Development of Easy-To-Use Authoring System for Noh (Japanese Traditional) Dance Animation

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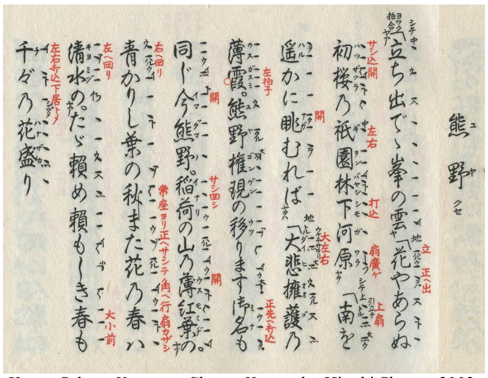

熊野

立ち出でゝ峯の雲、花やあらぬ初桜乃祇園林下河原、南を遥かに眺むれば、大悲擁護乃薄霞。熊野権現の移ります御名も同じ今熊野。稲荷の山乃薄紅葉の青かりし葉の秋また花乃春は清水のたゞ頼め頼もしき春も千手乃花盛り

Kanze Sakon, *Kanzeryu Shimai Katatsuke*, Hinoki Shoten, 2002.

Figure 1. Example of Noh dance notation (*Katatsuke*). Lyrics and motion units for the dance are written down. The large black letters describe the lyrics and the small red letters on the right describe the corresponding motion units (*Shosa*).

Figure 2. Screenshot of our easy-to-use authoring system for Noh dance animation. A user of this system can synthesize Noh dance animation by composing motion clips of motion units (*shosa*) according to the Noh dance notation (*katatsuke*).

***Abstract*—Noh is a genre of Japanese traditional theater, a kind of musical drama. Similar to other dance forms, Noh dance (*shimai*) can also be divided into small, discrete units of motion (*shosa*). Therefore, if we have a set of motion clips of motion units (*shosa*), we can synthesize Noh dance animation by composing them in a sequence based on the Noh dance notation (*katatsuke*). However, it is difficult for researchers, learners, and teachers of Noh dance to utilize existing animation systems to create such animations of Noh dance. The purpose of this research is to develop an easy-to-use authoring system for Noh dance animation. In this paper, we introduce the design, implementation and evaluation of our system. To solve the problems of existing animation systems, we employ our smart motion synthesis technique to compose motion units automatically. We classify motion units as either pattern or locomotion units. Pattern units are specific forms of motion and can be represented as shot motion clips, whereas locomotion ones denote movement towards a specific position or direction and must be generated on the fly. To deal with locomotion-type motion units, we implemented a module to generate walking motion based on a given path. We created several Noh dance animations using this system, which was evaluated through a series of experiments.**

Keywords – animation system, traditional dance, motion synthesis.

I. INTRODUCTION

Noh is a genre of Japanese traditional theater, a kind of musical drama, which has been performed for over 600 years. Similar to other dance forms, Noh dance (*shimai*) can also be divided into small, discrete units of motion (*shosa*). The continuous motions performed on stage are written down using a traditional notation called *katatsuke* (Figure 1). A main performer called *shite* dances accompanied by singing or instrumental music by aligning consecutive motion units according to the Noh dance notation (*katatsuke*). In theory, if we have a set of motion clips of motion units (*shosa*), we can synthesize Noh dance animation by composing them in sequence based on the Noh dance notation (*katatsuke*). However, it is difficult for researchers and learners of Noh dance to imagine what the Noh dance looks like based on the notation (*katatsuke*), which gives only a series of names of motion units. It would thus be most beneficial if they could visualize the Noh dance notation as an animation by using an animation system.

However, it is difficult for researchers, learners, and teachers of Noh dance to utilize existing animation systems (e.g., Motion Builder, Maya, Softimage, Max, etc.) to create animations of Noh dance. To synthesis a continuous and natural-looking motion by composing motion units, users of existing animation systems are required to edit many parameters, such as which parts of the original motion clips must be used, how each motion clip should be aligned with the previous one, and how the transitions between sequential motion clips should be generated. To utilize existing animation systems, the user is required to have extensive knowledge of motion editing. Moreover, even for a user who has such knowledge, it takes a long time to edit the numerous parameters to obtain a satisfactory animation.

