Computational Model of Human Creativity in Dance Choreography

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Abstract

Dance choreography is a system of techniques used to create new dances. The choreographer devises body movements using internal and external cues to express feelings and concepts, from the most abstract ideas to very concrete human situations in a highly creative manner. In 3D Tele-immersive Environments (3DTI) the choreographer has exponentially more options to create new body movements in the new dance since the 3DTI technology offers an array of visual stimulations, called Digital Options, which influence this movement making process. In this paper, first, we explore the creative process of dance choreography through Laban/Bartenieff Movement Analysis (LMA) representation via computational models in the 3D technology. Second, we elaborate on the creativity framework and the design of dynamic compositions that are placed in the geographically distributed multi-stream, multi-party 3DTI environment. Third, we discuss some very preliminary results of our creativity framework and first findings that validate parts of our computational modeling and 3DTI design.

Introduction

Dance choreography is a system of techniques used to create new dances. Creating a new dance requires choreographer/dancers to engage with inner motivations to express feelings as well as to dialogue with the external environment, whether that be visual, aural, tactile or kinestethics environmental stimulus on a stage or in a laboratory. The choreographer devises body movements using internal and external cues to express feelings and concepts, from the most abstract ideas to very concrete human situations in a highly creative manner, wherein a body or bodies in time and space are the central tools of this choreographic process. Choreography is simultaneously deeply abstract and physical. Imagine a movement when a dancer enters into a 3D tele-immersive (3DTI) room surrounded by multiple 3D digital cameras and displays, where internal and external cues for creative movements come not only from physical objects in the 3DTI room, but also from a remote dancer who is placed in geographically-remote 3DTI room and appears in a joint virtual space with another dancer. Suddenly the choreographer has exponentially more options to create new body movements in the new dance since the 3DTI technology offers an array of visual stimulations, called Digital Options, which will influence this movement making process. Random, non-deterministic behaviors found within this new dance-making process will interact with the distributed 3DTI system initiating different functional and data configurations and compositions; a creative interactive feedback loop between the expressive art of making dances and the more dynamic capabilities of the Information Technology allows the unexpected, random, at least non-deterministic (if desired) behaviors as the distributed 3DTI system changes and works with different functional and data configurations and compositions.

In this paper, we present (a) how to map and represent one aspect of a dance choreographer's creativity in relationship to the 3DTI technology, and (b) how the compositional framework within the 3DTI digital system itself will react to the dance choreographer's creativity with a set of creative and dynamic compositions and configurations. This response will consist of new and different functional and data elements that inject their own level of "creativity" by returning visual/acoustic clues to the dance choreographers.

The mapping process of dance creativity into the 3DTI technology is based on the system of Laban/Bartenieff Movement Analysis (LMA). LMA commonly used in dance choreography and dance analysis in the United States since the 1950s, has become a very useful system for describing not only the functional aspects of movement but also the expressive aspects of movement, which define us as embodied humans. The major principles of LMA rely on the belief that the human body movies through the space in dynamic constantly changing patterns. There is a relationship between the outer realm of sensation and the inner world of intent and emotion. These two worlds interact with one another in space and time. The body is constantly coordinating, balancing, copying and expressing in relations to the environment. Through the use of a series of complex symbols, which represent the major principles within the system, a dancer utilizing LMA can record and analyze dance movements, developmental movement patterns, gestures, postural shifts, etc. It is a systematic method for describing qualitative changes in movement and body adaptation within space.

Based on LMA, we investigate computational models of LMA inside the 3DTI system in the form of geometric point clouds and subsequently extracted geometric features and dynamic motion models so that then the manipulation of LMA symbols and the overall internal IT creativity process can occur inside the 3DTI system. The 3DTI system offers the dance choreographer digital options, for example, changing a virtual space background, enabling flying artificial objects through the virtual space, or scaling some of the dancers to small or very large size, in the common virtual space which allows the dance creator to either stay in the same movement sequence or change the flow of the dance. The digital options within the 3DTI system represent control points for the dance choreographer to interact with non-deterministically. The challenges of creating computational models for LMA are (a) creation of geometric and spatial configurations and dynamic motion models/representations in real time via point clouds collected from multiple 3D cameras, and (b) manipulation and updates of geometric/spatial configurations and motion models as the speed of the dance changes.

