Generative Dance - a Taxonomy and Survey

Daniel Bisig
ad5041@coventry.ac.uk
Coventry University
Coventry, United Kingdom
Zurich University of the Arts
Zurich, Switzerland

ABSTRACT

Generative Art is a creative approach that has found applications in several artistic disciplines. In some of these disciplines, formalization has historically played an important role, which predisposes them for employing generative methods. In dance, the relationship to Generative Art is less obvious and the role of formalization is more contested than in other disciplines. This paper tries to contribute to an understanding of the specific role that Generative Art currently plays in dance. It does so by proposing a taxonomy of topics that cover both common and dance specific aspects of Generative Art. This taxonomy is used for comparing a wide diversity of generative works that have been created in the context of dance.

CCS CONCEPTS

• **Applied computing** → **Performing arts**; • **Human-centered computing** → *Interactive systems and tools.*

KEYWORDS

generative art, dance and technology, taxonomy

ACM Reference Format:
Daniel Bisig. 2022. Generative Dance - a Taxonomy and Survey. In *8th International Conference on Movement and Computing, June 22–25, 2022, Chicago, USA.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3537972.3537978

1 INTRODUCTION

Generative Art is a creative approach that has found applications in several artistic disciplines. Some disciplines have a long tradition of employing formalization and abstraction as elements of artistic thinking and to represent and structure creative processes. This predisposes these disciplines for the adoption of generative methods. In dance, formalization and abstraction play a less prominent role and their usefulness is more contested. Some of the reasons for this involve dance's reliance on tacit knowledge and a preoccupation with the human body as material object and experiential resource, both of which are difficult to formalize. This renders the creative possibilities that Generative Art offers for dance less obvious. This paper tries to contribute to an understanding of the specific role that Generative Art currently plays in dance. It does so by proposing a taxonomy of topics that cover both common and dance specific aspects of Generative Art. This taxonomy is used to structure an survey of and comparison among generative works that have been created in the context of dance. To illustrate the usefulness of such a taxonomy, some topics are identified that rank prominently in generative art but lack attention in generative dance, or vice versa. These topics can serve as starting points for future research and creation that would benefit from and foster a mutual exchange between Generative Dance and Generative Art.

MOCO '22, June 22–25, 2022, Chicago, USA

ACM ISBN 978-1-4503-8716-3/22/06…$15.00
https://doi.org/10.1145/3537972.3537978

2 BACKGROUND

The term Generative Art employed here refers to artistic approaches that delegate the creation of an artwork to a partially or fully automated process[17, 29, 35]. The term Generative Dance is used here in alignment with these definitions for dance specific applications of Generative Art. While generative processes don't necessarily have to be realized through technical means, this is by far the most popular approach. For this reason, Generative Dance strongly overlaps with the field of Dance and Technology.

Several overviews highlight the potential of technology for dance. An overview[93] outlines different dance-specific motivations to work with technology such as: experiment with other environments than the stage, blur boundaries between audiences and performers, render hidden aspects of dance visible, or provide new methods for teaching. Another overview[52] focuses on creative applications of motion capture, including for example gestural interaction, character animation, and computational art. Many of these motivations and applications also play an important role in Generative Dance. Three reviews focus on choreographic software and describe their role as artistic material and language[26], their approach to movement representation[1] and their changing use of algorithmic techniques[77]. These reviews identify a close proximity between choreographic thinking and algorithmic approaches for which they provide a historical context.

The relationship between dance and technology is the subject of several debates, some of which raises principled concerns. Blades characterizes this relationship as schizophrenic[16] since technology is readily accepted as a tool and simultaneously criticized for being dismissive of the body and incompatible with the ephemeral characteristics of dance. This raises fears that technology *dehumanizes* dance[76] and alienates dancers and audiences from an experiential and intellectual relationship with movement[88]. Others have countered this opinion by emphasizing technology's capability to challenge our understanding of dance[16, 74] and to open up new avenues for envisioning[80] and experiencing dance[41].

Other debates deal with more practical issues. These include the removal of essential context in digital representations of dance[93], the blindness of sensing technology to nuanced and invisible aspects of dance[65], and the difficulty of formalizing dance as highly idiosyncratic creative practice[1, 95]. Technological developments have emerged to address some these issues. Examples include the framework of *Somaesthetics*[81] which takes into account somatic practices for designing interaction technology [79] and the field of interactive machine learning which adopts machine learning as creative technique to support idiosyncratic and exploratory artistic workflows[34].

Generative Dance is in a potentially unique position to reflect on and contribute to this debate in a constructive manner. This is because it has garnered expertise in formalizing idiosyncratic creative processes to bring them into the computational domain. And it is also because it has adopted in many instances sophisticated techniques for modeling biological, social, and cultural processes. Accordingly, Generative Dance contributes to the development of principled approaches for converging natural and artificial forms of embodied creativity.

3 TAXONOMY

The chosen taxonomy identifies six main topics, each of which is divided into several subtopics. The main topics are: *Domain*, *Contribution*, *Manifestation*, *Autonomy*, *Representation*, *Process*.

The topic *Domain* refers to the domain of application of generative systems. Subtopics are: *Creation*: systems support dance creation, *Performance*: systems employed during performance, *Exhibition*: systems created for exhibitions, *Teaching*: systems for dance education, *Dissemination*: systems created for explanatory purposes, *Research*: systems created for research

The topic *Contribution* deals with the contribution of dancers to the realization of generative systems. Subtopics are: *Performer*: dancers participate as performers on stage, *Data*: dancers contribute to data acquisition, *Survey*: dancers evaluate a system, *Consultation*: dancers are consulted as experts, *Participation*: dancers directly contribute to development, *Collaboration*: dancers are members of the project team

The topic *Manifestation* specifies how generative systems are made perceivable. Subtopics are: *Human*: humans play the role of a generative system, *Score*: systems create scores for humans, *Artificial Dancer*: systems appear as artificial dancers, *Media*: systems generate synthetic media

The topic *Autonomy* addresses the agency of generative systems. Subtopics are: *Control*: systems respond to discrete inputs with discrete outputs, *Instrument*: systems respond to continuous input with continuous output, *Support*: systems support human creativity, *Collaboration*: systems contribute to decision making, *Autonomous*: systems make decisions of their own

The topic *Representation* deals with the abstractions generative systems operate on. Subtopics are: *Pose*: systems manipulate dance poses, *Motion*: systems manipulate dance motions, *Behavior*: systems specify behaviors, *Cognition*: systems model mental processes, *Group*: systems specify group behaviors, *Structure*: systems deal with choreographic structure

The topic *Process* refers to the operational principle of generative systems. Subtopics are: *Random*: systems mainly use randomness, *Rules*: systems employ computational rules, *Simulation*: systems employ computer simulations, *Evolution*: systems adapt through artificial evolution, *Machine-Learning*: systems adapt through machine-learning

An overview of the taxonomy including the different approaches employed within each subtopic that are described in this publication is provided in figures 1 and 2.

