An Overview of Formalizing and Computerizing Dance

Literature Review for Honors Project

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ABSTRACT

Dance is one of the most remarkable performance art forms and is considered to be an ancient, cultural heritage. Therefore, it is imperative to provide a means to archive and preserve this art form. Methods used in the preservation of dance should exploit new technologies for quality reassurance, safety and efficiency. Equally important, is the communication of dance between experts and novices who wish to develop and practice their dance skills. Primitive methods of teaching dance are prone to error and may be unreliable or confusing. Thus, we investigate alternate approaches to improve the learning process. This review highlights how dance was communicated throughout history and currently is, using notations to denote a collection of moves for a dance. The significance of notation use is pondered and the possibility of creating one's own notation is deliberated. We discuss some of the most well-known notations and applications they may have. Given that 2D representations do not illustrate all the information about an entity, the notion of 3D representations plays a pivotal role in graphics today. Hence, it is essential to decipher techniques for 3D annotations and motion capture in virtual 3D environments. Approaches to annotation systems and learning models are inspected in this review. We explore and analyze the different methods for devising a tool to define dance moves, to inspect different sequences of moves and to improve dance skills.

1. INTRODUCTION

1.1 The Problem

Dance is a performance art and is considered to be an ancient, cultural tradition. Consequently, the importance of preserving dance is intangible. Oral communication is prone to error and humans are circumscribed by memory, concerning the intricacies of past and present dance art forms. Therefore, it is imperative to archive various performance arts for future generations in order to facilitate the survival of dance.

Due to the lack of comprehensive dance documentation, dance novices are likely to video a dance lesson with the intention of using this video to practice a dance. This approach often proves to be futile because the video quality may be substandard, there is no formal clarification of moves into clear steps and positions and the overall method is inefficient.

The task we presented to us is to create a tool that addresses the aforementioned shortcomings. The resulting tool must allow experts to define moves clearly, allowing learners to review and explore various sequences of these moves. This entails formalizing and computerizing a specific dance language that may be accompanied by a visualization of dance figures. This tool should not only provide a platform for learners to develop and improve their skills and teachers to plan their lessons, but should be easy to use.

1.2 Research Purpose

The aim of this research is to consider information relating to and discover existing approaches to the problem mentioned in Section 1.1. This will allow us to contemplate tactics regarding the assigned task.

Firstly, dance notations will be deliberated. We will discuss the applications of these notations and the implications of choosing such a notation. Furthermore, these notations will be evaluated compared to each other in order to distinguish their differences and reflect on which notation would integrate well with the task at hand. In order to do this, the advantages and disadvantages of each notation will be discussed in Sec 4. This analysis will aid us in choosing whether to use an existing notation for defining a dance or if we should devise and implement our own notation. The latter would entail contemplating the various approaches to creating a unique notation and the effect it may have on us and the users.

An additional reason for this research is to discover any projects involving capturing motion and annotation systems. This relates to the visualization aspect of our project. Once we implement a definition for a dance, we need to provide a 3D representation of the movement in order for teachers to plan lessons and novices to practice dance moves. Therefore, we explored various options for annotating dances. Trade-offs for the different approaches will be discussed in Sec 4, which will allow us to examine a feasible option for this component of our tool.

A crucial part of the research is deliberating the integration of these aforementioned components. The objective of the research is to gain insight into what has previously been done which will allow us to formulate a strategic plan for design and development.

2. APPLICATIONS OF DANCE NOTATIONS

"A dance notation, similar to musical notes, is a symbolic form of representing the movements of the dancers using various graphical symbols such as lines, circles, rectangles, squares, bars etc. The primary use of a dance notation is the documentation, analysis and reconstruction of choreography" [22]. Dance notation entails expressing four-dimensional movement into two-dimensional space [8] and provides a means to conduct theoretical analysis on choreography [21].

2.1 Background

One would assume that the way in which dancers learn their parts is from direct, visual and verbal communication from a choreographer [25] but the use of notation to represent dance dates back to 3rd century BC [8].