The purpose of this research is to develop an easy-to-use authoring system for Noh dance animation (Figure 2). The system should be able to synthesize a Noh dance animation based on the notation (*katatsuke*) by composing motion units prepared in advance. The system should also be usable by users with little knowledge of motion editing.

In this paper, we introduce the design, implementation, and evaluation of our system. To solve the problems of existing animation systems, we employ our smart motion synthesis technique [1] to compose motion units automatically. We classify Noh motion units as either pattern or locomotion units. Pattern units are specific forms of motion and can be represented as shot motion clips, whereas locomotion ones denote movement towards a specific position or direction and must be generated on the fly. To deal with locomotion-type motion units, we implemented a module to generate walking motion based on a given path. We created several Noh dance animations using our system, which was evaluated through a series of experiments.

The ultimate goal of our research is to identify how professional performers move their bodies especially during the intervals between motion units, the dynamics of which is not clearly documented, but passed from teachers to apprentices tacitly during their training. By analyzing the differences between the synthesized motion and the motion captured from a professional performer, we expect to grasp their way of moving. Our findings should assist further development of the motion synthesis technique to realize natural connecting motions. We also expect that our results can be extended to other kinds of dance forms and even non-dance human motions too. We believe that the proposed system will be a first step toward this goal.

The rest of this paper is organized as follows. Section II reviews related work in the literature. Section III describes the form of Noh dance and the requirements for our system, while Section IV explains the implementation of the system. Section V presents some experimental results and an evaluation thereof. Finally, Section VI concludes the paper.

II. Related Work

A. Dance Animation Systems

There are a few animation systems that are specialized for creating dance animations. Choensawat et al. [2] developed a Noh animation system based on Labanotation [3][4], which is a well-known method for describing the movements of each body part during dance. However, since Labanotation is designed for European modern dance and can represent only roughly the moving directions of bodies, it is not suitable for describing the movements of Noh dance motions. Consequently, Choensawat et al. [2] had to use specialized templates to convert Labanotation symbols to Noh-like movements and change the templates dynamically depending on the user-specified motion unit. Because Labanotation describes the movements of each body part individually, it is difficult for users to describe the motions of Noh motion units using Labanotation. Moreover, when Labanotation is used, the motion of the character is generated by composing the motions of individual body parts that are generated based on the Labanotation notation and prepared keyframes. It is therefore difficult to realize natural-looking motions of the character by utilizing motion capture data.

With respect to animation systems for other types of dance, Soga et al. developed animation systems for ballet [5] and contemporary dance [6]. Their systems generate animation based on a sequence of motion units specified by the user or determined automatically by an algorithm. However, their systems simply play back motion capture clips and realizing natural-looking transitions between sequential motions is not considered in their study. Moreover, control of the execution timing of motions and the position orientation and path of the motions are not considered. Since these components are important for creating Noh dance animation, our system includes these components.

Various commercial/non-commercial systems for authoring dance animation are available for use. There are systems for editing dance notation based on Labanotation and for converting it to an animation [3]. DanceForms (formally Life Forms Dance) [7] allows the user to choreograph a dance with multiple characters by using keyframes or motion-captured motion clips. This software is aimed at professional dancers and choreographers who have adequate knowledge of dance choreography and usage of this software. Miku Miku Dance [8] is a popular system for creating dance animations that are widely viewed on the Internet (YouTube, NicoVideo, etc.) in Japan. Although many resources (character models, background models, etc.) for this software are available on the Internet, it is a keyframe-based animation system, and thus creating dance motions is not easy; both extensive knowledge and a great deal of time are required.

Existing animation systems for animations in general such as Motion Builder, Maya, Softimage, and Max can be used for creating dance animations. However, as explained in Section I, in order to synthesis continuous and natural-looking motion by composing motion units using these systems, the user is required to edit numerous parameters. This too requires extensive knowledge and much time.

B. Dance Animation Generation

Various studies have proposed systems for generating dance animation. Shiratori et al. [9] generated dance animation automatically based on the given music by composing short motion clips. They considered the rhythm and intensity of the motion and music to find matching motion clips for each segment of music. Since they use simple interpolation between sequential motion clips, the transitions between these may become unnatural. Zhang et al. [10] proposed a similar system that solves the transition problem by using a network structure of motion sequences. These methods are suitable for certain improvised dances,

Figure 3. Pictures of Noh (left and center) and *shimai* (right) performances.

but not for Noh dance, which is expected to follow specific dance notations.

