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Expressing Technological Metaphors in Dance Using Structural Illusion from Embodied Motion

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ABSTRACT

We illustrate how technology has influenced creative, embodied practices in urban dance styles by analyzing how technological metaphors underlie conceptual representations of the body, space, and movement in three related styles of urban dance: *liquid*, *digitz*, and *finger tutting*. The creative and technical embodied practices of urban dancers are not well understood in either the ethnographic or creative movement scholarly literature. Following an exploratory netnography of movement practitioners, we claim that unlike most dancers of traditional genres or other urban dance styles, dancers of these three styles frequently employ representations of the body and of space that are geometrical, mathematical, mechanical, or digital. To explain how viewers perceive and understand these metaphors, we extend the perceptual theory of *structure from motion* in order to apply dance performance reception theory to a model we call 'Structural Illusion from Embodied Motion' (SIEM). Our analysis of performance techniques of these styles suggests that during performance, dancers leverage SIEM to represent two types of 'illusions' to viewers: a) the dancer's body has a reconfigurable structure; and b) the dancer is immersed in a virtual environment that contains invisible, mutable objects and structures that are revealed only through the dancer's movement. The three dance styles exemplify a trend in popular dance in which body, space, and time are understood in the language of technology.

Author Keywords
Embodied cognition; perception of motion; popular culture; dance; performance.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous; J.5 Arts and Humanities: Performing arts

General Terms
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INTRODUCTION

From prosthetics to mobile devices to full body interfaces, technology is changing the way we use our bodies. What is less well-understood is how technology influences our mental representations of the body and of space, and how these representations influence creative, embodied practices such as urban dance. While the history and social practices of urban dance and underground subcultures have been studied by cultural theorists and social anthropologists, few have investigated the creative embodied practices of urban dancers. Little research has been conducted that explores embodied cognition in underground urban dance forms, despite the existence of many these styles for over a decade. Moreover, little research has related basic theories of visual perception and spatial cognition with how dancers leverage these perceptual and cultural representations to create expressive, meaningful movement.

In this paper, we illustrate the influence of technology on human movement by arguing that technological metaphors underlie conceptual representations of the body, space, and movement in three related styles of underground urban dance styles known as *liquid*, *digitz*, and *finger tutting*. These three styles exemplify what has been called *underground illusion-based* dance styles, so named because these dancers frequently talk about creating "illusions" [25]. Our main contribution is a model based on the perceptual theory of structure from motion. Our model, which we call 'Structural Illusion from Embodied Motion' (SIEM), explains how dancers of underground illusion-based styles use movement to express imaginative, technology-driven conceptual representations of the body and space to their audience. During performance, dancers leverage SIEM to persuade viewers of two types of illusions: a) the dancer's body has a reconfigurable structure; and b) the dancer is immersed in a virtual environment that contains invisible, mutable objects and structures that are revealed only through the dancer's movement. In order to illustrate the model of SIEM, and as a secondary contribution, we also advance a detailed description and a movement-centric analysis of the dance techniques that have been uniquely developed by these dancers. This analysis is based on a netnography (an internet-based ethnography [16]) of the

online communities of practice in which these dancers participate. In a discussion forum post to other illusion-based dancers, dancer phedhex states that "as a culture, [our community] pretty much spawned from computers. The dance is borne out of technologically based music, and many of us are in computer related fields… What I'm saying is that we inhabit 3d computer space" [22]. The goal of this paper is to support and elaborate on phedhex's proposition. We argue that unlike most dancers of traditional dance genres or other urban dance styles, dancers of these three styles systematically and uniquely employ representations of the body and of space that are 'technological', We define this as having a geometrical, mathematical, mechanical, or digital form of representation that supports the movement form. Our research is significant to studies in creativity and cognition because the urban dance form incorporates a sophisticated set of transformations operating as a technological metaphor that correlates with the sophistication of the movements and movement 'operations' chosen to represent that metaphor*; technological metaphors that support more variation, complexity, and detail result in movement with greater expressiveness, articulation, and phrasing.*

We begin by describing how illusion styles dance emerged from the context of an evolving technological culture. We review the use of technologies in movement construction for dance, as well as the perceptual theory of structure from motion on which our model relies. We describe how we used internet-based ethnographic methods for collecting and analyzing examples of illusion-based dance styles, and present our analysis of movement techniques. From our analysis, we develop and describe the SIEM model. To conclude, we summarize our contributions and our main findings, suggest further applications of SIEM, and briefly review other trends in popular dance in which body, space, and time are understood in the language of technology.

BACKGROUND

We review the history of liquid, digitz and finger tutting in order to show that the development of these underground illusion-based styles is strongly linked with the emergence of various technologies. Our review supports the argument that references to geometry, Cartesian mathematics, mechanics, or digital technology that are used in descriptions of canonical movement techniques point to underlying technological metaphors that dancers use in their imaginative construction of dance movement to promote greater nuance and expression. We show how unlike contemporary underground illusion-based styles, a dance style called the *robot* uses technological metaphors that are limiting instead of emancipating.