The ancient Egyptians were among the first people that made use of dance notation, using hieroglyphics to describe certain dance moves [8]. On the contrary, during the Renaissance, an individual step was recorded using one letter [8]. These historical notations attest to the fact that dance notations could possibly play a critical role in the preservation of dance.

2.2 Considering the Use of Notations

We have to contemplate the ramifications of opting to utilize an existing notation or devise our own to represent dance moves for our project. Therefore, we reviewed a study on "the effect of notation use of the development and learning of dance" [26]. This study [26] is reassuring, as they have used participants to test their hypothesis.

The results indicated that instructions for a dance given in the form of a notation, resulted in quicker recognition, improvements in performing movement and integrating the recognition ability required for advancement in dance [26]. Furthermore, the author had experience as a dance instructor, and stated, "that exposure to simple movement notations altered how dancers view dance and how they move when dancing" [26]. However, given that the participant base was comprised of only grade three students, one may ponder whether a more diverse participant base would yield the same results.

Both Lack [14] and Franko [5] commended the use of notation. It can be used as a valuable teaching-device when used correctly [14]. Therefore, it can be deduced that using a notation partnered with a 3D visualization aspect could prove to be successful in teaching novices how to master a dance.

2.3 Types of Dance Notations

2.3.1 Feuillet's Notation

The advent of track-drawing systems was spurred by an increased complexity in steps for several dance types [24]. Feuillet was responsible for the development of the most sophisticated track-drawing system at that time. His notation is able to document foot positions and a classification of steps corresponding to floor patterns [8, 20]. However, his notation is limited by its inability to represent movement for the upper part of the body [24]. This notation was adequate for court ballets, but as this dance grew less popular, the notation was unable to accurately portray modern forms of dance [20, 24].

2.3.2 Eshkol-Wachman Notation

Noa Eshkol, who was a dancer and a choreographer, was one of the two creators of this notation [12]. A diagram resembling a linear, stick figure of a body is the core of this notation. This figure is separated at the skeletal joints, which gives rise to the representation of the limbs [2]. Movement is defined for each limb [12]. The notation is paper based, with the intention of providing a means for dancers to evaluate the notation and reproduce the dance that it corresponds to [2, 12]. This notation has found widespread application in numerous fields, albeit it being first developed for dance [2, 12].

2.3.3 Labanotation

"Labanotation is a graphical notation scheme for describing human body movement that has been widely accepted for the purpose of recording human movements in the fields of choreography and dance education. Labanotation uses a symbolic description and it is said that the notation can even describe motions of the fine each finger of a dancer" [4]. In addition to facilitating the preservation of movement, Labanotation also elucidates movement [6]. A succinct description of Labanotation is that direction, heights and durations of movement are expressed by symbols which are put between lines [17], reminiscent of a musical staff.

Fügedi [6] hypothesized that in order to aid dance education, Labanotation can be introduced into curriculum. The focus of his study was reconstructing dance using Labanotation and videos. The current literature confirmed that Labanotation exposed the dance structure and made it possible to reproduce a dance that closely resembled the original performance. Warburton [26] conducted a study to investigate the effect of notation use on learning dance and mentioned that Labanotation still suffers from limitations, resulting in an incomplete and inaccurate representation of a dance. Lending a note of credibility to his argument, Warburton [26] postulates that there is still a need for further exploration into things like constraints of dance moves to devise a complete depiction of dance.

There have been previous uses of Labanotation to reproduce dance motion. Choensawat et al. [4] "investigated a method of describing and reproducing CG animation of highly-stylized traditional Noh plays using plain Labanotation" [4]. Noh plays reside in Japanese theatre [18]. They were hindered in their pursuit to use Labanotation to denote a complete set of moves, as some were too complex to comprehend, thus only basic moves were considered. According to Choensawat et al. [4], their system was beneficial [4] to choreographers, amongst others. This is notable as choreographers, or teachers, fall into our target group. Their findings inferred that they were able to utilize Labanotation to convey Noh plays using a restricted range of symbols.