Main Topics	Sub Topics	Approaches	Publications
Domain	Creation	Scores	[56, 75, 82, 84]
		Creativity Support for Choreographers	[10, 21, 22, 24, 42, 74, 86]
		Creativity Support for Dancers	[5, 6, 27, 59, 67, 68]
	Performance	Interactive Synthetic Media	[11, 12, 15, 19, 48, 49]
		Interactive Acoustic Instrument	[72]
		Software Dancers	[8, 33, 53, 57, 66]
		Robotic Dancers	[28, 32, 45, 47, 54, 92]
		Live Scores	[82, 83]
	Exhibition	Software Dancers	[46, 62]
		Robotic Dancers	[39]
	Teaching	Dance Techniques Professional Level	[2]
		Dance Techniques Beginner Level	[85, 90]
	Dissemination	Choreographic Techniques	[25, 80]
	Research	Automated Choreography	[70, 94]
		Computational Ecosystem	[4]
		Machine Learning	[60, 61]
		Interaction Design	[58, 63]
		Robotics	[78]
Contribution	Performer	Interact with Generative System	[8, 11, 12, 15, 19, 19, 23, 32, 33, 47–49, 53, 54, 56, 57, 66, 69, 72, 83, 92]
		Author Generative System	[19]
	Data	Publicly Available Videos	[60, 61]
		Original Motion Capture Recordings	[5, 6, 8, 10, 12, 13, 24, 38, 62, 66–68]
	Survey	Evaluate Educational Support	[33, 85, 90]
		Evaluate Creativity Support	[5, 22, 86, 86]
	Consultation	Motion Selection	[45]
		Rule Selection	[85]
		Behavior Selection	[46]
		Prototype Evaluation	[48, 92]
	Participation	Brainstorming	[2]
		Embodiment	[92]
		Improvisation	[47]
	Collaboration	Education Design	[2]
		Somaesthetic Design	[32]
		Movement Skills	[78]
		Movement Analysis	[21, 22]
Manifestation	Human	Dancers Follow Simulation Principles	[23]
		Dancers Follow Interaction Principles	[75]
		Dancers Follow Programming Rules	[82, 83]
	Score	Graphical Scores	[56]
		Numerical Scores	[57, 71]
		Text-based Instructions	[23, 75, 82, 83]
		Photographic Scores	[84]
	Artificial Dancer	Antropomorphic Software Dancers	[8, 53, 67, 68]
		Non-Antropomorphic Software Dancers	[8, 13, 33, 68]
		Antropomorphic Robotic Dancers	[45]
		Non-Antropomorphic Robotic Dancers	[28, 32, 39, 47, 54, 72, 92]
	Media	Synthetic Image	[11, 15, 15, 19, 48, 49]
		Synthetic Image and Music	[11, 13, 48]
		Acoustic Music	[14]
		Synthetic Scores and Music	[83]

Figure 1: Taxonomy Overview Part 1: Compilation of all approaches belonging to the topics *Domain, Contribution, Manifestation*

The choice of topics and subtopics is partially informed by previous classification systems. A topic similar to *Domain* has been employed in a survey to distinguish between different uses of interactive technology in the creative process [95]. The notion of *Autonomy* refers to the informal use of the term in dance and theater research to describe modes of interactive relationships between performer and digital instrument [50], forms of automation in robot theater[64], interaction patterns between dancer and visuals supporting kinaesthetic creativity [43], and combined levels of agency for choreographers and interactive systems[20]. The topic *Manifestation* relates to the notion of *Sensory Outcomes* employed in a framework for comparing generative artworks [29]. The topics *Representation* and *Process* are inspired by a survey of choreographic

Main Topics	Sub Topics	Approaches	Publications
Autonomy	Control	Action Selection for Human Dancers	[23, 75, 82]
		Action Selection for Robotic Dancers	[37, 46, 62]
	Instrument	Imitation of Physical Interaction	[2, 11, 19, 48, 91]
		Modulation of Robotic Behaviors	[28, 32, 54]
	Support	Score Interpretation	[56, 82–84]
		Body Abstraction	[42, 59]
	Collaboration	Movement Completion	[86]
		Pose Proposals	[22, 22]
		Exploration	[10, 12, 30, 31, 74]
		Choreographic Turn-Taking	[24]
		Live Coding	[83]
	Autonomous	Choreography Generation	[70, 94]
		Music to Movement Translation	[60, 61]
		Computational Ecosystem	[3, 4]
		Software Dancers	[59]
		Robotic Dancers	[39, 45]
Representation	Pose	Motion Capture	[5, 6, 8, 53, 74]
		Human Interpretation	[21, 22, 84]
	Motion	Sequence of Poses	[10, 46, 53, 60, 61, 74]
		Gestures	[46]
		Elementary Motions	[85, 90]
		Motion Vocabulary	[37, 56, 57, 66–68]
		Sinusoidal Rotations	[30]
	Behavior	Robotic Open Loop Control	[14, 28, 78]
		Robotic Closed Loop Control	[32, 47, 54, 92]
		Robotic Action Selection	[32, 47, 54, 92]
		Simulated Morphology	[13, 33, 42, 58, 59]
	Cognition	Gestural Memory	[46]
		Motivational States	[45]
	Group	Compositional Rules	[25]
		Computational Rules	[75, 82]
		Artificial Live Simulation	[3, 4, 11, 15, 31]
		Social Creativity	[39]
		Prescripted	[32]
		Remote Controlled	[28]
	Structure	Space and Timing	[23, 56]
		Stage Props	[82]
		Space and Motion Vocabulary	[70, 94]
		Feasibility and Motion Vocabulary	[85]
Process	Random	Choreographic Motion Selection	[86, 94]
		Response of Artificial Dancer	[5, 62]
	Rules	Rules for Human Dancers	[23, 75]
		Rule-based Score Generation	[82–84]
		Rule-based Choreographic System	[56, 85, 90]
		Rule-based Robotic Interaction	[32, 47, 54, 92]
		Compositional Rules	[72]
	Simulation	Physics	[2, 2, 12, 13, 19, 42, 59, 87]
		Neural Networks	[12, 13]
		Multi-Agent Systems	[11, 15, 25, 31, 63, 72]
		Computational Ecosystem	[4]
	Evolution	Automated Fitness Function	[3, 21, 22, 70]
		Interactive Fitness Function	[30, 31]
		Other Interactive Evolution	[12, 13, 39, 45, 57]
	Machine-Learning	Classification	[38, 46]
		Clustering	[62, 66–68]
		Encoding and Navigation	[5, 6, 8, 10]
		Sequence Prediction	[24, 53, 74]
		Sequence Transduction	[60, 61]
		Pose Proposals	[22, 22]
		Exploration	[10, 12, 30, 31, 74]
		Choreographic Turn-Taking	[24]
		Live Coding	[83]
	Autonomous	Choreography Generation	[70, 94]
		Music to Movement Translation	[60, 61]
		Computational Ecosystem	[3, 4]
		Software Dancers	[59]
		Robotic Dancers	[39, 45]

Figure 2: Taxonomy Overview Part 2: Compilation of all approaches belonging to the topics *Autonomy, Representation, Process*

software tools[1]. A recently published review[51] classifies computational techniques for dance automation under several categories. Those categories that are most directly related to the approach chosen here are: *dance semantics*, *dance generation*, and *dance processing*. The category *dance semantics* addresses similar aspects as the topic *Representation*, and the categories *dance generation* and *dance processing* are related to aspects discussed under the topic *Process*.

4 EXAMPLES

The survey presents a selection of examples that are considered representative of the diversity of the field. The search has mostly been limited to examples that are documented through academic publications and that provide a detailed description of their generative approach. This comes at a cost of neglecting a much larger body of works that is documented outside of academia.

4.1 Domain

4.1.1 Creation. Early on, generative systems have been applied for creating choreographies for human dancers[56]. Since then, the development of choreographic systems has developed into at least three directions. One direction maintains the principle of generating instructions for human interpretation[75, 82, 84]. A second direction involves generative systems that support the creative process of choreographers[10, 21, 22, 24, 42, 74, 86]. A third direction deals with the fully automated creation of choreographies mainly as proof concept for research purposes (see 4.1.6). Several generative systems have been developed to support dancers in their creative process[5, 6, 27, 59, 67, 68].