An overview of liquid, digitz, and finger tutting

Each of the three underground illusion styles have had separate but related histories, as the styles share common characteristics. All three styles focus on the expressive

mobilization of the arms, hands, and fingers. Dancers of one style often dance other styles equally well, or collaborate with dancers of other styles to form collectives known as crews. For instance, the Liquid Pop Collective (LPC) was an influential crew that, in 2001, released and widely distributed the All Access Liquid & Digitz Tutorial, a VHS recording that described canonical liquid and digitz techniques. Members of the LPC subsequently formed another influential crew, the Dark Matter Squad, which includes influential dancers of other styles such finger tutting. We return to the importance of recording technologies to the development of the styles in this section.

While the precise origins of liquid are contested, liquid is closely associated with the underground rave culture of the United States in the early 90s, which is founded on electronic music; we discuss the importance of electronic music with respect to movement aesthetics in the next section. Liquid dancers move their fingers, hands, arms, and upper torso with a flowing, continuous quality, as if these parts were made of a thick silk ribbon. Figure 1 illustrates a canonical liquid technique called a rail.[1]
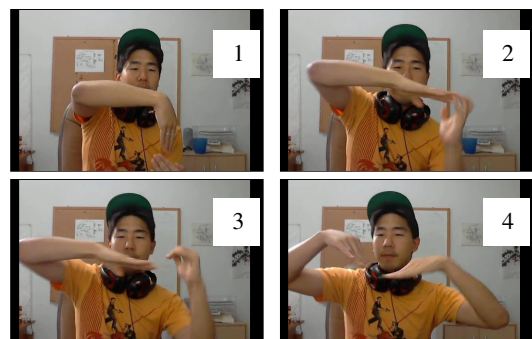
Figure 1. Still captures of one of the authors performing a rail
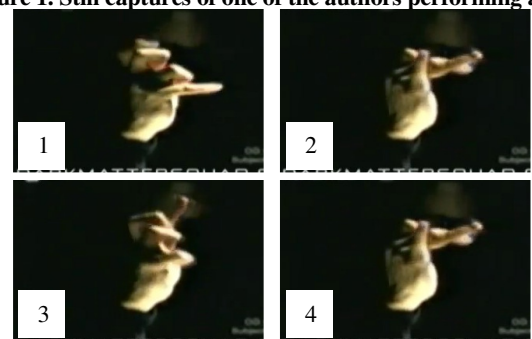
Figure 2. Still captures of a dancer performing a roll. From [7]

Digitz was reported to have begun in the club scene of New York City around 1997 and owes its name to one individual's observation that a particular dancer's "fingers looked like a set of 'mechanical digits'" [7]. As the name suggests, digitz focuses almost entirely on the expressive mobilization of the fingers. Figure 2 features still captures of a video demonstration of a technique called a roll.

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[1] Videos that demonstrate these dance techniques clearly are available on *http://archive.org/details/Illusioning*

Finger tutting is the most recent of the three styles. Various accounts of finger tutting's history suggest that it was derived through the combination of digitz and a genre known as *tutting*. The style's name derives from the Egyptian pharaoh Tutankhamun, purportedly referencing the 90-degree angle of the wrist, elbow, and shoulder joints in ancient Egyptian pictographs and murals [12]. For that reason, tutting is most distinctly characterized by the use of right angles in the shoulders, elbows, and wrists; in the case of finger tutting, there is additional attention to angles of the metacarpophalangeal joints and interphalangeal joints.
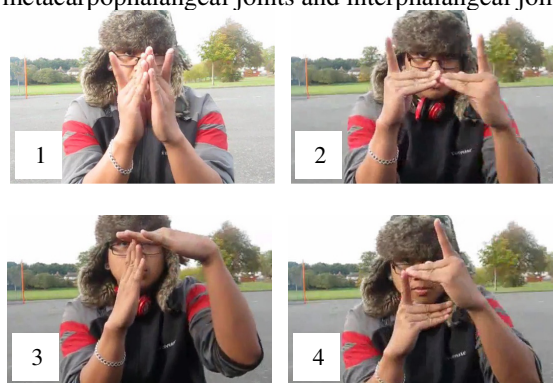

Figure 3. Still captures of a dancer performing finger tuts [21]

Cultural and historical links to technology

The development of underground illusion-based styles is directly connected with the emergence of technologies, electronic, recording, networked, broadcast, and digital technologies. For instance, underground illusion styles were originally danced to electronic dance music (EDM), a musical form originating in underground club subcultures and is typically created using synthesizers, sequencers, and analog and digital equipment and software. Characterized by the extensive use of rhythmic and tonal repetition or "looping" [11], EDM was a primary motivator for many underground illusion styles dancers [19]. The movement aesthetics of a dance form is in part influenced by the qualities of the music to which it is most commonly paired. Indeed, dancers have reported translating characteristics of the music to which they dance into their dance movement [19]. For instance, while an urban dance style such as *hip hop* uses dramatic shifts in the dynamics of weight, tension, and speed to accentuate the heavy downbeats of hip hop music, liquid's emphasis on continuous movement would seem to resonate with the more trance-like quality of, say, an EDM genre known as *house*. Thus, the aesthetics of underground illusion styles are often mediated by the particular qualities of electronic music to which they are danced, demonstrating how the expressivity of a technology-mediated phenomenon is subsequently correlated with the expressivity of the human movement practices that engage with that phenomenon.