They authors of the current literature made use of LabanEditor [4, 17] which "is an interactive graphical editor for editing Labanotation scores and displaying the 3D CG character animation associated with scores" [4, 17]. LabanEditor allows users to input and manipulate body movement simulating dance. This functionality is enhanced with an animated display of a 3D human body model [17]. The LabanEditor emulates the idea we are trying to implement.

Nakamura et al. [17] proposed an XML representation of Labanotation and its implementation onto an editor, enhancing the aforementioned LabanEditor. "In order to interchange Labanotation via the internet, text representation of Labanotation is required" [17]. They selected XML as the mode for text representation, which prior to this was not developed for Labanotation [17]. Thus, their attention was honed in on the development of LabanXML [17], "an XML representation of Labanotation scores" [4]. A design for LabanXML was accomplished and the aforementioned LabanEditor system was enhanced (LabanEditor2 [17]) to cater for reading and writing functionality for LabanXML data [17]. Components that still required deliberation is analysis of dance movement and archiving dance data [11] which relates to our project description. Hence, this study could prove pivotal in our efforts going forward as it may provide the foundation for what we are trying to achieve.

An underlying issue with dance notations such as Labanotation [4] and Benesh notation [22] is that experts in the field are in short supply. Furthermore, even though few are able to read Labanotation, even less are able to write scores for Labanotation [21]. A basic annotation process would include an expert to analyze the notation and successfully interpret the dance movement. For this reason, Hatol [10] designed MOVEMENTXML, a markup language, to specify the semantic meaning of Labanotation symbols. El Raheb et al. [21], built on this concept by creating an ontology that transforms the semantic meaning of Labanotation into ontology web language entities [21], so that it may be understood by both humans and machines. The use of this ontology allowed for a rich vocabulary for defining the dance movements, as ontologies can express complex relations, limitations and rules [21]. The main aspects of dance, which are time, space, dynamics and body [21], were successfully conveyed by this ontology [21].

2.3.4 Benesh Notation

"Benesh movement notation was designed to write the whereabouts of a dancer on the stage, the direction the dancer facing, the positions of the limbs, and the details of the head, hand and foot" [22]. This notation represents dance by doing markings on a matrix which correspond to a human figure [1]. The matrix is denoted by the musical staff and divides the human body at the feet, knees, waist, shoulder and top of head [25]. An extra ledger line is added above the staff to represent the maximum reach of hands when the arms are extended upwards [25]. Movements are represented as though they are being observed from behind the performer [25]. The cardinal coronal plane is as thick as the body and is used to represent where a limb is in front or behind this plane i.e. the body [25].

A graphics editor for the Benesh Movement Notation (BMN) was created by Singh et al [25]. The primary aim of the study was to achieve a sufficiently well rounded user experience whilst editing, creating and modifying movements [25]. In broad terms a dance score can be referred to as a piece of dance. More precisely defined, it is the notation used for dance / dance movements [25]. With regards to the user interface design, the main concerns were twofold. Firstly, it required a form of interaction language. Meaning, an interactive language through which the user could communicate with and issue commands to the system [25]. Secondly it required a form of user interface to display the state of the system as well as the numerous options that a user could access [25]. With their system Singh at al. [25] were able to offer a way to revise and produce dances based on the BMN. The issues faced in the process of implementing an effective user interface were well understood by the graphics community [25].

An ontology for video human movement represented by Benesh Notation was propositioned by Saad et al [1]. It would be the first time the ontology concept is applied to video human movements with BMN according to Saad [1]. The primary purpose of this ontology is to automate the annotation of video movement. The process paid special focus on the detailed approach to the video movement ontology [1]. The knowledge embedded into the ontology was exploited by the team through the application of Semantic Web Rules Language (SWRL) [1]. SWRL rules are used to improve the quality of movement annotation in videos [1]. SWRL rules are also used to perform rule-based reasoning [1]. This can be regarding both concepts and concept instances [1]. However, more research needs to be completed before the adequacy between the VMO approach and human perception can be definitively proved [1].