4.1.2 Performance. Several examples employ generative systems to create synthetic media with which dancers can interact[11, 12, 15, 19, 48, 49]. In one example, a generative system mediates between a dancer and an acoustic instrument[72]. Several examples stage a duet between a human and a software-based artificial dancer[8, 33, 53, 57, 66]. Sometimes, the artificial dancers appear as robots alongside human dancers[32, 47, 54, 92]. Two examples present performances with robotic dancers only[28, 45]. In some examples, generative systems generate live scores[82, 83] and/or dancers acts as generative system while performing[23, 75, 82].

4.1.3 Exhibition. Two examples enable a visitor to interact with a software-generated artificial dancer[46, 62]. One example presents a robotic installation[39].

4.1.4 Teaching. One example familiarizes professional dancers with specific movement techniques employed by the *Emio Greco | PC* dance company[2] Two examples teach basic dance techniques for Ballet[85], Hip-Hop, or Contemporary Dance[90] to beginner level students.

4.1.5 Dissemination. Several systems disseminate idiosyncratic techniques of individual choreographers such as the contrapunctual technique by William Forsythe[25, 80], the score-based patterns by Jonathan Burrows and Matteo Fargion[1], and the movement ideation technique by Thomas Hauert[2].

4.1.6 Research. Two systems create fully automated choreographies for Waltz[70] or Ballet[94]. One example employs a computational ecosystem as choreographic system[4]. Two examples deal with the automated generation of dance movements from music[60, 61]. Some examples employ dance principles to develop new methodologies for interaction design[58, 63] or robotics[78].

4.2 Contribution

4.2.1 Performer. In several examples, dancers are involved as performers in public showings in which they interact with generative systems on stage [8, 11, 12, 15, 19, 23, 32, 33, 47–49, 53, 54, 56, 57, 66, 69, 72, 83, 92]. In the case of *ViFlow*, dancers can both author a generative system and subsequently perform with it [19].

[1]Online Score "Seven Duets" scores.motionbank.org/jbmf/#/set/a-parallel-world
[2]Online Score "Two" scores.motionbank.org/two/#/set/impulse

4.2.2 Data. Two examples acquire data from publicly available video recordings of dance[60, 61]. Several examples task dancers to perform while being motion captured[5, 7, 8, 10, 12, 13, 24, 38, 62, 66–68].

4.2.3 Survey. For an educational installation, the interaction and the perception of movement was evaluated by professional dancers through interviews[33]. The ability of choreographic systems to support the creative process was evaluated by choreography students through observation combined with interviews[22, 86] or ratings[86]. The suitability of a choreographic system for basic dance education was assessed by dance teachers through ratings[85, 90]. The creativity support provided by an artificial dancer was evaluated through self-reporting, note-taking, and video recording of a single professional dancer[5].

4.2.4 Consultation. Poses and motions for an improvising humanoid robotic dancer were selected by professional dancers[45]. The formal rules for generating Ballet enchaînements were developed based on interviews with Ballet teachers[85]. Dancers were interviewed at the start and end of a dance production about their preferences for different versions of a generative system[48]. The choice of response behaviors for an artificial dancer was informed by advice from a theater practitioner[46]. Design and performance experts evaluated prototypes of a robotic dancer[92].

4.2.5 Participatory. Dancers contributed to the design of a software-based artificial dancer by sketching ideas, metaphors and inspirations for interaction scenarios[2]. For the creation of a robotic dancer, dance students explored CAD designs by embodying them and forms of interaction with a partially implemented prototype[92]. In iterative sessions, dancers contributed to the design of interactive behaviors for a robotic dancer[47].

4.2.6 Collaboration. The dance company *Emio Greco | PC* was involved as collaborator in the design of an educational installation[2]. A choreographer contributed to the development of drone robots through a somaesthetic design approach[32]. Dancers transferred their movement skills to a non-anthropomorphic robot by wearing a costume in the shape of the robot[78]. Dance experts contributed to the design of fitness functions for choreographic systems[21, 22].

4.3 Manifestation

4.3.1 Human. In the piece *Echo::system*, dancers' move at discrete time intervals along a grid in analogy to early computer simulations[23]. The *A/RMA* choreographic language instructs dancers to respond to stage props and audience members according to rules that are inspired by interactive media[75]. In several pieces inspired by live-coding, dancers act as interpreters of a programming language[82, 83].

4.3.2 Score. The scores generated by Lansdown's choreographic systems display graphical elements from the *Benesh Notation* system or semi-realistic body outlines, with the former shown to professional dancers and the latter to children[56]. The scores by Burrows and Fargion initially used musical notation and later on numbers and/or words as abstract references for dance movements[71]. Number-based references to dance movements were also used in scores for a duet between a human and artificial dancer[57]. Several text-based scores employ syntax and rules that are reminiscent of programming languages[23, 75, 82, 83]. The scores generated by the *Terpsicode* programming language consist of photographs depicting dance poses[84].

4.3.3 Artificial Dancer. Two examples display their software-based dancers as humanoid avatars to help with the readability of their relationship to human dancers[53, 67]. Two examples alternate between abstract and humanoid representations of an artificial dancer[68], one of them to illustrate the dancer's learning progress[8]. In other examples, the morphology of a non-anthropomorphic artificial dancer is visualized[13, 33].

Among robotic dancers, there is only one example with a humanoid shape[45]. The other examples employ non-anthropomorphic robots to avoid anthropomorphizing projections[47, 92] or because of functional requirements[32, 54, 72], or both[28, 39]. These robots include a re-purposed wheel-chair[47], inverted pendulums[28], a cube[78], a *SpiderCrab*[92], illuminated bars[39], quadcopters[32, 54], and an electromechanical piano[72].

4.3.4 Media. Several examples visualize the movement of a large number of elements as simple graphical elements that highlight their position or trajectory. These visuals are projected on the stage[15, 19, 48] or the dancers[15, 49] or both[11]. Some of these examples employ the same generative system to simultaneously create synthetic audio. This improves the system's readability [48], for instance by revealing aspects of its internal functioning[13] or by highlighting its spatial organization[11, 48]. Two examples deviate from this approach. The piece *Piano&Dancer* employs a generative system to play an acoustic instrument[14]. The piece *Sound Choreography<>Body Code* employs the acoustic output of a sound synthesis system to alter a dance score[83].

4.4 Autonomy

4.4.1 Control. Control mechanisms play a dominant role in those examples in which human dancers act as generative system. The rules specify trigger conditions for choosing a specific action or for modifying the currently executed action[23, 75, 82]. Discrete action selection mechanisms are also employed for some robotic dancers, to make them mirror actions of a human dancers[62], execute reflex reactions[46], or reproduce action-response patterns[37].

4.4.2 Instrument. Several examples establish relationships between dancers and generative systems through continuous interaction. Frequently, this relationship imitates physical principles such as the collisions between objects[19], the stirring of fluids[48], the damping of vibrations[2], or the propulsion by forces[11, 91].

Several dance robots modulate their behavior in response to continuous input. Examples include robots whose travel distance is proportional to the amplitude of sounds[54], that are directed through hand gestures towards different positions on stage[32], or that convert input oscillations into translational movements[28].

4.4.3 Support. Some score generating systems for human dancers offer room for interpretation. Both the system designed by Lansdown for children[56] and *Terpsicode*[84] create scores that specify peak poses and leave the gaps in between open for creative exploration. Several text-based scores offer dancers room of creative decisions either through interpretation or by modifying them[82, 83].

Two examples create motions for abstract bodies as source for creative inspiration. The *Choreographic Language Agent* creates geometrical animations that foster the dancers' use of mental imagery[59]. Another system supports the creativity of choreographers by translating metaphors of energy propagation into physical simulations[42].

