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ALGORITHMIC REFLECTIONS ON CHOREOGRAPHY

Pablo Ventura
Ventura Dance Company
Switzerland

Daniel Bisig
Zurich University of the Arts
Switzerland

Abstract: *In 1996, Pablo Ventura turned his attention to the choreography software Life Forms to find out whether the then-revolutionary new tool could lead to new possibilities of expression in contemporary dance. During the next 2 decades, he devised choreographic techniques and custom software to create dance works that highlight the operational logic of computers, accompanied by computer-generated dance and media elements. This article provides a firsthand account of how Ventura's engagement with algorithmic concepts guided and transformed his choreographic practice. The text describes the methods that were developed to create computer-aided dance choreographies. Furthermore, the text illustrates how choreography techniques can be applied to correlate formal and aesthetic aspects of movement, music, and video. Finally, the text emphasizes how Ventura's interest in the wider conceptual context has led him to explore with choreographic means fundamental issues concerning the characteristics of humans and machines and their increasingly profound interdependencies.*

Keywords: *computer-aided choreography, breaking of aesthetic and bodily habits, human–machine relationships, computer-generated and interactive media.*

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VERTAISARVIOITU
KOLLEGIALT GRANSKAD
PEER-REVIEWED
www.tsv.fi/tunnus

INTRODUCTION

The purpose of this article is to provide a first-hand account of how a thorough artistic engagement with functional and conceptual aspects of software can guide and transform choreographic practice. Choreographer Pablo Ventura's wish to get involved with computers developed slowly throughout the 1990s, after years of choreographing dance in a conventional manner, that is, by using his body and choreographic traditions as the main sources of inspiration. Prior to the reorientation of his choreographic methods, he became increasingly frustrated by the limitations of his own body and his preconditioning via internalized habits and compositional methods. This seemed to trap him in a vicious circle that limited his creative output, leading him to produce the same type of movements over and over again. This frustration led him to experiment with computers as a means of delegating aspects of creative decision making to neutral and abstract principles that are oblivious to any bodily, stylistic, and historical authority. From then onward, the software Life Forms played an essential role in Ventura's development of new choreographic ideas and techniques. Furthermore, his creative engagement with computational principles deepened considerably throughout his career and led him to develop, in collaboration with partners, additional software tools that further extended his choreographic repertoire. Finally, his engagement with the creative possibilities of computers was not limited to purely formal and stylistic experimentation but increasingly shaped the conceptual background of his artistic work. This mutual exchange between artistic experimentation and theoretical reflection informed Ventura's creative and conceptual interests along three main thematic strands:

- The use of algorithmic and formal processes to break and redefine bodily and aesthetic habits and principles;
- The identification and differentiation of inherently human and machine-like capabilities and their increasing interdependency and interpenetration; and
- The application of choreographic design processes beyond the human body to include all aspects of staging dance and scenography.

This article is written from the decidedly subjective point of view of Ventura. Accordingly, the text tries to highlight and render comprehensible his motivation and interests in using computer software as an integral element of his choreographic practice. This personal focus is reflected in the article's strong emphasis on the description and analysis of the various dance and media works that have been realized by Ventura. This focus is also apparent through a specific contextualization of Ventura's work within the academic and artistic background that has shaped his own artistic development. As such, this paper also documents the results of a research process in which the interests, methods, and goals are rooted within the artistic domain and where the mutual exchange between technical experimentation, creative innovation, and conceptual reflection become constitutive for a systematic and extended artistic endeavor (Borgdorff, 2006). We believe this emphasis provides a unique point of view within the field of dance and technology that is complementary to the more theoretical and distanced reflections characteristic of academic research. For additional documentation that exceeds the scope of this article and for video material of all dance productions by Ventura, the reader is referred to the website of his company.[1]

BACKGROUND

The background section attempts to situate Ventura's work within a research framework not only with respect to software-based approaches in the choreographic process but also in a broader context of academic debates that are characterized by an intense mutual exchange among philosophical thought, scientific progress, and technical innovations. These contexts have played an essential role in shaping Ventura's creative interests.

The structure of this chapter is as follows. It opens with a description of the impact of computer technology on art in general and dance in particular. It then presents a wider overview over scientific and philosophical thought that has both influenced and been influenced by developments in computer technology. The chapter concludes by returning to a narrower point of view in comparing several computer-based choreographic systems with Ventura's own use of software.

Impact of Computer Technology on Art and Dance

The impact of computers as powerful creative instruments for artists saw a boost with the introduction of personal computers in the 1980s and 1990s. Before then, the application of computers for artistic purposes had been limited typically to the institutional domain in that it required collaborations among scientists, engineers, and artists. But even after computers became readily available for independent artists, it took another 2 decades before software was no longer regarded as a mere tool supporting artistic creativity but as a medium in its own right for artistic expression and experimentation. The conviction that software code is an extremely plastic medium enabling entirely new forms of artistic creation was strongly articulated by, for example, John Maeda (2000). A similar statement in favor of treating software programming as an expressive form of creativity was also formulated by Scott deLahunta (2002). The impact of computers with respect to choreographic creativity is still part of an ongoing and partially controversial debate that originated in 1966 (Noll & Hutchinson, 1967).

Two aspects are important in this debate: how computers challenge central dance ontologies and how computers affect the creative choreographic process. According to Harmony Bench (2004), dance has been more thoroughly influenced by computers and new media than any other field due to the fact that new media has the potential to fundamentally challenge the natural perception of bodies and the environment. Zeynep Gündüz took an optimistic stance with respect to this challenge and highlighted the unique opportunity that technology provides for creating either a dialogue or a confrontation between aspects of corporality and incorporeality and thereby enables a renegotiation and reinterpretation of the human body (Gündüz, 2008). Hetty Blades (2012) extended this discussion in that she not only considered elements of corporality but also discussed the relocation of movement intentionality away from the human body and into software. Furthermore, Blades questioned the role of ephemerality in view of the abundance of digital recordings of performances. The notion that software puts into question the primacy of the human body to express choreographic ideas also was discussed by deLahunta and Shaw (2008). Erin Manning (2009) assumed a critical position concerning the role of software in dance, especially in interactive settings. She argued that, more often than not, software promotes stable rather than dynamic

body concepts and that interaction technology tends to enforce standardized and explicit body movements while being blind to expressivity and intentionality. With respect to the choreographic process, the multiplicity of roles that software can play was discussed by deLahunta (2002).

The possible use of software as a tool that provides creative input for a choreographer has been discussed from early on (e.g., Lansdown, 1978). More recent are considerations accounting for the conceptual impact of software on choreographic thinking. Linda Candy (2007) stated that software, through its requirement to precisely specify the abstractions and constraints for an artistic work, provides the opportunity to understand and thereby articulate a larger palette of creative methods. But according to deLahunta and Zuniga (2008), software has the potential to transform choreography on an even more fundamental level in that it can help to question current choreographic beliefs and conventions. This encourages the pursuit of new investigations into the understanding of movement (deLahunta & Shaw, 2008).

Scientific and Philosophical Aspects of Technology

With respect to the development and characterization of computational principles and their relationship to biological, societal, and cultural phenomena, there exists a substantial amount of shared interest and cross-pollination between philosophical debate, scientific investigation, and engineering innovation. Not only within the synthetic natural sciences, such as artificial intelligence and artificial life, is the distinction between technological and natural systems becoming increasingly blurred and ill-defined. Much of this confounding can be traced to the highly influential but by now extinct field of cybernetics. According to cybernetics, many of the fundamental principles that govern the behavior of organisms can be applied for the control of technical systems as well (Wiener, 1961). This approach of deriving and abstracting capabilities of natural organisms into generic and informational principles that are no longer bound to a particular physical and biological instantiation has been instrumental for the development of computational control principles.

Later, this line of reasoning was extended to address not only issues that are predominantly of interest in control engineering but that also deal with broader and more fundamental aspects of natural organisms, that is, their capability to generate and maintain their structural and functional organization in face of environmental perturbations. Humberto Maturana and Francisco Varela (1991) laid the systematic foundations of these phenomena in their autopoietic theory. This theory also introduced the notion of self-organization as a fundamental property of complex systems that enables simple processes to coordinate themselves through networks of local interactions into the higher level emergent organizations that form the defining properties of life and cognition. A complex system's definition of organisms informs many contemporary approaches for modeling general forms of intelligence in technical and computational systems (Goertzel, Pennachin, & Geisweiller, 2014). Notions of complexity and self-organization also exert a strong impact on the social and economic sciences. For example, William Green (1995) assumed a point of view that was heavily inspired by complexity science by describing factories as hybrid autopoietic systems in which humans and technical systems self-organize in their control and maintenance of factories' functionality.

A more thorough description regarding how principles from complexity science can be applied to enterprises and their management was provided by Randall Whitaker (1995).

Social and cultural consequences of complexity thinking and the increasingly blurred boundaries between humans and technological systems are also a relevant topic in philosophical debates. In their influential book *Mille Plateaux*, Gilles Deleuze and Félix Guattari (1988) applied notions of self-organization to describe the increasingly unstable construction of the human subject whose cultural and social contexts are no longer normative but rather emerge from a multiplicity of continuously changing interconnections. In a similar manner, Robert Nirre (2001) identified the feeling of being nested in recurring loops of fractionations and reconfigurations as a chief sensation in this period of human history.

Of particular relevance in the context of human-technology relationships are philosophical notions of *posthumanism* that address the increasingly deep interdependency between humans and technological and cultural artifacts. Gray Kochhar-Lindgren (2005) identified the cause for this interdependency in a primordial wish for immortality. He claimed that this wish is now becoming realized through cloning, genetic research, and artificial intelligence, Andy Clark (2001) took a decidedly different stance and argued that hybridism between body and technology is natural and commonplace due to the fact that the human mind is naturally predisposed to develop and incorporate tools into its own body image and body schema. Katherine Hayles (2008) defined the term posthuman in two different ways. On one side, the term posthuman overcomes a liberal notion of humanity that presupposes a fully self-determined and autonomous individuality and replaces it with a notion of subjectivity that integrates a human into a larger self-organized system with which the human shares his/her agency and cognitive capabilities. On the other side, the term posthuman can also be used in a negative way to characterize a literal fusion of human and machine that leads to a situation in which human agency is lost and the machine takes over control. In another publication, Hayles (2002) complemented this definition of posthuman with the term *mindbody*. The concept mindbody is meant to abandon the Cartesian dualism of mind and body in favor of a dynamic and holistic integration of abstract body concepts and experiential feelings of embodiment. According to Hayles, the mindbody concept can account for and integrate the coevolutionary dynamics between biology, culture, and technology.

Computer-based Choreography Systems

In their publication, Sarah Fdili Alaoui, Kristin Carlson, & Thecla Schiphorst (2014) provided a good overview of currently existing computer-based choreography systems. In their reflection concerning the development and application of choreography systems, they argued that a codification of choreographic thought and techniques is severely challenged by the often shifting attitudes towards body, mind, and culture within the domain of dance, and by a choreographer's need to tailor his/her work through an embodied experience and situated actions necessarily leads to highly idiosyncratic approaches.

This argument is interesting in that it deviates considerably from Ventura's use of the choreography software Life Forms. This software was developed originally as a computer-based system for Laban Dance notation (i.e., labanotation) and was later appropriated by the choreographer Merce Cunningham as a means to discover novel and unexpected movement possibilities (Schiphorst, 2013). Ventura's appropriation of this already existing software was motivated by his desire to create a style of movement that was not imbued with his own embodied experience. In this regard, Ventura's approach deviated clearly from Cunningham's

dance technique. Another interesting example is the choreography software Choreographic Language Agent (CLA). This software fulfills the role of a computer-based notebook. Its integration into the choreographic creation process is situated in between ideation and dancers performing movements (deLahunta & Shaw, 2008). The software uses a machine-readable language for specifying choreographic instructions. Furthermore, the software integrates a generative mechanism in the form of an autonomous agent that automatically translates the choreographic instructions into movements. The representation of the agent's body as minimalistic points, lines, and planes is not anthropomorphic and thereby does not evoke any associations with the human body. Accordingly, CLA places a much stronger focus on the ideation and experimentation phase during the choreographic process than does Life Forms and, at the same time, encourages creative serendipity by means of a generative mechanism. Similar to CLA, the choreography software titled Scuddle uses a decidedly minimalistic representation of a dancing character (Carlson, Schiphorst, & Pasquier, 2011) that serves as *movement catalyst*. This catalyst is meant to break the conventional choreographic process and to encourage choreographers to distance themselves from their own habits. This software integrates a generative functionality that uses a heuristic-based fitness function that rates body posture, execution height, and movement qualities in order to propose automatically created movement catalysts.

