Catching the ghost: the digital gaze of motion capture

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Abstract. Created with digital motion capture, or mocap, the virtual dances *Ghostcatching* and *as.phyx.ia* render movement abstracted from choreographic bodies. These depictions of gestural doubles or 'ghosts' trigger a sense of the uncanny rooted in mocap's digital processes. Examining these material processes, this article argues that this digital optical uncanny precipitates from the intersubjective relationship of performer, technology, and spectator. Mocap interpolates living bodies into a technologized visual field that parses these bodies as dynamic data sets, a process by which performing bodies and digital capture technologies coalesce into the film's virtual body. This virtual body signals a computational agency at its heart, one that choreographs the intersubjective embodiments of real and virtual dancers, and spectators. Destabilizing the human body as a locus of perception, movement, and sensation, mocap triggers uncanny uncertainty in human volition. In this way, *Ghostcatching* and *as.phyx.ia* reflect the infiltration of computer vision technologies, such as facial recognition, into numerous aspects of contemporary life. Through these works, the author hopes to show how the digital gaze of these algorithms, imperceptible to the human eye, threatens individual autonomy with automation.

Keywords. computer vision • digital performance • gesture • mocap • motion capture • movement • uncanny • virtual dance

In 1999, Paul Kaiser and Shelley Eshkar of Riverbed Media collaborated with choreographer Bill T Jones to produce *Ghostcatching*, a virtual dance installation at the intersections of dance, drawing and digital imaging. Using digital motion capture, or in common shorthand, mocap, they filmed Jones improvising in the studio and 'making what was to be called a virtual motion alphabet: a catalogue of isolations, undulations, shudders, and various other personal movement strategies that I employ in my dancing' (Jones, 2002: 107). The dots he wore on his body, first stuck to his naked form and later, to a suit, were coded as choreographic data. This captured data then went through various digital processes, including Eshkar's tedious stroke-by-stroke

modeling of 'hand drawn' splines, curves described mathematically by connecting a series of points which can deform with movement, to ultimately produce a figure reminiscent of a gesture drawing. Jones's sampled movement phrases were then remixed and released in virtual screenspace. The installation premiered at Cooper Union in 1999. As it unfolds, the original lone figure who opens the piece spawns more dancing figures. As these figures dance with each other, they perform an uncanny multiplication of Jones's dancing body. Slipping between the interstices of live and digital performance, these ghosts dramatize the disjunction between actual and virtual bodies.

Several virtual dance performances have since tested this tension in their onscreen renderings of movement. Described by some as 'dance freed from the body' (Boucher, 2011), mocap has been a rich resource for choreographic investigations into the formal qualities of dance. Merce Cunningham's collaboration with Riverbed Media, *Biped* (1999), William Forsythe and Ohio State University's *Synchronous Object for One Flat Thing Reproduced* (2009) project, Maria Takeuchi and Frederico Phillips' *as.phyx.ia* (2015), and RISE Interactive Umeå's *MocapTango* (2016) have each transformed dance into choreographic data objects that can be studied, visualized, remixed, mapped onto any virtual body, and placed into new aesthetic and institutional contexts. As a movement art invested in the virtuosic performances of live bodies, dance is a particularly rich field for exploring how digital forms of production mediate embodiment. Turning mocap's digital gaze upon living, moving bodies, works such as *Ghostcatching* make visible the computational filters through which even the most prosaic human movements become virtual. Such virtual performances have often sought clarified motion, distilled from the distractions of the corporeal body. The resulting figures dancing onscreen have made uncanny twins of the original dancers, ghosts reproducing an ineffable something of the source choreography.

This uncanny doubling is not unique to mocap, and has precedents in cinema and animation technologies like rotoscoping. Such phantasmic representations in early cinema aroused fear and astonishment in its first spectators, feelings often attending the arrival of new technologies. At their emergence, misunderstood new technologies might seem to come from a realm of magic and superstition, rather than one of science and rationality. In this respect, they can revive unconscious beliefs in a mystical, animate world. Framed within the theoretical history of the concept, these affects respond to a specifically technological uncanny, with features variously described by Ernst Jentsch (1995[1906]), Sigmund Freud (1955[1919]), Masahiro Mori (1970), and others. Understood as one manifestation of the technological uncanny, early cinema became a ghostly lens for a number of optical technologies born of the 19th century, symptomatic of what Tom Gunning (2008) calls the modern optical uncanny.

In its spectral doubling, the undecidability of its animate subjects and inanimate objects, and its ensuing provocation of unnerving affects, mocap emerges from this optical lineage of the technological uncanny. Yet, film and mocap dwell in different visual regimes; film records and reproduces the moving body as photochemical image, while the latter atomizes it into dynamic data through infrared measurement. Produced at the very end of the 20th century, *Ghostcatching* reflected a contemporary transition to digital imaging technologies in various personal, commercial, and governmental contexts. This includes the extensive commercial use of mocap in major studio films, such as *Star Wars: The Phantom Menace* (1999), *The Lord of the Rings: The Two Towers* (2002) and *Happy Feet* (2006), to name a few. Since then, digital technologies have only continued to infiltrate numerous aspects of daily life. In social media, shopping, banking, and corporate and state surveillance, much human activity is observed, tracked, measured, and transformed into data by inconspicuous algorithmic actors. Enforcing the logic of what Shoshana Zuboff (2019) calls 'surveillance capitalism', these data systems enable corporations to anticipate and structure human behavior. Created with a widely available personal device, the Microsoft Xbox Kinect, rather than the professional mocap system used for *Ghostcatching*, the recent virtual dance project *as.phyx.ia* (2015) represents this circumscription of everyday human performance into invisible streams of data. Through my analysis of *as.phyx.i.a*, I show how mocap interpolates the living body into a formalized and technologized visual field, remarkable for its digital granularity. Through this process, performing bodies and digital capture technologies coalesce into the virtual body of the mocap film. For performers, as for spectators, this virtual body signifies a properly computational optical agency at the heart of mocap's uncanny animacy. Further, I argue that mocap's animating gaze structures both real and virtual planes of experience for performers navigating the medium. For performers, mocap's material demands cultivate a distributed perception that ultimately blurs the distinction between original dancer and virtual double. Exercising its computational logics on these intersubjective embodiments, mocap choreographs both living body and digital ghost. Herein lies the disquiet at the heart of mocap's digital optical uncanny: not only do mocap's ghosts stoke resurgent fears about an animate world, but they also suggest that humans are both subjects and objects of this animation. Their uncanny motility, an agency bound to yet distinct from human movement, triggers uncertainty in embodied human volition.