The spread of underground illusion-based styles is also directly connected with the emergence of various recording, broadcast, and networked technologies. Peer-to-peer file sharing networks such as Kazaa and recording technologies such as VHS (as mentioned earlier) helped popularize video performances of and video tutorials for liquid and digitz in the late 1990s to early 2000s [19]. Currently, many illusion styles dancers interact with each other significantly (if not primarily) using digital and Internet media. Unlike most communities of dance practice, a significant number of illusion styles dancers discuss dance-related issues online more often than they do in person [19], while some have reported participating in online improvisation sessions.

Another reason to suggest that technology plays an important role in the development of underground illusion-based styles rests on the fact that many illusion styles dancers work in a field that regularly requires them to program, design, or build digital or electronic artifacts; in fact, compared to traditional dance communities, a disproportionately large percentage of illusion styles dancers know a low-level programming language such as machine code or assembly [19].

Figure 4.The Dark Matter Squad logo [7]

Dancers often construe their identity using technological tropes. Talking about his "personal philosophy about liquid", for instance, dancer 'phedhex' states that "it's about abandoning human form in favor of digital ones" [19]. His philosophy of favoring digital tropes in his dance is reflected in other aspects of the urban dance community. A sampling of names and profile pictures of the Facebook profiles of the EDM Dance Facebook group and of various liquid and digitz dancers' YouTube channels suggest that phedhex is not alone in recasting at least part of his identity as technological. On the Floasis.net forum, one member goes by the handle 'Mechanical psuedohuman'. The Facebook avatar of dancer CodeRed features him with his arm around a retro-looking robot. A dancer who goes by the name ShiftedShapes has observed the similarity between a now well-known gesture in finger tutting and the logo of a camera shop that was visible from the lineup of one of the clubs that EDM dancers had frequented in the past; the gesture mimes the viewfinder of a camera [19]. Most significantly and telling of all, the logo of the Dark Matter Squad (which, as mentioned, consists of highly influential dancers of liquid, digitz, and finger tutting) features a set of robotic fingers (Figure 4).

Technological metaphors and movement expressivity: The robot body in dance

That the Dark Matter Squad's logo consists of robotic fingers is significant. In dance, the arms, hands, and fingers frequently reflect the trope of the *robot* [19]. In most

popular dance-based interpretations of a robot body, the hands, arms, and fingers are stiffened and drawn tightly into each other, allowing little to no mobility. Yet the human arm, hand, and fingers are highly articulated and expressive bio-mechanical structure that consists of a great number of articulating joints. In the robot, however, these body parts are re-imagined as having fewer articulating joints and having a more limited range of motion. The fingers remain locked with the hand; the opposable thumb (one of the physical markers of humans as tool-makers and tool-users) is gone. In contrast, the Dark Matter Squad's logo suggests what is clear when watching dancers of liquid, digitz, and finger tutting: mechanism does not necessarily mean reduced bodily expression. We argue in this paper that the use of technological metaphors can create greater, not less, nuance and articulation.

RELATED WORK

We divide our review of related work into two parts: uses of geometric forms in the construction of movement in dance practice; and visual perception and spatial cognition.

Technologies and movement construction for dance

The use of geometrical forms in dance has a long history. Ballet—a highly codified form—has been developed from a large corpus of standard movements, such as the *battement* and the *port de bras*, that require dancers to extend their limbs towards predefined positions in space such as back, side, and front. Using ballet as a point of departure, Merce Cunningham—whose work was influenced by both Rudolf von Laban's theories and by computer technology [25]—explored combinatorial and chance processes to shape a unique choreographic vocabulary subvert typical movement patterns in the ballet tradition. In Martha Graham's 1930 work *Lamentation*, dancers are encased in a tube of stretchable fabric that augments the viewers' perception on the relationship of the moving body to space through the curves, lines, and surfaces created by the fabric as it is deformed by the dancer [2]. In Chunky Move's 2011 work *Connected*, dancers' limbs are attached by a series of cords to a multi-articulated kinetic sculpture [24]. Drawing from Laban and Ullman's [18] description of Platonic solids and crystalline forms, contemporary choreographer William Forsythe [10] superimposes lines and shapes in post-production editing that are used by dancers to imagine virtual objects in space and interact with them as if they were actually present. However, while all these examples use technology for imaginative movement construction, such approaches are uncommon in urban dance.

Visual perception and spatial cognition

While cognition and creativity research in dance has focused on areas such as dancers' neural activity during performance [4], kinesthetic empathy [3,20], and factors that enable creative decision making during choreography [6], little has been reported on how dancers leverage visual and spatial cognition principles for the purposes of creating

specific perceptual impressions on the viewer. Our results suggest that in order to embody certain technological metaphors, illusion styles dancers extend the theory of structure from motion as described by Ullman [28]. The term 'structure from motion' has been used to define different but related perceptual phenomena [1]. For instance, the term has been used in the context of inferring biological structures from motion cues. Johansson [15] established that sparse moving point-light displays can create the impression of "biological motion" such as walking and running. Kozlowski and Cutting [17] showed such point-light displays can suggest the sex of the mover.