Focused predominately on an educational context is a choreography software titled Web3D Dance Composer that has been developed by Asako Soga, Bin Umino, & Jeffrey Scott Longstaff (2005). The main purpose of this software is to create utilitarian choreographies that can be used as teaching material for classical ballet training. The software is generative in that it automatically creates short ballet sequences by chaining together basic ballet steps that have been recorded using motion capture. The resulting movement sequences are then displayed and executed by a realistic graphical rendering of a human dancer. Finally, a choreography software titled Dancer by Tina Yu & Paul Johnson (2003) employs principles of a swarm simulation in order to create a choreography that can be imported into Life Forms. Simulated dancers move across a virtual stage by executing steps that have been randomly selected from a predefined set of classical ballet steps or a floor roll and, at the same time, they avoid collisions. This software was intended as a proof of concept that demonstrated the feasibility and usefulness of using agent-based models for generating choreography. Yu and Johnson's software is somewhat similar to the software Choreography Machine (see Appendix A) in that it combines a generative mechanism with the manual manipulation and graphical rendering possibilities of Life Forms. On the other hand, Yu and Johnson's software focuses on the reuse of mostly classical ballet material and group performance and therefore clearly differentiates itself from Choreography Machine.

DANCE WORKS

This section describes various dance works that have been created by Ventura during his investigations into software-based approaches for choreography. The descriptions highlight, for each work, the aesthetic and technical considerations and innovations that led to its realization. Furthermore, the descriptions complement the information provided in the background section in that they elaborate on the conceptual underpinnings that are specific for each work. As a

result, this section provides a detailed insight into Ventura's profound artistic engagement with technology that led to the development of his unique choreographic language.

Deus ex Machina

The work *Deus ex Machina* that premiered in 1997 formed the first public manifestation of Ventura's experimentation with computer-based choreography.[2] This work resulted from an artistic curiosity into whether a software representation of a human in the form of an avatar could be choreographed and whether such an avatar is able to exhibit human-like movements. In a subsequent step, this artistic inquiry also addressed the feasibility of imitating the virtual movements of the avatar with the physical body of a human dancer. This detour of choreographing human dancers via the manipulation of an avatar allowed for the identification and exposition of similarities and differences in their respective movement capabilities and qualities.

These experiments were conducted in the Life Forms software. At the beginning, the choreographer manually created a palette of different poses. These poses were designed to lie at the limit of human feasibility, that is, they exhibited extremely extended limb positions or, at the other extreme, folded limbs into a very compact body shapes. At the time of the realization of this piece, the functionality of Life Forms was very limited and the arrangement of these poses into movement sequences turned out to be an arduous process. In addition, it quickly became clear that the animation of these poses by the software was too awkward to be transferrable to a human dancer. As a result, the rehearsal with the dancers focused on the imitation of the avatar's dance poses whereas, for the movement between these poses, the software-generated solutions were manually adapted to render them physically possible. This approach resulted in the realization of different short solo dance sequences for each of the four dancers who participated in the piece. All the other choreographic material, including all duos and trios, were choreographed in a traditional manner, that is, movements improvised by the choreographer's body and subsequently learned by the dancers.

During the performance, the computer-generated poses were performed as solo dance sequences during which both the virtual avatar and the human dancer were visible on stage (see Figure 1). The avatar was projected on a screen in the background and performed its movements concurrently with the human dancer, who was imitating the avatar. The avatar's role during these scenes was representative of the title of the piece. The avatar acted as a godlike entity that commanded the human dancers to break free from their limited and ingrained movement possibilities.

All in all, the realization of this piece was a limited success. It became clear that the movement capabilities of the avatar were too limited in its ability to mimic the capabilities of a human dancer. In addition, throughout the traditionally choreographed dance sequences, the dancers showed a strong tendency to immediately fall back into traditional movement habits. So both the avatar and the human dancers exhibited an inability to mimic each other beyond the direct control of the choreographer. Fortunately, this partial failure did not diminish Ventura's interest in computer-based choreography. Quite to the contrary, it spurred his motivation to further deepen the experimentation with and exploitation of the specific differences in movement capabilities between human dancers and computer-controlled avatars. This interest

Figure 1. Video still from the performance *Deus ex Machina*. The image shows a solo dancer on stage. The dancer performed the same movements as a virtual avatar that was projected on a screen at the back of the stage.

also led to a thorough engagement of Ventura with scientific and philosophical notions concerning the characteristic properties of humans and machines.

MADGOD

The work *MADGOD* premiered in 1999.[3] This 10-minute piece involved a single dancer whose movements had been created solely within a computer. This work served as a prototype to evaluate whether an entire choreography could be created using Life Forms. Based on the previous experience of creating the dance production *Deus ex Machina*, it was clear that a software-controlled avatar offered the possibility for creating movement material that was drastically different from the natural and habitual movements of a human dancer. Accordingly, the use of Life Forms provided the opportunity to thoroughly alter and break traditional choreographic working methods and movement styles. At the same time, it was also clear from the previous results that dancers would fall back to conventional movement styles whenever they were not instructed to directly follow a computer-generated choreography. By rehearsing a dancer solely based on computer-generated movements, the choreographer could introduce

machine-like movement qualities into the dancer's body. And by balancing these machine-like movements with natural movements, the dancer became an entity whose characteristics shifted between an inorganic puppet-like and an organic human-like identity (e.g., Kochhar-Lindgren, 2005). The thematic and stylistic focus of this work was to contrast the natural properties of the human body with the synthetic qualities of an entirely computer-generated performance situation. This focus also marked an additional research strand for Ventura that became increasingly important in his choreographic work: the application of choreography techniques to define and correlate all elements on stage, the movement of the dancers, and the content and dynamics of electronic imagery and music. The abstraction of the human body in combination with the simultaneous presence of a multitude of electronically generated media can be understood as a transfer of ideas from the concept of radical immanent criticism (van Toorn, 1997) into choreographic practice. This extended approach to choreography also was inspired by concepts from Deleuze and Guattari (1988), who emphasized the emergent qualities of autonomous and synergistic processes.

The piece combined a single naked dancer with a top-down video projection onto both the stage and the dancer's body (see Figure 2). This video image operated as a light source and as a costume for the dancer. This setting contrasted and merged the almost archetypical appearance of the dancer's naked, pregnant body with a synthetic polyphony of light, music, and movement. The purpose of this extended form of choreography was to emphasize the different perceptual and rhythmic qualities of the different media and to establish clear correlations among them.

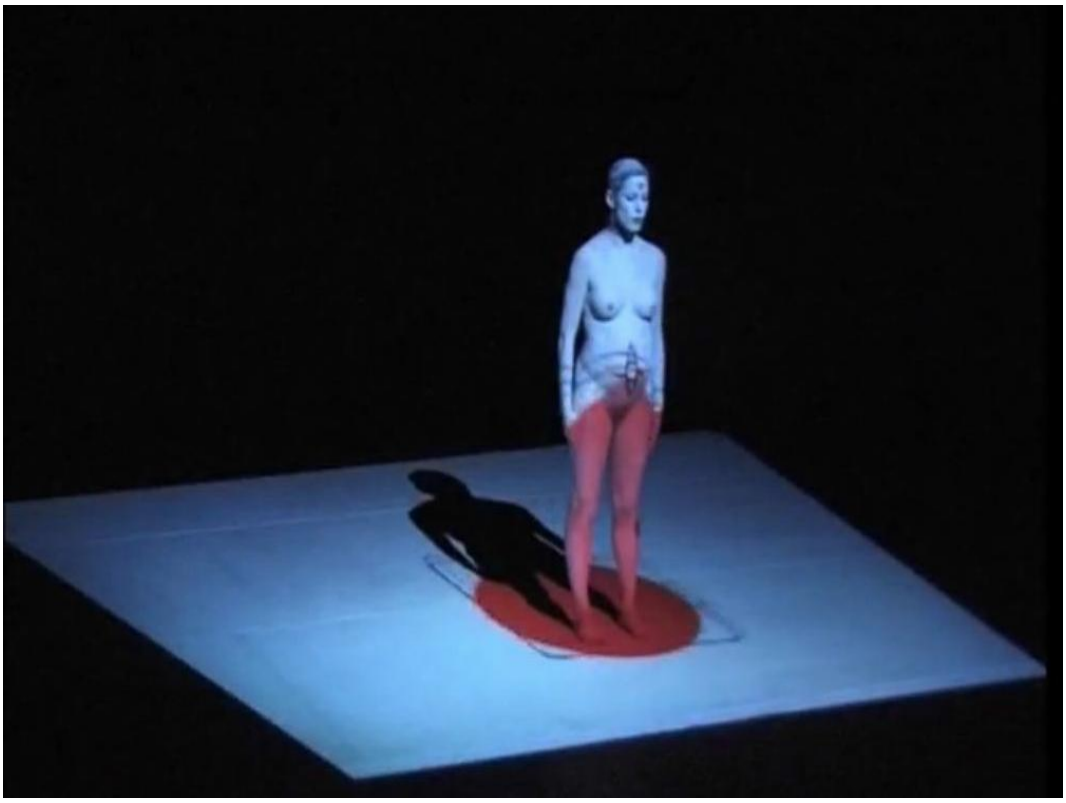

Figure 2. Video still from the performance *MADGOD*. The image shows a top-down video projection that served both as stage light and costume for a naked solo dancer on stage.

The outcome of this short performance laid the foundations for future dance works in that it demonstrated the feasibility and creative potential of working exclusively with computer-based choreography and of expanding the choreographic approach to address and shape the coexistence of body movement and electronic media on stage. The establishment of these foundations was reflected in Ventura penning a manifesto titled *The Gospel According to HAL*. The entire manifesto is printed in Appendix B. This tongue-in-cheek text defined a strict set of dogmas as to how the new technical possibilities of computer-based choreography and media design were supposed to thoroughly transform dance staging and thereby eradicate all stylistic dance baggage of conventional choreography and performance.

MADGOD 2.001

The piece *MADGOD 2.001* premiered in 2000.[4] This work was the first full-length dance-media performance by Ventura for which the entire choreography was created with the aid of the Life Forms software.

The realization of this work built upon and extended the choreography methods that had been developed for creating the previous piece *MADGOD*. This new work introduced two main choreographic innovations. First, new choreographic principles for developing novel poses from existing pose palettes in Life Forms were introduced. Second, the choreography abandoned the traditional use of space in that the dancers' movements were no longer coupled with traveling steps in space. Rather, the dancers were forced to execute disarticulated movements around their body axis.

The development of novel poses was based on a set of transformation principles that permitted the recombination and distortion of existing poses. The application of these transformation principles enabled the choreographer to further extend the already rich set of poses and movements that had been created for the previous two performances. In addition and more importantly, this new method shifted the focus of choreographic decision making further away from a body-centered approach. So instead of manually designing novel poses, as had been the case for the creation of the previous pieces, the choreographer manually selected from a set of abstract rules in order to modify body poses according to formal principles. Finally, the invention of transformation rules led to a further distortion of the movement capabilities of a human body. The application of these principles intentionally broke the wholeness of the human body by modularizing it into isolated elements that were manipulated separately. By decorrelating the movements of these isolated body elements, the natural synchronization and balancing of a human body was broken down and replaced by a machine-like control.

For this piece, a total of five different transformation principles were devised. Three of these principles applied to the transformation of poses; the other two served to modify movement sequences:

- The *disjoint* principle was used to randomize the rotation of joints in an existing pose.
- The *deconstruct* principle exchanged groups of joint angles either between different poses or between different joints within the same pose. For example, this principle allowed exchanging upper and lower body joint orientations in a pose.
- The *pi* principle mapped digits of the number pi to joint orientations.
- The *permutation* principle applied digits of the number pi to reshuffle the sequence of poses in a movement.

- The *reversed* principle inverted the sequence of poses in a movement.

In order to create new poses and movement material for *MADGOD 2.001*, these transformation principles were applied to pose palettes from the previous works (see Figure 3).

The second choreographic innovation broke with the conventional use of space in dance. Fixing a dancer's body to a particular location on the stage limited the dancer's movements to trajectories around his⁄her own body axis (see Figure 4). As a result, the dancers were forced to suppress any form of natural whole body dynamics. Because the dancers' movements needed to maintain a static stability, they became reminiscent of the behavior of stationary factory robots. Rehearsing these movements was far from trivial. With the explicit purpose of training the dancers to execute stationary movements, Ventura rented a small office space and repurposed it as highly constricted rehearsal space.

