

DANCE AND VIRTUAL PHYSICS: THE MASS OF THE OBJECT DOES NOT NECESSARILY EQUAL THE OBJECT OF THE MASS

Professor Kim Vincs, Director, Deakin Motion.Lab, Deakin University, 221 Burwood Highway, Burwood, Victoria 3125, AUSTRALIA.

E-mail: kvincs@deakin.edu.au.

Abstract

Motion capture and 3D animation enable the creation of dance in which relationships between mass, weight and morphology are not restricted to the parameters of real-world physics. This paper will draw on a range of motion capture projects to develop an understanding of the virtualizing potential of motion capture as an encoder of not simply spatiality or temporality, but of the physics of movement, and therefore as a potential means of encoding the gravitational poetics at the core of contemporary dance.

Keywords: motion capture, dance, new media performance

Introduction

Motion capture has been used for over 20 years in commercial film and game development. The technological challenge of using early optical and magnetic motion capture systems meant that motion capture was a relatively large undertaking requiring significant investment in equipment and pipeline development. Consequently, motion capture tended to be associated primarily with big budget film and AAA game projects. However, rapid development of hardware and software by motion capture manufacturers such as Motion Analysis Corporation, Vicon, Giant Studios, Animazoo, Optitrak and Organic Motion, among others, have provided the CG animation industry with a suite of motion capture solutions that range from high-end optical systems used to make major studio films such as *Happy Feet*, *Planet of the Apes* and *Avatar*, to more modestly priced systems used in smaller game development and new media art projects. The recent development of ‘prosumer’ motion capture systems such as Microsoft’s Kinect and the Xbox Motion Controller has added another layer of possibility to motion capture use by making basic figure-based capture affordable for independent artists and home users alike [1].

However, motion capture has something of a checkered history when it comes to creating kinaesthetically engaging and empathetic animation. Famous commercial film examples such as *Polar*

Express have demonstrated how the process of extracting optical motion capture data from a performance and re-mapping it onto a CG character can result in wooden, affect-less characters that are difficult to empathize with [2]. At the other extreme are the many highly successful feature films in which high-end motion capture combined with sympathetic and highly skilled 3D animation has created empathetic, even iconic characters [3].

These examples demonstrate that it is not simply recording and transcribing movement pathways that determines the efficacy of motion capture in mapping embodied performance to CG characters. It is the manner in which movement trajectories are translated onto the morphology of a CG character that results in believable (or alienating) animation.

Dance poetics and motion capture

Dance poetics provide a way of understanding the translation between lines of action and embodied movement that underpins the motion capture process. Dance poetics were famously described as ‘virtual force’ by Suzanne Langer in the 1940s [4]. In the 1980s and 1990s, dance theorists such as Hubert Godard and Laurence Louppe argued that muscular force, enacted via deeply inscribed patterns of muscular tonus, was a means of enacting movement intention and with it a moving, embodied subjectivity [5, 6].

Motion capture systems record movement as marker trajectories in x, y, z space. Trajectory data are mapped onto a CG character skeleton via a solving process in which the relative effects of specific data nodes on the movement of each CG joint are defined. This process is spatial (offsets between data and CG skeleton are constructed to deal with issues of scale and proportion) and morphological (the overall movement fit

between data and CG skeleton is optimized across all the virtual joints involved).

Because motion capture data are visualized via a ‘body’ of sorts, that is to say, a morphological structure created via 3D modeling software, the resultant animation has an apparent force. Drawing on dance poetics, it is possible to think of force as the virtual and virtualizing agent in the translation between marker trajectory/joint rotation data and the movement of a CG character.

Virtual or implied force indicates not simply a positional journey, but the implied muscular power needed to effect the dynamic movement of the CG character, and is generated precisely in relation to, and by means of, the structural and morphological properties of the CG skeletal model. The torque of a CG joint movement is implied by the length of a CG ‘limb,’ its apparent mass based on its volume and size, and the speed at which the relevant joint moves through its arc of rotation. For example, a virtual *King Kong* arm, supplied with the same motion capture data as a virtual *Gollum* arm, will appear to function within completely different registers of force and hence intention. The bulk of the *Kong* arm will possess a virtual power that is replaced in the finer *Gollum* arm by a more fluid, grasping, mobility [7].