C. Noh Dance Notation

Although the concept of motion units (*shosa*) stems from wisdom that has been handed down in Noh society over 600 years, it was Yokomichi [11] who examined all the units and classified them fully for the sake of scientific analysis of Noh performances. Our research relies to a great extent on his definition and classification of motion units. Brazell and Bethe [12][13][14] absorbed Yokomichi's theory and gave a full account of Noh dance with detailed explanation of the basic motion units. However, researchers of Noh theater are more interested in reading age old records than analyzing current performances. With the recent widespread availability of motion capture equipment, attempts have been made to record and archive the motion of traditional performances [15]. To the best of our knowledge, there has been no research on the motion of Noh performances and motion synthesis from motion units.

III. SYSTEM DESIGN

In this section, we first describe Noh dance, which our system aims to animate. We then explain the required features for our system.

A. Noh Dance and its Notation

Noh is a genre of Japanese traditional theater, a kind of musical drama that has been performed for over 600 years [11][12][13][14][15][16][17]. The main stage for Noh is square (5.9 m by 5.9 m) and connected with the backstage by a long bridge-like extension called *hashigakari*. *Shite*, the main performer, dances on the square stage as shown in Figure 3. There are musicians and chorus members at the back and on the left of the stage, respectively. Usually there are additional performers (called *waki* and *tsure*) as well. A whole Noh play is choreographed and performed in dance-like movements, but we can still differentiate the dancing parts from non-dancing parts where the chants and mimic movements are accentuated. These dancing parts are often extracted from a whole play and performed independently. This is called *shimai*, vocal dance. The vocal dance is usually performed by the main performer, wearing *montsuki* (a family-crest-adorned Kimono) and *hakama* (Japanese-style trousers) as shown in Figures 2 and 3 (on the right). Although exquisite costumes and masks are some of the characteristic features of Noh performances, the vocal dance does not include these, nor instrumental music; there is only the accompaniment of the chorus. In this paper, we focus on the vocal dance for the following reasons. First, without the elaborate costumes, each motion can be clearly observed. Furthermore, the first dances learned are vocal dances, where a novice performer begins to master the repertoire, working from the simplest dance passages to longer, more difficult ones [12].

Noh dance can be divided into small, discrete units of motion (*shosa*), which are used by Noh performers to notate their performances. Figure 1 shows an example of *katatsuke*, the Noh dance notation. The large black letters describe the lyrics while the small red letters on the right describe the corresponding motion units. Motion units are placed linearly, and when necessary, information about position or orientation on the stage is added.

In this paper, we classify the motion units broadly into two groups, pattern and locomotion units. The former is a discrete unit of motion that does not include positional information, whereas the latter is a motion that indicates movement on a large scale to an absolute position on the stage or in a direction relative to the performer's current position. The stage is divided into nine parts, each of which has its own name (Figure 4), and the position on the stage is specified using these names. Both pattern and locomotion units can last for a few seconds or up to 20 s. Although it is not a common concept to classify motion units as either pattern or locomotion, it is our insight that they should be treated differently in terms of motion synthesis, because the motion of the pattern is always the same and can be represented as a motion clip, whereas the motion of the locomotion varies depending on the position and orientation of the performer and must be generated on the fly.

For example, the dance from *Yuya* (Figure 1), which is about 3 min in length, consists of a sequence of the following motion units.

1. *Tatsu* (stand up)
2. *Shō e de* (go forward)
3. *Shashikomi hiraki* (forward point and open)
4. *Sayū* (small zigzag)
5. *Uchikomi* (scooping point)
6. *Ōgihiroge* (open the fan)
7. *Ageōgi hiraki* (raised fan and open)
8. *Ōzayu hidaribyōshi* (large zigzag with a single left stamp)