In this paper, we use the term 'structure from motion' to describe how motion cues can be used to infer the 3-dimentional properties of an object. It can be seen one of several pictorial cues that include shape from shading, cast shadows, and occlusion, each of which can imply underlying 3-dimensional structures [5]. These pictorial cues are crucial for conveying the spatial relationships (such as depth of scene and relative distances between objects) in cartooning and animation [31]. Structure from motion proceeds from what Ullman calls the *rigidity assumption*: if elements that undergo a two-dimensional transformation can be uniquely be interpreted as a rigid body moving in three-dimensional space, it should be interpreted as such [28].
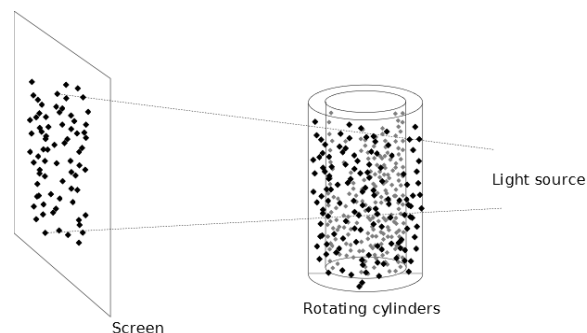

Figure 5. Reconstructing shape from motion using the rigidity assumption.

For instance, consider the experimental setup shown in Figure 5 first described by Ullman. Two nested transparent cylinders are covered in dots. Light passes through both cylinders and the dots cast shadows on a screen. When the cylinders are stationary, an observer looking at the screen cannot discern a pattern to the dots. When the cylinders rotate, however, the observer can infer that the dots form the contours of two distinct cylindrical shapes because of the rigidity assumption.

In this paper, we adapt the notion of structure from motion and conjecture that illusion styles dancers leverage viewers' assumptions about the fundamental properties of Euclidean space and of dancers' bodies to create illusions about the structural properties of the human body and the space around it, similar to how structure from motion relies on an assumption of rigidity for non-deformable shapes.

STUDY DESIGN

Because illusion style dance communities are understudied and are widely dispersed across the world, it was necessary to conduct an exploratory, netnographic study of the community. To this end, we collected data from a wide variety of primary sources. *Archival video footage*: We relied primarily on the LPC's All Access video and the Dark and sampled the digital cultural archive of the community consisting of thousands of videos publicly posted online of dancers performing liquid, digitz, finger tutting, and other related styles. *Informant interviews*: We extended interview invitations to dancers to liquid, digitz, or finger tutting. Six responded. The interviews focused on gathering the informants' personal views on dance technique and themes on the body, space, and technology. *Discussion forum posts and other digital cultural archives*: The EDM Dance Facebook group [8] was started in September, 2011 by one of the members of the Dark Matter Squad. The group currently has 507 members. We examined posts over an eight-month period starting from September 13, 2011 to May 21, 2012 as well as discussion forum posts from March, 2009 to April, 2011 on Floasis.net, a community site for liquid dancers. We also relied on material found on the website of the Dark Matter Squad, whose mandate centers on the goal of "preserving, documenting and archiving" liquid and digitz [7].

We organized and coded primary sources using Atlas TI, a qualitative analysis software program. During our analysis, we drew from our first-person, phenomenal experiences learning and rehearsing illusion styles techniques. The authors of this paper have significant experience in dance, technology, and movement analysis, with two being Certified Laban Movement Analysts, and one author being an active participant of urban and electronic dance music practices.

RESULTS

Across all three styles, we found that dancers used a canonical vocabulary for describing their movement techniques. The techniques often require the dancer to treat space and their bodies in geometric or mathematical ways.

Liquid

As mentioned, liquid dancers move their fingers, hands, arms, and upper torso with a flowing, continuous quality. Occasionally, this sinuous quality is transferred to the lower body. While the feet are richly-jointed, their full articulative possibilities are rarely explored (as they are in ballet, for instance), particularly since dancers tend to wear shoes that discourage mobility in the feet except at the ankle joint. Drawing from mime, liquid dancers also create illusions of shapes in the air by the rapid and fluid movement of their upper limbs. Table 1 lists selected canonical liquid styles and techniques and their descriptions, which are quoted from the All Access Tutorial video.

Liquid techniques (selected)	Description
Rail	To range in a line. This is accomplished through the use of imaginary paths along which you flow can travel.
Contour	To make or shape the outline of a figure, shape, body or mass. To contour is to make your liquid run the shape of the object. The objects themselves can range from imaginary geometric shapes to actual physical objects.
Build	Using liquid to move imaginary objects about in space. Consider exactly how that object would behave. Imagine how it would look if you actually held it in your hands.
Folds	Trace[s] the structure of a 2-dimensional plane in 3-dimensional space. The 'fold' is the act at which the hands turn to show both sides of the plane or move from one plane to the next. This movement emulates folding an imaginary piece of paper by tracing the linear lines within each plane.
Hand flow	Exceptional liquid dancers can create the illusion of having no bones in the hands and keep a steady flow indefinitely with no unintentional stops, stutters or breaks.
Speed control	Speed is important in liquid, the flow must always be kept in a constant steady speed to create and keep the illusion. Speed changes can also occur, but should be done in concert with the music's tempo or sounds.