The internal creativity process within the 3DTI system, executed through instantiation of digital options, is modeled via the compositional framework. The framework supports dynamic configuration and composition of functional entities, changes in algorithms to be executed, inclusion of dynamic sets of data to stimulate the dance creativity process, and reallocation based on user needs. The compositional framework explores (a) dynamic composition of functional paths, algorithms and data through sound execution paths to avoid any undesirable effects, (b) dynamic configuration of distributed resources that would correspond to the compositional path according to chosen digital options (e.g., scale of dancers, views of dancers, inclusion of graphics backgrounds), and (c) exploration of composition/configuration 'uncertainty', i.e., statistical selection of compositional functional/data paths, introducing 'creativity' on the part of 3DTI system, and presenting creativity opportunities to the dance choreographers at the same time.

The paper is organized as follows. We will first discuss the related work to identify our place in the large body of work done in this area. We will follow the discussion with description of the 3DTI systems and presentation of the symbiotic creativity framework that provides the umbrella of our work and the computational modeling of dance creativity. The computational modeling is then presented with respect to the LMA-based dance modeling, the computational finite state automata and motion analysis that are the foundation of the dynamic compositions within 3DTI systems. We close with a discussion of our preliminary experiments of the creativity framework and its usage of very simple computational models.

Related Work

The related work, that we rely and build on, spans across areas such as immersive tele-presence systems, vision systems, human motion modeling, composition management, and dance choreography.

Tele-Presence Systems. The first conceptual description of tele-immersive environments was the 'sea of cameras' paper (Fuchs et al 1994). After that a number of 3D video conferencing systems emerged such as the VIRTUE project (Kauff and Schreer 2002), the Colisium Tele-presence system (e.g., (Baker at al. 2005)), the virtualized Reality system at CMU (Kanade et al. 1996) and many others.

Vision Systems. The first commercial real-time stereo vision products are the triclops and digiclops by Point-grey Research, the Small Vision System by Videre Design, and Tyzx Inc's DeepSea based systems. These systems are not, however, associated with any tele-presence application yet. With respect to multi-camera systems, CMU's newest 3D room (Cheung et al. 2000), the view-dependent visual hull system at MIT (Matusik et al. 2000), the Keck laboratory at the University of Maryland (Baker et al 2000) and the Argus system at Duke University (Brady et al 2000) include such computer visions systems.

Human Motion Modeling. The problem of building a systematic framework to analyze human motion using visual data is an active area of research. In such a framework, models to describe motion are built in a layered manner, to represent categories of increasing complexity. For example, (Brand et al. 1997) use layered structures of Hidden Markov Models (HMM). In (Bregler et al. 1997) linear dynamic systems are used to model simple motions and more complex motions are modeling using HMM. In our work, we use an optimal control-based model for human motion. Optimal control-based models have been used in robotics and computer animation (Nori et al. 2005), for synthesis of motion and in the field of computational neuroscience as a model for human motor systems. Optimal control models of the human sensori-motor system (Kuo 1995, Harris et al 1998) have been successful in explaining several empirical observations about human motion. However, such a model has not been used to analyze human motion or recognize higher-level goals and subtleties of human motion.

Dynamic Composition/Configuration Management. There has been extensive work on designing configuration management tools for dynamically composed systems, support for dynamic composition of service components, self-configuration information management, web service composition, e.g., (Gu and Nahrstedt, 2004) and many others.

Dance Choreography. The current practice of creating choreography with technology primarily utilizes the system of motion capture, for example, the Life Forms system (e.g., (Carver, Beardon, Exton 2004). Life Forms approach uses animated bodies in time and space. However, the system lacks the depth and character that 3DTI can provide a choreographer. One can in principle reconstruct the 3D motion from a set of carefully chosen 2D frames, however the result is not immediate, and hence it does not provide interactive capabilities (e.g., (Goldberg 2000)).

3D Tele-immersive Environments

3DTI environments are rooms with collaborative technologies where full bodies are immersed in real time into the 3D tele-immersive space, integration and interactions with any other 3D data either synthetic or real 3D images are possible, and the body is free of typical virtual reality sensors and gear allowing he body to have full agency in the space.