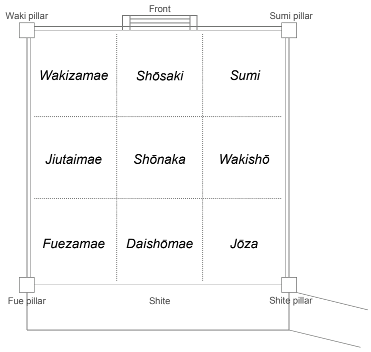
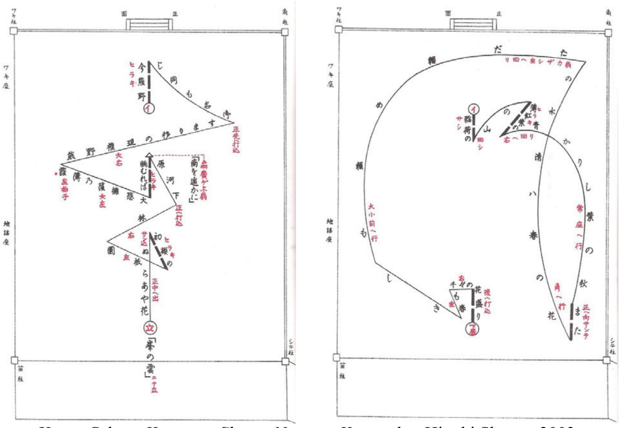


Figure 4. Noh stage, which is divided into nine regions.



Kanze Sakon, *Kanzeryu Shimai Nyumon Katatsuke* , Hinoki Shoten, 2003.

Figure 5. Example of the motion path of a dance from the Noh play "*Yuya*" described in Figure 1.

9. *Shōsaki e uchikomi hiraki* (scooping point toward Shōsaki)
10. *Sashimawashi hiraki* (sweeping point and open)
11. *Migi e mawari* (circle right)
12. *Jōza yori shō e sahi* (backing point from Jōza to front)
13. *Sumi e yuki* (go to Sumi)
14. *Ōgikazashi* (extend fan)
15. *Hidari e mawari* (circle left)
16. *Daishōmae sayū* (small zigzag in Daishomae)
17. *Uchikomi shitaitome* (closure scoop)

The English translation of each unit is taken from [14]. The words with a single underline indicate places on the stage, whereas those with a double underline indicate the direction from the performer's viewpoint. Motion units with these words are usually locomotion-type motion units. Figure 5 shows the motion path of the dance described in Figure 1.

Although more than 300 motion units of dance movements or of a more dramatic mimetic nature are used in the complete Noh repertoire, the basic vocabulary of a Noh dance is very small; most vocal dances consist of a total of about 80 units.

B. Required Features

Assuming that motion clips of the motion units are provided, the system should be able to synthesize a Noh dance animation based on the Noh dance notation (*katatsuke*) by composing these. We expect users of our system to choose pattern-type motion units from a list of motion units and to place these at the corresponding time on the timeline. For locomotion-type motion units, the user needs to specify the target position or the path of the locomotion. These operations should be simple enough even for users with no previous experience of existing animation systems. The system is then expected to generate the resulting animation without specification of any additional parameters for motion synthesis.

To realize this, the system should provide the following functionality.

1. **Automatic motion alignment** to determine the position and orientation of the subsequent motion based on the previous motion. In addition, the system should allow the user to adjust the orientation of the subsequent motion when necessary. Although in Noh dances each motion normally starts facing the front of the stage, this is not always the case, and therefore, the user sometimes needs to adjust the direction of each motion manually.
2. **Automatic motion transition** to determine appropriate blending methods and timings for the transition between sequential motions.
3. **Locomotion editing and generation** so that a user can specify the target position or the path of locomotion to create locomotion-type motion units.

Although existing animation systems allow a user to realize motion alignment and transition manually, the user must edit numerous parameters. Our system is expected to take care of this editing automatically. To create a walking motion in existing animation systems, the user must copy and deform the motion of one cycle of walking along the path of locomotion manually. This is a difficult and time-consuming task. Although some animation systems provide a locomotion editing and generation module, it is still difficult for novices to use.

IV. IMPLEMENTATION

In this section, we describe our developed animation system for Noh dance. The system satisfies the requirements outlined in the previous section.

A. System Overview

Screen shots of our system are shown in Figures 2 and 6. The lower area of the screen represents the timeline of the animation where users can arrange motion units. The upper area of the screen represents the scene view. Users can see the synthesized animation and edit various parameters such as initial position and direction, direction of each motion, and locomotion path. The menu and playback control panels are also displayed on the screen. At this point our system is limited to editing the motion of a single character, because Noh dance is mostly performed by a single actor. This simplification makes the user interface easy to use.