Concerning the narrative structure and media elements on stage, the piece *MADGOD 2.001* showed a further development of Ventura's extended choreography approach. In this work, up to six dancers performed on stage. The entire scenography was filled with projected images that covered the ground and screen surfaces on the left, right, and back wall of the stage. The video

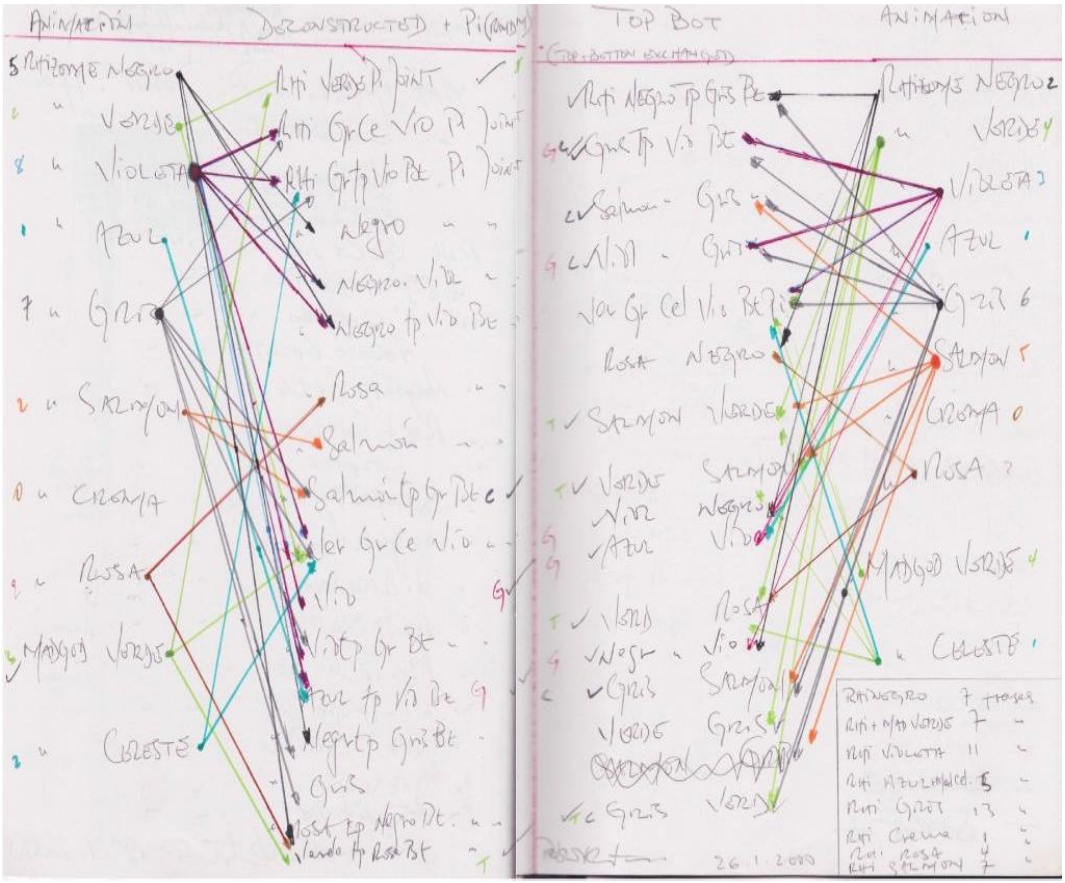

Figure 3. Scan of a sketchbook depicting the application of transformation rules to existing poses. The existing poses are listed on the left and right edge of the sketch and are labeled with color names. Each color corresponds to one of the six dancers of the *MADGOD 2.001* performance. The new and transformed poses are listed close to the center of the sketch.

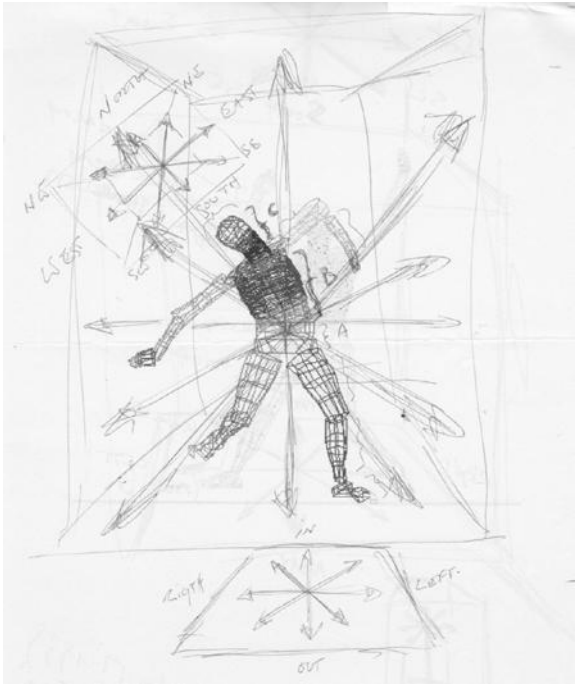

Figure 4. A graphical depiction of the movement possibilities of a dancer that is fixed to a stationary location on stage.

images exhibited strong rhythms that were synchronized with the electronic music and the dancers' movements. This complex combination of stage elements was treated as a synergistic whole in which the coherence among individual elements was made possible due to their strong correlation and merging. In addition, the piece exposed its conceptual underpinnings both in the narrative structure of the piece and in the content of the electronic media. The six dancers performed an abstract reenactment of the crew from Stanley Kubrick's film *2001: A Space Odyssey* (Kubrick, 1968). The narrative of the work followed the endangerment of the human crew by the onboard computer HAL that gradually took over the control of the spacecraft. In addition, textual content from fictional and academic sources that informed the realization of this piece appeared on stage, either as a voice-over track or text projections (see Figure 5). The main topics that informed the conception of the piece stem from fictional works, such as the book *Solaris* (Lem, 1972) and the film *2001: A Space Odyssey* (Kubrick, 1968), and from cognitive science and philosophy. The fictional works introduced the creation of intelligent machines by humans as a form of emancipation that challenges the omnipotence of God. By creating such machines, humanity overstepped its bounds. By not being able to anticipate and prevent this emancipation of humans, God was shown to be imperfect and fallible.

The influences from cognitive science and philosophy included texts by Ben Goertzel and Robert Nirre. Goertzel et al. (2014) defined the requirements for general forms of intelligence that both natural and artificial systems need to meet. These requirements included the capability to achieve goals within a complex environment. Nirre (2001) discussed how principles of autopoiesis and complexity render a clear distinction between parts of a system and a system as a whole unfeasible.

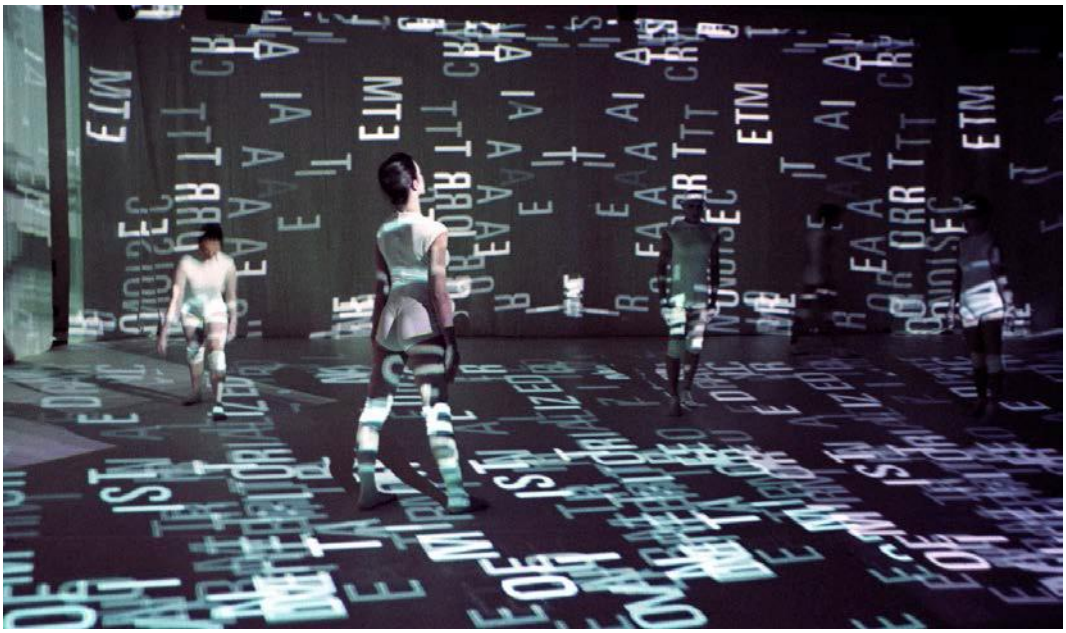

Figure 5. Video still from the performance *MADGOD 2.001*. The image shows the layering and merging of video projections and dancers with textual elements and quotations from fictional and academic publications that were influential for the development of this piece.

Zone

The work *Zone* premiered in 2001.[5] This second full-length production further emphasized the juxtaposition of man and machine by literally counterpointing dancers against a robot on stage. The movement material was developed by applying the previously described (*MADGOD 2.001*) transformation rules to palettes and pose sequences. The material from *MADGOD 2.001* played an important role in all subsequently created works and provided the so-called Adam and Eve sequences as source material for choreographic experiments.

For *Zone*, a novel choreography technique was developed. Numerical sequences, such as a Turing Chain (Stephenson, 1999) or a Pascal Triangle (Rogers, 1978), provided the organization principles for introducing rhythmic structures when creating sequences of poses (see Figure 6 and Figure 7). Here, each number in the numerical sequences determined the selection of a pose from a pose palette. Repeated numbers resulted in equally repeated poses leading to the creation of rhythmic intervals in the dancers' movements.[6] A further novelty was the introduction and adaptation of musical counterpoint techniques to choreography. These counterpoints permitted the creation of complex but coherent group movements. The complexity resulted from the diversity of different poses executed in parallel by each dancer on stage. The complexity was balanced by a clear synchronization of all these movements that followed a global and regular beat. The introduction of rhythmicity and counterpoints led to a crescendo in the group coordination among dancers. The piece began with a solo dancer who executed a Pascal Triangle phrase. Later, a Pascal Triangle duet was followed by a trio, a quartet, and quintet until culminating in a sextet in the act's climax, during which all dancers

19,39,59,79,99, 18, 38,58,78,98,
17,37,57,77,97, 16,36,56,76,96,
15,35,55,75,95, 14,34,54,74,94,
13,33,53,73,93, 12,32,52,72,92,
11,31,51,71,91, 10,30,50,70,90,

9,29,49,69,89, 8,28,48,68,88,
7,27,47,67,87, 6,26,46,66,86,
5,25,45,65,85, 4,24,44,64,84,
3,23,43,63,83, 2,22,42,62,82,
1,21,41,61,81, 0, 20,40,60,80

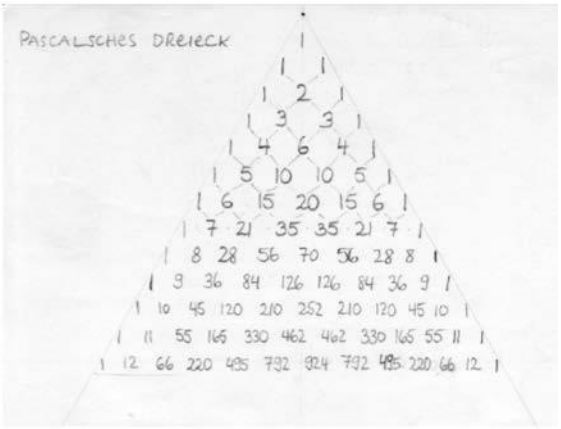

Figure 6. Numerical sequences from Turing Chain (left side) and Pascal Triangle (right side).

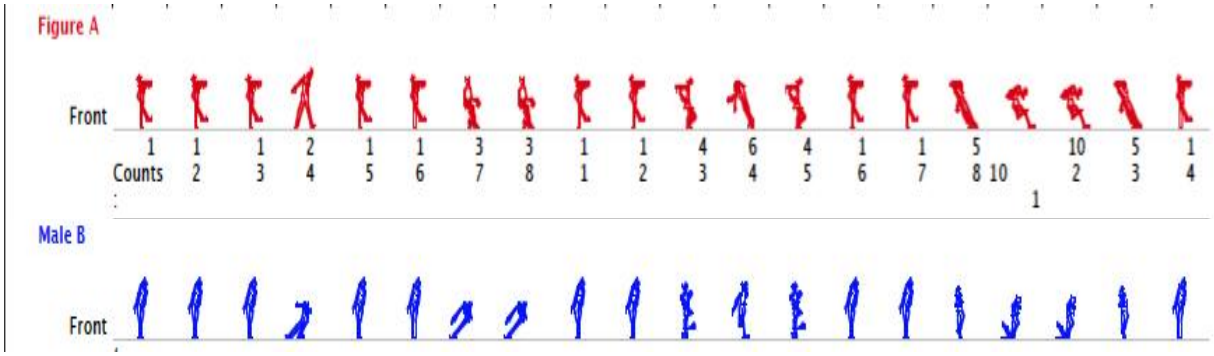

Figure 7. Screenshot of a Life Forms score derived from the Pascal's Triangle.

executed different Pascal's phrases counterpointed to each other and synchronized by a rhythm that was also derived from Pascal's Triangle numbers.

The aesthetic and narrative setting of this performance further accentuated the juxtaposition of man and machine. The stage assumed the role of a factory from which dancers emerged as mechanical artifacts that were mass-produced on a production line. The dancers performed highly mechanical movements that were contrasted towards the end of the piece with an artificial dancer in the form of an industrial KUKA robot (see Figure 8). This robot's movements had been choreographed by Ventura to appear much smoother and organism-like than those of the human dancers. Accordingly, the piece created a setting in which the normal preconceptions concerning the characteristics of natural organisms and machines were partially reversed.