Table 1. Selected liquid techniques. Adapted from the All Access Liquid & Digitz Tutorial video [7]

Digitz

Some digitz techniques recall the sinuous quality present in liquid; indeed, they can be seen as the focused application of liquid to a more confined, more distal section of the body. If in liquid the body appears to be made of silk ribbon, digitz can create the illusion that fingers are made of wire of variable flexibility. Other techniques create the impression of great control over the fingers. "Precision" and "isolation" are terms that can spring to mind when watching certain digitz techniques, reminiscent of the kind of facility required to play wind instruments and keyboard instruments at a virtuosic level. Skilled digitz dancers can also control each phalange at a time. Table 2 lists selected canonical digitz techniques and their descriptions.

Finger tutting

As mentioned, finger tutters often focus on angles of the wrists, metacarpophalangeal joints, and interphalangeal joints. Finger tutters are capable of precisely aligning joints into highly recognizable angles, notably 90-degree and 180-

degree angles, but also (to a lesser extent) other angles, such as 45 and 60 degrees. The style places a value on creating legible shapes using the limbs. In order to do so, tutters must 'hit' a shape and 'hold' it long enough for the image to register with the viewer. The use of right angles can result in a 'mechanical' feel to the movement. Dancers must be able to quickly but cleanly transition from shape to shape while retaining musicality in their movement.

Digitz techniques (selected)	Description
Finger Waves	The creation of a fluid flow from one side of the hand to the other using the fingers.
Rolls	A perfectly repeated rounded wave where the last part of the roll triggers the first origin of the roll. In all phases of the roll the pinkie and first finger remain at opposite sides of the diameter created by the roll.
Contortion	This technique involves bending a wave so that it appears to be pinched at its central axis and structuring back into another wave.
Axis Shifts	Taking any digit technique and shifting the hands opposite along a vertical or horizontal axis. A pause in flow occurs where hand [r]eorientation is achieved utilizing robotic straight lines and fixed-point rotations.
Fixed 45s	A linear fingerwave technique where a single iteration consists of pulling a line in the fingertips 90 degrees through a fixed point achieved by approaching and exiting the fixed point at mirrored 45 degree angles. Fixed 45s can be used to create square waves, triangle waves and sawtooth waves.

Table 2. Selected digitz techniques. Adapted from the All Access Liquid & Digitz Tutorial video [7]

Unlike liquid and digitz, a codified set of techniques does not currently exist for finger tutting. However, two canonical concepts are fundamental to the style: the tutting grid and the fixed point. The tutting grid is a three-dimensional lattice of imaginary points which dancers use as guides for aligning their arms, hands, fingers, and phalanges. Other body sections (such as the shoulder girdle area) may be used as well. The concept of a tutting grid structures space in way that evokes Cartesian coordinate geometry in Euclidean space. As one dancer, Kai, has described the grid, "Think of it as dots in space and also dots on your body. They're kind of dots in space that you align your body against." [9] Figure 6 illustrates these ideas. The image on the left shows blue dots that represent locations on the body, while the green dots represent imaginary locations in space that can be used for aligning body parts. The fixed point is "a stationary point within [the dancers'] environment…All other objects interact with that

point." [7]. Video tutorials posted by tutters place an emphasis on the fixed point [19]. Dancer Tiny Love—a prominent dancer in the urban dance community—goes so far as to emphasize that "absolutely everything we do is related to fix point", underscoring the fundamental importance of this concept [8]. The fixed point is also used in digitz [7].

Figure 6. A visual representation of the tutting grid [9]

We found that the movement techniques across the three dance styles could be grouped into two categories: a) techniques that convey the illusion that a dancer is immersed in an environment containing invisible, mutable objects and structures; and b) techniques that convey the illusion that dancing body has a reconfigurable structure. These illusioning categories can be broken down into three methods. To perform techniques from the first category, dancers engage in what we call *spatial tangibilization* and *spatial quantization*; to perform techniques from the second category, dancers engage in *rejointing*.