The 3DTI room is created by a network of cameras that enable us to capture and reconstruct in real-time the three dimensional (3D) representation of the dancers within and between different rooms (Bajcsy and Jung, 2006). The network of cameras is connected via Gigabit Ethernet, and between individual rooms, the cameras are connected via Internet2 to move the 3D streams between the sites and allow dancers to meet in a 3DTI space (Yang et al. 2006) as shown in Figure 1. Note that the figure shows only the flow of 3D streams from the sender to the receiver. However, in real system, each sender is also a receiver, hence dancers at each remote site not only produce video streams of themselves, but also receive video streams of the remote dancer, and see themselves in the same cyberspace with the other dancer. This is referred to as the virtual meeting point.

Symbiotic Creativity Framework

In this paper we present a symbiotic Creative Framework, based on computational models of human creativity, that consists of the creative process coming from the dance choreographer, and the creative process that happens inside of the 3DTI system as shown in Figure 2. The overall creative process consists of two major phases: (1) Feedback from the Dancer/Choreographer to the 3DTI system and (2) Feedback from the 3DTI system to the Dancer/Choreographer. The creative process, shown in Figure 2, is executed as follows:

1. The choreographer positions the dancers in the virtual space via the 3DTI system and initiates digital option (e.g., bring up a new virtual space background such as red stripes background) via the graphical user interface. The 3DTI system takes (a) the input of the digital option 1 (in Figure 2 red stripe background option), specified by the choreographer, and (b) the LMA-based computational state model of the dancer, specified via computer vision algorithms from multi-camera input, and feeds the input into the dynamic compositional framework.

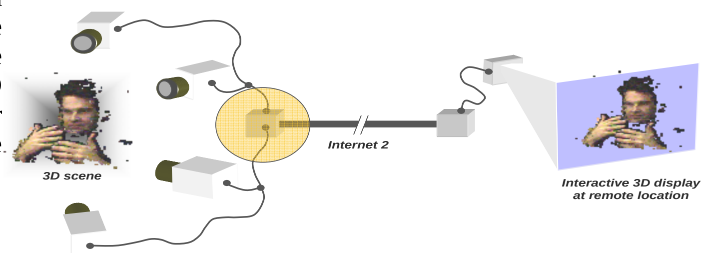

Figure 1: *Overview of 3D Tele-Immersive System*

2. Within the 3DTI system, the dynamic composition framework composes the functional dependency graph, in order to execute the digital option 1. The 3DTI internal composition takes into account the current computational state (LMAQ pose/shape in Figure 3 and 4) the dancer is in. Once the functional dependency graph is derived, a mapping to resource configuration must happen for the geographic-distributed TI system. The resource availability will determine in a 'creative' manner what form of the functional graph can be executed. In this stage the non-determinism comes to play. Once the correct functional graph and the resource graph are determined, visual feedback (e.g., red stripes background) will be presented to the dancer/choreographer, yielding a Dance Setup 1 within the virtual space.
3. The choreographer now creates a dance phrase (see Figure 5) within the Dance Setup 1 until she needs again a new 'creative' stimulus from the 3DTI system which enables Digital Option 2 (e.g., enabling black background digital option).
4. In the next step, the 3DTI system reconfigures in a 'creative' manner the functional and resource dependency graphs, yielding the choreographer/dancer Dance Setup 2 (e.g., black background).
5. Within the Dance Setup 2, the dancer deviates from the base-line set choreography, in essence she/he will create a new dance phrase in response to the 3DTI

system. This whole feedback-based creative process repeats.

.Modeling of Dance Creativity

The base of the symbiotic creative framework is the computational model that strongly depends on the user dance modeling and motion analysis. We will first discuss the user dance modeling, and then computational modeling and its relation to motion analysis.

