Scuddle: Generating Movement Catalysts for Computer-Aided Choreography

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Abstract

We present a tool for computer aided choreography titled Scuddle. Scuddle uses a Genetic Algorithm to generate *movement catalysts* for contemporary choreography. The use of movement catalysts challenge choreographers to distance themselves from habits to better explore creative movement. Scuddle was designed as a method for both facilitating creativity and supporting active reflection on creativity through awareness of the decision making process. The system is successful in generating complex catalysts that result in creative approaches to movement and support articulation of decisions. We detail the design motivation, implementation, analysis and results of a qualitative evaluation by choreographers.

Introduction

Choreography is a creative practice based in extensive embodied knowledge and physical exploration. Intuitive decisions often drive composition in order to craft a work through practice based expertise (Blom, 1982; Humphrey, 2003). Many choreographers self-impose limitations that require creative solutions in order to distance themselves from habitual decisions. These limitations may be seen as *catalysts* that fuel exploration and new solutions. The reflective distance created when using a catalyst can sometimes provide additional awareness of the decision making process, allowing a deeper look at intuitive decisions. We are interested in investigating the process of making creative choreographic decisions to move towards the modeling of creative decisions in computational choreography.

To initiate our discussion of decisions we divide choreographic process into 3 stages: 1) the investigation of movement itself as source material, 2) the development of movement material into phrases or sections and 3) the composition of the movement phrases into a final structure. Literature on choreographic process often focuses more on the creation of movement material (stage 1) and sequencing of material (stage 2) than the crafting of material into a finished work (stage 3). However, many computer based attempts at creating choreography limit focus to the sequencing of predefined movement material (stage 2) (Calvert, 1991; Lapoint, 2005; Nakazawa, 2009; Soga, 2006; Yu, 2003). Movement sequencing (stage 2) can be the most systematic stage of choreography, hence the easiest to model computationally. The select focus on algorithmic sequencing of codified movement can also reduce creative possibilities in composition instead of supporting them.

We present a case study in computer-aided creativity to focus on the *generative* element of creative movement exploration (stage 1). Scuddle, our digital tool, has been designed to create incomplete movement data that is used as a catalyst for movement material (stage 1) when executed by a choreographer. The use of *movement catalysts* problematizes the usual process for creating movement material while allowing for interpretation from a unique perspective. Incomplete movement data consists of a 2 dimensional body position, the height for execution and four Laban effort qualities. The body positions support inhibition of habitual movement patterns through the use of Bartenieff Fundamentals. Movement catalysts are generated by a Genetic Algorithm to create diverse combinations of movement data (Russell and Norvig, 2010). The use of a genetic algorithm to create movement catalysts triggers exploratory creativity in the choreographer (Boden, 1998). By problematizing the process for creating movement material, we hope to encourage verbal articulation to study the decisions choreographers make through their creative process.

Related Work

The concept of creative catalysts has been used extensively by artists throughout history. It is often used to explore ideas in new ways and to push the self beyond known answers. Merce Cunningham used the IChing and utilized Chance Procedures as ways of exploring new movement ideas. Several systems have been designed to computationally support choreographic process through a combination of choreographer input and artificial intelligence techniques. While many of these systems could function as catalysts (Cunningham also used DanceForms as a catalyst) they were designed for different goals.

Early systems explored innovative approaches to creative movement material through limited movement data. One system uses algorithms to create body outlines for interpretation by a choreographer while providing the body position with spatial directions and orientation (Lansdown, 1978; Gray, 1984). Menosky created an interactive silhouette that could be altered with the choreographer's touch of a body part through reconfiguration of the effort position or a library of suggested positions (Gray, 1984). Bradford used AI techniques to facilitate dance improvisation through spatial direction and orientation to generate rules for guiding dance quality and movement generation (1995). These approaches all focused on the creation of