4.4.4 Collaboration. One choreographic system completes a motion that has been partially specified by a choreographer[86]. The choreographic systems *Cochoreo*[22] and *Scuddle*[22] produce either complete or incomplete body poses as inspirations for deviating from dance habits. Some choreographic systems employ interactive artificial evolution to help choreographers explore a space of possibilities. Examples include the design of behaviors for artificial body limbs[12], the creation of movements for artificial dancers synchronized to music[30], and the creation of flocking-based group behaviors[31]. Two machine-learning based choreographic systems generate synthetic motions in a collaborative manner by taking turns with a human choreographer[24], or by providing different methods to explore pose or motion representations[10, 74].

Several examples employ artificial dancers as co-improvisation partners for human dancers. Principles of improvisation are based on matching movement qualities[33], the interpretation of live-generated scores[57], or the mirroring and variation of dance poses or motions[6, 8, 46, 66–68, 92]. The interaction with an electromechanical piano switches between instrument-type and collaborative forms with the dancer modifying through movement a musical score or affecting a swarm simulation[72].

The piece *Sound Choreography<>Body Code* creates a collaborative situation with two live coding systems, one for generating synthetic music and one for creating a dance score, mutually affecting each other[83].

4.4.5 Autonomous. Several choreographic systems created for research operate fully autonomously. This includes systems for generating Waltz and Ballet sequences[70, 94], systems for translating music into movement [60, 61], and an ALive inspired computational ecosystems[3, 4].

Some systems acting as artificial dancers operate autonomously. The system *Becoming* employs a software-based dancer to which human dancers can relate to through kinaesthetic empathy[59] The installation *Performative Ecologies: Dancers* hosts several robots that share learned movements among themselves[39]. The piece *Robodanza* employs a single robot that improvises to music [45].

4.5 Representation

4.5.1 Pose. Several examples operate on pose representations that are identical to those obtained from motion capture[5, 7, 8, 53, 74]. Synthetic motions that are created from these poses often lack realism, which is either critised[53] or embraced[5, 7, 8, 74].

Some examples employ pose representations that are suitable for human interpretation. The system *Cochoreo* adopts the pose representation of the *idanceForms* choreographic tool which lends itself to interactive manipulation[21]. The system *Scuddle* represents poses through graphical drawings and textual descriptions that specify keypoint rotations, height levels, and effort qualities[22]. The system *Terpsicode* represents poses as photographic images and classification labels[84].

4.5.2 Motion. Several systems represent motion as a sequence of poses[10, 53, 61, 74]. These systems typically preserve stylistic aspects of dance at the cost of physical plausibility. The *Viewpoints AI* system operates on pose sequences and gestural representations including aspects such as tempo, duration, repetition, topography, and shape[46]. The music to movement translation system by Lee and colleagues divides pose sequences into temporally standardized motion patterns that can be synchronized to musical rhythm[60]. The choreographic systems by Soga and colleagues operate on elementary motions correspond either to Ballet steps[85], or Hip-Hop steps, or the movement language of a specific Contemporary Dance teacher[90].

Several examples represent dance by a symbolic vocabulary that refers to elementary motions. Gillies and colleagues employ an artificial dancer that creates responses to a human dancer based on matching motion labels[37]. The *Dancing Genome Project* generates scores as sequences of numbers that index a vocabulary of basic motions[57]. Some examples combine a vocabulary of motions with a representation of their transitions[56, 66–68].

Dubbin and Stanley represent motion as sinusoidal rotational velocities of body joints for artificial dancers[30].

4.5.3 Behavior. At the most basic level, the behavior of robotic dancers is created through open-loop control. This method is employed for creating a vocabulary of motions[78], translating a midi score into motor commands for keys and pedals of an electromechanical piano[14], or switching between different locomotion behaviors[28].

Some examples combine closed-loop control with action selection for their robotic dancers. In the piece *Aeroquake*, the robots execute a single action (up-down motion) depending on the acoustic amplitude of a dancer stamping on the ground[54] In the piece *ReCallas/Medea*, the robots sense hand gestures executed by a performer based on which they either move towards the performer or towards a destination on stage[32]. In the piece *The Dynamic Still*, a robot chooses among the actions *wiggling*, *imitation*, or *following* based on its distance and orientation to a dancer[47]. The *Spidercrab* robot senses the position of a dancer's hand and then chooses one of the following actions: *imitation*, *follow*, and *oppose*[92].

Several examples create behaviors for artificial dancers by simulating their actuated morphologies. These behaviors represent specific emotional and aesthetic qualities [33, 58] or mimic specific dance movements[42]. Two examples combine an actuated morphology with a representation of the cause of actuation, which is either a neural network[13], the propagation energy[42], or the colors and contours in a video film[59].

4.5.4 Cognition. Two examples model cognitive capabilities for artificial dancers. The *Viewpoint AI* installation represents two types of gestural memories, a permanent memory for *innate* gestures and a volatile memory for learned gestures[46]. The piece *Robodanza* represents four motivational states of the robot that affect it's capability to learn to improvise to music[45].

4.5.5 Group. Some examples translate methods for coordinating human dancers or musicians into generative principles. The *Counterpoint* tool represents the alignment principle in the counterpoint technique employed by Forsythe[25]. The *Online Score Seven Duets* represents the score-based patterning mechanisms used by Burrows and Fargion to coordinate their stage behaviors[3]. The *Online Score Two* represents the group improvisation principle used by Thomas Hauert [4].

Two examples translate computational principles into rules for coordinating the activities between dancers[82] or between dancers, audience members, and stage props[75]. Some examples represent group behaviors using techniques from Artificial Life such as flocking simulations[11, 15, 31] or computational ecosystems[3, 4].

The installation *Performative Ecologies* draws inspiration from social mechanisms of creativity for evaluating and sharing successful movements[39]. In two other examples, the coordinated activities of robots are either prescripted[32] or created through remote control[28].

4.5.6 Structure. Several examples employ scores that specify structural aspects of a choreography. The system employed in the piece *Echo::system* represents stage space, directions, and timings of dance movements in discretized form[23] The systems by Lansdom generate scores that specify the dancers' poses, height levels, orientations, and movement timing or their body configurations, stage positions, and facing directions[56]. The piece *Hacking Choreography beta v.01* employs a score that represents categories of objects and their distribution on stage[82].

Several choreographic systems complement a vocabulary-based motion representations with choreographic information. The system *DANCING* specifies step sequences and spatial positions for Waltz dance[70]. The system *Tour Jeté, Pirouette* combines Ballet steps with a positional representation of dancers on stage[94]. A system for dance education represents basic Ballet steps alongside information about their enchainment, physical exertion, and ease of memorability[85].

4.6 Process

4.6.1 Random. The choreographic system *Tour Jeté, Pirouette* selects random steps and rejects those that cause collisions among dancers[94]. The choreographic system by Soga and colleagues extends a user selected motion by randomly choosing additional motions and timings that are compatible with the user's choice[86]. Two software-based artificial dancers employ randomness as part of an interaction mechanism, by randomly navigating a representational space of poses[5] or by randomly choosing one gesture[62].

4.6.2 Rules. Rules play a central role for generating scores for human dancers or for dancers who behave as generative system. Coleman and Byrne devised rules specifying the directions of dance movements and their timing[23]. The *A/RMA* system defines dance movements and rules for their triggering such as thresholds for distances to audience members or loudness of music[75]. In one of the *Hacking Choregraphy* pieces, the score contains rules for a dancer to select actions depending on the actions taken by another dancer[82]. The piece *Sound Choreography<>Body Code* combines to sets of rules, one for changing sequences of dance instructions based on the frequency of music, and one for changing functions for sound synthesis based on the position of the dancer[83]. The *Terpsicode* language provides rules that determine the sequence, timing, and rhythm at which photographs of dance poses are shown to dancers[84]. A choreographic system by Lansdown employs a state machine to handle transitions probabilities between dance movements[56]. Another choreographic system by the same author uses rules to test the compatibility of successive dance poses[56]. The choreographic systems by Soga and colleagues employs state machines to concatenate Ballet steps[85], organize the structure and repetition of Hip-Hop steps, or assign specific motions to dramatic sections in Contemporary Dance[90]

Rules are employed to control how robotic dancers responds to human dancers. The piece *Dynamic Still* employs different *Behavioral Sketches* for a robotic dancer, each with distinct rules specifying interaction patterns and triggering conditions[47]. The piece *Re-Callas/Medea* contains rules for identifying different gestures of a performer and translating them into response reactions for the drone robots[32]. The piece *Areoquake* contains rules for triggering up-down motions of drone robots which are executed immediately or with delay[54]. Rules control the mapping between Laban Effort Factors observed in human dancers and those exhibited by a *SpiderCrab* robot[92]. The piece *Piano&Dancer* employs rules for algorithmic composition that translate qualitative aspects of a dancer's movements into transformations of a musical score[72].

