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## **AUTOMATIC COMPOSITION OF BALLET SEQUENCES USING A 3D MOTION ARCHIVE**

**Abstract:** We have developed an automatic composition system for ballet choreographies by using 3DCG animation. Our goal is to develop some useful tools in dance education such as creation-supporting system for ballet teachers and self-study system for students. The algorithm for automatic composition was integrated to create utilitarian choreographies. As a result of an evaluation test, we verified that the created choreographies had a possibility to be used in the actual lessons. This system is valuable for online virtual dance experimentation and exploration by teachers and choreographers involved in creative practices, improvisation, creative movement, or dance composition.

**Keywords:** Dance, Motion Capture, 3D Motion Archive, Automatic Composition, Web

### **1. Introduction**

Many researches and applications on dance using 3D human animation through motion capture system have been developed. ‘LifeForms’ [2] is the most famous application which can compose and edit dance scores. In recent works, Calvert [1] has extended to computer notation systems such as ‘Laban Dancer’ and ‘Laban Writer.’ Hachimura and Nakamura [3] have worked dance education systems with multimedia such as 3DCG, dance notation and movie. Space Illusion [7] has presented a dance player which can change playing speed and human characters. It provides heaps of different dances to download and play with. By using these systems, the user can simulate already captured or strictly scored dance animation. However, it is difficult to compose creative and effective choreographies.

Our goal is to develop some useful tools in dance education such as creation-supporting system for ballet teachers and self-study system for students. As a dance animation system, we have developed an automatic composing system for classical ballet choreographies by using 3DCG animation. Our proposed system can automatically create utilitarian choreographies by computers. We suggest the algorithm which describes characteristic features for ballet lessons.

### **2. Web3D Dance Composer**

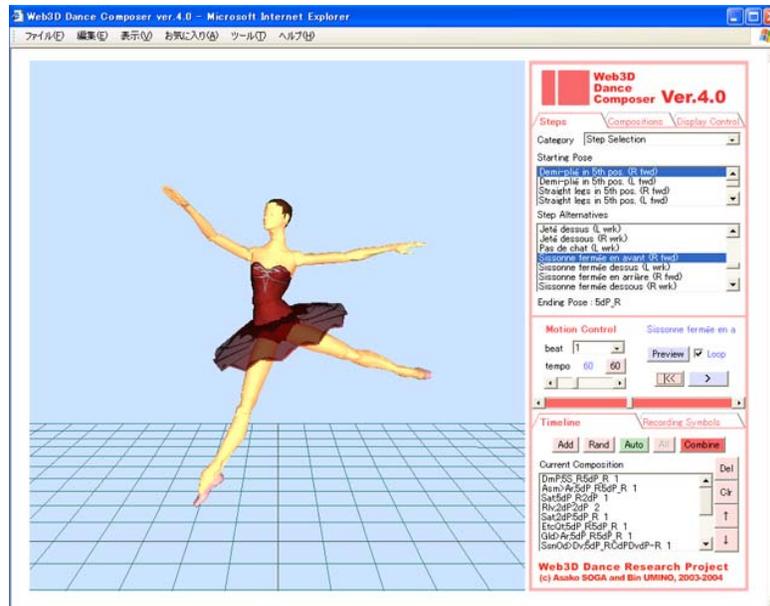
**2.1 System overview.** We have developed a Web-based interactive choreography simulation system for ballet called Web3D Dance Composer (WDC) [5] [6] [8]. Using WDC, one can easily compose and simulate ballet dancing using the motion data

captured from a professional dancer. The automatic composing system was developed as a part of WDC. Since classical ballet is a type of dance that typically consists of established steps, one can compose choreographies by connecting these basic steps. This system allows ballet teachers and students to create various choreographies for lessons in a short time.

WDC consists of an online archive and user-editable simulation system for ballet steps and step sequences, or ‘enchaînement’ that is a short phrase of choreography in a performance. The archive has exhaustively accumulated motion data of basic ballet steps for lessons. The archive of 3D ballet movements can be browsed, previewed, and selected to compose extended sequences. In addition the automatic composing system allows ballet steps to be combined automatically according to algorithm which describes characteristic features of enchaînement. The creatable choreographies are female “petit allegro” for beginners only, and for lower-body movement only at the present time.