Spatial tangibilization

To a dancer, space need not be a vacuum through which the body simply moves. Space can be imagined as being thick as honey, grainy as sand, or unrelenting as steel. One of choreographer William Forsythe's improvisational techniques, *volume avoidance*, calls for dancers to temporarily imbue the space with the physical properties of a well-defined solid (for instance, a cylinder) around which dancers must improvise while strictly respecting the physical properties of the solid [10]. The imaginative power and refined bodily skill of trained dancers allows them to regard space itself as tangible and expose this tangibility to the viewing audience through their movement. Talking about liquid, Dark Matter Squad member Code Red has remarked that "space around you needs to be seen as a substance, pliable and having resistance and physics" [19]. We call this dance-based, tangible treatment of space *spatial tangibilization*.
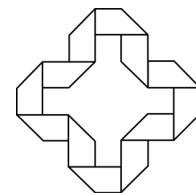

Figure 7. The imaginary shape mimed in a fold. From [19]

Contours and rails are techniques that use spatial tangibilization. Like Forsythe's volume avoidance, both create the illusion that a dancer's hands are outlining an object in space. A common approach to contouring would be to run one's hand along space in a straight, continuous way for some seconds, conveying the impression that the space is empty; at a certain point, the shape of the hands and fingers changes to signify that the hand has collided with an object and is now shaping itself around that object, which then also reveals the shape of the object to the viewer. A rail can be considered a specific instance of contouring. The object to be contoured consists of flat surfaces. In Figure 1, the dancer performs a rail by contouring the top and sides of a box. By moving his hands and his fingers in a precise and coordinated way, the dancer visually indicates where the seams of the box are. Builds and folds are two other liquid techniques that also rely on spatial tangibilization. While builds are described in sufficient detail in Table 1, a fold needs more explanation. A fold tangibilizes a complex structure in Cartesian space that is the result of "a two dimensional rail" which is shifted on along the cardinal axes as the dancer performs the fold [19]. Figure 7 is a rendering of the object resulting from these geometric operations.

Spatial tangibilization is also used in digitz. In the finger wave, while it is possible to do this technique slowly, speed is required to perform the movement in a compelling manner. One approach to the successful execution of a closed-fist finger wave is to imagine a small object (such as a marble) passing through the fists, and the fingers lifting in response to it. The movement is easier to execute than when "thinking muscularly", since imagery allows the neuromuscular system to create the appropriate connections [13:238]. The illusion is even more pronounced when the movement is performed quickly and in a repeated manner, creating the illusion that the movement is not due to the volitional movement of the dancer but due to the existence of an external agent acting upon the dancer (in this case, a virtual marble passing through the fists). To summarize, *spatial tangibilization creates illusions of objects in the performance environment where none exist*. In fact, one goal of a dancer would be to able to tangibilize space so skillfully that all viewers would be able to perceive the same imagined objects.

Spatial quantization

The subdivision of space into discrete segments (spatial quantization) is a metaphor often used in contemporary technologies. Consider, for instance, the Western system of subdividing a circle into 360 equal angular units [14]. Moreover, the subdivision of space into discrete points is fundamental to contemporary digital technologies. For instance, raster screens (which represent images using a discrete number of pixels) have now completely supplanted vector screens, which drew images through a combination of points and (analog) lines [32]. The tutting grid uses subdivisions of space that recall the work of Laban and Ullman [18], who distinguish between "space in general" and "the space within the reach of the body" (p. 10). They define the latter as the *kinesphere*, which can be understood as the volume around our body that circumscribes our 'personal space'. Laban and Ullman also describe locations embedded in the kinesphere, which they call *directions*. Laban describes twenty-seven distinct directions in total, each of which he assigned a symbol. Laban and Ullman's conception of directions in the kinesphere evokes the Cartesian coordinate geometry of Euclidean space, where an object's location in space is often given as a group of three numbers in the form *(x, y, z)*, as shown in Figure 8 on the left. The image on the right is one interpretation of the tutting grid, which strongly references Cartesian coordinate geometry. The image also suggests that the grid can be used to create shapes at a number of different scales. In fact, it suggests that the grid is fractal and "scaleable" [19] in order to accommodate the varying sizes of the limbs. To reinforce the illusion of a coordinate system, dancers will move their hands and fingers in specific with ways with reference either to one of the three cardinal axes or to an *ad hoc* axis created by a body part, such as an extended finger. Linear translations along, and rotation about, these axes are common. (See for instance [29].)
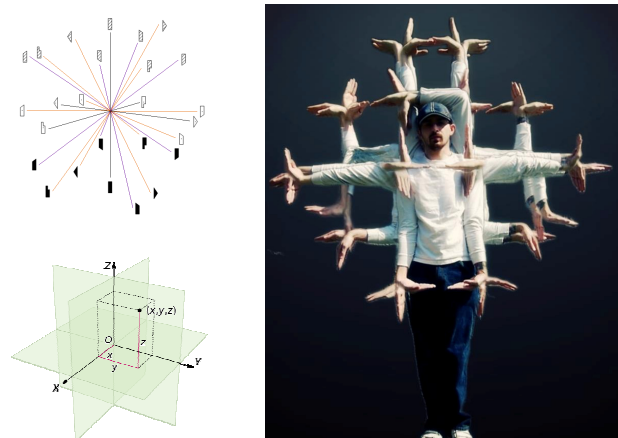

Figure 8. Laban's 27 directions, the Cartesian coordinate system, and an interpretation of the tutting grid [9]

Spatial quantization *suggests canonical directions and lattice points—invisible but substantial—that delimit the range of the movement of the body*. Both spatial quantization and spatial tangibilization suggest to the viewer that *the performance environment contains invisible, mutable objects and structures that are revealed only through movement of the dancer*.