Computer Aided Choreographic Systems:	Stage of Choreographic Process	Movement Generation (stage1)	Sequence Generation (stage 2, ~3)	Final Selection Method	Representation of Choreographic Data	Precision of Movement Description
DanceForms (LifeForms)	Movement, Sequence, Choreography	User or Library	User	User	Multiple Figures, Space and Orientation in 3D	High
Tour Jete, Pirouette	Sequence	User or Library	Swarm Technique	User	Multiple Figures, Space and Orientation in 3D	High
Web3D Composer	Sequence	Library	Interactive Possibilities	User	Single Figure, Space in 3D	High
Dancing Genome	Sequence	User/ Motion Capture	Genetic Algorithm	Fitness Function	Single Figure, Orientation in 3D	Medium
Dancing	Sequence, Choreography	Library	Genetic Algorithm and Music	Fitness Function	Two Figures, Space, Orientation in ASCII	Medium
Dance Evolution	Movement/ Animation of	Neural Net and Music	In Order of Creation	User	Multiple Figures, Orientation in 3D	Medium
Scuddle	Movement	Genetic Algorithm	In Order of Creation	Fitness Function	Single Figure in 2D	Low
Pre-1990 Systems	Movement	User or System	N/A	User	Shapes, Silhouettes, Minimal	Low

Table 1. Comparison of Related Computer-Aided Choreographic Systems

creative movement material (stage 1). One system that focuses on all three stages of the choreographic process, allowing complex movement to be designed and viewed with A high level of detail, is DanceForms (formerly LifeForms). DanceForms (Calvert et al., 1991) is a graphic animation program for designing and visualizing dance movement based solely on user input or library selection. The system is timeline-based and allows the choreographer to design sequences and timings of movement. DanceForms supports choreography of multiple figures, spatial patterns and orientation. Merce Cunningham used DanceForms to design movement on avatars, transposing the movement decisions onto live dancers. This process allowed him to explore movement options that he may not have otherwise considered while facilitating his use of chance operations (Schiphorst, 1993). Yu and Johnson explored autonomous sequence generation through the use of a Swarm technique within DanceForms on the project titled Tour, Jete, Pirouette (2003).

Systems that address sequence and composition (stages 2 and 3) focus on the linear arrangement of movement to create formulaic phrases. Web3D Composer creates sequences of ballet movements based on a predefined library of movement material. Through an interactive process the user selects movements from a pool of possibilities, which shift based on structural ballet syntax. This process allows the choreographer to select movements based on the possibilities presented by the system and presents nearly complete graphic movement information (Soga, 2006). The Dancing Genome Project (Lapointe 2005; Lapointe and Epoque, 2005) developed a genetic programming model to explore sequences of movement in performance. The movement material was created by gathering motion capture data and is using it to create a 'mutated' sequence that is performed by virtual avatars while the original sequence is performed by live dancers. Dancing (Nakazawa, 2009) used a series of music related parameters, stage use rules and a predefined library of traditional movements to generate Waltz choreography using a Genetic Algorithm. This system generates syntactically correct movements in a complete choreography as ASCII symbols.

Currently available contemporary systems that address the creation of movement material (stage 1) include DanceForms, Dance Evolution and Scuddle. Dance Evolution animates avatars by teaching them to dance to music through the use of an interactive evolutionary algorithm. Movement is generated by analyzing a rhythm and using it to control the energy an avatar uses to execute a position (Dubbin, 2010). Scuddle generates unique movement catalysts through the use of a genetic algorithm. The choreographer is provided with specific guidelines for execution that are controlled by the system yet require the choreographer's creativity for individual interpretation. This is the only current system that is designed specifically as a catalyst for creative movement material.

These systems are compared to evaluate the quantity of data given to the dancer, how the data is given to the dancer and the stage of the choreographic process that is addressed. Five systems focus on the sequencing of movement material while one focuses on the design of movement material and one focuses on the animation of movement (Table 1). Six systems focus on creating computer generated choreography by giving the dancer complete movement data while Scuddle focuses on generating incomplete movement data for creating computer-aided movement material (Shedel, 2009; Hagendoorn, 2008).