**2.2 System structure and user interface.** Fig.1 shows the user interface of WDC. It employs only one window, which consists of a 3D window based on Virtual Reality Modeling Language (VRML) and a control panel written in Java Applet. In the 3D window, the user can change the viewpoint freely, or select an already defined viewpoint. The control panel consists of five panels: a Motion Catalog Panel, a Play Control Panel, a Timeline Panel, an Archiving and Reusing Panel, and a Display Control Panel. The minimum system requirements are only Windows PC, Microsoft Internet Explorer, and a free plug-in VRML viewer [9].

The automatic composing system of WDC displays a selection of logical next steps so that the ending pose of the previous step becomes the beginning pose of the following step. These can be individually selected and added to the composed sequence. In addition, by using the ‘Auto’ button, the automatic composing system allows the creation of an entire 16 beat enchaînement according to an algorithm prescribing its structure.



**Fig. 1.** User interface of ‘Web3D Dance Composer Ver. 4.0’

### 3. Automatic composition

**3.1 Basic approaches.** This research intended to decipher underlying ‘rules’ or principles for describing the compositional character of enchaînements in ballet class. Enchaînement structure was probed by interviews with the expert ballet teachers to collect their insights and perceptions on the characteristics essential for a logical and harmonious enchaînement.

The algorithm is integrated into the system to create utilitarian choreographies. The algorithm approaches the task of automatic creation of an enchaînement by reducing the solution to path selection on a ‘directed graph’ in which vertices represent the steps and edges represent the connectivity between steps.

First of all, a simple but crucial constraint regarding transitions between steps was set; the algorithm selects a step so that the ending pose of the previous step becomes the beginning pose of the following step. The algorithm uses the family classification to give constraints about transitions between steps and repetition of steps.

**3.2 Classification of basic steps.** The enumerative catalogue of basic ballet steps needs to be constructed to allow for composition of enchaînement with computer. Although there were many ballet dictionaries and ballet syllabi all over the world, no comprehensive list of basic ballet steps for female petit allegro could be found. Therefore the catalogue of ballet steps was organized with a collaboration with expert ballet teachers in Tokyo.

Table 1 shows the classification of basic steps occurring in beginning level female petit allegro ballet class. A comprehensive list of 543 ballet steps was identified which comprises a basic vocabulary for women in ‘center lesson’ for ballet. Data for these ballet steps have been motion captured and currently 215 of these have been included in the step archive of WDC.

**Table 1.** Classification and the number of steps

Families	Listed steps	Archived steps
Allegro steps	206	111
Rotation steps	74	60
Liaison steps	145	20
Fragmentary steps	118	24
Total	543 steps	215 steps

Three hierarchical levels were distinguished. At the top level the steps were classified into 4 families:

(a) *Allegro steps.* “Allegro” is the “Term describing movements performed quickly and with exuberance, highlighting the dancer’s speed and agility” (Dictionary of Classical Ballet Terminology, p.2) [4]. Each allegro step starts a kind of pose called “demi-plié” that means half-bending action of the knees. An allegro step can be repeated several times.

(b) *Rotation steps.* A rotation step is a turn around dancers’ own vertical axis. It also includes both preparative movements which immediately precede rotations and terminative movements which follow after rotations.

(c) *Liaison steps.* A liaison step is a step which usually appears between steps in (a) or (b).

(d) *Fragmentary steps*. This family is needed since Families (a), (b), and (c) are not enough to compose a seamless series of ballet movements. A fragmentary step is not a real “step” but a movement which can appear between steps in any other families.

**3.3 Algorithm of automatic composition.** The system considers categories of steps, physical exertion required, allowable step repetitions, and selects one step from the logical alternative steps at an equal probability. Each subsequent composition by the same algorithm generates a new unique sequence.

