

# Touching Space: Using Motion Capture and Stereo Projection to Create a “Virtual Haptics” of Dance

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## ABSTRACT

This paper describes the work of a group of artists in Australia who used real-time motion capture and 3D stereo projection to create a large-scale performance environment in which dancers seemed to “touch” the volume. This project re-versions Suzanne Langer’s 1950s philosophy of dance as “virtual force” to realize the idea of a “virtual haptics” of dance that extends the dancer’s physical agency literally across and through the surrounding spatial volume. The project presents a vision of interactive dance performance that “touches” space by visualizing kinematics as intentionality and agency. In doing so, we suggest the possibility of new kinds of human-computer interfaces that emphasize touch as embodied, nuanced agency that is mediated by the subtle qualities of whole-body movement, in addition to more goal-oriented, task-based gestures such as pointing or clicking.

## Introduction

In computer-mediated environments, where actions and events are conceptual as much as material/physical, what does it mean to touch? In this context, a “touch point” might as easily be virtual as physical. But what would the nature of “virtual touch” be? Questions about the nature of touch and response are really questions about the nature of agency – the power and the will to act within/on an environment. A touch might not, in a digital context, be thought of as exclusively physical, but, on the other hand, given the complex relationships between embodied experience and haptic sensation, might not be entirely conceptual.

Dance has, in the wake of the objectivist, formalist dance that arose during the 1960s and 1970s, tended to think of agency primarily through the materiality of the moving body. Underpinned by the complex association between subjectivity and the materiality of the dancing body that has been traced back to Isadora Duncan and the beginning of modern dance [1], subjectivity has been considered to be inscribed in fundamental movement patterning [2].

Earlier theories, however, were more focused on the nature of agency itself in dance, than on its inevitable relationship with the materiality of the dancer’s physical body. Writing in the 1950s, philosopher Susanne K. Langer put forward the hypothesis that the primary illusion of dance is “virtual force” [3]. She argued that dancers create symbolic representations of agency and will – of power – by evoking “forces” that appear to animate their bodies/selves from within. Langer was describing what might, from a contemporary perspective, be re-versioned as a form of virtual haptics – a metaphorical “touching” of the space around a dancer.

There was no inherent materiality in Langer’s idea of dance as virtual agency because she believed that the original source of dance’s primary illusion, which she called “vital gesture,” was, itself, an illusion. For Langer, a dancer “perturbing” space was an illusion created by carefully calculated movement trajectories and dynamics. “Dance is actual movement, but virtual self-expression” [4]. She described dance as the first instantiation of a “mythical consciousness”

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in which the world was understood as a web of living forces, powers with will, agency, and purpose. Dance, in her view, crafts images of these experiences of agency and power.

Langer describes dance as pure agency. Leaving aside for the moment her critique of the “mythic consciousness” as an early stage of human development (which can be understood as specific to the historical context of 1950s evolutionist/universalist thought), Langer’s writings provide a provocative starting place for exploring the idea that dance might encompass virtual, as well as actual, physical, touch. Touch in digital environments has been “virtualized” – distanced from being, agency, sensation, by the abstract, utilitarian nature of most human-computer interfaces. Dance might provide a means of exploring ways of reinserting the complexity of whole-bodied agency – the nuance of physical sensation and action – within virtualized digital interfaces.



**Figure 1.** Dancers Lisa Bolte and Adam Thurlow perform a pas de deux with real-time motion capture–generated stereo-projected particle trails, created using Autodesk’s Motion Builder. The particle trails and levels of particle acceleration are generated by the movements of different combinations of markers from both dancers. The image is composited to give a sense of the effect, due to the difficulty in recreating the 3D illusion. Photo © James Lauritz Photography.