This indeterminacy afflicts human movement as well as human vision. It is the very act of spectatorship that consummates mocap's uncanny and animating gaze upon human subjects. By its very processes of decomposing gesturing bodies into musculoskeletal data, the medium utilizes aspects of visual perception that allow people to recognize human motion signatures. The experience of seeing human movement filtered through mocap's quantifying processes, I claim, conscripts spectators

into this computational perspective in a curious alignment of human and computer vision. Through this intersubjective perceptual encounter with its virtual body, mocap compels human recognition of its gestural ghosts. With the perceptual complicity of its human viewers, the medium lends its proliferating virtual figures a choreographic agency that places human volition into question. Mocap's uncanny effects arrive from the decentering of the human body as a locus of perception, sensation, and volition. Challenging any conception of a unified self, this experience of intersubjectivity reflects how digital culture fissures human embodiment into numerous virtual alter-egos. These works also anticipate how the widespread use of digital technologies may restrict users' repertoire of gestures into a lexicon legible to the machine.

This in turn highlights a corresponding model of racialization enacted by algorithms. Scholars (Eubanks, 2018; Noble, 2018) have shown how structural inequality is coded into various digital tools, from facial recognition to Google Images search. Despite claims to computational objectivity, these technologies reproduce the biases of the humans who program them. Through its conscription of human perception, mocap mirrors this human complicity in the construction, affirmation and dissemination of stereotypes. By erasing the epidermal markers of racial difference, *Ghostcatching* and *as.phyx.ia* dramatize how, in their very deployment, these supposedly 'colour blind' algorithms camouflage their intrinsic bias. Though imperceptible to the human eye, these algorithms structure manifold personal, social and governmental transactions, threatening individual autonomy with automation. This all matters because of the insidious penetration of computer vision, and other forms of data processing, into numerous facets of contemporary life. Though 'the digitization of everything' promises a more connected world, its more pernicious effects may be invisible.

Virtual dances, virtual others

The dancing ghosts of *Ghostcatching* refract the computational logics begetting mocap's virtual others. Upon arrival at the studio for the initial tests, Jones was aghast to find himself surrounded by technologies of reproduction – the lights, cameras, tripods and screens, and the 24 markers taped to his body. 'Dancers have a strange piety', he remarked, 'a romantic notion that only the ephemeral moment of performance counts' (cited in Rindler et al., 1999: 41). Invoking critics who saw recording as a blasphemy, he charged Kaiser and Eshkar with 'ghostcatching', a name that stuck. Certainly, media have long been haunted by ghosts. From the séances that emerged in the wake of wireless telegraphy, to the specters photographers swore they had caught on film, these amorphous spirits have shadowed media in curiously medium-specific ways. These ghosts, as Brian Rotman

(2008: 113) theorizes, are 'media effects, invisible, technological agencies that emerge, under appropriate circumstances, as autonomous, self-enunciating entities. They are medium-specific, their character an action being intrinsic to the medium in which their existence is manifest'. Such ghosts are manifestations of the specific virtualities that media midwife into being, and tell us much about the materiality of different recording media. Jones's digital ghosts show how mocap, unlike photochemical media, is built on the computational extraction, decomposition, and rendering of choreographic data.

Digital motion capture is a catchall term encompassing a variety of different protocols and systems that have evolved since the 70s and 80s. It involves the recording of a live movement event by tracking a number of data points in space and through space, its subsequent encoding into calculable mathematical data and a final rendering of these points into a three-dimensional dynamic representation of the performance. Or, as Alberto Menache (2000: 1) describes, 'it is the technology that enables the process of translating a live performance into a digital performance.' The ghosts flitting across *Ghostcatching* trace the slippages in this process of translation.

Ghostcatching explicitly frames itself as a reckoning with the erasure of the live body from choreography, but to a spectator something remains of this origin. Perceptible to the eye, this digital interplay of absence and presence animates the medium's uncanny effects. In the catalogue that accompanied the installation, Kaiser and Eshkar pose one question as a motivating force for the project: 'What is movement in the absence of the body?'[1] Dance critics have responded accordingly, expressing their unease at the elision of Jones' politically charged body as a gay, black man with a highly individual dance style. As Ann Dils remarks, in *Ghostcatching* 'Bill T. Jones's often fierce movement is performed by gutless animated line drawings' (2002: 94). Danielle Goldman (2004) situates this choreographic abstraction within a longer history of imaging technologies and their concealment of racialized working bodies. While the late 1990s saw Jones take a formal turn from explicitly political and identity-centered work towards aesthetic exploration, he never sacrificed his politics; in *Ghostcatching* he sought to 'challenge the so-called freedom of abstracted movement, the imagined purity of form' (Goldman, 2004: 83). Although intrigued by the technology's extraction of his motion, Jones informed his collaborators, 'I do not want to be a disembodied, denatured, degendered series of lines moving in a void' (cited in Rindler et al., 1999: 39). The installation, replete with images of his sweating, labouring body, resonant with his voice speaking and singing history, mitigates this absence. At the same time, something of Jones's essence as a dancer does survive in the wispy computer-modeled lines (see Figure 1).
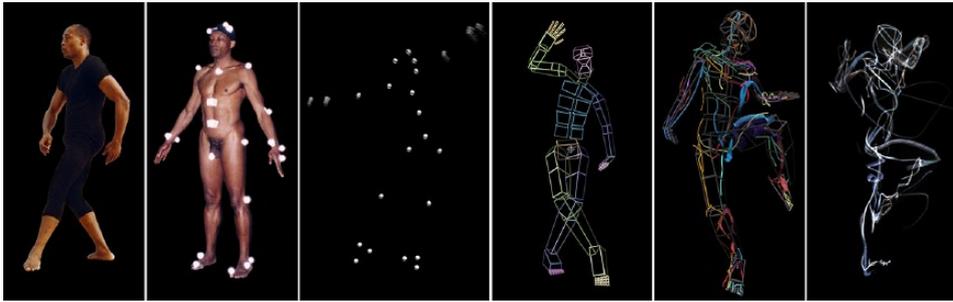
Figure 1. Transforming Bill T Jones into a dancing gesture drawing took a number of steps. From his initial improvisation in the studio to the discovery of the initial markers' failure to cling on to his sweaty body and finally the rendering of the captured motion data into its final form, the process wrestled with the simultaneous absence and presence of his body. Image: © 1999 Bill T Jones, Shelley Eshkar, and Paul Kaiser. Reproduced with permission.