4.6.3 Simulation. Two examples employ simulations of physical phenomena to create interactive synthetic media. The *ViFlow* system employs a particle simulation dancer's can interact with by means of shapes attached to hands and torso with which particles collide[19]. The piece *Encoded* employs an interactive fluid dynamics simulation to which the dancer's movements are added as velocity-based perturbations[87].

Several examples employ physical simulations to model the morphology of artificial bodies. The choreographic system by Hsieh and Luciani creates physical representations of specific dance movements by simulating how energy propagates through a minimalist model of a body[42]. The installation *Becoming* employs an artificial dancer that contorts its body consisting of a set of masses through simulated muscle activations[59]. In the piece *Effet Papillon*, a one-dimensional mass-spring system filters a dancer's movements for controlling light and sound[2]. The installation *Double Skin/Double Mind* employs two small two-dimensional mass-spring systems, one for creating motions and one for returning to rest[2]. The piece *Chiselling Bodies* employs a similar mass-spring system but adds a third layer with a large number of springs to create more complex movements[2]. A combination of mass-spring and particle system models the branches and leaves of an abstract three[58]. The pieces *Phantom Limb* and *Polytopya* employ a mass-spring systems to model the morphology of limbs and an artificial neural network that senses and changes the configuration of the morphology [12, 13].

Several examples employ multi-agent simulations. The *Counter-Point* tool simulates a group of agents that exhibit and coordinate their arm rotations and translational movements [25]. A flocking

[3]Online Score "Seven Duets" scores.motionbank.org/jbmf/#/set/a-parallel-world
[4]Online Score "Two" scores.motionbank.org/two/#/set/impulse

simulation is used for translating principles from Laban Movement Analysis into expressive animations for abstract objects [63]. A modified version of the *CounterPoint* tool extends a standard flocking simulation with three customized agent behaviors *Freeze*, *Explore*, and *Hide*[31]. This version also employs a state machine to control how behaviors change over time or based on conditions such as proximity and visibility of agents and obstacles. Several dance pieces employ interactive flocking simulations that include agent behaviors for perceiving and responding to poses and movements of dancers[11, 15]. Agent responses include: avoid a dancer's movements, propel along a dancer's movements, remain within the silhouette of dancer, trace the body contour of a dancer. The flocking simulation in the piece *Piano&Dancer* implements several agent behaviors for controlling a piano: a discretization behavior to map agents to key positions and velocities, a cohesion behavior that places agents at vertical intervals to create chords, and a behavior for timed parameter changes to create melodic motifs. Antunes and Leymarie developed a computational ecosystem in which the agent's needs for metabolism and procreation determine their choice of actions[4]. This ecosystem is translated into a dance performance, with agents born and dying entering and leaving the stage, and the agents' actions shown as dance movements.

4.6.4 Evolution. Several examples employ automated fitness functions to generate choreographic material. The *Dancing* system uses a generative algorithm to generate Waltz sequences using a fitness function that rates the quality of a sequence based on stage use, facing direction, and step distribution[70]. The systems *Scuddle* and *Cochoreo* employ a genetic algorithm to create dance poses whose fitness function rates how much the poses deviate from common dance habits[21, 22]. An extended version of the computational ecosystem by Antunes and Leymarie combines a genetic encoding of agent traits with reinforcement learning, artificial evolution, and an implicit fitness function based of reproductive success[3].

Two examples employ interactive fitness functions. The system *Dance Evolution* evolves a neural network that controls the synchronization of artificial dancers to music[30]. A user can select an individual dancer whose genome is used to create the next generation. The extended *Counterpoint* tool employs interactive artificial evolution to simplify the search for interesting flocking behaviors[31]. A user can select multiple simulations as parents for reproduction. Two examples provide interaction through other means than a fitness function. For the piece *Robodanza*, a robot's associations of movements to music are either manually or automatically rated. Highly rated associations are used for a similarity based fitness calculation[45]. For the evolution of scores for a human and artificial dancer, the dancers performances become new scores for artificial evolution to operate on[57]. A neural network for controlling artificial body limbs is evolved using a fitness function that favors limb movements which are synchronized to a human dancer[12, 13]. The fitness value can be manually overwritten to preserve or dispose of a limb behavior a user likes or dislikes. The robotic installation *Performative Ecologies* employs a fitness function that rates the robots' movements based on the amount of visitor attention[39]. If there are no visitors, the system switches to a fitness function that rejects movements that are dissimilar from each other.

4.6.5 Machine Learning. Two examples use classification to associate poses or motions of an artificial dancer with those of a human dancer. In one example, two sets of poses, one for a human and one for an artificial dancer are labeled using a weighted nearest neighbor classifier[38]. For interaction, the artificial dancer selects poses that possess the same label as those by a human dancer. The *Viewpoints AI* system employs a classifier to create gesture representations from human motions[46]. Response gestures for an artificial dancer are obtained from pairwise associations of representations that have been observed in previous interactions.

Some approaches employ clustering to organize and select motions. For the *LuminAI* installation, two models are used, one for dimension reduction and one for clustering[62]. An artificial dancer responds to interaction by selecting a random gesture from a cluster to which the current human gesture belongs to. McCormick and colleagues employ self-organizing maps for recognizing human motions and for synthesizing motions for an artificial dancer[67]. This approach has been extended with a Hidden Markov Model or a Synaptic Map to recognize and generate sequences of motions[66, 68].

Some examples employ machine learning to create maps of encodings that can be navigated to synthesize motions for an artificial dancer. Berman and James create pose maps by employing kernel principal component analysis[5, 6] or variational autoencoders[8]. From these maps, motions of varying originality are created by navigating the map at different distances from encodings of existing poses. The system *GranularDance* employs an adversarial autoencoder to create a map of encodings of short motions in combination with a concatenation mechanism to create longer motions[10]. For this system, navigation strategies such as random walks, trajectory following, and trajectory interpolation are proposed.

Some examples use sequence prediction models to create synthetic motions. Kasperson and colleagues employed a recurrent neural network to create an interactive artificial dancer for the piece *Singularity*[53]. The choice of architecture was informed by comparing the capability of different models to create synthetic motions for interactive scenarios. Pettee and colleagues conducted a similar comparison but focused on the usefulness of different models to operate as choreographic support system[74]. This comparison favored an autoencoder for poses since it offered the greatest amount of freedom for creative experimentation. The choreographic system *Chor-RNN* employs a recurrent neural network[24] to reproduce the style and syntax of a specific choreographer.

Two examples for translating music into synthetic movements employ fairly sophisticated machine learning models. One example combines a music style classifier with two variational autoencoders, one for disentangling short motions from starting poses, and one for creating sequences of motion encodings[60]. Another example employs two transformer models, one for representing pose sequences and one for extracting musical context[61]. Both examples generate synthetic motions that are synchronized to the beat of music, with the first example focusing on synchronization only, while the second example also takes into account the physical plausibility and aesthetic diversity of the generated motions.

