# CAPTURING DANCE AND CHOREOTOPOGRAPHY: ANALYZING AND VISUALIZING COMPLEXITY

Kim Vincs

Motion capture provides 'snapshots' of the complexity of movement patterning. This presentation explores both the power and limitations of quantitative motion capture analysis, drawing on *Capturing Dance*, a three-year collaboration with mathematician Vicky Mak-Hau and biomechanist Richard Smith at the Deakin Motion.Lab in Melbourne, Australia, and on the live motion capture / 3D performance *Choreotopography*.
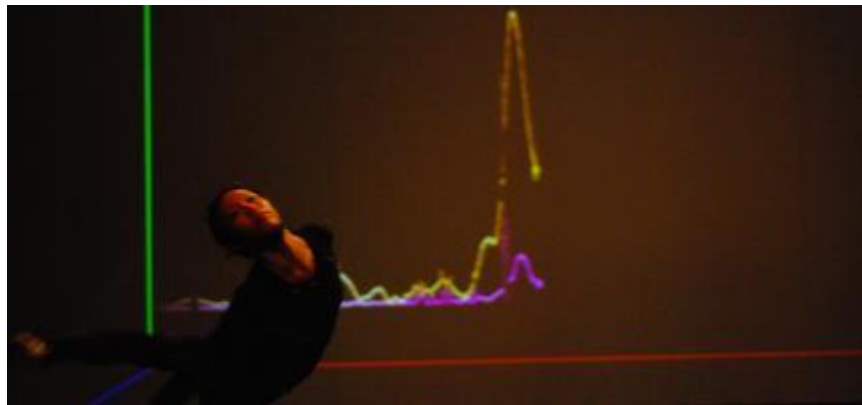
Fig 1. Velocity Engine / IK Dancer, Deakin Motion.Lab, 2011. Performer: May Yen Cheah, Interface: Peter Divers and John McCormick, Image: Kim Vincs.

Fig 2. Choreotopography, Deakin Motion.Lab, 2010. Performer: Sakura Shimizu, Choreography: Kim Vincs, Motion Graphics: Daniel Skovli.

The allure of motion capture for dance is that it can record the three-dimensional trajectory of movement in precise detail. However, dance is conceptual as much as it is physical, and dance movement only becomes meaningful via the artistically and culturally specific frames of reference that underpin its construction and interpretation. In this paper, I want to explore how motion capture analysis can potentially illuminate and drive creative processes in dance. However, understanding what is artistically meaningful

in motion capture data depends on an examination of the ontology of dance movement itself, and how that ontology both intersects and conflicts with quantitative analysis. In the *Capturing Dance* project, a three-year collaboration with mathematician Vicky Mak-Hau and biomechanist Richard Smith at the Deakin Motion.Lab in Melbourne, Australia supported by the Australian Research Council Discovery program (DP0987101), a team of artists and scientists came together to explore quantitative analysis of dance style using motion capture. This paper discusses the approaches the project has explored to date, as well as the studio-based and performance processes that have emerged as a response to the reductionism inherent in quantitative motion capture analysis.

I find motion capture data compelling because when I watch a marker cloud cross a screen, I see the traces of movement trajectories that are otherwise only accessible to me as abstractions – as what I thought I did and/or what I would have liked to have done. The possibility of accessing my movement, or another dancer's movement, in a way that doesn't immediately disappear, but can be replayed and watched over again, from any angle in a 3D volume, allows me the possibility of savouring a movement pathway in a way that is not possible when watching or performing a movement in real time.

Motion capture gives me a spatial and temporal perceptive mode in which to experience movement that is quite unlike the flat plane that comes back to me from video or mirror, but also qualitatively different from watching dance movement in 'real' time and space. The power of motion capture data is to visualize lines of movement from multiple, moving vantage points within a three dimensional volume. The ability of the virtual 3D in-computer world to let me spin the volume around, as if myself flying and swooping through space to better view and understand the movement I am watching, has the effect of allowing me access to the vantage point of a co-dancer. I can perceive the movement while 'moving' myself, as if I were dancing with the image, but this 'movement' allows me a spatiality that is free from gravity and physics, so that I can move in much faster and more extreme ways through the volume with my mouse and eyes than I could possibly hope to do in the flesh.

I am tempted to think that perhaps the dream of contemporary dance to de-hierachize the body, in its conventional standing, gesturing, speaking subjectivity, is stretched to its extreme limit in the potentially stomach-churning flying and falling pathways I can take as a viewer of motion capture data navigating a virtual volume. Laurence Louppe has argued that one of the key projects of contemporary dance has been a process by which the zones of the body associated with the semic and with power were "…caught up in a great reversal, a great work to de-hierarchize the role of the limbs: beginning with the head – at least as the support for the face which was no longer to be the imperial and immovable throne of expression, meaning or utterance." [1] Motion capture data, in its raw form of marker trajectory in *x, y, z* space, takes this deconstruction to its limit. Marker data may be named (e.g. top head, right wrist, etc.), but its movement is not yet defined by the hierarchy of the skeleton. In the visual apprehension of marker data moving, marker names are only significant in that they indicate a functioning software template. It is marker movement and the creative interpretation of the negative space between them that affords meaning, rather than anatomically determined relationships between markers.