For Jones, this some*thing* becomes some*one* else, a performance of alterity that both does and does not resemble him. When he first saw his mocap dots on screen, Jones highlighted the ambiguous agency enlivening his ghost, asking, '*Who* am I looking at?' (cited in Rindler et al., 1999: 41, emphasis added). Although committed to live performance, Jones was struck by the strange veracity of the captured movement, later telling Eshkar and Shelley that it was like the 'first time you saw the back of your head in a mirror and went, "Oh, so that's what I look like!"'. While this anecdote casts Jones as the spectator to his own performance, this moment of visual recognition highlights the material interplays that trigger the medium's uncanny effects for others watching.

Imaging the technological uncanny: from photographic doubles to digital ghosts

Like some other moving-image media, mocap produces a double at once alien and familiar. These doublings of real people, real movements, real spaces and real life have often inspired a kind of narrative working-through onscreen. Since their beginnings, many narratives in cinema and animation have reflected these media's technical conjuring of artificial life, from the cinematic sorcery of Georges Méliès' trick films to more playful cartoon depictions such as the *Out of the Inkwell* cartoons of the 1920s and 30s, whose technique of rotoscoping is often cited as a precursor to mocap. Yet, more than just mediated doubles, these representations give life to resurgent feelings that are the province of the technological uncanny. Scholars (Bloom, 2000; Gunning, 2008; Mulvey, 2006) have cast such early depictions as phantasmic revelations of the unconscious, incarnations of the fear and astonishment these technologies aroused upon their emergence. In this respect, while mocap finds its spectral lineage in a number of other media, it is distinct from mechanical or photochemical forms of the uncanny.

Technology has long animated debates about the nature of the uncanny. As is well known, uncanny feelings are attuned to the particular technologies that produce them, be they mechanical, photochemical, or digital. Examining the psychical conditions of its emergence, German psychiatrist Ernst Jentsch (1995[1906]) theorized that clockwork automata could induce an uncanny feeling due to their categorical mutability, an unnerving similarity of animate subjects and inanimate objects. Jentsch built his account on the character of Olympia in ETA Hoffman's story 'Der Sandmann' (1816), a lifelike automaton whom Nathaniel, the tale's protagonist, takes for human and falls in love with. Questioning Jentsch's claim that uncanny feelings take root in the undecidability of human beings and nonhuman objects, Sigmund Freud (1995[1919]: 220) interprets Hoffman's story differently. Freud finds the locus of the uncanny in the Sandman who tears out children's eyes, through which he ultimately connects it with processes of repression and repetition. Through his etymology of the German term, *unheimlich*, he identifies the uncanny as 'that class of frightening which leads back to what is known of old and long familiar', characterizing it as the revelation of that which 'ought to have remained hidden but has come to light', or in Freudian terms, the return of the repressed (pp. 222–223). Driven by the compulsion to repeat, the uncanny is realized in aesthetic experiences such as déjà vu, the appearance of a doppelganger, paranoid behaviors, and so on. In this respect, the advent of new technologies may arouse feelings associated more with magic and the unknown than the scientific rationality that sires these developments.

As incarnations of the technological uncanny, emerging media can refract these affects in medium-specific ways. Describing the technological uncanny, Laura Mulvey (2006: 43) diagnoses the return of long-buried feelings: 'As new technologies are often outside popular understanding when they first appear, the most advanced scientific developments can, paradoxically, enable and revive irrational and superstitious beliefs in an animate world.' Where Jentsch located the source of uncanny feelings in clockwork automata, cinema filtered this fear through the lens of optical technologies. According to Mulvey, early cinema instantiated a new and varied form of the uncanny that can be understood from the perspectives of both Freud and Jentsch. Linking the realist films of the Lumière Brothers with Méliès' fantastical trick films, she casts live-action cinema as epitomizing the medium's uncanny properties:

> From the perspective of the uncanny, the arrival of celluloid moving pictures constitutes a decisive moment. It was only then that the reality of photography fused with mechanical movement, hitherto restricted to animated pictures, to reproduce the illusion of life that is essential to the cinema. (p. 52)

Understood in this way, the cinema manifested the illegibility of the moving body as neither here nor there, at once real and unreal, human and almost-human.

Emerging from the scientific revolution in imaging technologies, such realist depictions exorcised an ancient, yet essentially modern fear. Tom Gunning (2008) frames this cinematic uncanny within the context of modernity, articulating how cultural conditions shaped by radical new technologies stirred these dormant feelings. In Gunning's account, early cinema's uncanny effects harnessed the 19th-century preoccupation with visual devices, ranging from the scientific, such as microscopes and telescopes, to media such as magic lanterns and film. At its origins, cinema confronted spectators with profoundly lifelike images that they knew to be illusions, 'generat[ing] its own uncanny optical fantasies in its first audiences' (p. 83). In these fantasies, cinema's optical unconscious surged into visibility, ignited by the ostensibly mystical effects of modern technologies. Straddling the uncanny boundary between perception and misperception, in their novelty such devices seemed to stoke magical effects and, with them, unnerving affects. Characterizing this as the 'modern optical uncanny', Gunning says:

> Modern skepticism about supernatural causes and mastering of the principles of optics through modern science and mechanics gave birth to a modern uncanny in Freud's sense: an encounter with a mode of thought seemingly surmounted whose apparent recrudescence causes an unsettling yet fascinating sensation ... With the modern science of optics the possibility of generating such sensations directly and intentionally gave birth to a modern optical conjuring. (p. 85)

Symptomatic of a time when visual devices were understood as prosthetic extensions of the human eye, this modern optical uncanny has, by and large, waned. Computer-generated images bypass the relationship of human eye and visual machine, abetting the emergence of digital forms of the optical uncanny and, with it, resurgent anxieties. Like the once-new technologies that preceded it, mocap resuscitates primitive beliefs in an animate world. Enlivened by digital processes, however, this non-human agency assumes a distinctly computational form.