The stage scenography reflected the highly structured setting of a factory. In this setting, both space and time were subdivided by repetitive elements consisting of arrays of video screens that hung from the ceiling and the rhythmic movements of the dancers. The dance movements, video, and music were perfectly synchronized by a global timing mechanism throughout the 60-minute duration of the piece. This mechanism was audible as a 60 bps drum beat that was embedded into the sound track of the performance. Finally, similar to the approach

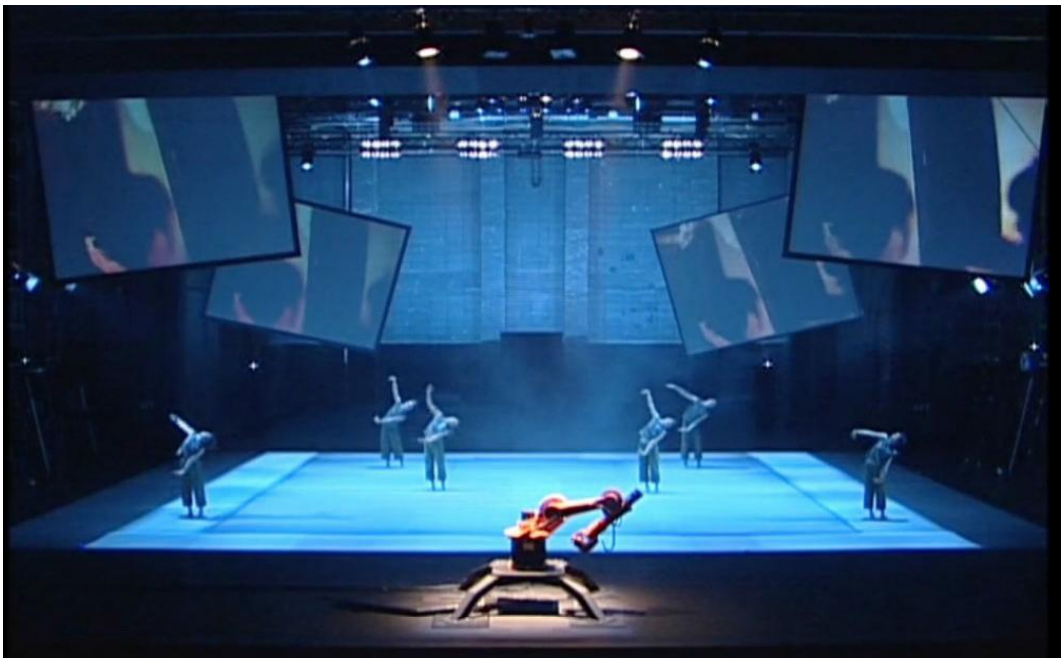

Figure 8. Video still from the performance *Zone*. The image shows an industrial KUKA robot performing choreographed movements that are more human-like in their appearance than the perfectly synchronized and rhythmic movements of the human dancers.

in *MADGOD 2.001*, the conceptual underpinnings of the piece were exposed as prominent media elements on stage, either as voice-over in the sound track or as video projections of textual elements.

De Humani Corporis Fabrica

The work *De Humani Corporis Fabrica* represents a trilogy of pieces that were developed over the course of 3 years. *De Humani*, the first part of the trilogy, premiered in 2002.[7] The second part, *Corporis* / *Cluster II*, premiered in 2003.[8] The final part, *Fabrica* / *Cluster III*, premiered in 2005.[9] The trilogy received its title from the famous anatomy book *De Humani Corporis Fabrica Libri Septem* (*On the Structure of the Human Body*) by Andreas Vesalius 1543/2003), which marked the initial breakthrough in the medical understanding of the inner structures and mechanisms of the human body. The three pieces exhibited a progression through different relationships between humans and technology and also recapitulated in condensed form the choreographic developments of Ventura's earlier works.

Throughout the trilogy, the dancers' poses and movements, created with the aid of Life Forms, underwent a subtle development. In *De Humani*, the movements appeared organic and natural. In *Corporis*, the movements became more distorted and at times even grotesque, whereas in *Fabrica*, the movements were collapsing, suggestive of the dancers' increasing dehumanization.

In *De Humani*, technology was used to expand the movement possibilities of the dancers but not to influence their movement interpretation. Accordingly, the dancers were prompted to rehearse the computer generated poses not by literally mirroring them but rather by interpreting

and translating them into natural and subtle body movements. In a similar manner, the coordination of group movements followed more traditional choreography techniques in that dancers were allowed to dance together and touch each other. The only new formal invention for this piece involved the introduction of a new transformation rule. This rule employed sums of two odd numbers to reshuffle previously existing pose sequences.

In *Corporis* / *Cluster II*, the choreographic situation changed radically. Here, the dancers' appearance and behaviors were reminiscent of genetically engineered clones (see Figure 9). For these clones, the formally natural behavior was literally mutated into more extreme and grotesque movement material. The issue concerning the manipulability of the human genotype informed the choreographic decision to use existing DNA nucleotide sequences to derive pose sequences. This derivation was based on the establishment of a mapping between nucleotide types and pose types. Because DNA sequences consists of only four unique nucleotides, this organization principle gave rise to highly repetitive movement patterns.

In *Fabrica* / *Cluster III*, the development of the choreography followed a similar principle as in *Zone*. The movement material was created from the Adam and Eve sequences that originated in *MADGOD 2.001*. These sequences were subjected to all the previously described transformation rules to create a collapsing movement style. A breaking down of movements associated to the deterioration of human relationships and with the dancers performing their

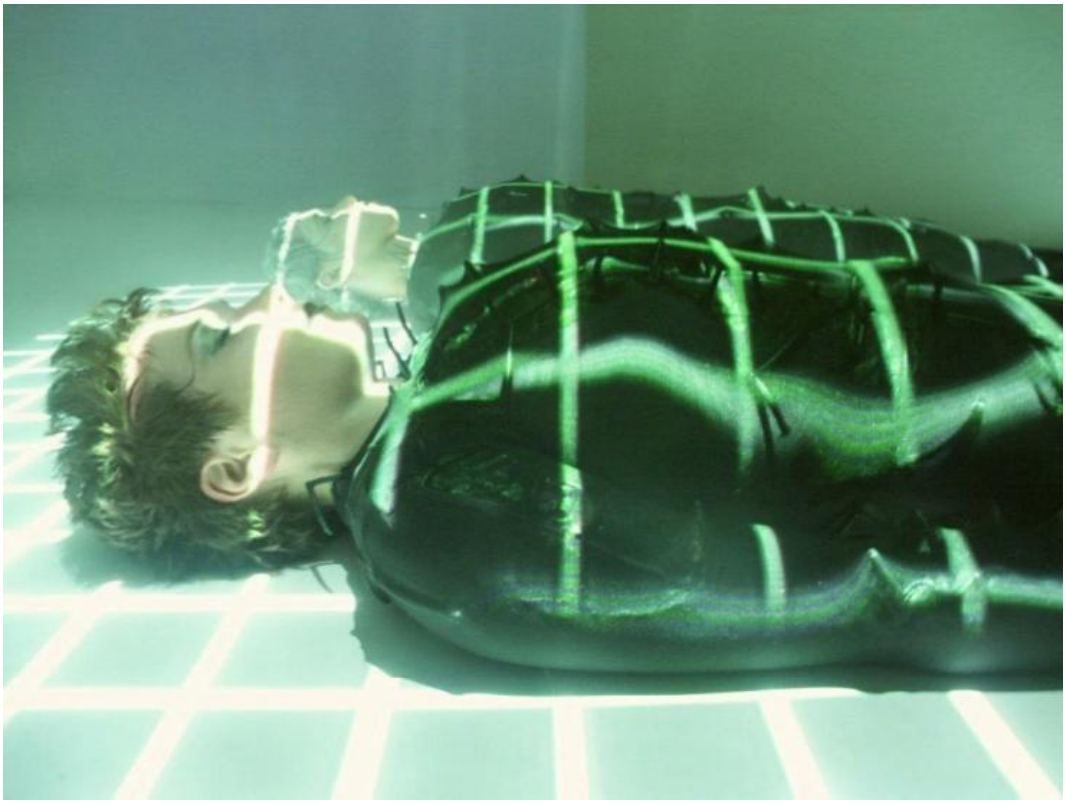

Figure 9. Video still from the performance *Corporis* / *Cluster II*. The image shows two dancers wearing custom-designed costumes whose spike-like protrusions evoked an association with mutations.

movements, at times, far from each other on stage, suggested an autistic isolation. Similarly to *Zone*, this work concluded the trilogy with the performance of a robot. But contrary to *Zone*, the robot does not appear as an almost organic entity. Rather, the robot exceled in its machine-like appearance and movements and completely superseded the presence of the human dancers. This robot with the name of Kubic was specifically developed for Ventura by artist and roboticist Louis Philippe Demers (see Figure 10). The design of the robot bore no resemblance to a biological organism. The robot, which hung above the stage, consisted of a foldable metallic frame whose nine joints could be moved individually by pneumatic actuators. Ventura's programmed choreography of this robot gave rise to jerky and aggressive movements that seemed to threaten the comparatively vulnerable and soft appearance of the human dancers.

As in the previous performances, the choreographic, scenographic, visual, and musical elements were tightly interrelated and synchronized. However, in this trilogy, this principle was further expanded in that the various elements were not only correlated with each other during a single piece but also across the entire trilogy. This self-referentiality formed recurring leitmotifs that appeared as rhythmic patterns and repetitions among and across different media and performances. The mechanism for synchronizing these various performance elements was made even more explicit and was brought to the foreground as functional, conceptual, and aesthetic element of the performance. Each dancer carried a metronome that was attached to his/her chest to provide through an earphone a common beat. At the same time, each metronome possessed an

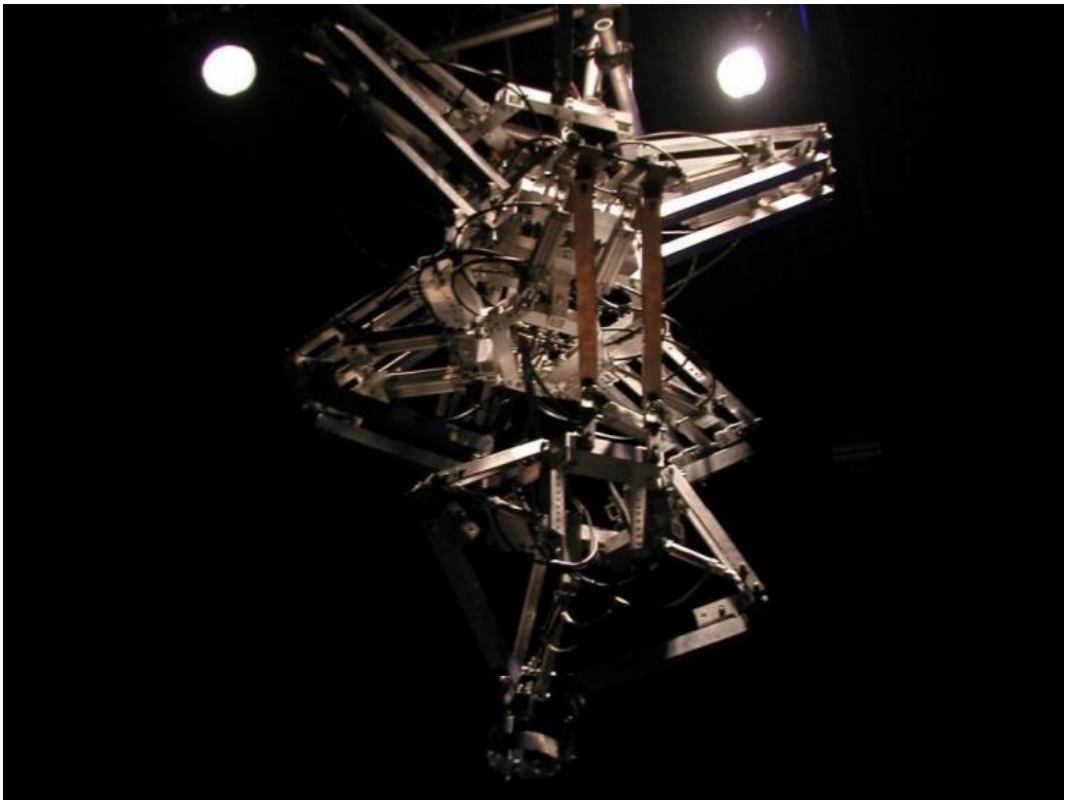

Figure 10. Video still showing the robot Kubic which was custom designed for Ventura by Louis Philippe Demers and used as a robotic dancer in the performance *Fabrica* / *Cluster III.*

externally visible LED that also blinked in synchrony with the common beat. This technical and visual expansion of the dancer's body formed another leitmotif throughout the trilogy.

Novel elements in the scenography of two of the three pieces of this trilogy are actuated stage elements that directly interfered with the dancers' performance on stage. In *De Humani*, upper body sections of male mannequins represented stylized ideals of human beauty. These mannequins could be moved vertically and, at particular moments of the piece, they were lowered onto the stage floor (see Figure 11). In *Fabrica* / *Cluster III*, there existed five vertical neon rods that could be moved up and down (see Figure 12). These light rods represented metaphorical harbingers of robotic dominion. When they were lowered towards the end of the piece, they literally pinned the human dancers to the ground and incapacitated them for the remainder of the performance.

The scenography setups of the trilogy partially followed the sequence of stage situations in previous works but in reversed order (see Figure 13). In *De Humani*, the stage was structured in a similar manner to *Zone* by a regular array of video projection regions on both the floor and hanging screens. In the later pieces of the trilogy, these hanging screens were removed but the number of floor projection regions increased. These isolated image zones increased in number from three in *De Humani*, to four in *Corporis* / *Cluster II*, and five in *Fabrica* / *Cluster III*. These image zones operated in a similar manner as in previous pieces in that they created a visual crescendo in which the dancers' bodies and electronic media overlapped and merged.