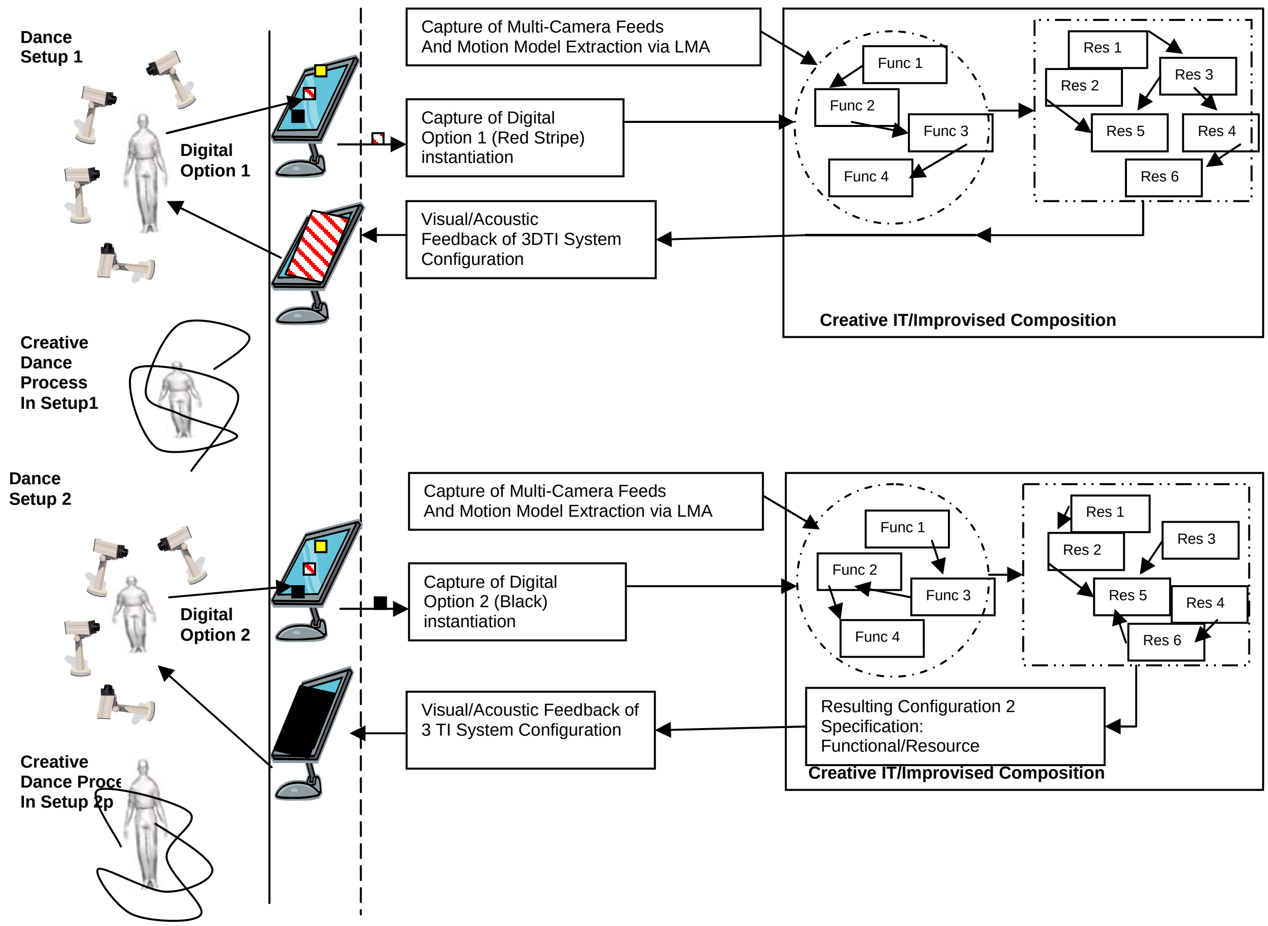

Figure 2. *Symbiotic Creativity Framework*

LMA-based User Dance Modeling

We use Laban/Bartenieff Movement Analysis (LMA) system in our dance creative process which consists of four major categories. Each of these categories has its own set of principles, symbols, and theories which would be far too complex to discuss in this paper. We will discuss only few main points here.

Body. Body is the core area in LMA. The body, our basic physiology, is tied to how we function in the world and therefore how we express ourselves and respond to our environment. There are six patterns of total body connectivity that are used within the LMA system to analyze body movements : breath pattern, core/distal pattern, head/tail pattern, body half pattern, upper/lower pattern, cross lateral pattern.