This paper describes a project that “re-reads” Langer by designing an interactive dance performance system that “touches” space with kinematics, which have embedded in them the subtle, poetic, embodied dynamics of dance; trajectory, velocity, acceleration – the “how” of movement, rather than the utilitarian “what” of task-based gestures such as pointing or clicking. The system embeds live dance performance in a large-scale 3D stereo projection environment driven by live motion capture, to create an interface that responds to the quality of movement, which we argue can be understood as a poetic rendering of agency, a state of being and acting in the world. The system is, in a sense, a literal realization of Langer’s theory, made using a technology that reinterprets her idea of virtual force as extended physical agency. This paper describes i) the system design, ii) the aesthetic issues involved in creating choreographic processes that would facilitate a visualization of Langer’s ideas, and iii) an evaluation of this process as a means of creating a “virtual haptics” of dance.



## Designing and Implementing a Large-Scale 3D Projection System and Live Motion Capture Pipeline

The primary design goal of the project was to develop a visually integrated live/3D stereo environment. The dancer would need to be integrated in physical space with the surrounding 3D imagery, and the whole synthesized by an audience into a cohesive visual percept. This necessitated designing a system with sufficient scale to allow life-sized images to be projected behind the dancer, and enough screen width to provide stereoscopic image separation sufficient to bring images forward to the depth of the dancer. Because the stereoscopic effect of 3D images projecting into the space is produced by presenting separated polarized images to each eye, if an image moves partially off the edge of the screen, the stereoscopic effect is immediately lost. A 400-inch silver-coated reflective screen was installed that provided sufficient area to create stereoscopic images that were large enough to provide an immersive background for the performers, and which could be moved both behind and in front of the plane of the screen.

The system was designed to be portable to allow for use in different performance configurations. We therefore opted for a customized projector/polarized lens-and-glasses system that can be repositioned and recalibrated for different performance configurations, rather than an off-the-shelf system that is difficult and time-consuming to recalibrate and cannot be easily moved to trial different performance configurations.

Motion capture was integrated using a 24-camera Motion Analysis optical system capturing a 10m x 10m volume. The stereoscopic screen was positioned at the back of the capture volume. The audience viewed the performance wearing polarized glasses and saw 3D imagery, driven in real time by the dancers' motion capture data, projected both behind and in front of the projection plane. The 3D imagery appeared, at different times, to expand the dimensions of the performance space behind the projection screen, and to come forward off the screen to swirl around the dancers. Positional motion capture data from 30 markers was streamed in real time to Autodesk's Motion Builder software and to the Unity game engine to provide a range of possibilities for constructing motion graphic environments. As this was an exploratory project, the team decided to trial a number of different approaches to creating stereo imagery that were subsequently shown as a series of seven short (approximately five-minute) vignettes.



**Figure 2.** Dancer Lisa Bolte performs with real-time motion capture-generated single marker trace stereo created using Unity game engine. A single marker (in this case the wrist marker) is used to generate a standing trace of an entire sequence of movement. The image is composited to give a sense of the effect, due to the difficulty in recreating the 3D illusion. Photo © James Lauritz Photography.

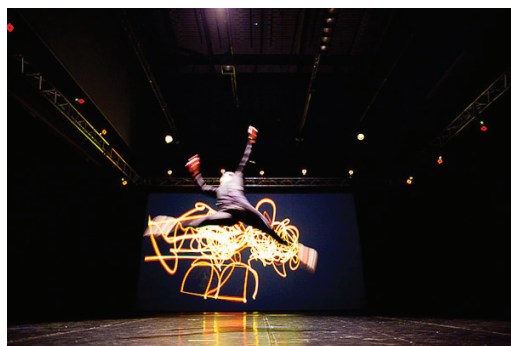
Figures 1 through 4 show the main visual elements used across the seven vignettes. The images are composited to recreate the live effects, given that it is impossible to recreate the stereo experience using either still or moving images. The vignettes used variations on three main approaches to create different kinds of virtual “topographies” from the dancers' movements that were projected across the performance space in 3D. The first approach was to create particle systems that acted as trails, creating a moving topography that both mapped and amplified into the space the movements of specific markers (Figure 1). The second approach created a continuous trail from the movement of a single marker (Figures 2 and 3), which created a visual record

of the entire movement sequence. Virtual camera controls within the program allowed us to “fly through” the trace as it was created, which had the effect of rotating and zooming the image as it was created. The third approach generated a moving topography of geometric shapes that expanded and contracted in response to the dancers’ movements (Figure 4).