Data asphyxiates: photogrammetry and mocap's optical uncanny

As early cinema engendered uncanny fantasies rooted in modernity's fascination with optical devices, so too has the digital medium of mocap. Mocap, however, arrives from technological structures of looking fundamentally different from the analogue visual devices that shaped the advent of cinema. Analogue optical devices like film cameras have been cast as artificial eyes that nevertheless sustain the perceptual centrality of the human body. In an era increasingly defined by digital imaging, looking no longer requires a human subject. Computational images move 'vision to a plane increasingly independent from the position of an embodied observer.

They replace the human eye with practices and techniques that no longer refer to the presence of a viewer whose gaze may structure or even produce the visual field' (Koepnick, 2004: 98). Instead, the visual fields people inhabit are often structured by a computational gaze bereft of a human observer. Characteristic of contemporary modes of surveillance, tracking, and data-mining, this digital gaze measures human activity in bits, figuring human embodiment within a formalized field. For human viewers of captured choreographic data, this 'sightless' vision contours mocap's digital uncanny, reviving repressed beliefs in an animate world. Where the modern science of optics enabled early cinema's primitive fantasies, however, mocap conjures the specter of a properly computational visual agency. At moments of glitch and failure, this agency becomes visible. Psychic expressions distilled by the technology, these aesthetic qualities intimate a contradiction at the heart of mocap's uncanny, precipitating where bodies attempt to break free from its constraints, and from its malfunction.

Somewhat paradoxically, the medium gains its expressive possibilities from its enclosure of performing bodies within the virtual space constituted by its visual field. In *Ghostcatching*, the uncanny arrives where embodied freedom meets mediated confinement. During capture sessions for *Ghostcatching*, Jones felt his choreographic freedom curtailed by the material demands of recording. He found the concrete studio floor cold and unyielding, and wires also tethered him to a smaller space than when he was improvising his movement alphabet in earlier sessions. Despite this, as Paul Kaiser (cited in Rindler et al., 1999: 47) describes, 'in between equipment malfunctions, he kept breaking free of these restrictions, performing magnificently' and 'much of this ambience made its way into *Ghostcatching*. The wire tethers, the constricted space, the effort to break free – all of it is there.' As it bubbled to the surface of the captured image in *Ghostcatching*, mocap straddles this paradox. At the same time, *Ghostcatching* renders other images of confinement that conjure the specter of structural racism; the virtual spawns that emerge from the initial figure are ultimately frozen in space by blue traces and boundaries. Noting that 'confinement plays a critical role in the auction block and black exploitation that haunts Jones,' Danielle Goldman argues that these images 'evok[e] the historical criminalization of black mobility' (2004: 85, 84). From the time of the Southern slave system in the USA, which prohibited the free movement of black people, to current 'stop-and-frisk' laws that are unjustly used to police people of colour, restrictions on black mobility have enacted structural racism. These government policies are not perceived to be structurally racist in and of themselves. However, their inequitable deployment, rooted in implicit bias, affirm a model of racialization based on visible racial difference (Richardson, 2017). Yet, though *Ghostcatching* evokes this history, its erasure of the epidermal markers of race portend a new model of racialization built on computation. Racism remains a visual pathology, even if the viewing subject is no longer human.

A more contemporary virtual dance piece created with mocap rehearses its spatial paradox; in so doing, it manifests the medium's digital optical uncanny for the human viewer. *as.phyx.i.a* (2015) is an experimental film project by Maria Takeuchi and Frederico Phillips that uses motion capture technology to explore human movement in dance. At once defining and confining the dancer, it dramatizes how the medium interpolates the living, dancing, performing body into a digital visual field. The intervening 16 years between *Ghostcatching* and *as.phyx.ia* saw the proliferation of digital devices for personal, corporate and state use. Created with a widely available personal technology, rather than the professional system used to produce *Ghostcatching*, *as.phyx.ia* reflects this tightening of algorithmic processes on daily life. At once defining and confining the dancer, it dramatizes how the medium interpolates the living, dancing, performing body into a digital visual field. *as.phyx.i.a* (2015) is an experimental film project by Maria Takeuchi and Frederico Phillips that uses motion capture technology to explore human movement in dance. The team used two inexpensive Xbox One Kinect sensors to capture the dancer Shiho Tanaka's yearning choreography and then rendered the gestural data inside a near photo-realistic environment. However, the final rendering arrives in stark contrast to the constructed realism of the environment. Tanaka's dancing body, neutered of any identifying features, is a writhing cloud of points and lines that connect these dots all over her body. The contours of her dancing figure flicker as dots on a surface, her organic motion laminated by a shimmering veil of wires, like an ephemeral cloud of data (see Figure 2).

In its depiction of a dancer's yearning but restricted movements, *as.phyx.ia* dramatizes the tension between the 'eloquent choreography that stresses the desire to be expressive without bounds' and the aesthetic markers of the technology that have brought it into being (Takeuchi and Philips, 2015). Here, Tanaka's movement signature as a dancer is legible, yet as the distilled movement animating the piece unfurls, it cannot breach the veneer of flickering points and lines that both define and confine it. So rendered, this data cloud makes visible the optical processes of motion capture; abetted by infrared light, the medium enframes the moving body within its visual field and computationally decomposes it into discrete dynamic data.