Design Motivation

In an attempt at computationally modeling improvised theatre, Magerko recognized the need to better understand the active creative process (2008). Scuddle was designed to begin to address this issue through the author's direct experience of choreographic process and the desire to understand how intuitive movement decisions are made. As the knowledge behind intuitive decisions is deeply embodied and often could be considered tacit knowledge, an active approach to exploring process is needed. One observation of compositional practice is that both movement material and compositional structures develop into habit and can then facilitate a personal set of instructions for creation. Another observation is that movement material and compositional structure are often intricately entwined. In order to attempt a disruption of habits while still facilitating the entwinement of movement material with the compositional process, the concept arose to use specifically developed incomplete movement data. The incompleteness of data facilitates 'open' exploration, enabling multiple solutions to be generated from an 'incomplete' movement catalyst.

Laban Efforts and Bartenieff Fundamentals

The design of incomplete movement data is based on studies in movement patterns and effort qualities by Laban and Bartenieff (Laban, 1947; Hackney, 1998). Rudolf Laban developed a method of categorization to analyze, notate and create movement. One property of movement that Laban explores is 'effort', the quality used to execute a movement. He emphasized that every movement possesses effort qualities as forerunners of the movement execution. He describes four quality components (See Figure 1.A): weight (light to strong), time (sudden to sustained), space (direct to indirect) and flow (bound to free). For example, 'Movements performed with a high degree of *bound flow* reveal the readiness of the moving person to stop at any moment in order to readjust the effort if it proves to be wrong, or endangers success. In movements done with *fluent flow*, a total lack of control or abandon becomes visible, in which the ability to stop is considered inessential' (Laban, 1947). Scuddle uses all effort quality components as 'instructions' for executing a position. The combinations of qualities are designed to create interesting yet complex physical patterns for the body to execute.

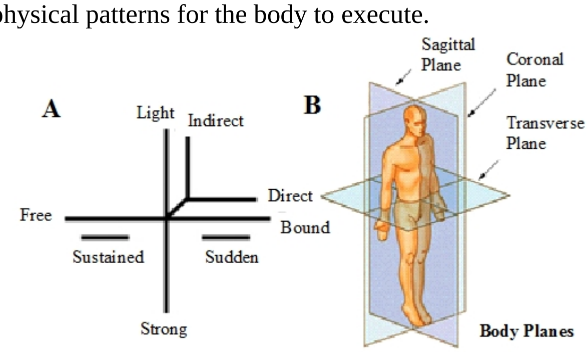

Figure 1.A Rudolf Laban's Effort Quality Graph (Newlove and Dalby, 2003) and **Figure 1.B** Bartenieff Separation of Bodily Planes (Hackney, 1998).

Bartenieff Fundamentals are a further development of Laban's research to the moving body (Hackney, 1998). Bartenieff uses anatomical body planes to deconstruct movement into categories such as pathways of movement, movement patterning, spatial intent and core support. The body planes (see Figure 1.B) sagittal, coronal and transverse help to illustrate movement patterns. For example homologous positions (same limb positions for one side of the transverse plane), homo-lateral positions (same limb positions for one side of the sagittal plane), contra-lateral positions (same limb position for one opposing limb on each side of the sagittal plane). Additional movement pathways include distal positions (all limbs fully extended) and medial positions (all limbs fully contracted). Bartenieff Principals are used in Scuddle to explore and inhibit habitual movement patterns. To create complex catalysts, emphasis on inhibiting habitual movements is designed through the use of asymmetry and complex variations between joint angles on a position (Birkhoff, 1956).

Genetic Algorithm

A Genetic Algorithm is used to evolve movement catalysts. This allows the system to control fundamental components that problematize the dancer's process of generating movement. Genetic Algorithms are typically used to explore a wider range of potential solutions than other search algorithms can (Holland, 1992). Initially a large population of random individuals are generated and given a score for their fitness against the prescribed goals for success. This initial population is then subjected to an iterative cycle of selection and breeding. Once a cycle is complete the new population is judged on its fitness once again and the process continues for a fixed number of iterations or until a certain fitness threshold is reached (Floreano and Mattiussi 2008; Russell and Norvig 2010).

System Description

A movement catalyst consists of movement data that is graphically represented as a 2 dimensional figure with text for height and effort quality instruction (See Figure 3). The 2D figure represents body position through the use of straight lines as limb positions with curves to suggest torso positions. This allows the 3 dimensional orientation and limb position to be determined by the choreographer. The interface has five button options that have the functions of Start (to run the algorithm), Watch (to view the 6 catalysts in order), Pause (to pause the playback), Back (to view the previous catalysts) and Clear (to erase the values to re-start the algorithm cleanly). Still images of the generated catalysts are saved every time the algorithm is run.