### **Choreographic/Artistic Processes – Developing Aesthetic Approaches that Would Underpin a “Virtual Haptics” of Dance**

The aesthetic goal of the project was to augment the dancer’s physical influence by extending it into the surrounding volume. We were not interested, therefore, in creating an improvisational, interactive environment between the performer and the imagery. Improvisational approaches position the dancer within an explicitly interactive “dialogue” with the technology by cultivating and presenting for view reiterative “feedback loops” of intentionality in which dancers respond to images driven by their own actions. While improvisational approaches have dominated computer-mediated dance performance because they foreground the interaction between dancer and technology as systems of relationship [5, 6], and we have ourselves employed this approach in the past [7, 8], this project called for a different approach. We were interested in creating an environment that seemed to extend the dancers’ influence, their apparent interiority in Langer’s terms, across a volume of external space. The image here is not one of feedback, of responding to a system that is, at least partially, a result of one’s own actions, but rather one of influence, in which one’s own sense of physical agency radiates outwards and imposes itself on the surrounding space.

This approach had a certain practical resonance with the fact that, when using this particular 3D projection system, the performer cannot see the stereo images she creates. Even if the performer wears polarized glasses, the image separation is calibrated for the audience and the image appears at radically different depths from the projection plane for audience and performer. This, in itself, might be surmountable through a reverse engineering process in which a performer could rehearse with polarized glasses and mentally re-calibrate the image position from the audience’s point of view. However, the immersion in a 3D environment, the sudden visual/visceral shifts in the z-axis that characterize the 3D experience, remain unavailable to the performer because visual perception of a 3D image is only possible when facing directly to the screen. Consequently, true interaction between the performer and 3D images based on the



**Figure 3. Dancer Adam Thurlow performs with real-time motion capture-generated stereo single marker trace created using Unity game engine. A single marker (in this case the wrist marker, to take advantage of the multiple turns and leaps in the movement material) is used to generate a standing trace of an entire sequence of movement. The image is composited to give a sense of the effect, due to the difficulty in recreating the 3D illusion. Photo © James Lauritz Photography.**

performer’s embodied, kinesthetic/artistic sensibility is impossible in this kind of project. Use of a head-mounted display would give the dancer an awareness of their relationship to the 3D environment, however the works were designed from the perspective of an external audience viewpoint, not the dancer’s subjective view.

A further aesthetic issue was the question of genre. Contemporary dance, by virtue of its historical underpinnings in modern dance, brings with it strong and complex contextual associations with the presentation of subjectivity. Modern dance embraced the apparent production of subjectivity, which Daly terms, in her discussion of Isadora Duncan, the process of making “ongoing movement a



Figure 4. Dancer Lisa Bolte performs with real-time motion capture-generated geometric topography created using Unity game engine. The spheres unfold in different configurations, the scale, direction, and configuration of which are driven by the movement of a single marker (in this case the ankle marker, to take advantage of the linear shapes of the adagio movement). The image is composited to give a sense of the effect, due to the difficulty in recreating the 3D illusion. Photo © James Lauritz Photography.

metaphor for what they then termed ‘soul,’ what we call the self” [9]. Objectivist dance, firstly through the influential formalism of Merce Cunningham and then through the work of the “postmodern” dancers of the 1960s and 1970s, problematized this emphasis on dance as a metaphor for self, using the material physicality of dancers’ movement to expose the “illusory” nature of the subjectivity it had come to suggest. However, the material reality of the dancing body and the production of images of subjectivity in dance are not mutually exclusive, but are interrelated in complex ways, even in the work of artists who might seem to be purely expressive and objectivist choreographers, such as Graham and Cunningham, respectively [10].