Rejointing

The effective execution of certain techniques is best accomplished by the dancer conveying the illusion that their bodies are configured differently than those of a human being. Consider hand flow in liquid. As Table 1 indicates, "exceptional" dancers can "create the illusion of having no

bones in the hands" when performing a hand flow. In order to perform this successfully, it is productive to imagine that the hands are linked together at the fingertips. Indeed, in a tutorial on hand flow, YouTube user tuberroni [27] recommends the use of a sock held between the hands to simulate imaginary joints, thus allowing the successive sequencing of joints to occur across the hands. The sinuous, coordinated, yet unnatural movement of the hands (motion) can suggest to the viewer that the anatomy of the dancer is configured in a particular way (structure). A similar analysis can be applied to the digitz technique of finger waves, which involves the difficult task of extending and flexing the third finger and the fourth finger of the hand independently. Because the audience has implicit knowledge of how difficult this action is based on an awareness of their own bodies [26], a fluid and even execution of a finger wave could suggest to the viewer that the joints of the dancer's hands are structured differently than their own. The half-finger wave [19] is even more challenging: it requires the fingers to fold halfway, at the second set of interphalangeal joints, in rapid succession while keeping the first set of interphalangeal joints extended. Because of the difficulty of mobilizing the second interphalangeal joint independently from the first interphalangeal joint, a viewer might be temporarily fooled into believing that the first interphalangeal joint may be immobile or even that it simply does not exist.

Figure 6 shows still captures of a move from tutting called 'boxing'. While the resulting shape is simple, the body mechanics required to produce it is sophisticated. One shoulder needs to stabilize while the scapula on other shoulder abducts and rotates upwardly; the wrist on one hand needs to flex at exactly the same rate as the wrist on the other hand extends all the while keeping the metacarpopholangeal and interphalangeal joints fixed. In order to perform the movement with ease, it is productive for the dancer to imagine that finger joints simply do not exist, that the wrists have equal mobility in both flexion and extension (which is typically not true), and that an (imaginary) articulating joint physically connects the fingertips to the crook of elbow. When the move is performed skillfully, these reconfigurations of the body's joints are legible to the viewer.
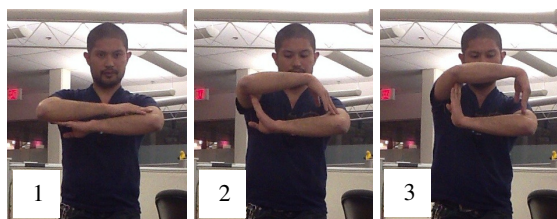

Figure 6. One of the authors performing a 'box'.

To summarize, rejointing requires the dancer to reconceptualize the connections between body parts in different ways. *It prompts the audience to endow dancers'*

bodies with joints where there are none and to believe in an absence of joints where they are in fact present.

DISCUSSION

Across all three illusion styles of dance, dancers use body movement to convey the illusion that the dancer is immersed in an environment that contains invisible, mutable objects and structures, or that the dancing body has a reconfigurable structure. In both instances, they convey illusionary structures, either of space or of the body, through movement. We propose that the illusions work because viewers hold assumptions about the fundamental properties of Euclidean space and of dancers' bodies. First, the performance space is assumed to be empty and continuous, and when dancers treat the space as non-empty (through spatial tangibilization) or discontinuous (through spatial quantization), viewers also perceive the space as such because it is the 'simplest' explanation for movement that viewers understand (through the embodied knowledge they hold) would be difficult to perform. Second, when dancers move using techniques grounded in rejointing, the movement is often so sophisticated to perform that a viewer might receive the impression that the dancers' bodies are configured differently than theirs because this is also the 'simplest' explanation that can account for what they see. These two points can be summarized by the following conjecture: *When gestural movement is observed which appears to the viewer as difficult to execute, all other things being equal, there is a preference to choose an interpretation at some cognitive level which requires the least sophisticated mechanics of the body, even if the interpretation requires the viewer to accept alternative models of the structure of space or the body*. This conjecture is what we call Structural Illusion from Embodied Motion. Unlike explanations of perceptual phenomena such as structure from motion or the Gestalt principles, SIEM is prone to "instructional bias" [30]. Furthermore, it is enabled or confounded by factors which vary depending on the gesture being performed. These factors include the following: **Speed**—An illusion succeeds only if the movement is performed at a minimum optimum speed, the value of which depends on the particular movement technique. **Stability/Mobility Precision**—A convincing, 'clean' execution of an illusion requires retraining the neuromuscular pathways to alternately stabilize and mobilize various parts of the arms, hands, and fingers in unfamiliar ways, such as moving the fifth finger independently from the fourth finger. **Repetition and spatial consistency**—Many illusions work only if they are repeated, and only if the repetitions involve the movement follow similar or identical trajectories through space.