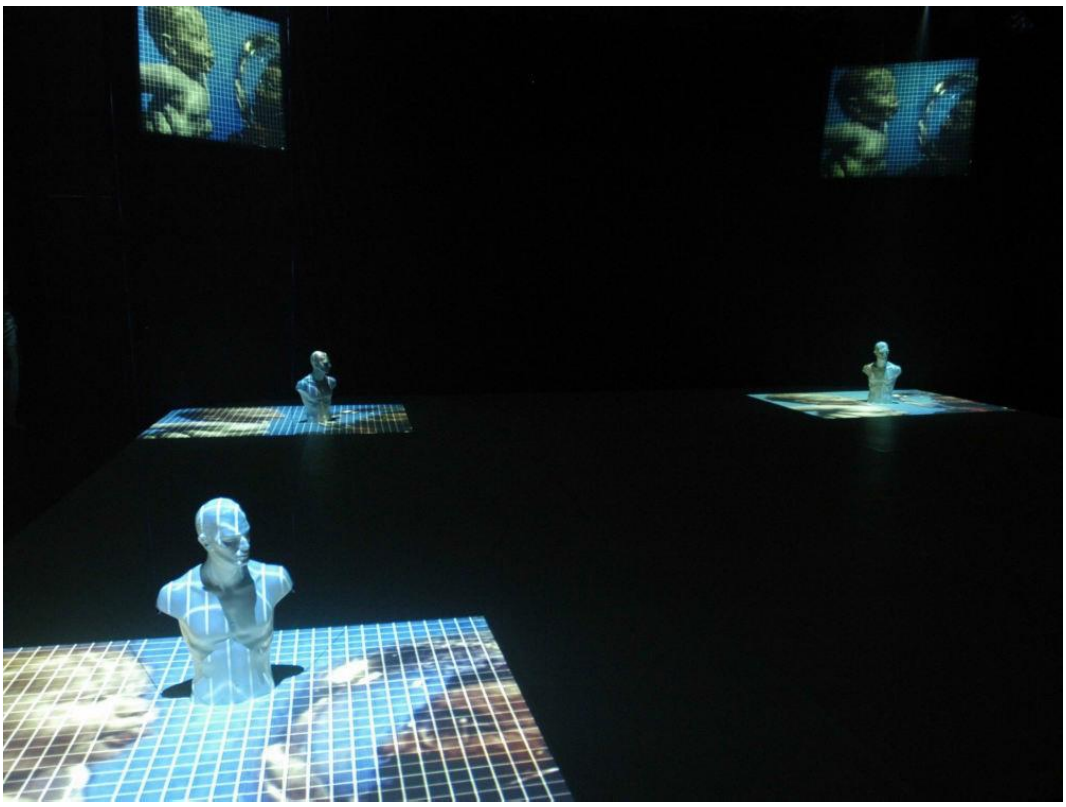

Figure 11. Video still from the performance *De Humani*. The image shows the three mannequins lowered into three video projection zones on the ground.

Figure 12. Video still from the performance *Fabrica* / *Cluster III*. The image shows five dancers performing in isolation within their respective video projection zones and five neon light tubes descending precariously above them.

The narrative of the three pieces followed a metaphoric journey of the human body, a process spanning from the humane (*De Humani*) to man's increasing interdependence with technology (*Corporis* / *Cluster II*) to man's dehumanization and eventual substitution by a robotic machine (*Fabrica* / *Cluster III*). This narrative was inspired by philosophical considerations concerning the influence of genetic engineering and artificial intelligence on the self-perception and self-image of humans and their impact on human society. Among the main inspirations for this trilogy were the notion of evolved artifacts that enter and form a dynamic, unpredictable, and fluent network of rich and rhizomatic relationships (Deleuze & Guattari, 1988). A further inspiration came from the acknowledgement that code as a universal principle has entered the biological and human domain due to advances in genetic engineering. And finally, the issue of an increasingly blurred distinction between humans and machines and the question whether conscious agency represents a last exclusive privilege of human beings formed an important background (Hayles, 2008; Weizenbaum, 1976).

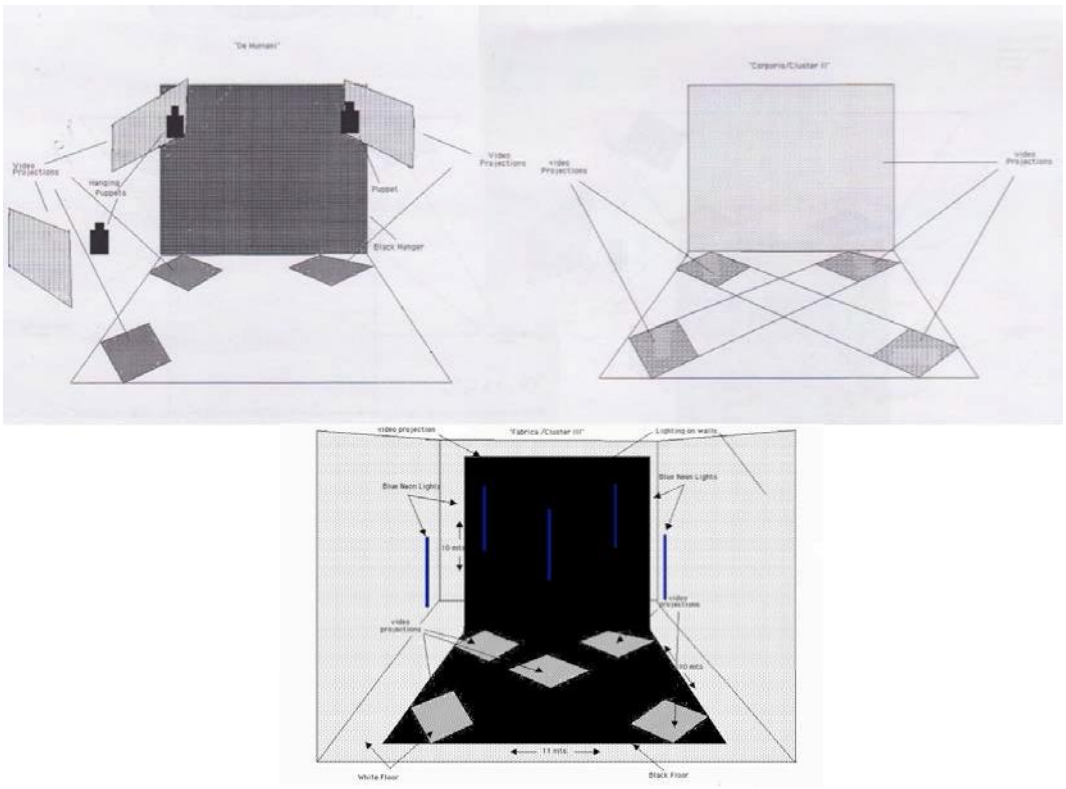

Figure 13. Schematic stage settings for the trilogy *De Humani Corporis Fabrica*. The stage for *De Humani* (top left) showed hanging mannequins, hanging screens, and a stage backdrop, as well as three zones on the ground that served as video projection surfaces. The stage for *Corporis* / *Cluster II* (top right) depicted a back screen and four video projection zones on the ground. The stage for *Fabrica* / *Cluster III* (bottom) displayed five neon light tubes hanging from the ceiling, a backdrop, and five video projection zones on the ground.

2047

The work *2047* premiered in 2009.[10] This piece marked a further shift in Ventura's works towards a more conceptual and narrative focus that addresses social and emotional aspects in human–machine relationships. The narration was based on the android characters from the film *2046* by cinematographer Wong Kar Wai (Wong, 2004). This narrative explored the ambivalences that arise between human and nonhuman stereotypes as depicted in films and science fiction literature and, in particular, the issue of falling in love with a robot/android and whether androids can develop affectionate feelings over time.

The creation of *2047* was also the result of several technical and choreography innovations. These innovations involved the development and application of the software Choreography Machine and the integration of interactive elements for controlling sonic and visual elements on stage. The software Choreography Machine was developed as a collaboration between the two authors of this article during their residency at the Artificial Intelligence Laboratory of the University of Zurich, Switzerland. The software implements a fully automated generative algorithm that permits the creation of new poses and pose sequences either wholly new or from pre-existing pose palettes. A detailed description of this software is provided in Appendix A.

The capability of the software to produce entirely new movements relinquishes the need for a manual intervention by a choreographer and also abandons the previous incremental approach of modifying existing movement material through the application of transformation rules. As a result, this software permits the delegation of parts of the choreographic process entirely to a computer and thereby eradicates any remaining traces of subjective authorship and stylistic habituation.

The movement material that was created for this piece consisted of stylized postures and movements that are reminiscent of androids. This material was subsequently modified according to the deconstruct transformation rule. But unlike previous approaches, this rule was not applied in Life Forms but directly to the dancers' bodies.[11] During rehearsal, dancers were instructed to copy and learn from each other the segmented elements of the movement sequences in order to create new movements. The feasibility of this procedure was due to the fact that some of the dancers had ample previous experience in working with Ventura. As a result, their bodies had adapted to and integrated some of the software-based and algorithmic movement creation principles that thereby became second nature for them. These deconstructed movements were applied to all dancers with the exception of two dancers who moved in a natural manner because they assumed the role of humans in the narration. The application of this transformation rule directly to the dancers' bodies was demonstrated in scenes within the work and became a choreography technique in itself with the name *Top÷Bottom*.

The choreographic presentation *2047* was also the first piece by Ventura that integrated an interactive system. The system employed video tracking to analyze the movements and postures of the dancers. This analysis formed the basis for implementing an audio triggering mechanism that allowed dancers to control aspects of the soundscape of the piece. Whenever movement within a zone on stage exceeded a threshold, the playback of a specific audio file that is associated with that particular zone was triggered. Interactive control of a video projection that fell on a sloped panel in the center of the stage also was based on video tracking. This tracking employed a continuous movement and contour analysis of each dancer (see Figure 14). In this setting, the dancer controlled an interactive swarm simulation that was made visible by rendering the simulated agents as graphical lines. The movement of simulated agents was affected both by the movement and posture of the dancer. Fast movements by the dancer scattered the visible lines whereas slower movements caused an aggregation of the lines along the body contours of the dancer. A more thorough explanation of this interactive system is available in Bisig & Unemi (2009).

Dancescapes

The work *Dancescapes* premiered in 2011.[12] This piece represents a distinct departure from previous works in respect to both choreography techniques and conceptual motivation. Rather than emphasizing the contrast and relationship between humans and machines, the conceptual and narrative elements of the piece addressed the transformation of cultural and natural phenomena through the process of their mediation. Furthermore, the choreography tried to establish a synthesis between software-generated movements and the natural and idiosyncratic movements of each dancer.

Figure 14. Video still from the performance *2047*. The image shows the interaction between one of the dancers and a visual rendering of a swarm simulation that is projected onto a sloped surface.

The original movement material for this work was created by using the software Choreography Machine. But instead of transferring the resulting synthetic postures and movements to the dancers' bodies, this material served as inspiration for the dancers to improvise in a traditional manner with their bodies and thereby develop their personal movement material.

In addition to the dancers' presence, prerecorded video and audio material played a very prominent role on stage (see Figure 15). This content was not created synthetically but rather consisted of audio and video recordings from the volcanic island Fuerteventura.

The music combined natural sounds of the environment and the weak and frequently interrupted transmissions of folk music from North African radio stations. The visual content consisted of video recordings of dancers performing within the landscape of Fuerteventura. These media elements were interwoven and connected with the dancers' movements by means of a camera-based interaction. Contrary to the previous work *2047*, the soundscape consisted in its entirety of audio files that were triggered by the dancers. The video material, on the other hand, was interactive during only a part of the performance. Here, the original video recordings were distorted by a superimposed visual grid structure that became deformed in response to the dancers' movements.

Figure 15. Video still from the performance *Dancescapes*. The image shows the stage setting that consisted of a single dancer performing in the foreground, while the background screen projected imagery from previously recorded landscapes and the tilted screen on the ceiling displayed video recordings of a sky.

Heliopolis

The work *Heliopolis* premiered in 2014.[13] The thematic focus of *Heliopolis* emphasized the relationship between natural and artificial humans. The piece loosely followed the narrative of the classic film *Blade Runner* by Ridley Scott (Deeley & Scott, 1982).

In this film, five "replicants" search for the master who created them and who could reprogram them to extend their short lives. The choreographic creation of this performance followed the same principle as in *Dancescapes*. The movement for the dancers was created with the software Choreography Machine and some sequences were subsequently altered by applying the Top÷Bottom technique directly to the dancers' bodies. The main technological and choreographic innovation of this piece was reflected in the collaborative development of the software Choreophony by Ventura and media artist Chris Ziegler. This software extends the interactive and musical possibilities of connecting the dancers' movements to sonic material. A more detailed description of this software is available in Appendix A. The application of this software allows dancers to control a polyphonic composition of sound material both via their body movements and by entering motion-sensitive zones on stage. The sound and video material that was shown during the performance combined excerpts from the film *Blade Runner* (Deeley & Scott, 1982), from autobiographic childhood memories in the form of Super 8 films, and from video recordings from the city of Shanghai. Apart from a projection screen at the back of the stage and a top-down projection on the performance area, the

scenography consisted of a large light column that towered in the center of the stage (see Figure 16). Accordingly, the stage became a location where the dancers' presence was combined with various physical and mediated elements and narratives. The juxtaposition and presence of these elements played a central role in the piece.