Shape. The body can be seen as the contents within the container. The container can be seen as plastic and malleable. It is the form that the body takes within space. How we shape into the world is an expression of our inner body physiology and our conscious or unconscious intentions to move. Within the Laban system shaping into the work is how we create relationship to others and to space and the environment. Within the shape category there are numerous subcategories including modes of shape change, shape qualities, shape forms, shape flow support and trace forms.

Effort. Effort refers to the inner impulses or drives of an individual from which movement originates. These impulses are visibly expressed in the rhythms of a person's bodily motion; the way she uses her movement energy. Effort can be understood as the dynamics of movement, the texture and quality of movement. It is taken from the German word antrieb, meaning a force exerted against a body which makes it move forward. There are four categories that Laban created to describe the dynamics of movement. Each of these categories exists in varying degrees of intensity on a continuum. There is Weight: strong and light; Focus or Spatial intent: direct or indirect; Time: sudden or sustained; Flow: free or bound. These categories can also be combined into constellations of three efforts (called drives) or two efforts (called states). There are 56 possible configurations of the states and drives within the system. Furthermore, individuals can activate all the efforts together in what is called "full effort".

Space. Space is the most complex category within the system as it encompasses and informs all of the other categories. Space refers to the infinite area that surrounds the form of the body externally, and the space that exists within the form of the body internally. There is a dynamic relationship between body, effort, shape and space. Within the space category we ask the questions: Where is the movement going? What spatial pulls and sequences are being activated?

> "Spatial intent organizes body connections by establishing a clear pathway/goal for the movement. These pathways are "alive highways" which the body can ride in both vertical and off-vertical movement. The clearer the spatial intent or goal of the movement, the more easily the neuromuscular system can

accomplish the action in a fluid way". (Hackney)

Laban worked within the Platonic solids, symbolically placing the human figures at the center of each crystalline form. He theorized that the center of the human body could be placed in the center of the sphere.

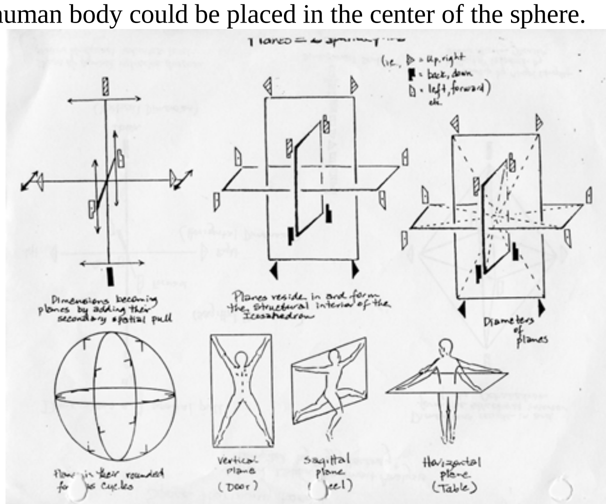

Figure 3. *Simplification of LMA Space Category and Coordinate System in which LMA occurs*

Each crystalline form (he worked with the cube and the icosahedron) has specific spatial points that he used to analyze where a movement is going. For example, specific points are forward high, right side high, left back low, etc. He created a series of spatial for dancers to work within in order to expand how the body functions and also how expression could be expanded. Space is an expressive force and how humans move within it defines them as individuals and defines architecture, design and culture. Within the space category, there are concepts of kinesphere, spatial pulls, scales, space harmony, phrasing, zones, pathways and central/transverse/peripheral approaches to kinesphere.

LMA-based Computational Model

The choreography used within this project consists of a series of composed dance phrases. Each phrase represents three temporal states: the beginning is characterized by the initial body shape and relationship of the body in the 3D space; the middle is characterized by the body in motion; the end is characterized by the final body shape and relationship of the body in the 3D space. While the beginning and the end phrases consist of states representing body location and shape, the middle state is represented by a motion equation/transformation. Then the computational representation of choreography is a computational finite state diagram (FSA) in which in subsequent dance phrases the initial state is the end state from the previous phrase. If the dancer adheres strictly to the state diagram, the performance is predetermined and highly rehearsed. As digital options get invoked, phrase states

poses change. The state diagram dynamically changes. For example, the middle phrase is replaced by a new phrase instantiated due to the invocation of digital options by the choreographer.