5 DISCUSSION

The proposed taxonomy represents an attempt to organize multiple perspectives on the field of Generative Dance in a structured manner. These perspectives complement formal and aesthetic principles that are normally foregrounded in discussions about Generative Art with conceptual, experiential, and collaborative aspects of integrating generative methods into creative dance practice. It is hoped that such a broad view helps to identify common grounds and shared interests between dance and generative art that go beyond purely practical considerations for artistic production.

As a concrete example, the taxonomy can be used to draw attention to topics and methods that occur frequently or rarely in Generative Dance. Such topics can help to identify starting points for potential future direction in research and creation that would benefit from and foster a mutual exchange between Generative Dance and Generative Art. A few such topics are briefly mentioned in the following.

Many examples in Generative Dance that employ robots in the role of artificial dancers deal with aspects of agency at surface level only. While this form of agency simplifies the authoring of the system's behaviors, it limits the system's capability to take into account the uniqueness of each interaction situation and adapt to it. A first step towards unlocking this largely untapped potential could involve the adoption of techniques that have been developed for some of the more elaborate software-based artificial dancers. As next step towards the realizations of stronger forms of creative agency for robotic and software-based dancers, research in field of computation creativity can serve as useful resource, in particular those research strands that focus on the importance of embodiment (e.g.[40]).

Improvisational settings that involve multiple artificial entities have been extensively explored within the field of *Musical Metacreation*[89]. A variety of approaches have been developed that model principles of communication and co-creation among improvising musicians (e.g. [18, 44]). Some of these approaches could be adopted for simulating ensembles of improvising artificial dancers. By doing so, Generative Dance could contribute its attention to embodied aspects of social creativity which in turn might inspire new research in *Musical Metacreation*.

In Generative Art, several artists and researchers have experimented with the creation of site specific works by employing generative mechanisms that respond to the conditions of the environment (e.g. [9, 55]). Despite the fact that site specific practices have their place in contemporary dance, their recognition in Generative Dance seems marginal. Site specific artworks in Generative Art could provide some inspiration for adopting this practice in Generative Dance.

In both dance and Generative Dance, qualitative aspects of movement have been studied extensively. Generative Art has focused on qualitative criteria for evaluating aesthetic properties of static artifacts such as images (e.g. [36]) and lacks principled approaches for evaluating artifacts in motion. Generative Art could likely benefit from adopting some of the criteria and methods for evaluating movement and thereby extend the repertory of aesthetic principles that are at its disposal.

Physical artifacts such as robots exist both in Generative Dance and Generative Art. What is fairly unique to Generative Dance is its focus on aspects of tangibility and kinaesthetic empathy, both as design principle during development and as mode for interaction. Generative Art typically focuses more strongly on the visual and acoustic manifestation of its artifacts. By taking tangibility more strongly into account, Generative Art can create artifacts that offer a wider range of sensorial and cultural experiences for audiences and that provide affordances that lend themselves to interaction.

Some research projects within which Generative Dance works have been realized explore means of incorporating the expertise of dancers and choreographers on a wider range of topics than movement creation and kinaesthetic empathy. This includes the interdisciplinary research project entitled *(Capturing) Intention*[73] that lead among others to the realisation of an educational installation[2]. Projects such as this are relevant for Generative Art in that they highlight how implicit artistic knowledge can be made explicit and thereby becomes accessible for formalization. As a conrete example, Generative Art could explore some of the mental imagery techniques employed by choreographers and dancers. Establishing a close connection between mental magery and generative principles could foster the creative imagination of audiences beyond a purely aesthetic appreciation of a generative work.

This list of topics is obviously far from complete. Hopefully, this publication inspires other artists and researchers to search for topics they consider worthwhile for further investigation. But even more importantly, this publication is meant to contribute to a wider discussion about the unique role that generative approaches play in dance, and which aspects of dance can potentially inform the wider field of Generative Art.

ACKNOWLEDGMENTS

This research conducted in the context of a Marie Curie Fellowship (H2020-MSCA-IF-2018 - Grant agreement no: 840465).

REFERENCES

[1] Sarah Fdili Alaoui, Kristin Carlson, and Thecla Schiphorst. 2014. Choreography as mediated through compositional tools for movement: Constructing a historical perspective. In *Proceedings of the 2014 International Workshop on Movement and Computing*. 1–6.
[2] Sarah Fdili Alaoui, Cyrille Henry, and Christian Jacquemin. 2014. Physical modelling for interactive installations and the performing arts. *International Jounral of Performance Arts and Digital Media* 10, 2 (2014), 159–178.
[3] Rui Filipe Antunes. 2016. Human Crowd Simulation: What CanWe Learn From ALife?. In *ALIFE 2016, the Fifteenth International Conference on the Synthesis and Simulation of Living Systems*. MIT Press, 38–45.
[4] Rui Filipe Antunes and Frederic Fol Leymarie. 2012. Generative choreography: animating in real-time dancing avatars. In *International Conference on Evolutionary and Biologically Inspired Music and Art*. Springer, 1–10.
[5] Alexander Berman and Valencia James. 2014. Towards a live dance improvisation between an avatar and a human dancer. In *Proceedings of the 2014 International Workshop on Movement and Computing*. 162–165.
[6] Alexander Berman and Valencia James. 2015. Kinetic Dialogues: Enhancing creativity in dance. In *Proceedings of the 2nd International Workshop on Movement and Computing*. 80–83.
[7] Alexander Berman and Valencia James. 2015. Kinetic Dialogues: Enhancing creativity in dance. In *MOCO '15 Proceedings of the 2nd International Workshop on Movement and Computing*. 80–83.
[8] Alexander Berman and Valencia James. 2018. Learning as Performance: Autoencoding and Generating Dance Movements in Real Time. In *International Conference on Computational Intelligence in Music, Sound, Art and Design*. Springer, 256–266.
[9] Peter Beyls. 2016. Açores, A Systemic Island. (2016).

[10] Daniel Bisig. 2021. Granular Dance. In *Ninth Conference on Computation, Communication, Aesthetics & X*. i2ADS, 176–195.

[11] Daniel Bisig and Pablo Palacio. 2012. STOCOS-Dance in a Synergistic Environment. In *Proceedings of the Generative Art Conference*. 96–109.

[12] Daniel Bisig and Pablo Palacio. 2014. Phantom Limb – Hybrid Embodiments for Dance. In *Proceedings of the Generative Art Conference*. Rome, Italy, 92–107.

[13] Daniel Bisig and Pablo Palacio. 2016. Neural Narratives: Dance with Virtual Body Extensions. In *Proceedings of the 3rd International Symposium on Movement and Computing*. 1–8.

[14] Daniel Bisig, Pablo Palacio, and Muriel Romero. 2017. PIANO & DANCER (Paper) Topics: Dance and Music. (2017), 1–8.

[15] Daniel Bisig and Tatsuo Unemi. 2009. Swarms on stage-swarm simulations for dance performance. In *the Proceedings of the Generative Art Conference. Milano, Italy*.

[16] Hetty Blades. 2012. Creative computing and the re-configuration of dance ontology. *Electronic Visualisation and the Arts (EVA 2012)* (2012), 221–228.

[17] Margaret A Boden and Ernest A Edmonds. 2009. What is generative art? *Digital Creativity* 20, 1-2 (2009), 21–46.

[18] Oliver Bown, Benjamin Carey, and Arne Eigenfeldt. 2015. Manifesto for a Musebot Ensemble: A platform for live interactive performance between multiple autonomous musical agents. In *Proceedings of the International Symposium of Electronic Art*.

[19] Taylor Brockhoeft, Jennifer Petuch, James Bach, Emil Djerekarov, Margareta Ackerman, and Gary Tyson. 2016. Interactive augmented reality for dance. In *Proceedings of the Seventh International Conference on Computational Creativity*. 396–403.