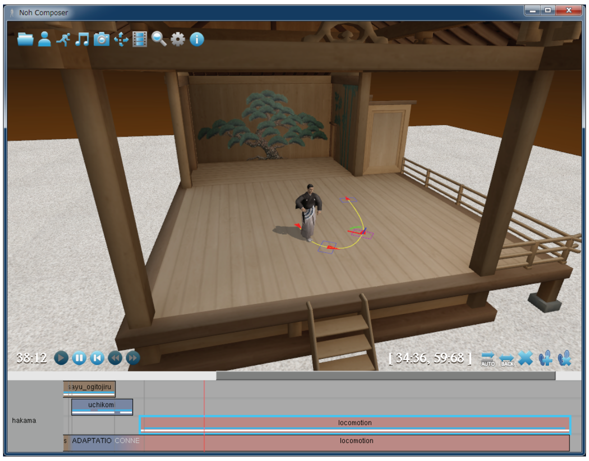


Figure 6. Screenshot of our animation system during locomotion editing.

There are three lines on the timeline on which the user can arrange motion units, while the line at the bottom represents the continuous output motion that is synthesized from the motion units on the lines above. The user can select a motion unit and put it as a motion track on the timeline. By dragging the motion track, its execution timing can be edited. Motion tracks can overlap each other on the timeline. By dragging the left or right edge of the motion track, the motion duration (motion speed) can be edited as well. By manipulating the scroll bar at the top of the timeline, the time range of the animation to be displayed on the timeline can be varied. These are all standard interface functions that are used in many authoring systems for music, movies, and animation. Even for novices who have no experience with existing systems, the concept of this user interface is simple enough to understand quickly.

The initial position and orientation of the character is edited in the scene view. Since the Noh stage is horizontal, only the horizontal position and direction (three parameters) need be edited. The user can edit these using the handles in the scene view as shown in Figure 7. By dragging the blue or red bars, the front-back or left-right position is controlled. By dragging the center of the rectangle, the front-back and left-right positions are controlled simultaneously. By dragging the green arc, the horizontal orientation is controlled. This matches the standard interface used in existing animation systems. Users of our system can easily use this interface, especially since the number of handles is relatively small as our control is limited to horizontal position and direction.

The male character model in *montsuki* and *hakama*, the background models (a typical Noh stage), and all motion clips for pattern-type motion units are prepared in advance and integrated into our system. Users need not be concerned with preparing these. Although it is possible to change such data if necessary, creating the data is difficult for ordinary users, and thus they are not expected to do it themselves.

B. *Motion Capture Data*

We captured motion data of Noh motions of pattern-type units using a VICON motion capture device with the help of a professional Noh performer, Masaki Umano. Acquired motion data were edited and retargeted to the character model used by our system in advance. Finally each motion unit was stored in a BVH (Biovision Hierarchical Data) file. We captured a total of 83 motions.

Figure 7. User interface for editing initial position and orientation of the character.

In an actual Noh dance, the same motion unit can be performed in a number of ways depending on the storyline of the play and type of character (male, female, god, demon, etc.). It is thus, difficult to determine which variation of motion should be used from the Noh dance notation. Therefore, at this point, we have captured the standard motion for each motion unit.

Since we do not capture the motion of the fingers of the performer, the finger joints are set separately in a fixed posture. The relative position and orientation between the right hand and the fan held by the character are also specified. At this point, these cannot be changed during animation, although the performer can open and close the fan and sometimes moves it between the right and left hands during the performance.

C. *Automatic Motion Alignment*

By using our method [1], each motion is automatically aligned to the previous motion. The motion is placed so that the position of the supporting foot when the motion starts matches the position of the same foot at the end of the previous motion. The supporting foot is detected based on the constraints between the foot and the ground and the distance between the foot and the character's center of mass.

The orientation of each motion is determined so that its moving direction matches the moving direction of the previous motion [1]. This method works well on motion synthesis of general human motion. However, as explained in Section III.B, in Noh dance animation, the user sometimes needs to adjust the initial direction of each motion rather than keeping the moving direction between the previous and subsequent motions. Moreover, since a single motion unit sometimes consists of movements in different directions, it is difficult to determine the moving direction robustly. To address these issues, our system allows the user to adjust the direction of each motion manually after its initial direction has been determined automatically.