This is the core of the motion edit process. Motion capture data is not simply transcribed onto a CG skeleton, but creatively deployed to create a character that appears to move with a spatial and dynamic intention that blends the performer’s movement intentions with an alternative physical presence. Motion capture is, therefore, aligned with the processes of defining a virtualized force, rather than simply recreating a human performer’s mobility.

Erin Manning defines virtual force via her concept of pre-acceleration, which values movement not in terms of actual displacement from one set of coordinates to another, but as the “... virtual force of movement’s taking form” [8]. Manning’s virtual force arises from incipency – the sense that the movement is in the process of taking form before it actually occurs. Directionality is not pre-defined but provisional and emergent. This is precisely the case within motion capture data, since the dynamics of pre-acceleration are present at every point in time. Motion capture data streams as a time series, and at any given moment within that stream, future trajectory can be suggested but has yet to be actualized.



Fig. 1. Deer ready for motion capture for *Nocturnal Migration*. (© Deakin Motion.Lab / Altv.fx. Photo © Megan Beckwith.)

Manning argues that “By the time movement displaces, few options for surprise remain: gravity’s pull over the movement’s directionality has taken over” [9]. Because the relationship between morphology and action can be re-thought and re-formulated within the motion edit process, motion captured movement is not subject to “gravity’s pull” in a real-world sense, but can be re-imagined and re-formulated to manipulate body and gravity to co-exist in ways that are not possible in ‘real’ space. Motion capture renders gravity itself virtual, both in the sense of being computer generated *and* in the sense of being an emergent process of possibility, by instantiating a disjuncture between intentional movement generated by a live performer and the effects of that intention when ‘enacted’ by a CG character.

Motion capture has sometimes been considered an alienating technique in relation to dance because it seems to ‘extract’ the body from movement. If motion capture is conceptualized as a series of static poses, then its affective function is reduced to positionality. If, however, motion capture is considered in terms of its ability to embed virtual weight and intentionality within CG bodies, then motion capture is fundamentally concerned with encoding movement weight, force and intention, rather than simply movement ‘*écriture*’ [10]. Commercial motion capture exists precisely because it aims to articulate the weight, force and intention of movement performance in a CG context.

Examination of commercial motion capture projects demonstrates this functionality of motion capture. The following examples, drawn from work undertaken at the Deakin Motion.Lab in Melbourne, Australia, are intended to begin to articulate a continuity of practice between commercial and experimental motion capture. Through this analysis, I aim to open up new ways of considering the potential of motion capture for re-defining the role of dance in new media practice.

Commercial motion capture

Motion capture is often used to generate realistic moving CG characters where it is not possible to film ‘live’ actors. *Noc-turnal Migration*, a television commercial created by Brisbane visual effects company Alt.vfx for Toohey’s Beer, provides an example of this approach. The spot replaces young partygoers with deer, who ‘migrate’ from their homes to the city to participate in a ‘night out’.

Alt.vfx filmed deer on location in New Zealand, and combined this footage with CG deer animation created using motion capture of a deer at the Deakin Motion.Lab (Fig. 1).

The process required the development of a marker set that would capture the movement of each ‘joint’ within the virtual deer created by Nigel Haslam of Motion Circus [11, 12]. Working backwards from the degrees of freedom of each joint in the virtual character model, a system of marker placement was developed to ensure that the motion of the live deer could be mapped, joint-by-joint, to the CG skeleton to drive the character’s movement. The resulting movement of the CG skeleton is used to drive the movement of the surface (mesh) of the character.

The process of mapping of movement data to CG model involves approximations because the CG skeleton differs, if subtly, from an actual deer in size, proportion and the number and configuration of joints. Compensations for the spatial offsets and changes in dynamics caused by this mismatch are made through the motion edit process.

In this example, the process was designed to match, as nearly as possible, the sense of weight in the movement of the CG deer with the actual deer’s movement. While the CG deer was not identical in size and hence apparent mass compared with the real deer, the sense of weight in the finished animation approximated that of a real-world deer. In this case, the process was successful in creating an animation in which the differences in the movement of filmed and animated deer were not readily noticeable [13].

