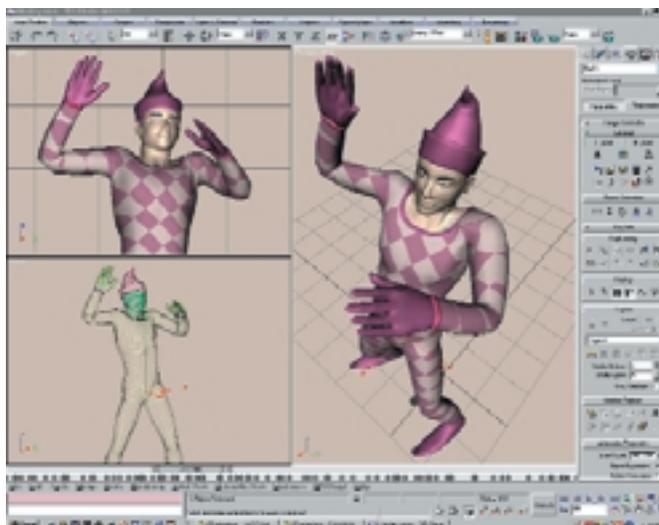
Asked if performing “Biped” differs from performing other Cunningham works, she noted that only rarely is she aware of how this piece is different. “Biped” begins with five solo dances before the first computer graphics character appears. Steele moves on stage as the first virtual dancer appears. She described her first performance with the character as bringing feelings of “being safe” or “having another person dance with me” and “dancing in an imaginary realm” because the dancers see what the audience sees. However, because the dance phrasing is so complex and requires complete concentration, she said these feelings were quickly replaced by her focus on executing her part of the performance.

The dance company’s choreography and rehearsals follow the tried and true Cunningham approach. Every step is choreographed and repeated in each performance. Likewise, the motion-capture data was cut up, recombined, reworked, and recombined again, until each virtual dancer’s program was fixed prior to the premiere. Similarly, the set, costuming, and score do not change. The only changes Cunningham permitted were for Kaiser and Eshkar to revise the artwork used as texture maps on the virtual dancers. However, each element rehearses alone, which makes room for evolution and freshness in performance.

At the premiere performance in Berkeley, one audience member familiar with Cunningham’s work by reputation only commented on “Biped’s” raw quality and how scaling the virtual dancers at normal and larger-than-life size added heroism to their stature. She acknowledged her earlier skepticism about mixing a light show with dancers and had been prepared for disappointment. But afterward she found the dancers needed their virtual colleagues—they provided wings.

Where will they go from here?

The obvious question is “What’s next?” “Biped” will tour Europe this fall and the Western United States in the spring. Steele said she’s not planning beyond that date, although she sees



Cunningham using Life Forms almost daily on his Macintosh G4. There are no current plans to produce “Biped” on film or video. Kaiser and others are hoping to work with Cunningham again on “Loops,” one of Cunningham’s earlier pieces with motion capture, involving only the maestro’s hands.

Kaiser’s solo piece at the California College of Arts and Crafts Gallery in San Francisco departs from the technologically based work done on “Biped.” Named “If By Chance,” the piece involves projecting a series of randomly distributed black and white cubes on screen while a soundtrack composed of dial tones, sine waves, and silence plays in the background.

I, for one, have two hopes for future directions. Modern Uprising is exploring the first—to develop motion capture into an inexpensive, flexible technique for archiving human movement.

The second is for these parties to build on what they’ve done and advance “Biped” the next step. With “Hand-Drawn Spaces” we saw motion capture applied to skeletons and hand-animated with gestural drawings to create the dance. With “Biped” the drawings were mapped onto the skeletons, and the resulting virtual dancers are projected onto the scrim and stage. I’d like to see real-time virtual reality applied to the mix. That is, by spanning the performance across two networked spaces—each with a separate dance group and audience—using real-time motion capture to generate the virtual dancers. The physical performance before one audience simultaneously generates virtual dancers for the other and vice versa.

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Figure 2. Screen shot of the Character Studio plug-in.