The system begins by generating an initial population of 200 random 'catalysts'. Body positions are designed to allow unlimited possibilities for positions in eight major joints; the shoulders, elbows, hips and knees. Positions are initially generated by calculating random angles between 0-360 degrees for each joint to alter the configuration of the position's limbs. Effort qualities are randomly generated as 1 or 2 (for fighting or indulging as later explained) and height as a random level from low to high. Therefore, a catalyst is composed of 13 values: 8 joint angles, 1 height level and 4 effort qualities. An example of the values from Figure 2, showing height and effort qualities are:

Body Position / Height / Effort Quality

[340, 220, 240, 310, 110, 40, 240, 320, Mid-Low, 2, 1, 2, 1]

Fitness Function

A rule based system is used to evaluate the fitness of each movement catalyst. We have developed heuristic rules based on movement patterns discussed in Bartenieff Fundamentals and the author's expertise in contemporary dance practice to inhibit traditional habits when creating movement. The fitness function evaluates each catalyst component separately (body position, height, effort qualities and Bartenieff) and then calculates the overall score.

To compare the catalyst components we map each value separately. Each of the 8 joint angles are weighted based on their location within quadrants. For example, angles between 0-90 degrees are placed in one quadrant and 90-180 degrees in another. The orientations of quadrants are based on their location from the center of the body (See Figure 2). This weighting is designed to lower the score for fully outstretched or contracted limbs by placing all joint angles on diagonals that score 1, creating an overall body position score of 8 (1 x 8 joints). For example, the bent arms in Figure 2 have scores as follows: the left shoulder is 340 degrees which is mapped to 4 and the left elbow is 220 degrees to map to 1. This sum of these mappings gives Figure 2 a body position score of 14. Height is the level at which the body position is to be executed. These values are used to emphasize more unstable positions such as balancing in crouches and on the toes (See Table 2).

Effort Qualities refer to the effort used to execute a body position and height. Fighting efforts are direct, strong, sudden and bound. Indulging efforts are indirect, light, sustained and free. A combination of four fighting or indulging

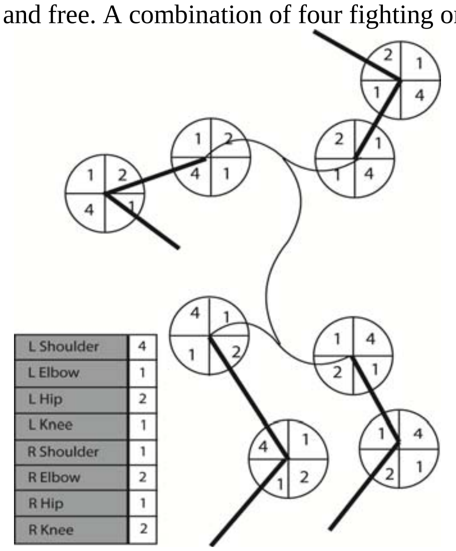

Figure 2. Weighting of Quadrants for Body Position

Height Weighting		
Jump	High	2
Raised	Mid-High	3
Stand	Middle	1
Crouch	Mid-Low	3
Floor	Low	2

Table 2. Height Weighting

Bartenieff Modifiers	
Contralateral	+30%
Homologous	-40%
Homolateral	-50%
Distal	-60%
Medial	-50%

Table 3. Bartenieff Modifiers

efforts results in modifying the sum of the position and height by -60%. Combinations of two fighting and two indulging efforts modify the sum of the position and height by +20%. Three fighting efforts and one indulging effort or three indulging efforts and one fighting effort modify the sum of the position and height by +40%.