A second example demonstrates the potential of motion capture to amplify the apparent muscular force of a character’s movement. For Rugby League Live 2, created by Melbourne animation company Big Ant Studios [14], the goal was to create in-game animation that would provide a compelling experience of rugby league play. Since rugby league foregrounds impact between players, between player and ball and between players and the ground, it was necessary to emphasize the muscular force of the players’ movements. For this project, Big Ant Studios and Deakin Motion.Lab used contemporary dancers to create the behind the scenes play to enable a nuanced sense of touch and presence in actions such as hugging, celebrating, expressing discouragement and injury. Professional rugby players were used to

generate the tackles of the game play. In both cases, the enactment of muscular impact was critical to the feel of the game movement. Impact and force were deliberately emphasized by both the dancers and the rugby players in their performances. The apparent force of the movement was further amplified via its re-situation within overly muscular CG player characters [15].

These two examples demonstrate the conventional use of motion capture as a means of representing approximations of realistic character movement. However, the disjuncture between live performance and CG character action created through the motion capture process can also be used to overturn real-world physics. In a project by Alt.vfx, in which loaves of bread were animated as if they were animals roaming a pastoral farmyard scene, a deliberate mismatch was created between the ‘normal’ mass of a character (a loaf of bread) and the way it moved.

The context was a television commercial for Abbott’s bread, which aimed to convey the idea of bread as ‘slow food,’ made from locally grown ingredients [16]. To animate the loaves of bread, a small sausage dog was motion captured walking, running and playing (e.g. rolling over, having its tummy scratched). The dog’s playful movements were translated to the bread, which seemed to ‘roam’ the pastoral landscape. In this case, the disjuncture between the physical mass and movement ability of performer (dog) and character (bread) was extreme. The ‘bread’ assumed a muscularity and playful mobility that would be impossible given the structure of bread, yet which assumed a degree of believability because the proportions of the ‘bread’ and the sausage dog matched reasonably well. The finished animation communicated the idea of animal behavior along with a clear sense of the ‘artificial’ nature of the construction, even in the presence of overtly cinematic/realist landscape design elements.

Interactive Performance

In an artistic context, it is possible to use the ability of motion capture to re-map the movement of a physical performer onto a CG object with different physical characteristics to manipulate the apparent ‘weight/flow’ of performed movement.

Weight and flow are aspects of what Laban, in his systematized description of human movement, called effort qualities [17]. Effort qualities are further defined by Bartenieff as ‘inner intention’ [18] in

the sense that they convey not simply the metrics or positionality of movement (i.e. how far, how fast, at what angle), but the mover's intention in relation to the physical world. Weight, as defined in Laban Movement Analysis, is a primarily gravitational concept. It proceeds from the amount of muscular effort with which a movement is executed, and can only be generated through contact with the ground or other gravitational support. Flow relates to the degree of muscular resistance with which a movement is performed, and is therefore primarily a concept of force.

When using motion capture to transfer dance movement to a CG model, it is possible to alter the apparent weight and flow of the movement by mapping it to CG characters of different designs. For example, a CG character with finer, longer limbs than a real performer appears to move faster, and with more flow (lack of resistance) because the motion of the performer is extrapolated through a longer line of action. Yet the sense of weight in the character remains realistic since the timing and dynamic of the weight shifts (e.g. footsteps, leaning of the body) are preserved (Figure 2).

This process, which formed part of an investigation into the possibilities of stereoscopically projected CG 'performers' in contemporary dance [19], allowed the creation of a character that seemed both 'real', by virtue of the clear articulation of weight/flow, but also mythical in its ability to move more smoothly through a greater range of displacement than could be achieved by a human performer. This CG dancer could be thought