Shrouding Tanaka's choreography in a data field, *as.phyx.i.a* performs the Kinect's technical process of motion capture. The Kinect works by using processes known as structured light and machine learning. It projects a predetermined, speckled pattern of infrared light onto the scene, analyzing the data to create a depth map. It employs two techniques of computer vision, depth from focus and depth from stereo, to do so. The depth information gleaned from this map is then used to infer body parts and calculate a skeletal model of any humans using a randomized decision forest. A sophisticated version of a decision tree, this random decision forest classifier sorts each pixel as being either a body part or background. Trained on over a million

Figure 2. *as.phyx.i.a* depicts Tanaka's body as caught in a viscous web of data from which she cannot escape, despite her dancer's flexibility and reach. Her arms stretch and her back arches, expressing the graceful motility of her figure, but the lines move with her. The lines here both define and confine her movement even as they erase all corporeal markers of identity. Screengrab from *as.phyx.i.a* (Maria Takeuchi and Frederico Phillips, 2015), Vimeo, https://vimeo.com/121436114.

examples of skeletal models, the machine then clusters pixels of body parts together on a frame-by-frame basis. Unlike videogame controllers, which are highly specialized devices, the Kinect is considered a Natural User Interface (NUI) for multimedia (Carmody, 2010). While it can and has served as a gaming interface, since its release in 2010 it has found extraordinary traction in diverse fields, including medicine, fashion and robotics. Its deployments as a creative technology, as in *as.phyx.i.a*, reveal some of the broader cultural and ontological stakes in its use.[2]

From technics to aesthetics, the Kinect sanctions Tanaka's metamorphosis from dancer to a writhing cloud of data. After the Kinect sensors captured her choreography, this transformation took many steps. As the project site (Takeuchi and Philips, 2015) describes:

> Once all the scanned point cloud data was combined, that was then used as the base for the creative development on the piece. A series of iterative studies in styles followed and several techniques and dynamic simulations were then applied using a number of 3D tools for various results.

Like digital strings wrapping her body, at once defining and confining her movement, these rendering choices merge technics and aesthetics, making visible the infrared field that laces the space through which she moves. Where the technological processes that begat *Ghostcatching* also employed machine vision, the data field deployed by the Kinect far exceeds the number of dots used to capture Jones's choreography. *as.phyx.i.a* performs the atomization of the moving body into data, visually rendering a digital subject. Indeed, while motion capture is most often associated with the cinema, mocap does not reside in the regime of the image. Optical motion capture is 'more about photogrammetry data analysis than visual interpretation, since the actual visual "look" of a captured body might be intended to change once the data is mapped onto the "look" of a digital avatar' (Salazar Sutil, 2015: 204). While electromagnetic motion capture solicits this gestural data differently, it abides by a similar logic, a mathematization of human movement. Through this process, motion capture formalizes human gesture, breaks it down into calculable bits, stores these parts and ultimately recombines them.

As both Jones' and Tanaka's experiences of dancing with mocap show, this field embodies the unnerving animacy of digital optical devices. The uncanny quality of their digital ghosts arrives from the computational processes that observe and quantify their movement. As a recording medium, mocap solicits choreographic data through infrared vision and measurement, an operation different from photography. As Paul Kaiser (Rindler et al., 1999: 108) observed from his experiences using optical motion capture with Bill T Jones's extraordinary choreography in *Ghostcatching*, 'it's true that motion-capture is a process of subtraction, of taking away. The infrared cameras have eyes only for the reflective markers worn by the performing bodies, and not for the bodies themselves.' His language here is telling, as he emphasizes the optical agency of the mocap cameras and the machines interpreting the data. So described, the motion capture system redefines human embodiment as granular data set, legible to the machine if invisible to human eyes. According to Danielle Goldman, this abstraction of the moving body from sweat and skin places *Ghostcatching* within a racialized 'genealogy of [18th and 19th century] automatons and mechanized figures' that fetishized labour without fatigue (2004: 69). Ernst Jentsch (1995 [1906]) theorized such automatons as early harbingers of the uncanny. Their digital reincarnation in mocap's ghost discloses a racialized dimension in the history of the uncanny, embedded in the medium's digital gaze. For Goldman, Jones' performative assertions of his political identity challenges these prior 'mechanized commodifications of the body' (2004: 83). Where *Ghostcatching* emphasized Jones' racial identity through his oral history, however, *as.phyx.ia*'s abstracted subject does not speak. Shiho Tanaka's identity as a Japanese woman is obscured. Extinguishing epidermal markers of race, gender, and labour, *as.phyx.ia* imagines computer vision's digital gaze as totalizing.

Used for mocap, the XBox Kinect paradoxically extends the optical regime begun by earlier systems even as it does away with the corporeal burdens that have dogged these efforts. Unlike Jones during capture sessions for *Ghostcatching*, Tanaka is unencumbered by the technical requirements of the technology, or the spatial dissonance of the studio. Although the Kinect sensors and the computers processing the data were certainly present and visible, the piece was performed and captured in a dance studio, and Tanaka did not have to wear a specialized suit or the reflective markers that have long been associated with mocap. Clad in comfortable dancewear, Tanaka was able to move through the studio with ease and freedom. This physical mobility, however, is in service to a different mediation of space, as she dances in a literal optical field projected by the Kinect. This virtual field blankets her body more thoroughly than the 24 markers stuck to Jones's body yet its span is invisible. In this way, *as.phyx.ia* highlights a contemporary shift towards a model of racialization enacted by computer vision technologies such as facial recognition. While the lack of a human observer might promise objectivity, recent studies (Eubanks, 2018; Noble, 2018; Zuboff, 2019) have shown that supposedly neutral algorithms reproduce the biases of their human programmers. Like the Kinect's infrared visual field, the very deployment of algorithms camouflages the biases that inhere in them. In *Algorithms of Oppression* (2018), Safiya Umoja Noble shows how Google Images reinforces racial stereotypes as a result of search protocols, advertising, and marketing. In Noble's telling, these results 'normaliz[e] structural and systemic isolation', with oppressive outcomes for marginalized groups (2018: 10). Like mocap's digital gaze structures Tanaka's field of movement, so too do these invisible algorithms structure the virtual spaces of daily human performance. Registering a paradoxical tension between expressive freedom and mediated confinement, these digital ghosts show how mocap's animating gaze choreographs performing bodies.

Uncanny space, distributed perception

By structuring performance space, mocap's digital gaze choreographs the linked embodiments of original dancer and virtual double. As a medium, motion capture fissures choreographic bodies into dynamic bits by situating them within a quantifying virtual field. Although invisible to the human eye, this virtual field exerts its digital logics over the bodies it cocoons. Exercising its animating force on both real and virtual bodies, mocap blurs the boundaries between original performer and digital ghost. Distributed across real and virtual planes of experience, a performer must navigate more than one dimension. This distributed perception fosters a spatial ambiguity that scaffolds the intersubjectivity of real and virtual performers, and undercuts any sense of a unified self. At the same time, this intersubjectivity underwrites the medium's capacity to animate both human and nonhuman actors. In this

way, not only do *Ghostcatching* and *as.phyx.ia* depict the medium's optical agency, but they suggest human movements might not be entirely their own. Reflecting the increasing prevalence of algorithmic forms of vision in daily life, corporate and state governance, their ghosts thus testify to the transformation of the concept of the uncanny within digital culture. Mocap's digital optical uncanny forebodes that computational processes choreograph human movements in ways that place embodied human agency at stake.