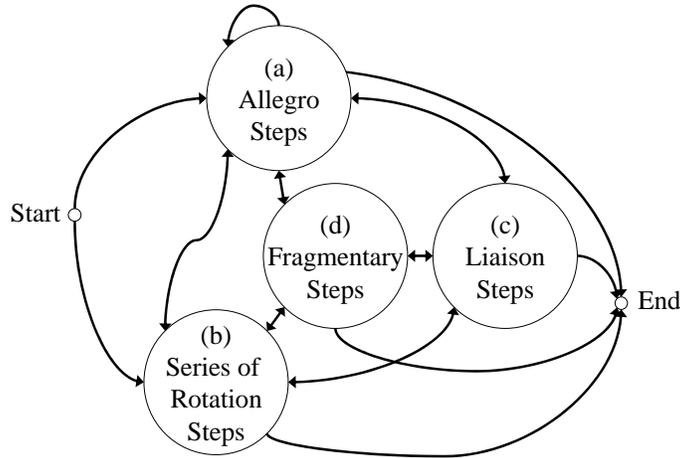


Fig. 2. Transition diagram

We abstracted the knowledge of the teachers, and schematized the rules identified for composing an enchaînement which included the following five factors:

(1) *Proper step selection*. Proper means appropriate for ballet education, and appropriate for particular skill level. Certain steps are selected according to dancers’ skill level. This factor was surmised to be the most essential for ballet learning. Therefore the enumerative list of 543 basic steps was created out of the interviews.

(2) *Proper transitions between steps*. Steps are arranged in a consecutive order, such that they follow in a logical progression. This is determined by physical constraints such that movements are able to be efficiently performed. Order of steps is also determined by aesthetic considerations. The transition diagram by families is displayed in Fig. 2.

(3) *Proper repetition*. Some steps, or types of steps, might be repeated several times in the same enchaînements, while others may appear only once. This allowance for repetition of different types of steps is related to the proper mobility for transitions between different movements and also the physical exertions required for different types of movements.

(4) *Proper physical exertion required*. Over the entire course of an enchaînement the overall energy exerted is not allowed to exceed a critical threshold. This is related to the length of the enchaînement, and also the physical exertion required by the individual steps which are selected.

(5) *Proper memorability*. Enchaînements are composed so as to be readily remembered, according to the dancer's skill level. This might be accomplished by using repetitions of steps, symmetrical alternations or typical links between steps.

These five factors were formulated into an algorithm which describes the logical and harmonic structure of enchaînements as envisaged by the expert ballet teachers. This algorithm was then embedded in the system to be used in the automatic composition of enchaînements.

#### 4. Experiment and discussion

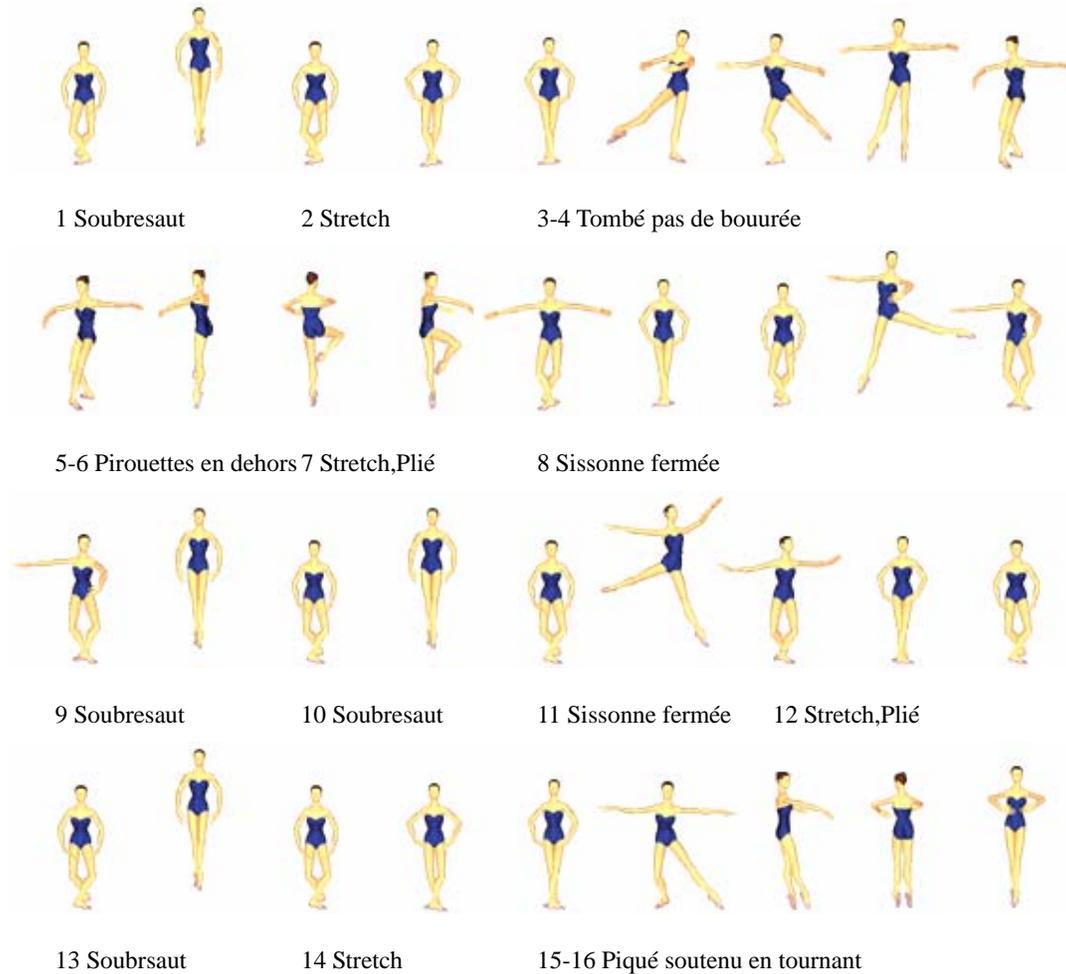
We conducted an experiment on automatic composing system to evaluate its practicality. Five ballet teachers evaluated the twenty enchaînements. The average length of teaching experience of these teachers was 16.8 years, with the minimum being 7 years, and maximum 25 years. The results of the experiments were used to assess the efficacy of the enchaînement algorithm for ballet education, specifically, whether the algorithm automatically choreographed enchaînements appropriate for an elementary level ballet classes. Fig. 3 is an example of enchaînement created automatically. Each of the 5 experimental subjects rated each of the 20 enchaînements yielding 100 ratings for each factor. Percentage results are presented here.