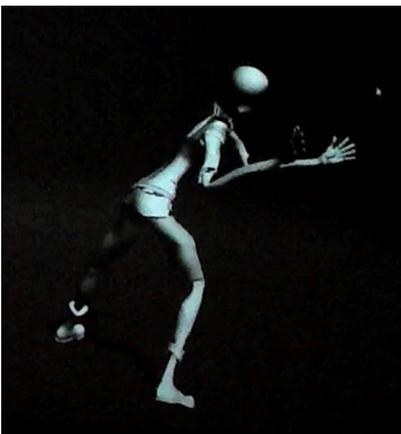


Fig 2. Real time motion capture of CG avatar, performer Ben Stuart-Carberry, development for *Crack Up* (© Kim Vincs, Peter Divers, Deakin Motion.Lab. Photo © Kim Vincs.)

of as a study in what Lepecki calls 'motility' [20]. This is not to say that, abstracted in this way, the CG 'dancer' was necessarily aligned with Lepecki's understanding of motility as an exclusively modernist exercise in dance. To the contrary, this character to some extent challenges the connection between modernist dance and motility through its extraction of dance motility from an exclusively 'human' context. The effect is of an intentionality (in Manning's terms) that is both human and inhuman, possible, since the movement pathways come from motion capture of a real performance, yet rendered impossible by their 'performance' by a virtual (CG) morphology.

A more extreme disjuncture between the morphology of human and CG performers is made possible by developing a CG character that has an implied volume that varies continuously because its surface is created using a cloth simulation algorithm. The CG 'cloth' moves, in real time, in response to the motion captured performer's movement, and continues to move of its own accord even after the motion capture data driving it has stopped. This character mapping was created for Melbourne director Gorkem Acaroglu's investigation of the use of digitized bodies in dramatic theatre, and was designed to play the role of a 'ghost' [21]. The translucent nature of the 'character's' surface, combined with its undulation even in the absence of movement input, gives an appearance of weightlessness (Figure 3). The character was modeled as a torso that trailed into a dress-like structure. As a result, the concept of a normative gravitational movement was radically displaced since the character literally had no ground supports with which to enact an impact and a push away from a ground surface.

In the case of CG scenography, imagery is further distanced from the physicality of human performers. In a work in development by Australian Dance Theatre Artistic Director Garry Stewart in collaboration with the Deakin Motion.Lab [20], the concept is to place dancers in juxtaposition with 3D stereographic imagery that is not driven by motion capture, but which instantiates an overtly inorganic set of movement characteristics. In this piece, 3D scenography is created and positioned, using stereoscopic projection, as if it exists in space besides and around the dancers (Fig. 4). While the dancers themselves are not technologically modified, they are positioned adjacent to CG images that appear massive in bulk, yet move as if light and



Fig 3. Performer Steph Hutchison with 3D cloth simulation avatar in rehearsal for Gorkem Acaroglu's *Avatars, Ghosts & Robots* (© Gorkem Acaroglu/Deakin Motion.Lab. Photo © Alison Bennett.)

mobile. This disjuncture between form and movement places the dancers in an 'unworldly' landscape in which their very gravitational normality appears odd and out of place. This effect serves Stewart's aim of creating a work that explores the 'Multiverse' possibilities predicted by string theory by creating a scenographic landscape that seems, like the bizarre geometrical predictions of string theory, literally impossible to spatially comprehend.

Conclusion

This discussion poses a continuity between commercial and dance/art uses of motion capture by considering both applications as processes that map the real-world physics of a performer's movement onto CG characters to generate a 'virtual' physics of movement generated by combining real-world movement data with the 'apparent mass' of a CG object. While dance and commercial motion capture processes may seem, on the surface, very disparate practices, through motion capture they share the ability to minimize or amplify disjunctures between the real-world physics of a performer's movement and the apparent physics of the CG world.

In the field of dance technology, this ability opens up the possibility of effecting radical deconstructions of movement style and therefore, as Louppe [23] would argue, embodied formulations of subjectivity, through the ability of motion capture and CG animation to destabilize normative physicality. In the field of commercial motion capture, dancers' profound understanding of and ability to creatively manipulate physicality, weight and flow represents a potentially valuable resource for creating both realistic and unrealistic character animation. Perhaps further to both these opportunities is the idea that combining dance and

motion capture practices offers a means of considering movement as not simply positional, directional or even temporal/dynamic, but as fundamentally concerned with the mobilization of force as a means of enacting intention. In this context, Manning's idea of movement as intention is 'given weight,' so to speak, by the real and virtual physics of performance.