In mocap, reframed by some filmmakers and scholars as performance capture or performance animation, performance is the beginning of a collaboration between performer, digital capture technology, and animator. Some have thus emphasized the inadequacy of the moniker motion capture as a label that fails to convey the technical and creative intricacies of the medium. According to Brad DeGraf and Emre Yilmaz (1999: 34), both renowned for their work in using motion capture for computer animation, mocap 'combines the qualities of puppetry, live action, stop motion animation, game intelligence and other forms into an entirely new medium'. They prefer the term 'performance animation', casting motion capture as only the first step, the sampling and recording of data, in a creative process. The other two steps, of that motion being applied to a digital 3D scene representing a character's various body parts in a three-dimensional scene (which can be human, animal or abstract) and the rendering of that scene into a digital image either in real-time or post-production, is where animators can apply their creative palettes. Rather than comparing it with photographic forms of recording, Maureen Furniss (1999) argues that mocap more resembles electronic music recording and production, particularly sampling. Like sample-based music, 'mocap plays great jazz – a jazz of movement, that is' (Salazar Sutil, 2015: 204). So conceived, the fragments of choreographic data parsed by the capture technology become a kind of digital clay, available for remix and transformation. For performers, this transformation begins at the very moment of capture.

Due to its anchoring in live performance, mocap is sometimes known as digital rotoscope, an appellation that signals its ambiguous relationship with reality. The rotoscope is a hybrid animation technology that merges traditional hand-drawn animation techniques with motion picture technologies. Rotoscoped bodies are drawn by animators tracing over projected frames of live-action footage. Developed by Ko-Ko the Clown's creators, Max and Dave Fleischer, the technique lends, as Joanna Bouldin (2004: 7) suggests, an 'ontological or phenomenological thickness or presence' from the original body to the animated figure. This 'contagious contact with the original' brings the animated body 'in closer proximity to the real' (p. 13). Via several layers of analogue connection, the gestures of this animated body claim a connection to reality. Certainly, like rotoscoping, mocap negotiates an unstable territory between the real and the virtual. In its uncanny duplication of gesturing bodies, the rotoscope has elicited its own unease from audiences. However, as it navigates

both live and virtual planes of gesture, mocap straddles a different form of what Bouldin identifies as the 'ontological ambiguity' of the rotoscoped body. While several layers of mediation intervene between live body and onscreen image, the rotoscope secures its connection to the real via the indexical force of film. At the same time, rotoscoping doubles this indexical imprint through the gestures of the drawing hand. Against this analogue multiplication of live gesture, mocap occupies a different aesthetic regime. Mobilized by quantifying computational processes, the medium affords its ghosts an uncanny motility that both tethers and exceeds their originals. By exercising its material demands on living performers, mocap induces a spatial misperception that shores up their experience of intersubjectivity with their doubles.

Mocap structures new spatial parameters for performers, who may have to navigate unfamiliar studio conditions in parallel with a virtual screenspace. For performers, traversing this multiplanar space fosters a distributed perception that heightens their experience of the uncanny, wherein they are neither here nor there, in their bodies or others. In his experimental research, Matthew Delbridge (2015) has developed a series of training exercises to help performers acclimatize to mocap's peculiar spatial demands. Delbridge draws a distinction between motion capture and performance capture[3] (or PeCap), the latter term referring to the use of motion capture techniques to capture an entire performance in one take. Delbridge's focus on PeCap reflects his focus on how mocap technologies and performance shape each other, and much of his work is concerned with developing the kind of craft, embodied awareness and perceptual acuity possessed by fine actors and other movement artists. Such a regimen, he notes (Delbridge, 2013), is designed to prepare an actor for the 'rigors of performance capture'. One exercise, 'Walking Through', requires the performer to navigate a series of virtual objects existing in screen space while attentive to the physical particularities of the studio. In another, 'The Donut', the performer has to step through the middle of a virtual torus, once again moving through studio space with the screen as a guide. As Delbridge observes, 'these signifiers are immediately endowed with new meaning, based on the performer's activity in the space', such that a physical marker on the floor of the studio, whether tape on the ground or a join in the floor, 'becomes more than its observable presence … and becomes a location on a map'. This spatial straddling has a palpable effect on a performer's perception. After successfully navigating the tasks, the performer remarks that she 'can feel [her] brain working, somehow, in a different way'. This is a multidimensional consciousness, as she goes on to say: 'There's something else, an awareness of something that isn't actually there, that makes your brain work differently. It's an awareness of a different dimension.' Native to digital augmented realities, this multidimensional awareness, or distributed perception, is a symptom of uncanny experience.

For performers, this experience of moving within a virtualized field cultivates a misperception central to notions of the uncanny. In this way, mocap incarnates subjectivity as distributed, and unlocatable within the body

itself. In *The Architectural Uncanny* (1992), Anthony Vidler appropriates the concept for the study of architecture, offering the translation 'unhomely' for Freud's *unheimlich.* He applies the concept to two important contemporary spaces, the home and the city, interpreting such buildings as architectural embodiments of the essentially 'unhomely' condition of modern life. In his analysis, the uncanny is, 'in its aesthetic dimension, a representation of a mental state of projection that precisely elides the boundaries of the real and the unreal in order to provoke a disturbing ambiguity, a slippage between waking and dreaming' (p. 11). Vidler's description of this spatial slippage echoes the distributed perception of Delbridge's performers. Provoking a similarly disturbing ambiguity for performers and spectators alike, mocap intimates a deeply digital uncanny: people are not at home in their own bodies, or in the very movements they make. Distributed across real and virtual spaces, mocap performers relinquish proprioceptive possession of their own subjectivities.