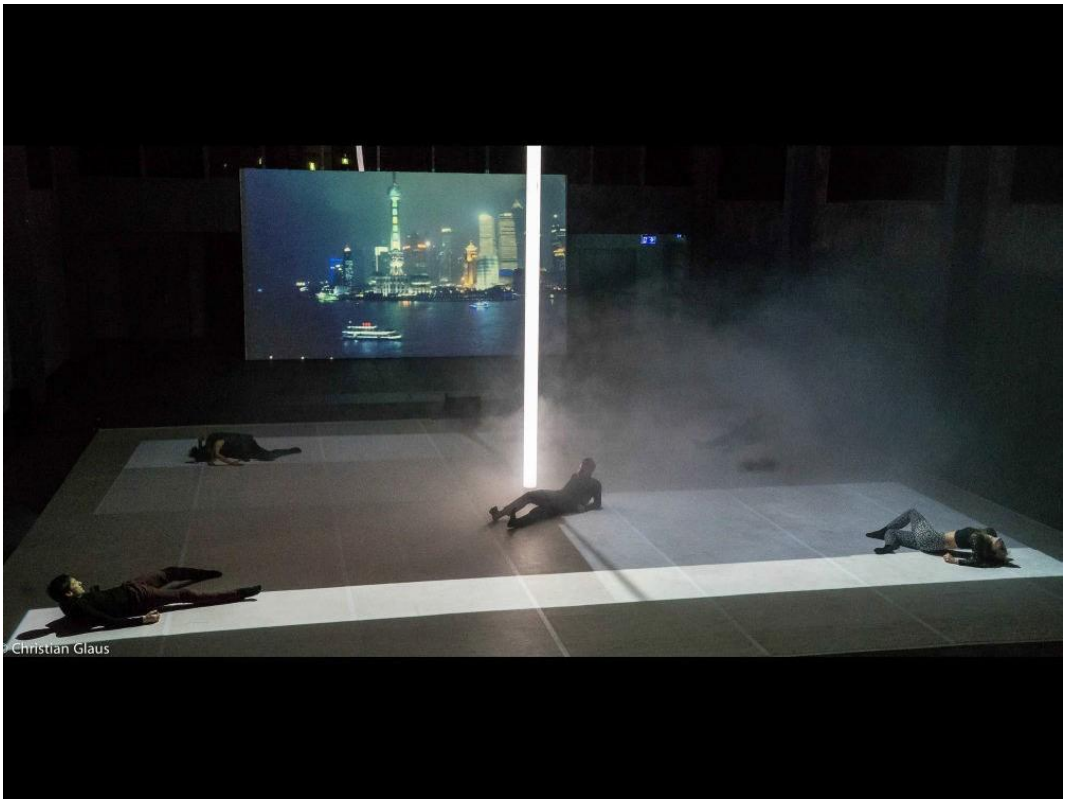

Figure 16. Video still from the performance *Heliopolis*. The image shows a scenography that was dominated by a central light pillar. Other elements on stage included a video projection screen at the back and a top-down projection onto the stage.

THREE STRANDS OF TECHNOLOGY-ENHANCED CHOREOGRAPHY

This section provides an overview as to how the three thematic strands that run through the main body of Ventura's work manifested in each piece and how they evolved over time and in the various works. The following paragraphs briefly recapitulate the main thematic strands presented in the Introduction.

The first strand focuses on the usage of algorithmic and formal processes to break and redefine bodily and aesthetic habits and principles. This strand employs choreography methods and movement principles that allow both the choreographer and dancers to break free from habitual traditional styles and dance techniques, which then enables the creation of entirely novel choreographic languages and movement materials.

The second strand addresses the identification and differentiation of inherently human and machine-like capabilities and their increasing interdependency and interpenetration. This strand explores the characteristics and relationships between humans and machines. It draws from philosophical notions of the posthuman body, systemic thinking, and scientific progress in the fields of artificial intelligence and genetic engineering. This conceptual background motivated the choreographic and scenographic experiments involving the juxtaposition, reversal, and confounding of human, cultural, and technical attributes.

The third strand experiments with the application of choreographic design processes beyond the human body to include all aspects on the stage. This strand focuses on an extension of choreography principles to the organization of body movement, space, and media. It experiments with the establishment of correlations among all these elements and the transfer of stylistic and organizational principles across different media.

Breaking Habits

Ventura used the Life Forms software for the first time in the realization of the work *Deus ex Machina*. In this case, the application of Life Forms was limited to creating short dance sequences. This approach made it evident that dancers would fall back into their habitual movements whenever they stopped following the computer-generated dance sequences. For this reason, Ventura decided to extend the usage of Life Forms to create all movement material for his next work, *MADGOD*. In the succeeding work, *MADGOD 2.001*, the invention of transformation rules marked another significant step away from traditional choreography. These rules dispense with the necessity to manually arrange poses and sequences and thereby help to establish a new dance language that is unaffected by choreographic habituation. As an additional innovation, the conventional use of space was abandoned by restricting the dancers' movements to local rotations around the body axis only. The work *Zone* brought the introduction of numerical sequences whose application allows for creating rhythmic movement sequences. For the middle piece in the trilogy *De Humani Corporis Fabrica*, Ventura derived pose sequences from existing DNA nucleotide sequences. Later, the development of the software Choreography Machine constituted an important innovation in that this software permits fully automated creation of novel poses and movements. This software was used for the first time in the creation of the work *2047*. The work *Dancescapes* combined computer-generated and natural movements and therefore marked a deviation from the previous emphasis on increasing alienation from choreographic and movement habituation. The last work, *Heliopolis*, did not introduce additional choreographic innovations and employed methods similar to those in the work *2047*.

Human–Machine Relationships

In the work, *Deus ex Machina*, the computer-generated avatar of Life Forms was depicted on stage as an artificial character that attempted to execute human-like movements. Human dancers followed those movements. This juxtaposition between artificial and human characteristics was further accentuated in the work *MADGOD*. Here, the primordial appearance of a naked dancer was put in contrast to the synthetic movements and media. In the next work, *MADGOD 2.001*, the human body itself was treated as a machine whose modular parts could be moved individually and independently. In the work *Zone*, the relationship between humans and machines

reached a pinnacle in that it confronted dancers with an actual robot on stage whose movement qualities were more humanlike than those of the dancers. This reversal of roles was further accentuated in that the stage served the role of a factory whose products were the human dancers. The trilogy of works *De Humani Corporis Fabrica* exhibited in condensed form the progressing relationships between humans and machines. In the first work of the trilogy, *De Humani*, the dancers interpreted the computer-generated movements with natural movements. In the second work, *Corporis / Cluster II*, the humans maintained their biological characteristics but their distorted movement and appearance evoked associations with cloning and mutation principles. In the work, *Fabrica / Cluster III*, the dancers were further dehumanized and their movements broke down as the individuals were isolated. This final work of the trilogy contrasted the vulnerability of the human body with the aggressive superiority of a robot. For the next work, *2047*, Ventura invented the Top÷Bottom technique that applied a computational rule directly onto the dancers' bodies. Additionally, this work marked a turn in Ventura's choreographic treatment of human–machine relationships. Rather than expose these relationships through an explicit contrasting of human and machine-like properties, *2047* established conceptual and narrative connotations with the film *2046* (Wong, 2004), which emphasized the social and emotional aspects of human–machine relationships. The work *Dancescapes* constituted an exception in this sequence of works in that it completely abandoned the topic of human–machine relationships. For the last work, *Heliopolis*, these topics once again came to the forefront and followed a similar approach as in *2047*. Here, humans and machines formed symbiotic entities that operated as perfected dancers in analogy to replicants from the film *Blade Runner* (Deeley & Scott, 1982).

Extended Choreography

The work *Deus ex Machina* employed a video projection of an avatar that exhibited concurrent movements with dancers on stage. In *MADGOD*, the role of video projection was increased considerably as it replaced the dancer's costume and stage lights. Furthermore, music, image, and movements were all correlated choreographically by focusing on rhythmic relationships. In the work *MADGOD 2.001*, Ventura converged all elements on stage into a synergistic whole. Video projection on three walls and the stage floor established a stage scenography and led to a superposition between the dancers' bodies and digital media. The rhythmicity of the projected images was coordinated with the choreography and synchronized with music. Furthermore, the conceptual underpinnings of the work were foregrounded with voice playback and video projections of text. The narrative of the work followed the film *2001: A Space Odyssey* (Kubrick, 1968). In the work *Zone*, video projection once again played a prominent scenographic role in that it served to fragment space into multiple regions. For this work, Ventura also appropriated the counterpoint technique and applied it to movement and media. The dancers and music were coordinated via a regular drumbeat. For the trilogy of works *De Humani Corporis Fabrica*, Ventura continued in merging compositional and choreographic principles. Here, returning leitmotifs appeared across various media and different works. In *De Humani* and *Fabrica / Cluster III*, the introduction of an actuated scenography formed a dramatic choreographic element that directly impacted and interrupted the dancers' activities on stage. Finally, the entire choreography was synchronized to a common timing that was perceived by the dancers through metronomes attached to their chests. The work *2047* reenacted the narration from a scene in the film *2046* (Wong, 2004). This work also marked the introduction of

interactive media elements on stage. Here, dancers, through their movements, controlled sounds and visuals during a short period within the performance. In the work *Dancescapes*, the role of interactive media was extended. In this case, the application of the software Choreophony permitted the dancers to control and modulate the entire sound track of the performance. In addition, this work juxtaposed prerecorded and live media, thereby highlighting the transformation of cultural and natural phenomena through the process of their mediation. The final work, *Heliopolis*, reenacted the narration from the film *Blade Runner* (Deeley & Scott, 1982). This work combined different physically present and mediated elements on stage. The differentiation between live and mediated settings was further developed by presenting and interrelating different environments and narratives.

DISCUSSION

The initial motivation for Ventura to experiment with software was triggered by his desire to create novel movements for dancers that were as removed as possible from internalized bodily and stylistic habits. The fact that software-based simulations of the human body constitute formal and disembodied abstractions opens up the possibility for introducing algorithmic and computational methods into the choreographic process of working with the human body.

Ventura's work can be considered pioneering not so much because of the particular software tools and techniques that he used but due to his continued engagement with software that allowed him to achieve, in a thorough and systematic manner, a deep integration of choreographic experimentation and conceptual reflection. After the first struggles and failures of using an early version of the Life Forms software for creating the piece *Deus ex Machina*, he chose to exploit the very specific characteristics and limitations of this software as a main source for choreographic innovation. From then on, his systematic engagement with Life Forms allowed him to gradually develop for his works a new choreographic language that integrated algorithmic experimentation and thinking within all aspects of choreographic creation. In addition, the limitations of the choreography software triggered Ventura's interest in the characteristics of humans and machines and their increasingly profound interdependencies. Particularly inspired by debates within the field of complex systems and posthuman theories, he started to employ choreography as a means of artistic investigation. Most of the questions that moved increasingly to the foreground during his choreographic creations dealt with the attribution of machine-like and human properties to performers on stage:

- How can human beings be dehumanized to such a degree that they can be operated like machines?
- What properties must a machine fulfill to evoke associations with a living organism?
- What specific human qualities remain even if the dancers' appearances and movements deviate as far as possible from their natural characteristics?
- Can human beings and machines coexist symbiotically or will one of them eventually overcome the other?

Dance as investigation provides the opportunity to complement scientific research in that it allows one to embody philosophical ideas. Embodiment exposes these theoretical notions in a

tangible form. Performance-based staged experiments enable both the dancers and the audience to acquire an experiential appreciation of and reflection on theoretical notions. In this context, the dancers' perspectives are particularly valuable due to the fact that their training has led them to develop an embodied virtuosity and awareness for the quality and precision of body mechanics. This awareness is combined with the capability to follow an exact timing and movement instructions. Accordingly, dancers can adopt and combine in their behavior formal control principles and thereby become test subjects for exploring hypotheses and algorithms, for example, from the field of artificial intelligence. Due to the fact that some dancers participated in multiple productions by Ventura, the previously mentioned principles could be empirically verified. As Ventura developed his choreographic vision by using Life Forms, the dancers too gradually incorporated the algorithmically specified movements into their bodily repertoire. This coevolution of software usage and body capabilities culminated in the fact that Ventura could apply formal pose transformation principles directly to the dancers' bodies.

Parallel to the investigation of computer-generated movements, Ventura also experimented with the extension of choreography principles beyond the human body. By developing a keen sense of the formal and aesthetic principles of different media, he was able to apply some of his choreography techniques to control and correlate movement, music, video, and scenography. For his latter works, Ventura started to integrate interaction technologies that allowed him to directly influence via the choreographing of the dancers' bodies also the musical and visual elements on stage. This led to the expression of a holistic choreographic practice that integrated all elements of a performance into a synergistic relationship.