2.3.5 Salsa Dance Notation

Renesse and Ecke [23] investigated "Salsa dance positions and dance moves from a mathematical point of view" [23]. They considered defining a collection of dance positions to discover what moves are available to dancers at any point during a dance. This investigation is insightful as it can defines constraints for a notation and involves the Salsa: our choice of dance for this project.

The notation they created was a 5-tuple system: (leader orientation; follower orientation; leader's arms; follower's arms; how many times the arms cross) [23]. The collection of moves they were able to represent involved the dancers facing each other and join same hands, facing each other and join opposite hands or arms behind the leader's back [23]. There were no considerations for no arms being held or when both the dancers' arms are in motion [23]. Therefore, it can be deduced that the placement of hands is what made the moves differ from each other and difficult to represent.

During the study [23], diagrams depicting the dancers for different dance moves were presented. Unfortunately, some were too complex to draw using the approach they had. Additionally there was no clear separation between the leader's and follower's arms which made the diagram challenging to decipher. Given that this was also a paper-based notation, it was difficult to conceptualize.

Additionally, a Cartesian plane was defined according to the following guidelines: "an x-axis for both arms up, a y-axis for leader's left are up and right arm down, and a z-axis leader's left arm down and right arm up" [23]. Some moves were unable to be represented using this system e.g. "arm over the head". [23] then tried to incorporate arm positions into their notations, but this addition did not ease the understanding as it increased the complexity.

Despite these aforementioned problems, this investigation was still useful as it provided a means for pondering the implications of dance and dance notation. This study [23] shed light on concepts and possible ideas on how to devise a notation for a dance such as salsa.

3. MOTION CAPTURE AND ANNOTATION SYSTEMS

3.1 E-Learning

Kavakli et al. [29] and Bakogianni et al. [11] both conducted investigations into the WebDANCE project. The aim of the WebDANCE project was to develop a 3D platform in the interest of being able to visualize dance movements in a virtual environment [29, 11]. Consequently, this would exploit the concept of e-learning by providing a more intuitive approach to learning. The following learning goals were achieved: development of skills relating to specific dances, ability to compose traditional dances and perform these composed dances and providing significant information concerning the social, cultural and historical influence of dance [29, 11]. Dance teachers communicated their interest in WebDANCE and discussed the transformation it may have on the learning process.

Following the launch of WebDANCE, a project called OpenDANCE [11, 16] was created. This project used the experience and results obtained by WebDANCE. An improvement that was made was providing functionality for users to input dance content on-line giving rise to dance lessons [16]. This was done to enhance the interactive component between the web-learning environment and the user [16]. Another consideration was to further assess the effect of e-learning tools on dance education [11].

To further elaborate, The OpenDANCE [16] project finds application within the industry of dance education. Its aim is to further the capacities for displaying information. It does this through encouraging the use of interactive multimedia to portray information, as well as using the internet as a learning medium [16]. Magnenat-Thalmann et al. contributed to the 3D simulation and the web interface of the OpenDANCE project. They conducted a study [16] involving teachers and students, who interacted with their web3D platform. A 3D dancer was displayed online and the user could observe and manipulate this dancer [16]. The user was able to select the zoom level, point of view and animation speed of the model [16]. The results concluded that the dance learning process was enhanced when their platform was used.

3.2 Annotation Approaches

A paper [21] is based on a scenario in which two videos exist: a 'target person' video and a 'source subject' video. The source subject's motion is to be imposed onto the target person and the target person's video needs to be synthesized. Motion transfer occurs using an 'end-to-end pixel based pipeline' [21]. Supervised learning and a stick-figure method to depict the body was used [21]. Using a source video, containing body movement of a subject dancing as input, the model had the ability to produce videos of a target subject dancing [21]. However, many errors exist in this method due to the inaccurate representation of the body model [21]. During the training sequence, when the target subject is trying to copy the dance given by the source subject, shakiness and quivers are present in the results. In spite of the aforementioned issues, their method produces convincing results when various inputs are provided [21]. However, more research on representing human motion is required to improve this model.