1. inappropriate for a ballet lesson	12 %
2. upper limit for an advanced lesson	17 %
3. appropriate for a normal advanced lesson	39 %
4. upper limit for an elementary level lesson	28 %
5. appropriate for a normal elementary level lesson	4 %

No enchaînement was evaluated as "inappropriate" by more than 2 subjects. 9 enchaînements received at least one "inappropriate" rating. 7 enchaînements were rated as appropriate for beginners' lesson (at either normal or upper limit) by at least 3 subjects. 11 enchaînements were evaluated as appropriate for advanced lesson by more than 3, and 3 of 11 were evaluated so by all subjects.

The results demonstrated that the algorithm composes no enchaînement undanceable, and about 90% are usable in real ballet lesson. Since ballet teachers could choose their preferred enchaînement from what WDC composes, it should be concluded that the algorithm has enough high practicality. On the other side, although the algorithm was created for beginners' lesson, only one third was evaluated as proper for beginners', and the average of difficulty exceeded beginners' level.

The interview to the subjects after the rating suggested that there are three main reasons why some enchaînements exceeded beginners' level; (1) the enchaînement includes a step which the subject considers as inappropriate for beginners, (2) the enchaînement was composed from only proper steps for beginners, but it includes too difficult transitions between steps for beginners, and (3) the enchaînement was too difficult to memorize for beginners. In order to improve the algorithm, we must reconsider the step coverage which the 3D motion archive contains, the portion of the algorithm which defines transitions between steps, and memorability of enchaînement.



**Fig. 3.** An example of enchaînement created automatically (number: beat, alphabet: the name of step)

## 5. Conclusion and future works

We have developed an automatic composing system for ballet choreographies by using 3DCG animation. The algorithm for automatic composition was integrated to create utilitarian choreographies. As a result of an evaluation test, we verified that the created choreographies had a possibility to be used in the actual lessons.

The system will be further developed allowing users to create new modern and unique variations of enchaînement. Possible movement sequences will then be automatically constructed from these enchaînement within the VRML. New varieties of rules or principles will also be included which had not previously been part of the ballet enchaînement algorithm. This list of rules will be displayed in the user interface where many can be selected and combined together into the same algorithm, while others will be mutually exclusive. This will allow the user to create their own personalized, original algorithm governing the creation of new movement sequences. This system is valuable for online virtual dance experimentation and exploration by teachers and

choreographers involved in creative practices, improvisation, creative movement, or dance composition.

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