For this project, we sought to drive a disjuncture between what Langer termed self-portraiture as the central motif in solo modern dance, along with the reaction it creates – objectivist, “non-subjectivist” dance – and the notion of agency in movement [11]. Drawing inspiration from Langer’s idea of a world alive with teleological forces, we wanted to avoid locking those forces too quickly into either the psychologically charged portrait of dancer-as-self or the objectivist denial of interiority, which are associated, respectively, with expressionist and formalist

formulations of contemporary dance. Instead, we chose to explore contemporary ballet, with its more distanced understanding of the performer-character relationship as one of expression but not necessarily autobiographical association. This genre offered, perhaps in some ways ironically, our contemporary dance team a less familiar and conventionalized space in which to explore a “virtual haptics” of dance. Ballet, while certainly subject to its own conventions of expressivity, provided a movement palette that allowed us to venture into emotionally charged territory without automatically referencing the complex ramifications of the modern dance tradition of dancing self as an embodiment of Nietzschean will [12], in which a created personality is given the dancer’s name [13].

For the first vignette, we developed a choreographed solo that played on the strengths of the female dancer, who is an Australian principal ballerina known for her virtuosic technique, musicality, and powerful emotional interpretations. We created a stereo environment that used the position and speed of head, wrist, spine, hip, shoulder, and ankle markers to generate particle streams. The use of a high-end, commercial optical motion capture system was critical to achieving traces that contained the precise trajectory and dynamic of the dancer’s movement. These were rendered with virtually no perceptible time lag between movement and trace. This ensured that the poetic of the movement quality inherent in the trajectory and dynamics of the marker movement was preserved within the 3D environment. Creating and maintaining a stable full-body template of the performer in real time was challenging, but essential to this process, as well as constituting a significant technical achievement in and of itself.



The spatiality of the projected 3D imagery was mathematically resized and repositioned to compensate for effects of the virtual cameras in the software, which amplify the performer's movement closer or further away along the z-axis with respect to the "real" space into which the environment is projected. This amplification causes mismatches between the scale of the performer and the relative positions of the marker-driven particle trails, which presented both a technical problem to be solved and also an opportunity for creating levels of abstraction in the imagery. Rován et al. argue that a degree of abstraction is necessary in interactive performance to prevent an over-predictable system [14]. In our process, while the particle trails were clearly related to the performer's movement dynamics, they were also spatially offset and their trajectories magnified, so that they seemed to move in the space with the dancer but not to consistently correlate with specific body parts. The spatial mapping between marker and resultant particle trail varied with the distance of the performer from the origin of the capture space along the x- and z-axes, resulting in an ambiguous, if clearly related, connection between performer and image.

The particle trails were imbued with extra acceleration that responded to a threshold root marker velocity, so that the trails, which seemed to stream behind the dancer as she moved, elongated with faster movement, but also seemed to fly further out into space, to disperse and decay, when the dancer moved through space at speed. The effect was of an increased impact on the space with movement, while, conversely, less movement resulted in more compact trails that seemed to coalesce into fiery streams. Complicating this pattern was the different dynamic of the twelve markers driving the trails, which gave rise to constant variation within the appearance of the different particle effects. The conceptual coherence of a highly skilled dancer's body moving in harmonic, physically "grammatical," ways, contrasted with the particle trails, which seemed to amplify the discordance of the movement parameters (velocity, acceleration) that create the seemingly composed, integrated physicality one sees watching the dancer. Juxtaposing these two radically different percepts of the dancing body, in the context of an elite, virtuosic contemporary ballet performance, created a layered and nuanced sense of agency. Rather than a purely or simply psychological metaphor, the work created a sense of the dancer's agency that rippled out into the surrounding volume in ways that were at once psychological/imagistic and mathematical/abstract.

#### **Performance Outcomes – Topographies of a "Virtual Haptics" of Dance**

The effect of projecting real-time 3D images around a dancer was to require the explicit complexity of the audience. The perceptual concentration required when watching the final performances was reminiscent of attempting "magic eye" puzzles in which one must create a disjuncture between visual accommodation (focus) and convergence to accept two separated images as a single visual percept that seems to float off the page. Helen Bailey, discussing her *Stereobodies* project, which presented audiences with two dancers, one real and one a stereo projection, suggests that this process requires a significant suspension of disbelief that highlights the theatricality of the event [15]. The complex 3D pathways of the stereo imagery in our project, and the constantly changing spatial relationships between performer and images, demanded a fundamentally perceptual synthesis of spatial topography. Audiences had to fuse dancer and projected "trompe l'oeil" into a single geometrical percept before a theatrical suspension of disbelief could occur.