Symmetry of body position is analyzed as movement patterns (based in Bartenieff Fundamentals). Contra-lateral motions explore the diagonals made across the body. In homologous motions the relationship of the top half of the body is compared to the lower half. Homo-lateral motions compare the limb position of one side of the body. All limbs fully extended are considered distal and all limbs fully contracted as medial. To address habit inhibition, heuristic rules are designed to favor contra-lateral motion (asymmetry) while hindering homologous and homo-lateral motion (a tendency of codified dance techniques). See Table 3 for the assigned modifier that is applied.

The fitness for a movement catalyst is calculated as the sum of body position and height that is modified based on the combination of Laban effort qualities and Bartenieff movement patterns. See Figure 3 for an example of mappings and fitness score. The equation for the score is:

$$\text{Fitness(mc)} = BP_{mc} + \text{Height}_{\text{mc}} \times (1.0 + Bartenieff_{mc} + Laban_{mc})$$

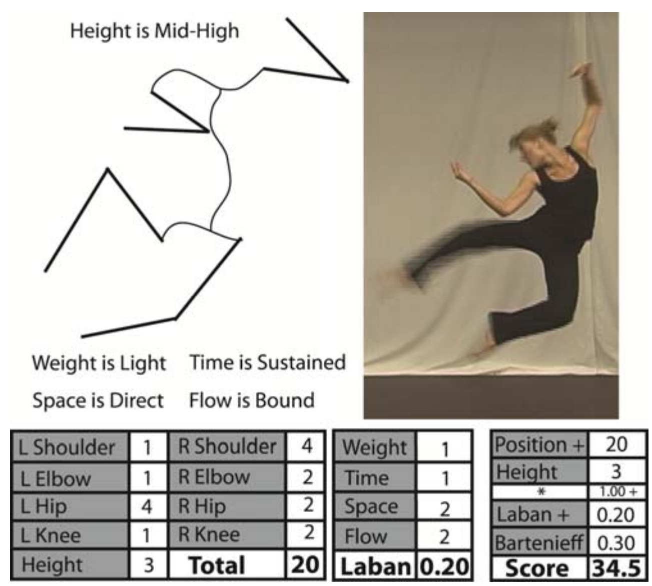

Figure 3. Example of Scoring for Fitness Function

Selection, Cross Over and Mutation

We select 20 percent of the movement catalyst population by Roulette Wheel to be parents for the next generation of offspring. The Roulette Wheel process selects individuals with likelihood proportional to their fitness. Two individuals at a time are bred through two-point cross over, chosen from the pool of parents. The breeding takes place by selecting two random placeholders from the two individual's values and switching the values between placeholders (See Table 4). The offspring are added into the new pool of individuals. The breeding process continues until the population has grown back to the original size. Once the size of the population has regenerated, ten percent of the individuals are randomly selected to mutate. The mutation occurs by choosing a random placeholder in the values of the individual and generating a new value for that place (See Table 5).

Individual 1	[4, 1, 2, ||1, 1, 2, 1, 2||, 3, 2, 1, 2, 2]
Individual 2	[1, 1, 2, ||2, 4, 2, 3, 1||, 3, 1, 1, 2, 2]
New Indiv 1	[4, 1, 2, ||2, 4, 2, 3, 1||, 3, 2, 1, 2, 2]
New Indiv 2	[1, 1, 2, ||1, 1, 2, 1, 2||, 3, 1, 1, 2, 2]

Table 4. Example of Cross Over

Individual 1	[4, 1, 2, 1, 1, 2, 1, ||4||, 3, 2, 1, 2, 2]
Mutated 1	[4, 1, 2, 1, 1, 2, 1, ||2||, 3, 2, 1, 2, 2]

Table 5. Example of Mutation

The cycle of Selection, Cross Over and Mutation repeats until the termination criteria has been fulfilled. This has been set at 6 generations to retain diversity in the population. For the final selection of individuals, Roulette Wheel selection is used to choose 5 individuals from the population to be presented in sequence to the choreographer. The system is available online at:

http://www.metacreation.net/kcarlson/Scuddle/applet/

Results

A pilot study was performed with 7 choreographers using participant-observation methods followed by open-ended interviews. Five choreographers were given the system on a laptop to generate their set of movement catalysts and two were given printed copies of a generated set. Choreographers using laptops were given instructions to generate catalysts and all participants were asked to explore the movement catalysts on themselves. After time was spent exploring and reflecting on movement, they were asked to pair up and take the roles of dancer and choreographer.