[20] Kristin Carlson, Sarah Fdili Alaoui, Greg Corness, and Thecla Schiphorst. 2019. Shifting spaces: Using defamiliarization to design choreographic technologies that support co-creation. In *Proceedings of the 6th International Conference on Movement and Computing*. 1–8.

[21] Kristin Carlson, Philippe Pasquier, Herbert H Tsang, Jordon Phillips, Thecla Schiphorst, and Tom Calvert. 2016. Cochoreo: A generative feature in idanceForms for creating novel keyframe animation for choreography. In *Proceedings of the Seventh International Conference on Computational Creativity*.

[22] Kristin Carlson, Thecla Schiphorst, and Philippe Pasquier. 2011. Scuddle: Generating Movement Catalysts for Computer-Aided Choreography.. In *ICCC*. 123–128.

[23] Grisha Coleman and Daragh Byrne. 2014. 36 Walk: a case study of reciprocity in movement and computation. In *Proceedings of the 2014 International Workshop on Movement and Computing*. 55–60.

[24] Luka Crnkovic-Friis and Louise Crnkovic-Friis. 2016. Generative choreography using deep learning. *arXiv preprint arXiv:1605.06921* (2016).

[25] Shannon Cuykendall, Thecla Schiphorst, and Jim Bizzocchi. 2014. Designing interaction categories for kinesthetic empathy: A case study of synchronous objects. In *Proceedings of the 2014 International Workshop on Movement and Computing*. 13–18.

[26] Scott DeLahunta. 2002. Software for dancers: coding forms. *Performance Research* 7, 2 (2002), 97–102.

[27] Scott DeLahunta. 2009. The choreographic language agent. In *Conference Proceedings of the 2008 World Dance Alliance Global Summit*.

[28] Louis-Philippe Demers. 2016. The multiple bodies of a machine performer. In *Robots and Art: Exploring an Unlikely Symbiosis*. Springer, Singapore, 273–306.

[29] Alan Dorin, Jonathan McCabe, Jon McCormack, Gordon Monro, and Mitchell Whitelaw. 2012. A framework for understanding generative art. *Digital Creativity* 23, 3–4 (2012), 239–259.

[30] Greg A Dubbin and Kenneth O Stanley. 2010. Learning to dance through interactive evolution. In *European Conference on the Applications of Evolutionary Computation*. Springer, 331–340.

[31] Jonathan Eisenmann, Benjamin Schroeder, Matthew Lewis, and Rick Parent. 2011. Creating choreography with interactive evolutionary algorithms. In *European Conference on the Applications of Evolutionary Computation*. Springer, 293–302.

[32] Sara Eriksson, Åsa Unander-Scharin, Vincent Trichon, Carl Unander-Scharin, Hedvig Kjellström, and Kristina Höök. 2019. Dancing with drones: Crafting novel artistic expressions through intercorporeality. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–12.

[33] Sarah Fdili Alaoui, Cyrille Henry, and Christian Jacquemin. 2014. Physical modelling for interactive installations and the performing arts. *International Journal of Performance Arts and Digital Media* 10, 2 (2014), 159–178.

[34] Rebecca Fiebrink and Baptiste Caramiaux. 2016. The machine learning algorithm as creative musical tool. *arXiv preprint arXiv:1611.00379* (2016).

[35] Philip Galanter. 2003. What is generative art? Complexity theory as a context for art theory. In *Proceedings of the 6th Generative Art Conference*.

[36] Philip Galanter. 2012. Computational aesthetic evaluation: past and future. *Computers and creativity* (2012), 255–293.

[37] Marco Gillies, Harry Brenton, and Andrea Kleinsmith. 2015. Embodied design of full bodied interaction with virtual humans. In *Proceedings of the 2nd International Workshop on Movement and Computing*. 1–8.

[38] Marco Gillies, Rebecca Fiebrink, Atau Tanaka, Jérémie Garcia, Frédéric Bevilacqua, Alexis Heloir, Fabrizio Nunnari, Wendy Mackay, Saleema Amershi, Bongshin Lee, et al. 2016. Human-centred machine learning. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. 3558–3565.

[39] Ruairi Glynn. 2008. Conversational environments revisited. Emerald Group Publishing Limited.

[40] Christian Guckelsberger, Anna Kantosalo, Santiago Negrete-Yankelevich, and Tapio Takala. 2021. Embodiment and Computational Creativity. *arXiv preprint arXiv:2107.00949* (2021).

[41] Mark BN Hansen. 2012. *Bodies in code: Interfaces with digital media*. Routledge.

[42] Chi-Min Hsieh and Annie Luciani. 2005. Generating dance verbs and assisting computer choreography. In *Proceedings of the 13th Annual ACM international Conference on Multimedia*. 774–782.

[43] Stacy Hsueh, Sarah Fdili Alaoui, and Wendy E Mackay. 2019. Understanding Kinaesthetic Creativity in Dance. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–12.

[44] Patrick Hutchings and Jon McCormack. 2017. Using autonomous agents to improvise music compositions in real-time. In *International conference on evolutionary and biologically inspired music and art*. Springer, 114–127.

[45] I Infantino, A Augello, A Manfré, G Pilato, and F Vella. 2016. Robodanza: Live performances of a creative dancing humanoid. In *Proceedings of the Seventh International Conference on Computational Creativity*. 388–395.

[46] Mikhail Jacob and Brian Magerko. 2015. Interaction-based Authoring for Scalable Co-creative Agents.. In *ICCC*. 236–243.

[47] Elizabeth Jochum and Jeroen Derks. 2019. Tonight We Improvise! Real-time tracking for human-robot improvisational dance. In *Proceedings of the 6th International Conference on Movement and Computing*. 1–11.

[48] A Johnston. 2013. Fluid Simulation as Full Body Audio-Visual Instrument. (2013). http://nime2013.kaist.ac.kr/program/papers/day1/paper2/151/151_Paper.pdfpapers2://publication/uuid/8DFCACDA-3476-4087-9CE6-92FC9E920C73

[49] Andrew Johnston. 2015. Conceptualising interaction in live performance: reflections on'encoded'. In *Proceedings of the 2nd International Workshop on Movement and Computing*. 60–67.

[50] Andrew James Johnston. 2009. *Interfaces for musical expression based on simulated physical models*. Ph.D. Dissertation.

[51] Manish Joshi and Sangeeta Chakrabarty. 2021. An extensive review of computational dance automation techniques and applications. *Proceedings of the Royal Society A* 477, 2251 (2021), 20210071.

[52] Laura Karreman. 2017. How does motion capture mediate dance? In *Contemporary Choreography*. Routledge, 492–510.

[53] Esbern Torgard Kaspersen, Dawid Górny, Cumhur Erkut, and George Palamas. 2020. Generative Choreographies: The Performance Dramaturgy of the Machine. In *Proceedings of the 15th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications-Volume 1: GRAPP*. SCITEPRESS Digital Library, 319–326.

[54] Heesoon Kim and James A Landay. 2018. Aeroquake: Drone augmented dance. In *Proceedings of the 2018 Designing Interactive Systems Conference*. 691–701.

[55] Marinos Koutsomichalis. 2011. Site Specific Live Electronic Music: A Sound Artist's Perspective. In *Proceedings of the Electroacoustic Music Studies Conference, Sforzando*.

[56] John Lansdown. 1978. The computer in choreography. *Computer* 11, 08 (1978), 19–30.

[57] François-Joseph Lapointe and Martine Époque. 2005. The dancing genome project: generation of a human-computer choreography using a genetic algorithm. In *Proceedings of the 13th annual ACM international conference on Multimedia*. 555–558.