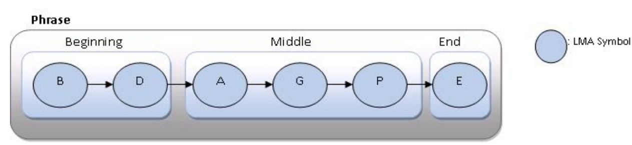

Figure 4. *Dance Phrase consists of dancer's LMA poses and shapes and is expressed by beginning, middle and end*

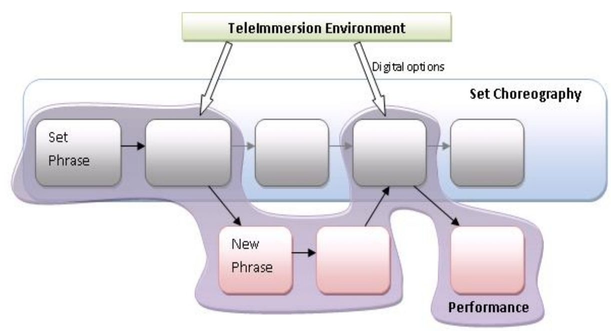

Figure 5. *Computational State Diagram and its Dynamic Transition from Base-Line State Diagram to New Composed State Diagram after Feedback from 3DTI Environment.*

Motion Analysis. The LMA movements of the dancer need to be recognized to drive the computational FSA. To achieve this goal, we use motion analysis in each 3DTI room/system. The fundamental assumption of the 3DTI system is that all sites based on calibration (Bajer et al. 2000, Svoboda et al 2000, Daniilidis et al 2000) are working in the same coordinate system. Furthermore, our geometric representation is object centered in this case dance centered. Since we also utilized the background subtraction procedure, we are working with the data representing only the dancers. On this data we apply kinematic analysis and dynamic motion models to automatically annotate the dancer's movements according to the LMA system. We fit a skeleton to the 3D point cloud representation of the dancer. The extraction of the skeleton provides us with raw kinematics data (position of limbs, joint angles) which can then be used to extract higher-level features related to the LMA elements.

The Effort dance element reflects the dynamic qualities of the movement and the inner attitude towards exertion. This subtle element is best captured by using a dynamic motion model that allows us to model the control forces and torques exerted by the human body. We utilize Optimal Control Models of the human sensorimotor system which do this in a natural manner. These models quantify the high-level goals as a performance criterion or cost function which the human sensory-motor system optimizes by picking the control strategy that achieves the best possible performance. Thus optimal control models of human motion place the high-level goals and the strategy center stage, while the movement details arise naturally as a consequence of these goals.

The different Effort categories can be mathematically expressed as different components of the *cost function* that encapsulates the inner intentions. For instance, the Weight element can be expressed as the cost attached to the expenditure of energy and the Time element (which describes the sense of urgency) can be expressed as the cost attached to the time duration of the movement. This framework allows for multiple elements to be present simultaneously and to varying degrees as reflected by the weights attached to the corresponding terms in the *cost function*. The problem that needs to be solved for automatic extraction of the Effort element is as follows: given the movement details (limb trajectories, joint angles), estimate the weights attached to the different Effort terms in the underlying cost function. The weights can be calibrated by learning them from an annotated database of movements or the rehearsals of the choreographed sequence. Creative variations in the Effort element can be quantified by comparing the weights for different performances of the same choreographed sequence.

The Shape and the Space elements, both require recognition of kinematic patterns in the movement. Graphical Models (e. g., Hidden Markov Models) can be used to learn and recognize these elements from the kinematic data. We explore different higher-level kinematic features (e.g., variance in different directions) for representation and recognition of these elements. Spatial intent can also be recognized using optimal control models which have been using extensively to model reaching motions. The extraction of the Body element requires a representation that encodes the participation of different body parts and can be used to recognize patterns in initiation and sequencing.