The study found five main results when choreographers used Scuddle: 1. The process of using Scuddle prompted comparison to their usual creative process (5 choreographers), 2. There was a heightened awareness of personal habits when a habit was explicitly addressed by Scuddle (5), 3. Choreographers tended to re-examine their approach to structuring movement when using Scuddle (4), 4. Movement was initiated in non-habitual and creative ways (7), 5. The experience could be articulated verbally to facilitate further study into creative cognition (4).

Choreographers felt that working with the movement catalysts was very different from their typical processes. Statements that movement is often generated from a concept, through improvisation, to make creative decisions based on what feels 'right' or 'interesting' internally were made by 5 choreographers. Participant 2 stated 'I usually start with a concept but this time I started with pure movement and I still made the movement meaningful to me.' Participant 5 discussed 'a heavy reliance on the body's survival skills' that took time to explore before reflection could occur. This was noticed by 3 others, though was dependent on how exuberant the choreographer was in execution. Choreographers found a heighted awareness of particular habits when the system directly addressed them, especially in relation to body symmetry and balance. For example, participant 3 stating that the system 'forces me to think of my arms at all times, which I never do' and participant 2 'it is weird for my body but actually feels really interesting - it makes me be really asymmetrical'. Participant 1 found 'with the legs I wanted to revert back to what I was comfortable with, but the arms I could really do something interesting with'.

Decisions to structure movement based on the catalysts varied and required a re-examination of their personal approach. Participants 3, 4, 5 and 6 read the components from top to bottom in order of height, body position, effort qualities and attempted execution in that order. However, participant 1 selected height and the effort qualities first, and attempted to fit the position into these components second. When confused by a movement catalyst she changed her perspective to a bird's eye view, stating that 'it was most important to find out what *I* think this is and then shift it to or adjust it for my body'. Participant 1 and 2 both tended to attach different effort qualities to different parts of the body, for example Time as Sustained to the legs with Weight as Strong to the arms. Participant 4 would focus on Weight and Time when executing a movement catalyst and assumed that Space and Flow would emerge automatically. Participant 2 looked for the similarities and differences between two catalysts and attempted to execute them consecutively.

All choreographers initiated movement in non-habitual and creative ways. Participant 3 stated that 'It pulls me out of my body at first, but it doesn't feel bad.' Participant 2 stated 'This is not a narrative but makes me connect the dots in an interesting way.' Participant 6 stated that Scuddle 'gives you these very specific guidelines, but being creative people we interpret them in our own way. It's a very valuable tool and gives an interesting angle to work from.' Participant 1 thought Scuddle would be useful 'to get out of a rut or the habits you go back to.' Participant 4 felt 'disjointed now physically but I am interested and would want to explore more artistically.' Choreographers found they could better articulate their experience verbally with the technical perspective of Scuddle. Participant 3 said ‘yes, this helps me to verbalize my decisions’ and participant 2 stated ‘I am talking about it more technically as opposed to making decisions that feel right’.

Conclusion and Future Work

This paper details a system that generates catalysts to challenge choreographers in making creative movement choices. Our results illustrate that the use of Scuddle prompted: comparison to choreographer’s usual creative process, heightened awareness of personal habits when explicitly addressed by Scuddle, choreographers to re-examine their approach to structuring movement, non-habitual and creative movement choices and an experience that could be articulated verbally with the added technical perspective. From these initial results, we deduce that Scuddle is guiding the choreographer to explore creative movement while supporting articulation of creative decisions. This analytical approach to developing creative movement material separates the decision making process into concrete events that can be identified and verbalized. The articulation of events are able to facilitate a deeper exploration into the creative decision making process. This approach provides insight into the process of making creative choreographic decisions to move towards the modeling of creative decisions in computational choreography. We believe this tool will be useful to researchers of dance and technology while contributing to the exploration of creative decisions in computer-based choreography.