Annotated videos can be used as an effective learning tool for dance [24]. Ribeiro et al. [24] built on the existing functionality of Creation-tool. They proposed a system that fully reconstructs a performance in 3D and allows a free range of viewpoints [24]. A choreographer and dancers participated in this study, by executing unplanned performances so that video and point-cloud data could be recorded [24]. This was followed by annotating the data. The annotated data was used in a 3D environment to visualize how text annotations may be depicted [24]. Point clouds, which are sets of data points in space, are able to accurately define three dimensionality of a dance performance [24]. However, point clouds do suffer from shortcomings concerning visualization [24]. Hence, alternate methods for visualization need to be considered to improve realism. Other issues pertaining to annotations exist. The most troublesome issue is that difficulties may arise when transcribing 2D annotations to 3D [24]. This is because 2D annotations may not contain all the necessary information for an object [24]t. Therefore, more research is needed to explore annotation options for 3D environments to circumvent these issues. The solution provided for documenting dance was to capture 3D data of a live performance using depth sensors and then using annotations to enhance it [24].

Güler et al. [9] proposed a paper on a system known as DensePose. This work sought to achieve dense human pose estimation [9]. Dense human pose estimation refers to the task of establishing dense correspondence between an RGB image and a surface-based representation of the human body [9]. The purpose of the work is to is to further human understanding in imaging [9]. This is achieved by establishing dense correspondences between an image, which is 2D, and a surface based representation of the human body, which is 3D [9].

The approach taken can be considered as the next step in the progression of works regarding human pose estimation [9]. The methodology used distinguishes it from prior works in that it takes a complete and exhaustive approach based on supervised learning as well as gathering ground truth correspondences between images and a precise, detailed parametric surface model of the human body [9].

The DenseReg Framework [9] is the closest in concept to this work. In terms of the DenseReg Framework [9], CNNs were trained with the purpose of establishing dense correspondences between 3D models and 2D images without the assistance of fixed variables. Whilst the focus of the DenseReg work was primarily on faces and providing evaluations on datasets with moderate pose variability, this work aims to tackle newer challenges [9]. These challenges stem from the inherently higher flexibility and complexity of the Human Body as well as the greater variation of scale [9]. These increased challenges can be tackled with the correct architecture design [9]. The appropriate architecture can achieve large improvements over a DenseReg-type architecture which is fully convolutional [9].

In this work dense correspondence from 2D images to surface based representations of the human body is achieved through the application of human annotators [9]. An annotation pipeline is created through which it becomes possible to collect annotations for image-to-surface correspondence in a manner which is efficient [9]. The annotators are commanded to estimate the actual body parts under clothing, not just the general shape as seen from the outside [9]. Thus, the type of clothing worn does not affect nor disturb any following correspondence annotations.

They combined the application of the DenseReg framework and Mask-RCNN architecture [9], to produce a new, improved system, 'DensePose-RCNN'. This system recovers "highly-accurate dense correspondences between images and the body surface in multiple frames per second" [9]. The authors hope that this study will aid in the augmented reality and graphics industry [9].

Li et al. [15] introduce an approach to developing an improved dense pose estimation feature by employing 'markerless' motion capture data [15]. This outcome of this is a reconstruction of a human model supporting multiple views. In order to cater disparities in body shapes, statistics deformable body models [15] were incorporated. A downfall of this model is that inaccurate results are produced when thick layers of clothing are worn. The real time performance and accuracy are among some of the difficulties. The real time performance problem has been greatly solved due to advancement in technologies [15]. The authors hope to improve the accuracy by utilizing dense parsing techniques [15].

4. DISCUSSION

There are records promoting the use of notations to symbolize dance (Sec. 2.2.). Therefore, the use of notations may aid in formalizing a language for a dance. On the contrary, even though the above statement stands, if a notation is too complex it may hinder the learning and documenting process yielding undesirable results. Hence, choosing the 'right' notation is important. This may seem like a subjective decision but conducting user studies may be valuable to the notation selection. Considering the end-users would provide reassurance in the end-product.