The LMA system analyses movement at multiple levels. Combining the different elements gives us a rich description of movement which can be used to compile the movement signatures of different dancers, represented in a symbolic description of motion. The creative variations introduced by a performer are likely to be subtle, in which case representing a movement by a sequence of poses would fail to capture them. LMA does not simply view movement as a sequence of poses/shapes. Rather, it emphasizes the process and manner in which the change in pose is affected. Thus, the comparison of the descriptions also provides a systematic manner of quantifying the difference between a choreographed sequence and the variations introduced during the performance, either by the performer's intent or style, or by the exercise of digital options. Systematic experiments could possibly tease apart these influences.

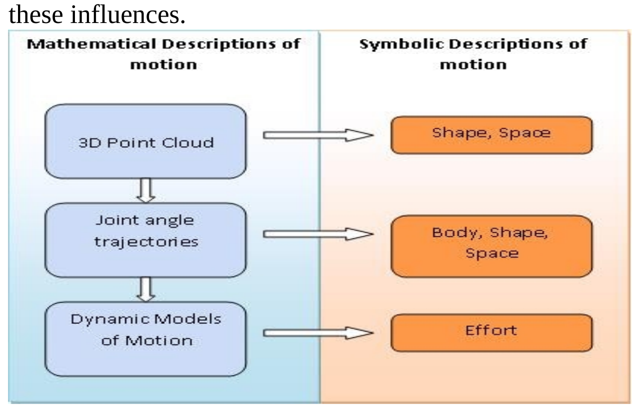

Figure 6. *Capturing of Dancer's Laban Movements via 3D Cameras, Derivation of Mathematical Description of Motion and Mapping to Symbolic Description of Motion*

Digital Options

In the 3DTI spaces we experiment with different digital options that support and influence the creative process of dance making. The digital options are functions, enabled at a certain time point, that modify the virtual space the dancer is placed in. The digital options are able to (a) change the scale of the dancers, (b) multiply or distort the dancers, (c) change the viewer or user vantage point and utilize multiple viewing angles, (d) change background or cyber-location, (e) include synthetic objects which can be manipulated, e) allow the body to be viewed as partially or fully represented, abstracted or non-visible. The richer the set of digital options is, the more variation can be provided to the choreographer within the creative process of making dance.

Digital options have a unique representation at the graphical user interface through the TI viewer at each site. At this point we will assume that only one site (one choreographer) sets/decides on the digital options to be activated and since multiple sites participate, the chosen digital option command needs to be disseminated to each involved site and all sites need to be automatically calibrated to adjust to the new selection. We are exploring distribution protocols that will provide the consistency in state among all participating 3D TI sites and are going to be part of the dynamic compositions in the future.

Dynamic Compositions and Configurations

The goal of the dynamic composition framework is to respond in a creative IT manner to the selected digital options and to the computational state in which the LMA and motion analysis indicates the dancer is within the virtual space. The configuration framework consists of three major parts which are connected in a feedback-loop control: (a) the functional composition, (b) the resource composition components, and (c) configuration management operations.

Functional Composition: In the functional composition subsystem we are exploring the derivation of functional dependency graphs that specify in which order and when certain functions need to be called in order to execute the selected digital option as well as sustain the prior selected digital options. Once the functional graph is specified, it is mapped to allocated resources, including number of CPU/GPU processing, camera, display, and networking resources.

Resource Configuration: The resource allocation and configuration is a non-deterministic ‘creative’ process since the geographically distributed 3D TI system does not control underlying resources and we are working with best-effort resource allocation policies within the operating system (Windows) and Internet2 (Note: If underlying OS/Network real-time, guaranteed services become available, we utilize them.). Hence, the resource dependency graph resulting from the functional dependency graph is loosely connected and adapts during the execution and transmission according to resource availability. We also provide a feedback to the functional composition component to alter the functional graph if not sufficient resources exist to execute proposed functional graph. However, we assume a minimal functional graph that provides the terminating condition for which resources should exist, otherwise the digital option cannot be executed at all and feedback to the choreographer is provided. Once the resource configuration graph is found, the visual feedback of the functional and resource composition is presented to the choreographer.