IMPLICATIONS FOR RESEARCH, APPLICATION, AND POLICY

This publication provides a direct insight into a choreographer's long-term process of developing his own choreographic language. This process elucidates in a unique manner how the tight integration of aesthetic motivations, conceptual reflections, and technological experimentation leads to choreographic innovations. The detailed description of this process is meant to demonstrate to researchers and practitioners how technology and its conceptual underpinnings can provide both a practical and theoretical framework for choreographic investigation and creation. In particular, we authors hope that the publication can contribute to the development of a theoretical basis concerning the impact of computer-based and algorithmic approaches in contemporary choreography. For practitioners, the publication demonstrates in its most immediate form how the tools and methods that have been developed by Ventura and colleagues can be applied for choreographic creation. These methods and tools include, for example, the Top÷Bottom technique and the software Choreography Machine and Choreophony. Beyond their direct application, these methods and tools can serve as inspirations and starting points for choreographers to experiment on their own with generative and machine-like forms of creativity and to extend their choreographic activities to include digital and responsive media. Finally, our paper also is meant to highlight to policy makers in education and cultural funding the importance of transdisciplinary know-how and practice. Within education, the fields of dance and technology strongly benefit from curricula that are highly permeable between computer science, new media, and choreography. Concerning cultural funding, the adoption of funding schemes that do not enforce strict separation between

the artistic and technological domains would help foster the creative output of dance and technology. The implementation of such curricula and funding schemes would constitute an important step for promoting future creative developments in this field and thereby guarantee its long-term viability.

ENDNOTES

1. Ventura, P. (2016). Website of the Ventura Dance Company. Retrieved June 25, 2016 from https://www.ventura-dance.com/
2. Ventura, P. (1997). Deus ex Machina. Retrieved June 25, 2016 from https://ventura-dance.com/works/deus-ex-machina
3. Ventura, P. (1999). MADGOD 1999. Retrieved June 25, 2016 from https://vimeo.com/channels/pabloventura/87560736
4. Ventura, P. (2000). MADGOD 2.001. Retrieved June 25, 2016 from https://ventura-dance.com/works/madgod-2-001
5. Ventura, P. (2001a). Zone. Retrieved June 25, 2016 from https://ventura-dance.com/works/zone
6. Ventura, P. (2001b). Life forms score based on the pascal's triangle. Retrieved June 25, 2016 from https://youtu.be/c3Sa6xiHP8U
7. Ventura, P. (2002). De Humani. Retrieved June 25, 2016 from https://ventura-dance.com/works/de-humani
8. Ventura, P. (2003). Corporis / Cluster II. Retrieved June 25, 2016 from https://ventura-dance.com/works/corporis
9. Ventura, P. (2005). Fabrica / Cluster III. Retrieved June 25, 2016 from https://ventura-dance.com/works/fabrica
10. Ventura, P. (2009). 2047. Retrieved June 25, 2016 https://ventura-dance.com/works/2047
11. Ventura, P. (2011a). Rehearsal of top / bottom phrases. Retrieved June 25, 2016 from https://youtu.be/sv68eA2bv5o
12. Ventura, P. (2011b). Dancescapes. Retrieved June 25, 2016 from https://ventura-dance.com/works/dancescapes
13. Ventura, P. (2014). Heliopolis. Retrieved June 25, 2016 from https://ventura-dance.com/works/heliopolis
14. Ventura, P. (2012a). Video documentation of the software Choreography Machine. Retrieved June 25, 2016 from https://youtu.be/pMlRUa8mwx0
15. Ventura, P. (2012b). Video documentation of the software Choreophony. Retrieved June 25, 2016 from https://youtu.be/EtQ31OHI60o

REFERENCES

Alaoui, S. F., Carlson, K., & Schiphorst, T. (2014). Choreography as mediated through compositional tools for movement: Constructing a historical perspective. In *Proceedings of the 2014 International Workshop on Movement and Computing* (pp. 1–6). New York, NY, USA: ACM.

Bench, H. (2004). Virtual embodiment and the materiality of images. *Extensions: The Online Journal of Embodied Technology, 1*, [unpaginated].

Bevilacqua, F., Zamborlin, B., Sypniewski, A., Schnell, N., Guédy, F., & Rasamimanana, N. (2009). Continuous realtime gesture following and recognition. In S. Kopp & I. Wachsmuth (Eds.), *International gesture workshop* (pp. 73–84). Berlin, Germany: Springer.

Bisig, D., & Unemi, T. (2009). *Swarms on stage-swarm simulations for dance performance*. Paper presented at the Generative Art Conference, Milano, Italy. Retrieved October 11, 2016 from http://generativeart.com/on/cic/GA2009Papers/p10.pdf

Blades, H. (2012). Creative computing and the re-configuration of dance ontology. In *Proceedings of Electronic Visualisation in the Arts* (pp. 221–228). London, UK: BCS, The Chartered Institute for IT.

Borgdorff, H. (2006). *The debate on research in the arts*. Bergen, Norway: Kunsthøgskolen i Bergen.

Candy, L. (2007). Constraints and creativity in the digital arts. *Leonardo*, *40*(4), 366–367.

Carlson, K., Schiphorst, T., & Pasquier, P. (2011). Scuddle: Generating movement catalysts for computer-aided choreography. In *Proceedings of the Second International Conference on Computational Creativity* (pp. 123–128). Mexico City, Mexico: ACM.

Clark, A. (2001). Natural-born cyborgs? In M. Beynon, C. L. Nehanic, & K. Dautenhahn (Eds.), *Cognitive technology: Instruments of mind* (pp. 17–24). Berlin, Germany: Springer.

deLahunta, S. (2002). Software for dancers: Coding forms. *Performance Research*, *7*(2), 97–102.

deLahunta, S., & Shaw, N. Z. (2008). Choreographic resources: Agents, archives, scores and installations. *Performance Research*, *13*(1), 131–133.

Deeley, M. (Producer), & Scott, R. (Director). (1982). *Blade runner* [Motion Picture]. United States: The Lad Company & Shaw Brothers.

Deleuze, G., & Guattari, F. (1988). *A thousand plateaus: Capitalism and schizophrenia*. London, UK: Bloomsbury Publishing.

Goertzel, B., Pennachin, C., & Geisweiller, N. (2014). *Engineering general intelligence, Part 1* (pp. 197–214). Amsterdam, the Netherlands: Atlantis Press.

Green, W. (1995, November 26). The man from chaos. *Fast Company Magazine*. Retrieved November 18, 2016, from https://www.fastcompany.com/26316/man-chaos

Gündüz, Z. (2008). Interactive dance: The merger of media technologies and the dancing body. In D. Riha (Ed.), *Humanity in cybernetic environments* (pp. 71–82). Oxford, UK: IDP Interdisciplinary Press.

Hayles, N. K. (2002). Flesh and metal: Reconfiguring the mindbody in virtual environments. *Configurations*, *10*(2), 297–320.

Hayles, N. K. (2008). *How we became posthuman: Virtual bodies in cybernetics, literature, and informatics*. Chicago, IL, USA: University of Chicago Press.

Kochhar-Lindgren, G. (2005). *Technologics: Ghosts, the incalculable, and the suspension of animation*. Albany, NY, USA: SUNY Press.

Kubrik, S. (Producer & Director). (1968). *2001: A space odyssey* [Motion Picture]. United States: Metro-Goldwyn-Mayer.

Lansdown, J. (1978). The computer in choreography. *Computer*, *11*(8), 19–30.

Lem, S. (1972). *Solaris*. Hamburg, Germany: Marion-von-Schroeder-Verlag.

Maeda, J. (2000). *Maeda at media*. New York, NY, USA: Rizzoli International Publications.

Manning, E. (2009). *Relationscapes: Movement, art, philosophy*. Cambridge, MA, USA: MIT Press.

Maturana, H. R., & Varela, F. J. (1991). *Autopoiesis and cognition: The realization of the living*. Berlin, Germany: Springer.

Nirre, R. (2001). Spatial discursions: Flames of the digital and ashes of the real. *CTheory*. Retrieved October 11, 2016, from http://ctheory.net/ctheory_wp/spatial-discursions-flames-of-the-digital-and-ashes-of-the-real/

Noll, A. M., & Hutchinson, A. (1967). Choreography and computers. *Dance Magazine*, *41*(1), 43–45.

Prezemyslaw, P., & Lindenmayer, A. (1996). *The algorithmic beauty of plants*. Berlin, Germany: Springer.

Rogers, D. G. (1978). Pascal triangles, Catalan numbers and renewal arrays. *Discrete Mathematics*, *22*(3), 301–310.

Schiphorst, T. (1993). *A case study of Merce Cunningham's use of the lifeforms computer choreographic system in the making of trackers*. Unpublished doctoral dissertation, Simon Fraser University, Canada.

Schiphorst, T. (2013). Merce Cunningham: Making dances with the computer. In D. Vaughan (Ed.), *Merce Cunningham: Creative elements* (pp. 79–98). New York, NY, USA: Routledge, Tayler & Francis Group.

Soga, A., Umino, B., & Longstaff, J. S. (2005, September). *Automatic composition of ballet sequences using a 3D motion archive*. Paper presented at the 1st South-Eastern European Digitization Initiative Conference, Ohrid, Macedonia.

Stephenson, N. (1999). *Cryptonomicon*. New York, NY, USA: Avon.

van Toorn, R. (1997). Architecture against architecture: Radical criticism within supermodernity. *CTheory*. Retrieved October 11, 2016 from http://ctheory.net/ctheory_wp/architecture-against-architecture/

Vesalius, A. (2003). *The fabric of the human body: An annotated translation of the 1543 and 1555 editions* (D. H. Garrison & M. H. Hast, Trans.). Basel, Switzerland: Karger Medical and Scientific Publishers. (Original work published 1543)

Weizenbaum, J. (1976). *Computer power and human reason: From judgment to calculation*. New York, NY, USA: W. H. Freeman.

Whitaker, R. (1995). *Self-organization, autopoiesis, and enterprises*. Retrieved October 11, 2016, from http://www.enolagaia.com/RW-ACM95-Main.html

Wiener, N. (1961). *Cybernetics or control and communication in the animal and the machine* (Vol. 25). Cambridge, MA, USA: MIT press.

Wong, K. (Producer & Director). (2004). *2046* [Motion Picture]. China: Jet Tone Films, Shanghai Film Group, Orly Films, & Paradis Films.

Yu, T., & Johnson, P. (2003). Tour Jeté, pirouette: Dance choreographing by computers. In E. Cantú-Paz, J. A. Foster, K. Deb, L. D. Davis, R. Roy, U. O'Reilly, H. Beyer, R. Standish, G. Kendall, S. Wilson, M. Harman, J. Wegener, D. Dasgupta, M. A. Potter, A. C. Schultz, K. A. Dowsland, N. Jonoska, & J. Miller (Eds.), *Proceedings of the Genetic and Evolutionary Computation Conference* (pp. 156–157). Berlin, Germany: Springer.

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All correspondence should be addressed to
Pablo Ventura
Ventura Dance Company
Pfarrgasse 34
CH-8704 Herrliberg
Switzerland
info@ventura-dance.com

Appendix A

This appendix provides a detailed description of the software programs Life Forms, Choreography Machine, and Choreophony.

Life Forms

The software Life Forms was developed in the 1980s at Simon Fraser University by a team led by Thomas Calvert, a computer scientist and expert in kinesiology. The software was initially intended to serve as a computer-based system for labanotation but later exceeded this objective. The software became famous through its use by the choreographer Merce Cunningham. The development of Life Forms and Cunningham's application of it in his piece *Trackers* was described by Thecla Schiphorst (1993).

While the functionality of Life Forms has changed considerably since its initial invention, certain core elements remain. Life Forms provides a graphical user interface that permits the interactive manipulation of an avatar that serves as a three dimensional representation of a dancer's body. The so-called figure editor provides precise controls for moving selected body parts of the avatar into desired positions. Poses that have been created in such a manner or are loaded from a repository of pre-existing poses can then be assigned to particular time positions in the time line editor window. The sequencing of these poses provides the means to control the timing and synchronization between multiple avatars. Finally, a stage window provides a perspective rendering of a virtual stage onto which a single or multiple avatars can be placed and arranged. A screenshot of the Life Forms software is shown in Figure A1.

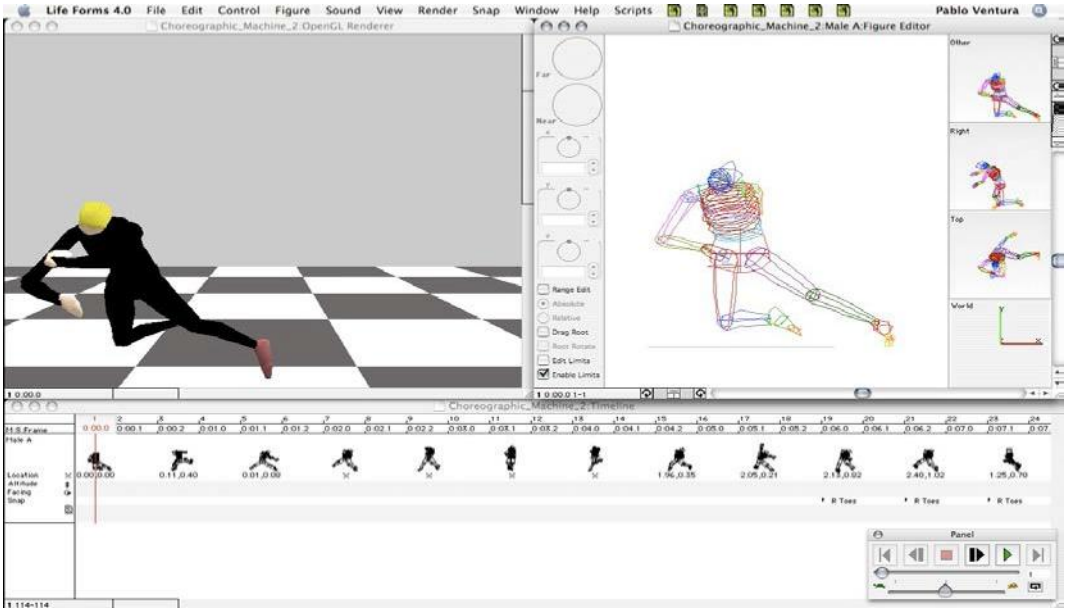

Figure A1. Screenshot of the Life Forms software Version 4.0 running on an Apple Macintosh computer. The screen shot depicts the stage window (top left), the figure editor (top right), and the timeline editor (bottom).