Figure 7 illustrates how we propose Structural Illusion from Embodied Motion operates in the context of performance and viewing of underground illusion-based dance styles. Consider how the Structural Illusion from Embodied

Motion conjecture might be used to explain why the rail illusion in Figure 1 works.
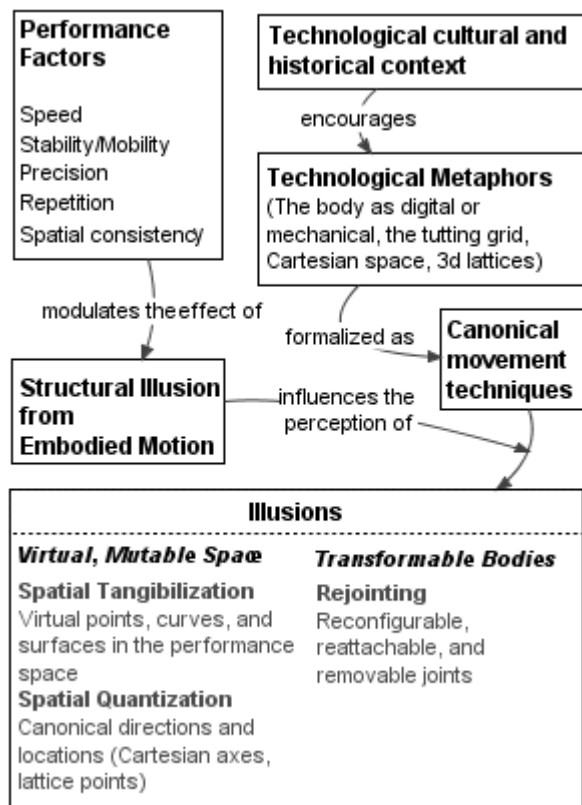

Figure 7. SIEM applied to illusion-based dance styles

We suggest that when viewing the rail, the viewer picks from one of two interpretations. **Interpretation 1: There is no box in the space. The dancer is merely moving in a very complicated way.** The dancer would need to follow a complex sequence of actions that includes keeping the a sequence of body parts in precise angles of 90 and 180 degrees using a sophisticated sequence of flexion and extension of the joints of the hands and arms. The movement as a whole needs to be done quickly and repeatedly, yet in time with music. This is not easy to execute, though it is precisely what a skilled dancer would do. According to the Structural Illusion from Embodied Motion conjecture, a more 'reasonable' explanation might be **interpretation 2: There *is* a box in the space. The dancer is simply allowing the shape of the box to guide their movement.** The arms—magically joined at the finger tips—are simply being pulled up, around, and down the box. On some level, the 'viewer's eyes tell them' that there is no box, and that there is nothing keeping the dancers fingers tied together; but the 'body tells them' that the presence of the box would provide the most 'sensible' explanation from an embodied perspective. At least for a moment. *We propose that this moment of embodied/cognitive dissonance makes the movement compelling,* and that the strategic ordering and

accumulation of such moments through choreography explains (at least in part) the efficacy of the movement aesthetics of all illusion-based styles.

CONCLUSION

Our research advances two contributions. The first is a model entitled 'Structural Illusion from Embodied Motion' that explains how dancers use movement to express technology-driven conceptual representations of the body and space to their audience. We suggest that SIEM can be applied to analyses of the expressive and communicative function of human movement in general and creative movement in particular, such as dance, mime, and puppetry. The skilled leveraging of SIEM could be seen as an indicator of *virtuosity* for such practices. We also advance that the cognitive and motor abilities of illusion-based dancers are worth further investigation. Recent research suggests that mental imaging tasks related to objects external to the body are implicated in the development of motor skills. For instance, Pietsch and Jansen [23] suggest that the ability to perform mental rotation is correlated not only with rotational hand movement but gross motor skills. If movement practices of underground illusion-based dancers facilitate heightened spatial abilities, these practices could be adapted to math and science learning, or for learning complex mechanical structures or systems.

Our second contribution is an argument on how technological metaphors and operations on these metaphors can strongly influence imaginative conceptual representations of the body, space, and movement. We argue that the range by which the metaphors can have variations and can be operated on, is strongly correlated with the expressive range of embodied representations of these metaphors. It is well-established that the tools we use influence the creative practices that depend on them; in this study of three related urban dance styles, we illustrate how this can be true even in the realm of dance, particularly if one considers electronic music and digital media as "tools" that are used in dance practice. Furthermore, while technology has inspired the creation of new movement vocabularies in popular dance—such as hydraulics and its influence on the robot dance—the three urban dance styles described in this study represent deep and systematic uses of computational and geometric metaphors to an extent that is unprecedented in the history of popular dance. We anticipate that as technologies (and the metaphors that arise from them) develop, we will see increasingly more movement behaviors that evoke these metaphors. Iindeed, liquid, digitz, and finger-tutting exemplify a trend in urban dance in which body, space, and time are understood in the language of technology. The robot style continues to evolve, while a dance style involving LED-tipped gloves ("gloving") is gaining popularity. "Animation" and "strobing" are styles that evoke the effects of cel animation and strobe lights respectively by creating illusions of *time* rather than space or the body; one particularly arresting

example of which involves a dancer moving as if they were viewed on a videotape that was being rewound [19]. Such references to technology-mediated conceptions of time, space, and the body appear more frequently in popular culture and bear further inquiry.

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