Fig 4. Daniel Jaber in rehearsal for Garry Stewart's *Multiverse* (© Garry Stewart / Australian Dance Theatre / Deakin Motion.Lab. Photo © Bradley Axiak.)

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lor, Ben Stuart-Carberry, Stephanie Hutchison, Megan Beckwith, Emma Corbett, Gemma Corlass-Brown and Shannon Ellis.

References and Notes

1. Systems such as Kinect offer skeleton-based recognition of human form and movement, but provide a lower level of resolution of individual joint action compared with high-end optical systems. Kinect systems do not, at present, offer precise mapping in the 'z' axis (towards and away from the camera). However, while the resolution gap between Kinect and optical motion capture systems is currently significant, this can be expected to narrow rapidly over the next few years with new generation devices due for release in 2013 and beyond.

2. For examples of reviews of motion capture use in *Polar Express* see High-Def Digest, *Are we done with motion capture yet?* <http://www.highdefdigest.com/blog/motion-capture-animation/> (accessed 19 July 2013), and CNN Entertainment, *Review: 'Polar Express' a creepy ride*, <http://www.cnn.com/2004/SHOWBIZ/Movies/11/10/review.polar.express/> (accessed 19 July 2013).

3. Examples include *Avatar* and *Lord of the Rings*, which were popular successes. For an example of positive reviews of these films' use of technology in the popular press, see IGN 'How the Lord of the Rings Trilogy changed movies forever', <http://au.ign.com/articles/2012/11/22/how-the-lord-of-the-rings-trilogy-changed-movies-forever> (accessed July 19 2013).

4. Langer, *Feeling and Form: A theory of art developed from philosophy in a new key* (London: Routledge & Kegan Paul: 1953).

5. H. Goddard in Daniel Dobbels and Claude Rabant, "The Missing Gesture: an interview with Hubert Godard." *Writings on Dance* 15 (Winter 1996) pp. 38–47.

6. L. Louppe, *Poetics of Contemporary Dance*, Translated by Sally Gardner (Alton Hampshire, England: Dance Books 2010).

7. I refer here to well-known CG film characters *King Kong* (2005), film and Gollum in *Lord of the Rings, Fellowship of the Ring*, film (2001).

8. E. Manning, *Relationescapes: movement, art, philosophy*, kindle edition (Cambridge, Mass: MIT Press 2009) location 105.

9. Manning [8], location 72.

10. I refer here to Laurence Louppe's [8] term.

11. Alt.vfx are a Brisbane Visual Effects company, <http://altvfx.com>.

12. Motion Circus is a Queensland based animation company, <http://motioncircus.com>.

13 Behind the scenes videos of the making of *Nocturnal Migration* can be viewed at http://www.cgsociety.org/index.php/CGSFeatures/CGSFeatureSpecial/altvfx_nocturnal (accessed July 19 2013).

14. Big Ant Studios is a Melbourne game development company, <http://www.bigant.com> (accessed July 19 2013).

15. Footage from *Rugby League Live 2* can be viewed at <http://www.bigant.com> (accessed July 19 2013).

16. Behind the scenes videos of the making of *Abotts' Bread TVC* can be viewed at <http://altvfx.com/videos/abbotts4a.php> (accessed July 19 2013).

17. R. Laban, *Laban's Principles of Dance and Movement Notation* (London: Macdonald and Evans, 1975).

18. I. Bartenieff, *Body Movement: coping with the environment* (London, New York: Gordon and Breach, 1980).

19. This character was created as part of Vincs' transmedia dance development *Crack Up*, ARC Discovery Project DP120101695.

20. A. Lepecki, *Exhausting Dance: the performance and politics of movement* (New York and London: Routledge 2006).

21. This character was created as part of Australia Council Artlab project *Mixed Reality Performance* by Gorkem Acaroglu, and supported via DP120101695, The Deakin Motion.Lab and Deakin University's Centre for Intelligent Systems Research.

22. This work was created as part of Garry Stewart's Thinker in Residency program at Deakin University in 2012. The work is, at time of writing, under development for premiere in 2014. It is also supported via DP120101695 and Australian Dance Theatre.

23. L. Louppe, 2010.