[58] Caroline Larboulette and Sylvie Gibet. 2016. I am a tree: Embodiment using physically based animation driven by expressive descriptors of motion. In *Proceedings of the 3rd International Symposium on Movement and Computing*. 1–8.

[59] James Leach and Scott Delahunta. 2017. Dance becoming knowledge: designing a digital "body". *Leonardo* 50, 5 (2017), 461–467.

[60] Hsin-Ying Lee, Xiaodong Yang, Ming-Yu Liu, Ting-Chun Wang, Yu-Ding Lu, Ming-Hsuan Yang, and Jan Kautz. 2019. Dancing to music. *arXiv preprint arXiv:1911.02001* (2019).

[61] Jiaman Li, Yihang Yin, Hang Chu, Yi Zhou, Tingwu Wang, Sanja Fidler, and Hao Li. 2020. Learning to Generate Diverse Dance Motions with Transformer. *arXiv preprint arXiv:2008.08171* (2020).

[62] Lucas Liu, Duri Long, Swar Gujrania, and Brian Magerko. 2019. Learning movement through human-computer co-creative improvisation. In *Proceedings of the 6th International Conference on Movement and Computing*. 1–8.

[63] Matt Lockyer, Lyn Bartram, Thecla Schiphorst, and Karen Studd. 2015. Extending computational models of abstract motion with movement qualities. In *Proceedings of the 2nd International Workshop on Movement and Computing*. 92–99.

[64] David V Lu. 2012. Ontology of robot theatre. In *Proceedings of the workshop Robotics and Performing Arts: Reciprocal Influences, ICRA*, Vol. 2012.

[65] Erin Manning. 2006. Prosthetics Making Sense: Dancing the Technogenetic Body. *The Fibreculture Journal* 9 (2006).

[66] John McCormick, Steph Hutchinson, Kim Vincs, and Jordan Beth Vincent. 2015. Emergent behaviour: learning from an artificially intelligent performing software

agent. In *ISEA 2015: Proceedings of the 21st International Symposium on Electronic Art*. ISEA 2015, 1–4.

[67] John McCormick, Kim Vincs, Saeid Nahavandi, and Douglas Creighton. 2013-01-01. Learning to dance with a human. ISEA International; Australian Network for Art & Technology; University of Sydney.

[68] John McCormick, Kim Vincs, Saeid Nahavandi, Douglas Creighton, and Steph Hutchison. 2014. Teaching a digital performing agent: Artificial neural network and hidden markov model for recognising and performing dance movement. In *Proceedings of the 2014 International Workshop on Movement and Computing*. 70–75.

[69] Jodie McNeilly. 2014. A phenomenology of chunky move's glow: Moves toward a digital dramaturgy. *Australasian Drama Studies* (2014).

[70] Mario Nakazawa and Andrea Paezold-Ruehl. 2009. DANCING, dance ANd choreography: an intelligent nondeterministic generator. In *The fifth Richard Tapia celebration of diversity in computing conference: intellect, initiatives, insight, and innovations*. 30–34.

[71] Carlos Manuel Carvalho Santos Oliveira. 2015. *Choreographic Objects: Abstractions, Transductions, Expressions*. Ph.D. Dissertation. Universidade NOVA de Lisboa (Portugal).

[72] Pablo Palacio and Daniel Bisig. 2016. Piano&Dancer: Interaction Between a Dancer and an Acoustic Instrument. In *Proceedings of the 19th Generative Art Conference*. 138–154.

[73] Bertha Bermúdez Pascual. 2013. (Capturing) intention: The life of an interdisciplinary research project. *International Journal of Performance Arts and Digital Media* 9, 1 (2013), 61–81.

[74] Mariel Pettee, Chase Shimmin, Douglas Duhaime, and Ilya Vidrin. 2019. Beyond imitation: Generative and variational choreography via machine learning. *arXiv preprint arXiv:1907.05297* (2019).

[75] Megan Pitcher. 2015. Adaptive/responsive movement approach: dance making as interactive system design. In *Proceedings of the 2nd International Workshop on Movement and Computing*. 76–79.

[76] Richard Povall. 2001. A little technology is a dangerous thing. *Moving history/dancing cultures: A dance history reader* (2001), 455–458.

[77] Francisco Sagasti. 2019. Information technology and the arts: The evolution of computer choreography during the last half century. *Dance Chronicle* 42, 1 (2019), 1–52.

[78] Rob Saunders and Petra Gemeinboeck. 2018. Performative Body Mapping for Designing Expressive Robots.. In *ICCC*. 280–287.

[79] Thecla Schiphorst. 2009. soft (n): Toward a Somaesthetics of Touch. In *CHI'09 Extended Abstracts on Human Factors in Computing Systems*. ACM, 2427–2438.

[80] Norah Zuniga Shaw. 2014. Synchronous objects, choreographic objects, and the translation of dancing ideas. In *Emerging Bodies*. transcript-Verlag, 207–222.

[81] Richard Shusterman. 2000. *Pragmatist aesthetics: Living beauty, rethinking art*. Rowman & Littlefield Publishers.

[82] Kate Sicchio. 2014. Hacking choreography: Dance and live coding. *Computer Music Journal* 38, 1 (2014), 31–39.

[83] Kate Sicchio and Alex McLean. 2017. Sound Choreography<> Body Code: Software Deployment and Notational Engagement without Trace. *Contemporary Theatre Review* 27, 3 (2017), 405–410.

[84] Kate Sicchio, Zeshan Wang, and Marissa Forbes. 2020. Live Coding Tools for Choreography: Creating Terpsicode. In *Proceedings of the 2020 International Conference on Live Coding (ICLC2020)*. University of Limerick, Limerick, Ireland, 87–94. https://doi.org/10.5281/zenodo.3939135

[85] Asako Soga, Bin Umino, and Jeffrey Scott Longstaff. 2005. Automatic composition of ballet sequences using a 3D motion archive. In *1st South-Eastern European Digitization Initiative Conference*. Citeseer.

[86] Asako Soga, Yuho Yazaki, Bin Umino, and Motoko Hirayama. 2017. Automatic Synthesizing System of Choreography for Supporting Contemporary Dance Creation. In *Proceedings of the 20th Generative Art Conference*.

[87] Jos Stam. 2003. Real-time fluid dynamics for games. In *Proceedings of the game developer conference*, Vol. 18. 25.

[88] Nicolás Salazar Sutil. 2015. *Motion and representation: The language of human movement*. MIT Press.

[89] Kıvanç Tatar and Philippe Pasquier. 2019. Musical agents: A typology and state of the art towards musical metacreation. *Journal of New Music Research* 48, 1 (2019), 56–105.

[90] Bin Umino and Asako Soga. 2014. Automatic Composition Software for Three Genres of Dance Using 3D Motion Data. In *Proceedings of the 17th Generative Art Conference*. 79–90.

[91] Pablo Ventura and Daniel Bisig. 2016. Algorithmic Reflections on Choreography. *Human Technology, Agora Center, University of Jyväskylä* (2016).

[92] Mick Wallis, Sita Popat, Joslin McKinney, John Bryden, and David C Hogg. 2010. Embodied conversations: performance and the design of a robotic dancing partner. *Design Studies* 31, 2 (2010), 99–117.

[93] Sarah Whatley and Hetty Blades. 2019. Digital Dance. *Bloomsbury Companion to Dance Studies. London: Bloomsbury. DOI: https://doi. org/10.5040/9781350024489* (2019).

[94] Tina Yu and Paul Johnson. 2003. Tour Jeté, pirouette: Dance choreographing by computers. *Lecture Notes in Computer Science* (2003), 156–157.

[95] Qiushi Zhou, Cheng Cheng Chua, Jarrod Knibbe, Jorge Goncalves, and Eduardo Velloso. 2021. Dance and Choreography in HCI: A Two-Decade Retrospective. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–14.