Configuration Management Operations: As the choreographer works with the digital option user interface tool, specifying and modifying the sequence of digital options, and their timing relations, the composition framework stores the various functional and anticipated resource configurations in a distributed repository. The configuration management process within the composition framework provides operations that allow the choreographer to (a) view the existing configurations, (b) edit the existing configurations, e.g., the timing duration between two digital options, (c) insert new digital option(s), (d) play a new digital option, (e) remove digital option from the sequence, and others.

Within the dynamic composition framework, we investigate a suite of distributed networked protocols that provide the creating of functional and resource dependency graphs, map the functional graphs into the resources, as well as provide adaptive view-based protocols that adheres to the selected digital options and the views that the choreographer/dancer want to see. We have started to investigate some of the view-based networking protocols (Yang et al. 2007), but further investigations with respect to correlations with 3D TI viewers/rendering tools, 3D reconstruction and other functions need to be taken into account to provide appropriate performance of 3D reconstruction, 3D TI rendering and network traffic shaping in end-to-end fashion.

Preliminary Experimentation

We are just starting to put digital options graphical interfaces into 3DTI environments to expose dancers to interactions with 3DTI through digital options interfaces, and to evaluate how the creative process interacts with the 3DTI technology. Later on we plan to implement and execute the individual LMA functions and analysis, and computational and compositional models behind the digital options interfaces that will lead to enhanced LMA-based choreographic compositions.

In Fall 2007, we ran a seminar at University of California, Berkeley (UCB), where the students explored the digital options interface in the UCB 3DTI room. The digital options were (a) transformations on their images such as scale change and rotation in different planes, and (b) real-time dancing with pre-recorded person. The 3DTI system did not provide any feedback (as proposed in the symbiotic creativity framework), but the user’s creative reaction to the manual setup of certain digital options served us as the baseline for future experiments. The following baseline experiments were performed sessions 1-5: (1) the students performed a dance phrase based on one gesture, which they enlarged and looped into a repeatable phrase, prescribed by Professor Mezur without any visual feedback from the

3DTI environment; (2) the students performed the same dance piece with visual feedback from the 3DTI environment; i.e., they were able to see themselves on the screen as they performed; (3) the students danced with themselves, i.e., with their pre-recorded solo dance; (4) the students performed the same steps as in the 3rd session, but they added to their dance the usage of digital options. The students were asked to manipulate one of the images, i.e., shrink/expand their size, flip their images upside down, and dance with those pre-recorded images; (5) the students were asked to come up with their own creative choreography using the 3DTI visual feedback and digital option interfaces.

The students overall recognized the weaknesses of the current technology in terms of lower 3D video resolution than a regular 2D video, and lower recording rate of 3D video than in case of 2D videos. However, we also observed that the students used the current shortcomings of the technology creatively in the choreography and commented that this technology offers creative inputs which they never experiences before.

We present one example. The students very much liked the live performance with the pre-recorded person video piece from the previous session. The students commented that this digital option made the piece more interesting and funny. It offered something that was not possible in typical studio setting choreography. It was interesting because one could change the speed of the pre-recorded piece, and run the pre-recorded person faster than the performance in live session. Also, one could make the pre-recorded person super-sized or small. It was funny because the students could have the pre-recorded person shrunk and have the live person bend down to touch the mini-person. They were delighted with the surprising sense of creating "dream-like" or imaginary images and movements. Overall, the new choreographic opportunities provided by the digital options within the 3DTI system sparked the students' creativity and provided a unique environment for performance and movement.

Conclusion

In this paper we present the design for a symbiotic creativity framework for dance choreography based on LMA-driven models. We present dancer user models, computational models and compositional algorithms that need to be in place and interface through digital options with the dancers and choreographers. Our very preliminary experiments with the digital options interface show a clear beginning for the furthering of creative processes. In the future, we plan to refine the design and execution of the dynamic computational and compositional frameworks behind the digital options interface to provide much richer creation options for the making of new dances. Furthermore, an evaluation through the lens of LMA will offer a scientific and accurate documentation of the increased possibilities for movement that are unique to the 3DTI space. Our hope is that what is learned in this work will also translate to other creative applications both artistic and scientific.

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