Future work includes a comparative study to examine the affect our heuristic rules have on the choreographer’s creative movement choices. This study will be performed by providing choreographers with movement catalysts that use the current rule settings, catalysts that use the opposite values to the current settings and catalysts that are generated randomly, without the fitness function. We also plan to develop Scuddle to be customizable. This will provide choreographers with control over modifiers, adjusting for personal habits. We will implement machine learning for the chorographer to determine positions they like or dislike. An extended study of Scuddle will be performed using comparative analysis to document the choreographic decisions made using the current heuristic rules and individual choreographer’s custom rules.

References

Blom, L.A., 1982. *The Intimate Act of Choreography*, University of Pittsburgh Press.

Birkhoff, G.D., 1956. Mathematics of Aesthetics, in: Newman, J.R. [ed.], *The World of Mathematics*. Simon and Schuster, Vol. 4. 2185-2195.

Boden, M.A. 1998. Creativity and artificial intelligence, *Artificial Intelligence*, vol. 103, no. 1, pp. 347-356.

Bradford, J., Côté-Laurence, P., 1995. An application of artificial intelligence to the choreography of dance. *Computers and the Humanities*, 29(4), pp.233-240.

Calvert, T., Welman, C., Gaudet, S., Schiphorst, T. Lee, C.,1991. Composition of multiple figure sequences for dance and animation. *The Visual Computer*, 7(2), pp.114-121.

Dubbin, G., Stanley, K., 2010. Learning to Dance through Interactive Evolution. In *Applications of Evolutionary Computation*. pp. 331-340.

Floreano, D., Mattiussi, C., 2008. *Bio-Inspired Artificial Intelligence: Theories, Methods and Technologies*, MIT Press.

Gray, J., 1984. Dance in Computer Technology: A Survey of Applications and Capabilities. *Interchange*, 15(4), pp.15-25.

Hackney, P., 1998, *Making Connections: Total Body Integration Through Bartenieff Fundamentals*, Gordon and Breach Pub.

Hagendoorn, I., 2008. Emergent Patterns in Dance Improvisation and Choreography. In *Unifying Themes in Complex Systems IV*. Springer Berlin Heidelberg, pp. 183-195.

Holland, J. H., 1992, Genetic Algorithms, Scientific American, (267), pp. 62-72.

Humphrey, D., 2003. *The Art of Making Dances* New edition., Princeton Book Company.

Laban, R.V., 1947, *Effort*, London: Macdonald & Evans.

Lansdown, J., 1978. The Computer in Choreography. *Computer*, 11(8), pp.19-30.

Lapointe, F., 2005. Choreogenetics: the generation of choreographic variants through genetic mutations and selection. In *The 2005 workshops on Genetic and evolutionary computation*. ACM, pp. 366-369.

Lapointe, F., Époque, M., 2005. The dancing genome project: generation of a human-computer choreography using a genetic algorithm. *ACM international conference on Multimedia*. ACM, pp. 555-558.

Magerko, B., Riedl, M. 2008. What Happens Next?: Toward an Empirical Investigation of Improvisational Theatre. *5th International Joint Workshop on Computational Creativity*.

Nakazawa, M., Paezold-Ruehl, A., 2009. DANCING, Dance and Choreography: an Intelligent Nondeterministic Generator.*Richard Tapia Celebration of Diversity in Computing Conference*. ACM, pp. 30-34.

Newlove, J., Dalby, J., 2003, *Laban for All*, Routledge.

Russell, S.J., Norvig, P., 2010. *Artificial Intelligence: A Modern Approach* 3rd ed., N.J: Prentice Hall.

Schedel, M., Rootberg, A., 2009. Generative Techniques in Hypermedia Performance. *Contemporary Music Review*, 28(1), p.57.

Schiphorst, T., 1993. *A Case Study of Merce Cunningham's Use of the LifeForms Computer Choreographic System in the Making of Trackers*. Master’s Thesis. Simon Fraser University.

Soga, A., Umino, B., Longstaff, J.S., 2006. Web3D dance composer: automatic composition of ballet sequences. In *ACM SIGGRAPH 2006 Research posters*. ACM, p. 5.

Yu, T., Johnson, P., 2003. Tour Jeté, Pirouette: Dance Choreographing by Computers. In *Genetic and Evolutionary Computation — GECCO 2003*. p.156-157