The eye, in the sense of its dominating scopic perspective, has no privilege in a motion capture-enabled environment. The eye's habitual ways of conceptualizing bodies are displaced by motion capture, which is not so much more accurate, as differently accurate, organized via designated points (markers) and trajectories, rather than by lines and surfaces. Marker data, as well as being de-hierarchized, is semantically blind. A raw marker trajectory does not 'know' that it is part of a system. It is simply a record of where a particular point on the surface of the body travelled, and at what speed. No specific marker is more important than any other. The fact that the significance of marker data trajectories is not predicated on

their place within a skeletal organization of the body allows me to think differently about what those trajectories could be. The fact that naming, in this geospatial discourse, is relegated to an instrumental task, appeals to me as a reversal of the more usual epistemological situation in which naming reduces action to an instrumental rather than an investigative role.

The semantic blindness of motion capture data enables quantitative analyses that are independent of the artistic and cultural contexts of dance movements. Mathematical analysis of motion capture data effectively deterritorializes dance, to use Deleuzian terms, [2] because it looks for what is statistically significant rather than what is culturally significant. In our project, we began by applying Principal Component Analysis, a common statistical tool that compresses large data sets into fewer dimensions based on the strongest correlations between parameters, to see whether we could quantify the stylistic relationships embedded in motion capture data of contemporary dance movement phrases. The complexity of the principal components we identified was a revelation in terms of the disjuncture between what we might perceive as artists as key to the movement, and what is statistically significant in terms of the strength of the correlations in the data. Minute, complex interactions between relatively small and seemingly unrelated body segments, such as right mid-foot and centre-head, left thumb-base and right elbow, for example, characterized the analysis, and defied any attempt to derive information that could easily be used by artists in the studio.

A further revelation was the complexity of the movement analysis itself. In biomechanical applications such as gait analysis, most of the variability in the sample is usually accounted for by a relatively small number of principal components, typically $1 - 3$, which can then be used as surrogate for the whole. In our analysis, around 30 principal components were needed to account for 98% of the variation in the movement data, making any easy interpretation of such analysis out of the question. Vicky Mak-Hau's comparison of multiple classification methods, [3] which so far includes PCA, KNN nearest neighbor, Linear Discrimination Analysis, and Hyperplane, Hyperspheric and Hypersphere SVM methods, has produced recognition rates for specific movement phrases of over 99%. These results represent a major achievement in complex movement recognition, and have key applications in data retrieval, verification of movement style, and documentation. However, the mathematical basis of even basic PCA analysis, let alone the more complex data mining techniques needed to achieve reliable recognition rates, is too abstract to provide an intuitive tool that can be used by artists working in a studio.

This discovery led us to trial a number of more studio-based approaches, alongside the mathematical analyses. Firstly, we looked at marker cloud comparison as a rehearsal tool. Allowing a group of dancers to view their motion capture data projected within the studio in real time enabled us to develop a process whereby dancers and choreographer could work together to identify variations in style. The dancers and choreographer worked on a short piece of movement that needed to be performed in unison, yet was difficult to synchronize because it relied on small, idiosyncratic torso and arm movements. We found that being able to focus on specific markers helped to identify where and how the nuanced variations were produced. However, we were also able to view the whole marker cloud moving at once, so that information from the whole body's movement remained embedded in the representation. Because the data was visualized as raw marker movement, we were able to work directly with the trajectories and dynamics of the movement pathways without translating these into words or images. Of course there was talking, and a certain amount of 'naming'. However, the primary discourse was accomplished in terms of the three-dimensional trajectories themselves – a spatio-temporal rather than a linguistic discourse.

After the fact, we were able to apply different marker analyses to look at what had shifted in different dancers' performances. These 'after analyses' functioned in the same way as reductionist scientific methodologies in identifying specific movement variables of interest – in this case, the patterning of mid-back, hip and shoulder movement. However, a key advantage for the creative process was that we were able to do this retrospectively, and therefore without narrowing the exploratory and emergent nature of the dancers' processes in the studio.

Following the idea of marker trajectory as a primary mode of conceptualising movement, we developed another technique we called the 'IK dancer'. In 3D animation, an inverse kinematic (IK) effector moves a point on a character's skeleton, and the software solve engine determines a combination of joint actions to achieve the end position. We began to think of dancing as a living solve engine process that could be led by any marker functioning as an effector. We built a real-time program, created in the Unity game engine by John McCormick and Peter Divers, to visualize different markers and dynamic properties in real-time, such as top head velocity and acceleration. We used the real-time feedback from our 'velocity engine' to experiment with different movement aims, e.g. maximize top head acceleration in a jump. This process opened up for us a world of possibilities in movement exploration because it gave us access to marker data in a visualized space that we could record and examine in three dimensions, and in terms of movement *dynamic*, i.e. velocity and acceleration. While verbal language can specify positional instructions such as 'take your right hand and move it directly upwards until it reaches shoulder height and then circle it outwards through 90 degrees,' it cannot specify movement dynamics – velocity and acceleration – with the same precision. For example, an instruction to accelerate your hand 'quickly up and then slowly across' is indeterminate in quantity and direction. An instruction like this only aquires precision through physical demonstration. Our velocity engine gave us representational access to the dynamics of body trajectories in three dimensional space, enabling us to record, experiment with and manipulate the dynamic information contained in the marker kinematics.