Choreography Machine

The software Choreography Machine was developed in 2007 by Daniel Bisig during a residency with Pablo Ventura at the Artificial Intelligence Laboratory of the University of Zurich. The software allows the delegation of some of the initial stages of a choreographic creation process to a fully autonomous generative process. The generative process can be used to create novel pose and movement material de novo (see Figure A2) that subsequently can be imported into Life Forms. This approach expands and alters the ability of Life Forms in that it relinquishes the necessity for a manual approach to the design of choreographic material.

The generative mechanism is based on L-Systems. These systems can be interesting for creative purposes because they represent a powerful and flexible formalism for generating intricate and self-similar patterns from simple starting conditions. In addition, the syntactic elements on which L-Systems operate are semantically open and can therefore be easily attributed a choreographic meaning. L-Systems were introduced in 1968 by the theoretical biologist Aristid Lindenmayer as a means to employ computer simulations to model growth processes in plants (Prezemyslaw & Lindenmayer, 1996).

Choreography Machine implements several simple L-Systems as automated algorithms for generating choreographic material. The relationship between the character strings on which the L-Systems operate and a choreography is as follows: (a) Each character in the alphabet represents a particular body posture; (b) The body postures are based on the human body model and the rotational constraints from Life Forms and are defined prior to the execution of the L-System; (c) Character sequences are interpreted as a temporal succession

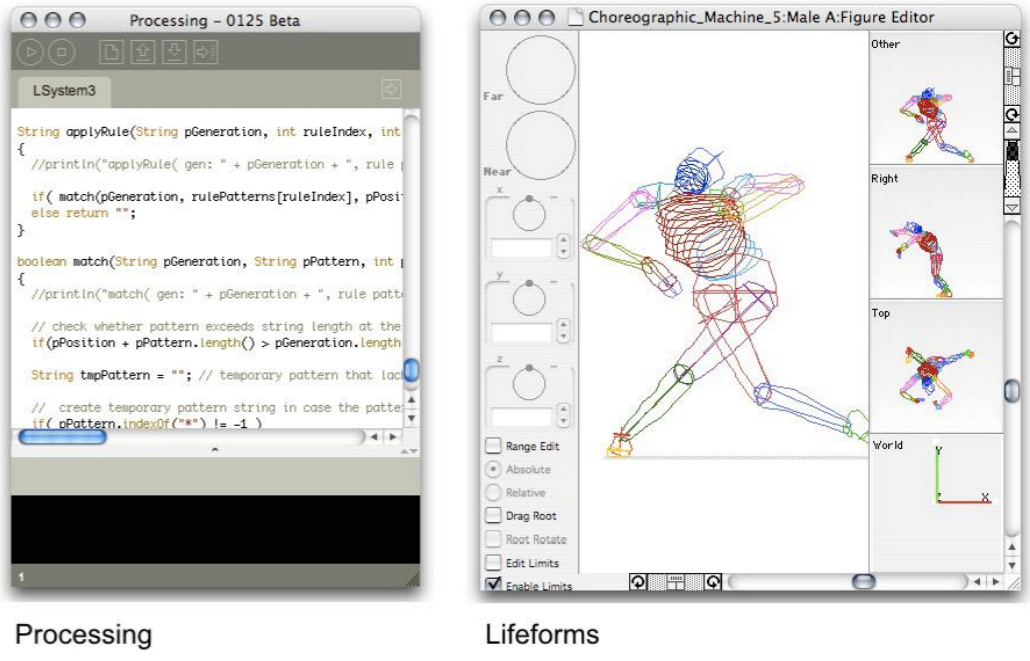

Figure A2. Screenshot of the software Choreography Machine. The screenshot shows, on the left, the source code for the generative mechanism in the Processing programming environment; the resulting visual rendering of an avatar in Life Forms is provided on the right.

of body postures; (d) The final character sequence, which results from the iterated application of the L-System's production rules, is translated into a choreographic score format that can be read by Life Forms. In Life Forms, this sequential arrangement of poses can then be further modified and displayed as a kinematic animation of a virtual dancer.

The L-Systems themselves are designed either manually or through a random process. The design of the L-Systems includes the following specifications: context free or context sensitive; deterministic or non-deterministic; the number of production rules, the input and output sequences of each production rule; the size and content of the axiom; and the number of iterations throughout with the manipulation of a character string progresses. The L-System, the pose palette, and the functionality for exporting a choreographic score are implemented in the processing programming environment.

Several variants of the software have been created; each differs from the others with respect to the following aspects:

1. Manually designed L-System. Manually designs poses. (The poses are stored in a single Life Forms pose palette.) The alphabet contains characters that refer to these poses.
2. Manually designed L-System. Manually designed poses (The poses are stored in multiple Life Forms pose palettes.) The alphabet contains both characters that refer to these poses and characters that refer to palettes.
3. Randomly created L-System. Manually designed poses (The poses are stored in multiple Life Forms pose palettes.) The alphabet contains both characters that refer to these poses and characters that refer to palettes.
4. Manually designed L-System. Randomly generated poses. The poses do not respect any joint limits.
5. Manually designed L-System. Randomly generated poses. The poses do respect joint limits.
6. Randomly generated L-System. Randomly generated poses. The poses do respect joint limits.

The most recent version of the software is titled Kinematics Randomizer. This version realizes the highest degree of autonomy for a choreographer's authorship in creating a choreographic sequence. With this version, a choreographer simply needs to start the program and then wait while the program automatically creates a unique set of poses and an equally unique L-System, then iterates through the production rules, and finally terminates by writing a new choreographic score. An excerpt of a choreographic score that has been produced by Kinematics Randomizer is depicted in Figure A3. A video documentation of this software is available online.[14]

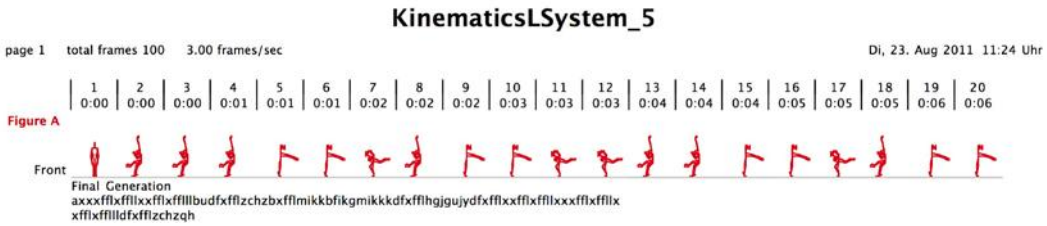

Figure A3. A pose sequence output of the Kinematics Randomizer, a software program that generates without input a choreographic design. This sequence represents an excerpt of a choreographic score that has been used by Ventura in the creation of the piece *Heliopolis*.

Choreophony

The software Choreophony was developed in 2014 as part of a collaboration between Ventura and the new media artist and programmer Chris Ziegler during their residencies at Sinlab, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland. The motivation for developing Choreophony arose from the desire to establish a direct correlation between body movements and movements across a stage in coordination with a generated polyphonic soundscape. Such a correlation permits a choreographer to situate the design of the sonic aspects of a dance piece as an inherent element of the creative process. Choreophony, which was implemented in the Max/MSP programming environment, integrates two different sensing techniques for analyzing a dancer's activities on stage (see Figure A4).

The first technique employs a camera tracking mechanism to detect a dancer's position and movement within predefined spatial zones on stage. Whenever movement within such a zone is

Figure A4. The software Choreophony. The photograph (copyright by Chris Ziegler) shows the software *Choreophony* running on a laptop together with two iPods which are being used as acceleration sensors for a dance rehearsal.

detected, the movement triggers the playback of an associated sound file. This interaction technique makes use of the SoftVNS extension library for Max/MSP that was developed by David Rokeby.

The second technique uses acceleration sensors to measure body movements. This technique is useful in that it complements the allocentric movement detection by the first technology with an egocentric movement detection that is more closely related to a dancer's proprioception. The three-dimensional acceleration values are used both for triggering and for modulating the playback of sound files. The modulation mechanism is based on a direct mapping of acceleration values to parameters that control the operation of audio effects during sound playback. The triggering and playback mechanism is based on the recognition of movement categories by the Gesture Follower machine learning technique (Bevilacqua et al., 2009). This technique was developed at the Institute for Research and Coordination in Acoustics/Music (IRCAM) and permits the training and subsequent recognition of short temporal sequences of sensor data. Whenever the machine learning mechanism recognizes the execution of a previously learned gesture by a dancer, it can trigger the playback of a sound file that has been associated with that gesture. In addition, the playback speed of the sound file can be correlated to the execution speed of the gesture.

A prototypical setup of an interactive stage situation is shown in Figure A5. In this setup, the top-down view of a tracking camera is divided into four regions that correspond to four spatial zones on stage. In addition, each of the three dancers on stage wears an iPod as an acceleration sensor whose numerical output is sent via Open Sound Control to the Choreophony software. Both the movement activities within each of these zones and the acceleration values are analyzed by Choreophony and used to trigger and modulate the playback of sound files. A video documentation of this software is available online.[15]

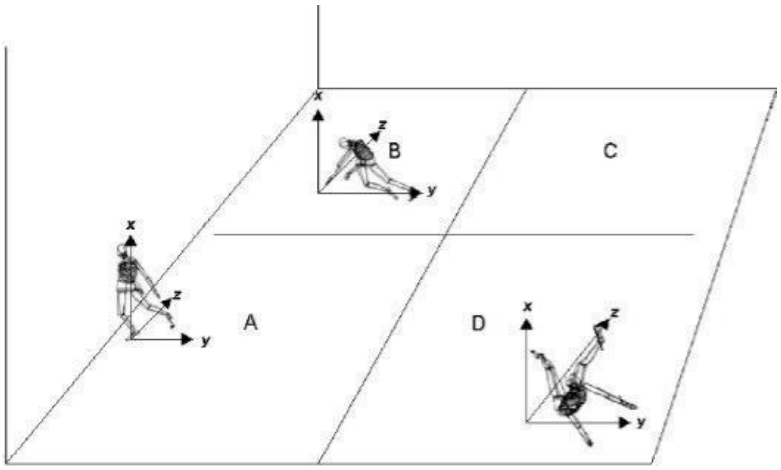

Figure A5. Tracking principles of the software Choreophony. The graphics shows four trigger zones in space labeled A, B, C, D and movement around the dancers' body axis labeled x, y, z.

APPENDIX B

This appendix provides the entire text of Ventura's manifesto titled *The Gospel According to HAL*. This manifesto is directed at choreographers and declares in an ironic manner five interdictions that are meant to enforce a thorough deviation from traditional choreography techniques. These interdictions address the techniques of body usage, space organization, music, scenography, and narration.

The Gospel According to HAL

I. Thou shall not use your body to choreograph. Thou shall not watch yourself in the mirror. Thou shall build your material exclusively in the computer. Thou shall manipulate a virtual body and will not use your body to transmit your ego, your vanity, and self-indulgent hedonism. Thou shall not exist except in the origin, in the computer, and your material will be transformed by the computer until your style and manners have totally vanished from earth's face. Thy kingdom come, thy will be done; thou will die in the computer and HAL on the third day will make His work.

II. Thou shall not delight in the sensuality of pleasurable and indulgent spatial geometries. Thou shall not construct your choreography following obsolete precepts such as the Renaissance perspective and symmetrical luscious or banal forms (triangles, squares, circles, etc.). Thou shall not take pleasure with the stage's navel, and shall not scheme diagonals, and you will remember always, always, that God dwells in the accident, and that the shortest distance between two points is never, the straight line.

III. Thou shall not succumb to the temptation of using classical, folkloric, and instrumental music, and thou shall fly from the music collage as from the devil himself. Thou shall only use electronic music made with the computer and exclusively for electronic means of reproduction.

IV. Thou shall not meddle with stage designs not attained with digital means. If there are projections on stage, their contents will be manipulated until all resemblance to reality has been totally exorcised. Costumes likewise shall flirt not with reality and they will be austere, anonymous, and preferably without genders.

V. Thou shall not bore the audience. Thou shall not entertain. Thou shall study Gilles Deleuze—and the book will be *A Thousand Plateaus*—until thou knowest that thou knowest not.