Echoing Jones's alienating recognition of his own movement in his digital double, other dancers working with the medium have testified to this uncanny, linked, and distributed embodiment. Susan Kozel (2007) characterizes her experience working with an electromagnetic mocap rig as a duet with a strangely familiar other. In one of these studio experiments, data from 10 capture points on her moving body were each rendered in real time onscreen as a cube such that Kozel 'entered into a duet with a pile of cubes. My movement gave it life but it was more than my movement. The pile of cubes had a spark of autonomy: it was cheeky, it experienced pain, indecision and pathos' (p. 227). Unlike the skintight suit often associated with mocap, Kozel wore a 'tunic-style garment' (p. 226) such that some of the motion markers did not contour exactly to her body, free to swing with the fabric although animated by her movement. This gestural slippage lent the cuboid being a wisp of differentiated agency. At the same time, glitches in the flow of data or animation due to lags in the system imbued her onscreen counterpart with a sense of volition, 'spontaneity and autonomy, with affect and responsivity, with expression and pain' (p. 228). Disrupting the fidelity of the data stream, these glitches highlight the transformative and enlivening materiality of mocap's computational processes. They trigger Kozel's experience of the digital uncanny, as the technical structures and failures of her mocap system refract her own movement back to her as oddly autonomous other. This autonomy is a digital incarnation of automata as 'disobedient machines', whose unruliness, in Scott Bukatman's (2012: 146) telling, 'makes creations into something more than mere machines' and imbues them with agency.

Like the modern optical devices that preceded mocap, Kozel's double conjures the medium's almost supernatural animacy and, with it, unconscious anxieties about the ambiguity of human and machine actors. Further, it erodes her primacy as an agent of movement. As the other half of this uncanny duet,

Kozel is both here and there, in this body and that one. Swathed in mocap's virtual field, as she animates her virtual other, so too does it animate her. Consequently, this figure rouses an unsettling lack of certitude in her own gestural volition. More than a return of repressed suspicions about an animate world, the digital uncanny portends that people are both subjects and objects of this animation. According to Kriss Ravetto-Biagoli (2016: 2), 'the digital uncanny exemplifies an irresolvable uncertainty as to whether or not those very affects and intensities amount to predesigned responses or programmed gestures triggered by various forms of algorithmically generated media stimulation.' In a world permeated by computational processes, the digital uncanny calls embodied human agency into question. Mocap poses an optical articulation of this fear, manifesting a usurpation of human vision by digital seeing machines. Like Jones, Kozel bears witness to the choreographic excesses in her own ghost. For her, the medium allowed a paradoxical experience of intersubjectivity, a choreographic confrontation with her differentiated self. While Kozel and Jones used different motion capture systems, it is this very moment of spectatorship that stokes fears about the nigh-supernatural agency of computational automatons over human movement. In this way, these virtual performances reveal how mocap conscripts the gaze of the spectator into its own.

Ghosts in the machine: intersubjective vision

As it dissolves the borders between moving subject and virtual object, so too does mocap enmesh human and machine vision. Mocap's virtual bodies are produced from its material processes of computer vision and data-driven decomposition. Enframing moving bodies within its infrared visual field, mocap instantiates a new virtual body. Signaling the notion of a unified self as a fiction, this virtual body dramatizes the intersubjectivity of living performers and their digital ghosts. For performers, subject to mocap's animating gaze and distributed across real and virtual spaces, uncanny feelings arise from their uncertainty in their own choreographic volition. An intersubjective encounter between mocap's virtual body and the body of the viewer, spectatorship consummates the medium's uncanny gaze. Utilizing aspects of human motion perception that allow people to identify individual motion signatures, the medium conscripts the gaze of the human spectator into its own. Compelling perceptual recognition of a virtual figure who is neither here nor there, mocap hinges on the very operations of human vision. As a technology, mocap works by transforming human perception into misperception; through this visual sleight of hand, the medium's virtual doubles achieve uncanny life. Through the act of spectatorship, the viewer incarnates Brian Rotman's (2008: 8–9) 'para-self', 'a self becoming beside itself, plural, trans-alphabetic, derived from and spread over multiple sites of agency, a self going parallel'. In this way, the medium makes the human gaze complicit in the computational erosion of embodied human agency.

Like cinema, the experience of watching a mocap film is an intersubjective encounter between two bodies. Yet, while cinema and mocap are both visual recording technologies, their particular materialities incarnate different modes of spectatorship. Vivian Sobchack (1992) recasts the cinematic experience as one constituted by two lived bodies, the spectator and the film, viewing each other, both subject and object of vision. In the presence of the viewer, cinema becomes a sensing, sensual and sense-making subject, its lived body constituted by the entire apparatus. According to Sobchack:

> Insofar as the film is visible as the successful realization of a perceptive act in an intended perceived object, the camera and projector and all other enabling cinematic technology are synaesthetically synopsized as the film's body. Together, co-operatively, they are the film's means of directly having and behaving in a world. (p. 215)

In Sobchack's account, cinema is an encounter between two viewing subjects, manifested by the photographic technology of the medium. While motion capture shares a lineage with cinema, its 'enabling cinematic technology' constitutes its virtual body differently. Instead, its body marshals the technologies of computer vision to recruit the gaze of the spectator. In the experience of watching digital motion capture, then, the lived body of the film is constituted by the entire apparatus, by the digital decomposition of a moving body and its inscription within a quantifying visual field. Its virtual body broadcasts a performer's enframing within its virtual field, and its subsequent production of a 'para-self' for whom the original performer is no longer primary. Mocap's uncanny effects precipitate from this encounter between these two viewing subjects.

Mocap's uncanny qualities emerge from the intersubjective encounter of a viewer with its unique virtual body; it arouses a fear not only that the machine is animate, but that it might be animating us. Seen in and as a data field, the figure in *as.phyx.i.a* embodies a movement-based encounter between sensing subjects, between dancing bodies and seeing machines. In 2009, Microsoft trumpeted their new line of motion-sensing devices for their Xbox video-game console. Alex Kipman (2010), the director of the then code-named 'Project Natal', heralded the Kinect as enabling a new form of intersubjectivity: 'This is much broader than just entertainment. Moving from an old world, where you have to understand technology, to a new world, where technology understands us, is a computer-industry-wide move.' Kipman's euphoric tone emphasizes the optical agency of mocap, even as he elides the powerfully structuring operations of that gaze. *as.phyx.i.a* offers one vision of what that understanding might look like from the machine's perspective. As the name Kinect, a portmanteau of the words 'kinetic' and 'connect', suggests, this intersubjectivity is grounded in movement itself.