A key aspect of both of these in-studio processes is that, because they focused on marker trajectories, the information the dancers worked with was not dependent on the hierarchy of the skeleton. This is not to say, of course, that the dancers moved without the physical support of their actual skeletons, but rather to emphasie that movement need not be conceptualized in skeletal terms. In this sense, our processes are aligned with Louppe's 'dehierarchizing' agenda of contemporary dance, [4] and more broadly, with a Deleuzian deterritorialization of the body that opens new possibilities for movement exploration. [5] Deterritorialization is, in a sense, the opposite of (or perhaps, in a Deleuzian framework, outside to) quantitative analysis in scientific contexts. Analysis has as its goal the identification of key parameters and structural features of datasets that are repeatable, definitive and predictive. The goal of deterritorialization, on the other hand, is to create the possibility of new and constantly evolving ways of connecting information, which is more consistent with the aims of artistic processes.

We took a further deterritorializing step by visualizing our motion capture data in performance using 3D stereoprojection. In *Choreotopography,* [6] we streamed motion capture data from four dancers into three dimensional motion graphics environments created in the Unity game engine, which were projected around the dancers in stereo and viewed by the audience through 3D glasses. We wanted to remove the data not only from its hierarchical/skeletal context, but also from its direct relationship to the dancer's physical bodies. Ruth Gibson, who creates motion capture and game-based environments, articulates the desire to "…translate live-ness into the virtual world, that is individual qualities, authenticity of capture, weight and gravity." [7] We wanted to deterritorialize live-ness by extending it beyond the confines of the dancers' bodies. We wanted to create an illusion of virtual force, as Suzanne Langer

[8] described it, through visualizing dancers' weight, trajectory and force via the kinematics of marker data, and distribute this illusion throughout a performance space.

Creating this visualization using 3D projection allowed the kinematics to escape the two-dimensional plane of a projection screen and access the 'z axis' – towards and away. We used a variety of approaches to visualize 'lines of force' in the motion capture data, including a 'flocking' protocol in which virtual stars followed the dancers' positions in space, an undulating mosaic pattern that was disturbed by the dancers' spatial incursions, and flying cloth simulations that followed dancers' wrist movement. We also created non-interactive environments in which the trajectories of the dancers' movements were framed and complemented by moving 3D 'architecture' such as a series of huge 'blocks' that moved inexorably forward over the performers, and a moving 'infinity field' of particles streaming away from the dancers towards a vanishing point beyond the screen plane.

In addressing what is, or could be artistically and culturally meaningful for dance in motion capture data, *Choreotopography* took an extreme deterritorializing path, extracting the kinematics of dance movement from the hierarchical semantics of the structure of the body, and extrapolating them across volume as well as area through the creation of a live/stereoscopic spatial 'grammar'. In doing so, *Choreotopography*was a means of embracing and even magnifying the complexity of dance motion capture data. The semantically blind, highly abstracted space of mathematical analysis represents different approach that enables precise classification of motion capture data, but at the expense of artistic and cultural valence. These two approaches define a domain within which different kinds of motion capture analysis can address both quantitative and artistic/cultural questions about dance. The challenge is perhaps to more closely link the two approaches, and to build more nuanced bridges between the scientific and artistic ontologies involved.

References and Notes:

1. L. Louppe, Poetics of Contemporary Dance, trans. S. Gardner (Hampshire, Dance Books Ltd, 2010), 41.
2. G. Deleuze and F. Guttari, A Thousand Plateaus: Capitalism and Schizophrenia(Minneapolis, MN: University of Minnesota Press, 1987).
3. V. Mak-Hau, K. Vincs, X. Wang, and K. Barbour, "Classification of Complex Movement Sequences using Motion Capture," forthcoming.
4. L. Louppe, Poetics of Contemporary Dance, trans. S. Gardner (Hampshire, Dance Books Ltd, 2010).
5. G. Deleuze and F. Guttari, A Thousand Plateaus: Capitalism and Schizophrenia(Minneapolis, MN: University of Minnesota Press, 1987).
6. Choreotopography, by K. Vincs, J. McCormick, R. Vincs, D. Skovli, P. Divers, and R. Burt, Gasworks Theatre, Melbourne, 2011.
7. R. Gibson, "Blurring the Boundaries: Performance, Technology and the Artificial Sublime – An Interview with Ruth Gibson and Bruno Martelli, igloo," in Interfaces of Performance, eds. M. Chatzichristodoulou and J. Jeffries, R. Zerihan (Farnham: Ashgate, 2009), http://www.ashgate.com/isbn/9780754675761(accessed September 8, 2011).
8. S. Langer, Feeling and Form: A Theory of Art (New York: Scribner, 1953).