Even when this synthesis was accomplished, it was somehow more a metaphorical, conceptual fusion than a simply visual one. Watching, one knows that the particle trails are artificial. They have no substance, no mass, and consist purely of light, so that while we may think we know where they are on the z-axis, we do not know what they are. This allows a metaphorical space in

which the imagery can be what we want it to be. However, it is still material in that it is precisely connected to the performer's movement dynamics by virtue of its replication of the spatial trajectory, velocity, and acceleration of the movement. The dancer walks forward with quiet tension, and streams of fire extend behind her head. She lies on her back and looks into the distance, and trails seem to swirl around her head. She pirouettes, and "fireflies" seem to float in the air around her.

Other vignettes created for this project suggested different kinds of metaphors. A classical ballet pas de deux generated particle trails from each dancer that interwove in an abstract/metaphoric representation of the touch between the two bodies, while enlivening the air above the dancers by extending their movement dynamics into space. The technical requirements of re-spatializing the particle trails generated by two dancers displaced the image further from the performers. This extended the reach of the dancers' apparent influence on the volume, but also stretched the conceptual and perceptual synthesis required of the audience as the spatial mapping became more abstracted. In contrast, the visually denser environments created using Unity generated a single "electrified" trace from the wrist movement of an entire dance and streams of geometrical shapes that created an evolving series of spiraling spheres. These processes created larger, more cohesive environments. The images were much larger than the performers and created a kind of all-encompassing backdrop to the dance that engaged large portions of the audience's peripheral vision. This approach was a much easier visual/perceptual prospect, and while the images tended to be behind rather than around the plane of the dancer, these works created the most cohesive visual effects.

Each of the works generated a different kind of "topography" by extending the illusion of agency embedded in the dancers' movements into the surrounding volume. This implies touch, but proprioceptive feedback in these systems is virtual, not actual. The space cannot "touch back." However, an audience can read into the imagery what they might feel were they to touch space in this expanded, amplified way. Virtual proprioceptive experience in this project could be thought of as similar to virtual kinesthetic experience in John Martin's formulation of "meta-kinesis," through which observers construct and "feel" kinesthetically while watching a dancer's movement that is based on their expectations of what they would feel if performing that movement [16].

### **Conclusion**

For Langer, influence was illusory, an image drawn from pre-scientific culture in which magical/spiritual forces were the only conceptual possibility, and transplanted into a scientific culture in which personal agency is a symbolic representation of the feeling of power. However, in the electronic/digital environment of the 21st century, an understanding of agency in precisely the sense of understanding the "world" as comprising a system of potentially, metaphorically, and—sometimes—actually teleological forces is needed to make sense of new technologies, new intelligences, new conceptions of being. This project uses interactive dance performance to question, challenge, and suggest new ways of imagining the haptics of touch as fundamentally intertwined with a new, perhaps "neo-teleological," understanding of personal agency and action.

Langer's idea of agency is about influence. It is holistic, but not exclusively material/physical. Langer's "virtual force" is not influence segmented by the discrete language of gesture – point, click, yes, no. But, equally, it is not exerted solely through an undifferentiated, organic/embodied physicality. This project provided a process for mapping dance movement to what might be thought of as a way of virtually "touching" space. The distinction between touch as a completed gesture and touch as a manifestation of presence, will, and agency can perhaps be defined by the



ability to embed the nuance of personal action, which in dance translates to the qualities of movement, within an externalizing technological system that also displays the brush strokes of trajectory – of “actions” that are not gestures as such, but gestural in their deliberate spatiality. This project, in creating such a system, provided, firstly, a comment on the nature of touch as agency and, secondly, a nuanced and sensitive system for extending the possibilities of dance beyond the dancer’s body and into the surrounding metaphorical and physical volume.

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