Mocap's optical extraction of movement turns on the intersubjective dynamics of vision utilized by the medium. In *Ghostcatching*, the dots taped to the major joints of Jones's dancing body, and that are typical of many optical motion capture rigs,[4] resemble point light walkers. Point light walkers are hypothetical figures from the field of research psychology, specifically in biological motion perception, used to test how much the idiosyncracies of movement can be boiled down in the eyes of an observer. Each point light walker is a set of coordinated moving dots simulating biological motion, each dot corresponding to specific joints of the human body. Studies using these figures have shown that it only takes 15 markers on the 12 major joints of the body, 15 dots digitally sampling human movement and reconstructing it visually onscreen, for a human viewer to identify the gender of the walker (Kozlowski and Cutting, 1977a; Pollick et al., 2005), their own movement onscreen (Prasad and Shiffrar, 2009) or those of their friends (Kozlowski and Cutting, 1977b),[5] like a gestural fingerprint in pure data. In 2002, M Alex O Vasilescu, a researcher in biometric computing and perceptual signatures, developed an algorithm to extract these motion signatures from a group of individual subjects and implement them in the animation of graphical characters, such that a collective corpus of movements could be synthesized into a new subject with never before seen motions in a distinct style. That is to say, movement signatures are constituted, in many ways, by the perceptions of others.

That perceptual recognition is the hinge to uncanny sensations of embodied indeterminacy. Mocap requires the perceptual complicity of its human spectator, fostering a misperception that ultimately animates its virtual bodies. This in turn constructs the experience of intersubjectivity for a spectator as these motion signatures seem to bear the imprint of a gestural soul, an animating ghost. Even in the most abstracted and disembodied renditions of live choreography, a spectator has to make corporeal sense of the data. In *as.phyx.i.a*, as in *Ghostcatching*, viewers recognise themselves in its gestural ghost; in so doing, they verify the virtual as the real. This recognition turns on how mocap's atomizing digital materiality structures spectatorship. By using the innate faculties by which people perceive motion, mocap recruits spectators into the medium's digital perspective, merging human and computer vision. In this way, not only do human spectators recognize the captured movement onscreen as an uncanny atomization of human bodies into para-selves, but the very gaze by which they perceive it. Through their own perceptual frames, mocap compels human viewers to accept and ultimately consummate the veracity of its spectral movement. In this way, it destabilizes the human body as a locus of perception and proprioception. As a medium, then, mocap affirms human collusion with vision machines, as moving and seeing beings.

In *Ghostcatching* and *as.phyx.i.a*, creators have peeled away human skin to peer at these uncanny ghosts of ourselves. In these aesthetic experiments, human bodies are figures rendered in data while, commercially, the skinning

of captured motion has often taken the form of aliens and monsters who stir the uncanny. Yet, this uncanny effect strikes deeper than the masks that captured movement wears. Mediating performing bodies and spaces with its quantifying digital gaze, mocap produces a new virtual body, the ephemeral ghosts dancing across *Ghostcatching* and *as.phyx.ia*. Figuring the gestural body within fields of data, these skeletal approximations of movement manifest visually the computational processes that increasingly filter and structure human embodiments. At once specter and spectator, these para-selves mirror the atomization of human subjects into the digital avatars and data bodies that populate digital culture. Similar to early cinema, mocap's digital optical uncanny revives dormant fears in an animate world; more than this, it stokes unconscious anxieties that people may be the objects of a computational agency, not entirely in control of their own embodiment. In a world increasingly permeated by forms of machine vision like facial recognition, digital surveillance and data collection, as well as daily technologies that choreograph users' repertoire of gestures, the uncanny renders human embodiment as indeterminate. At the same time, even as these virtual bodies showcase the dynamic cleaving of moving bodies and digital media, they also appropriate and redefine the parameters of human spectatorship. Incorporating the gaze of the spectator into its own, these virtual bodies compel an understanding of human complicity with digital machines. Replicating the biases of their human coders, algorithms structure countless interactions in the virtual spaces where people live, work, and play. From Google Images searches to facial recognition, these digital processes enact structural racism in their very concealment. Humans move in concert with their visual technologies. An intersubjective encounter between moving bodies and seeing machines, mocap is a collaborative process of creation. Under the aegis of digital production, people rehearse this constitutive process in their performances of interaction with their technologies, whether mundane gestures or virtuosic choreography. By design, these performances may shape digital media as much as they shape their performers. The skin of mocap, clothing these human ghosts, is still in the making.

Notes

1. Part of mocap's risk, critics charge, is its ability to erase or caricature politically charged aspects of identity, such as race and gender. This criticism of mocap's history of political forgetting has followed the medium through avant-garde and commercial contexts.
2. The Kinect's commercial success has been a double-edged sword. Microsoft released the Xbox Kinect as a competitor of Sony's Playstation and Nintendo's Wii, and its success has been transformative. As Nicolas Salazar Sutil (2015: 206) notes, 'as a consumer market, Kinect opened up an entirely new market engaged in the consumption of motion.' As an increasingly ubiquitous technology, the Kinect 'can immerse the user within a sphere of movement that is highly commercialized' (p. 207). Yet, this commodification of motion has arrived alongside Microsoft's release of the Kinect's noncommercial software platform. Although they initially resisted early hacks of their platform, the software giant has since savvily appropriated open-source ethics and culture. With the Kinect Software Development Kit, released in 2011, developers can write Kinect apps in a variety of programming languages.

3. The term performance capture was first used by the director Robert Zemeckis during the filming of *Polar Express* (2004) and is preferred by directors like James Cameron, who famously used the technology in the Hollywood blockbuster *Avatar*, and well-known PeCap performers such as Andy Serkis. As Delbridge (2015) notes, some devotees of animation deride PeCap for the way it diminishes the animator; he instead underscores the vital relationship between animator and performer.

4. While motion capture conjures, for many, the image of a performer wearing such dots, this model is used for optical motion capture. Electromagnetic motion capture allows for the capture of full position and orientation in real time. Mechanical motion capture tracks body joint angles directly and such systems are often referred to as exoskeleton motion capture systems.

5. The accuracy of these perceptions is contingent on a number of factors, such as the point of view from which these figures are perceived. For a further discussion of viewpoint-dependent recognition performance, see Jokisch et al. (2006).

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