From the mentioned notations (Sec 2.3.), both Feuillet's and the Eshkol-Wachman notation appear to be impractical. Feuillet's notation is unable to characterize movement for the upper body and would result in an incomplete representation. Furthermore, this notation has not been used for many years and was created for ballet and may not be compatible with other dances. On the other hand, the Eshkol-Wachman notation is productively used in numerous industries other than dance and is still used in research to this day. It can be deduced that this notation was not created solely for dance and has not had any significant impact in the field of dance.

Labanotation and Benesh notation are the most established dance notations. Both have been involved in editor creation and ontologies. More research has been conducted with the LabanEditor which infers that more information is available to us which is desirable. However, the LabanEditor suffers from shortcomings. Physical constraints to the human body were not considered, the relation of the body parts to the environment were not implemented and editor was unable to process extensive symbols of Labanotation. The editors for both notations employed good user interfaces which could serve as inspiration for the visualization aspect of our project. The use of an ontology to present dance movement for both notations provides insightful information for annotating movement, which is also discussed in Sec 3.2., with the integration of a notation. Both these studies provide valuable foundations to build upon for our project as it combines a notation with an annotation system which is the outline for this review. A weakness for the Labanotation based ontology was that the system was unable to accurately represent complex shapes due to the use of a defined notation rather than entities. It is possible that the Benesh movement ontology may also experience this drawback.

A weakness of the Benesh notation, mentioned in Sec 2.3.4., is that there is no specific sign for a limb which may make the notation confusing to interpret.

Although both Labanotation and Benesh notation are well-renowned, there is conflicting information regarding the complexity of using these notations. Not only would we have to implement one of these notations, if we choose to, we would also need to define a system to visualize the chosen notation which would need to be easy for our user to understand. Perhaps implementing a rudimentary notation, like the one discussed in 2.3.5 would serve as a better option. The Salsa notation differs from the aforementioned notations. It still has limitations but it may be easier to conceptualize. A trade-off between complexity and access to information may need to be considered.

Both projects mentioned in Sec 3.1 had pleasing results and desirable features. Given that OpenDANCE was an enhancement of WebDANCE, we need only consider OpenDANCE as a reference for past projects. We need to have first-hand experience with these systems to further analyze the features it contains. We could combine ideas from this project with a notation discussed earlier in order to define a language and present it in a 3D virtual environment. The method to define dance moves is not well articulated. It is mentioned that a user can interact with a system and input dance content, but the medium of this content is not specified. It is however, possible to define moves by manually moving a skeletal model in the 3D environment. This process is cumbersome, timely and inefficient. Conversely, Densepose, a project discussed in Sec 3.2., provides an automatic annotation system to model a human body in 3D from a 2D representation which could be used for the visualizing aspect of a dance. The details of these concepts are discussed further in Sec 3.2.

An interesting outcome would be to take inspiration for all the different projects and produce one incorporating all the features.

The inclusion of point clouds discussed in a study in Sec 3.2. could serve as an interesting way to define coordinates for a model but there are issues when dealing with this model in a virtual environment. This study enhanced the system, Creation-tool, to have a multi-view system in which dance performances may be viewed. This idea could also be considered when devising the visualization component, but it lacks the sophistication of the aforementioned DensePose project.

5. CONCLUSION

From the research conducted, there currently exists no tool with the level of sophistication, effectiveness and usability we a hoping to achieve.

The advent of computerized solutions to teaching dance is still relatively new. However, there are some existing implementations that are promising and that can be used as foundations for us to build upon.

Following the investigation of dance notations, we feel that opting to create our own notation to define a dance language is preferred. This will eradicate all instances of dealing with complexities that are brought on by existing notations. However, these notations will be used as a building block for our own creation.

Furthermore, from the research on annotation systems, both the OpenDANCE and DensePose projects exhibited innovative design solutions. It can be inferred that these two projects will provide insight for the visualization and modelling component for our tool.

An amalgamation of good software design with the above approaches provides a significant basis for the creation of our tool.

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