When a motion track is selected on the timeline, the user can adjust the initial direction of the selected motion in the scene view in the same way as editing the initial position and orientation as explained in Section IV.A except that only the green arc is shown and only the horizontal orientation is adjustable.

D. Automatic Motion Transition

Smooth transition between sequential motions on the timeline is also realized using our smart motion synthesis method [1]. An appropriate blending method and timings are automatically determined for each pair of sequential motions based on changes in the constraints between the foot and the ground during these motions. The key idea is that the blending method and timings are determined so that the constraints between the foot and the ground are maintained during motion blending. If we blend a motion while the foot is constrained to the ground with another motion, it causes foot sliding and the resulting motion becomes unnatural. For transitions between sequential motions, three types of blending methods are used depending on the constraints and timings: motion transition, motion connection, and motion adaptation. For details of these, refer to [1].

Our system is based on this smart motion synthesis method. However, some improvement was required to make it work with Noh dance motions. We improved the algorithm for detecting the constraints between the foot and the ground during motion. Since one of the characteristics of Noh dance movements is that the performers do not lift up their feet and instead slide them on the floor as they walk, the algorithm could not determine the supporting foot based on the height of the foot position. To address this, we tuned the conditions for determining these constraints. The system determines that the foot is a supporting one when it is on the ground (height of the foot position is less than 0.2 m) and the velocity is greater than a threshold over a certain period of time (0.1 s). We analyzed the captured motion data of Noh dance to determine an appropriate velocity threshold (0.4 m/s).

Our system visualizes the constraints between the foot and the ground on the motion tracks on the timeline as shown in Figures 2 and 6. The upper (blue) and lower (white) segments represent the constraints for the right and left foot, respectively. Because the motion synthesis is done automatically based on this information, the user need not be concerned with this. The constraints are merely shown as supplemental information.

The bottom line on the timeline represents the synthesized motion. It shows what parts of the motion clips are used and what blending methods are applied during which time period. Because this is also automatically determined by the system, the user does not have to worry about this information either.

E. Locomotion Editing and Generation

Many studies have focused on locomotion generation in computer animation [18][19]. A common way of generating locomotion along a given path is to repeat and deform one cycle of straightforward walking motion prepared in advance. A motion blending technique can also be used to control the speed, direction, and style of the walking motion cycles.

Our system employs the same approach. We captured an example motion of straightforward waking in Noh dance and extracted one cycle of walking motion. Given a locomotion path as curve $\mathbf{p}(t)$ (horizontal position and direction at time t), the example walking motion is repeated and deformed according to the path. First, the number of cycles N is determined based on the length of the given path L and the length of one cycle of example walking motion $L_{example}$.

$$N = \left\lfloor L / L_{example} + 0.5 \right\rfloor \quad (1)$$

where $\lfloor x \rfloor$ denotes the maximum integer number smaller than x. The example walking motion is then repeated and deformed. Although existing methods use the locomotion path as the trajectory of the pelvis of the character [18][19], this approach does not work well in our case. Because the walking speed is usually relatively slow in Noh dance and the style of walking is close to static walking rather than dynamic walking, that is, the pelvis is moved above the foot while the other foot is being moved forward and the pelvis trajectory projected onto the floor draws a zigzag path. To maintain this style of example walking motion, first the locomotion path for the example straightforward walking motion $\mathbf{p}_{example}(t)$ is computed as a straight trajectory based on the initial and terminal pelvis positions for the example motion. The horizontal position and direction of the pelvis $\mathbf{q}(t)$ is computed by mapping the displacement between the pelvis and path trajectories of the example motion $\mathbf{q}_{example}(t)$ to the given path. This is computed as

$$\mathbf{q}(t) = \mathbf{M}(t)\left(\mathbf{q}_{example}\left(w(t)\right) - \mathbf{p}_{example}\left(w(t)\right)\right) + \mathbf{p}(t) \ , \quad (2)$$

where $w(t)$ is the time warping function to compute the corresponding time on the example motion from the time on the given path based on N; $\mathbf{M}(t)$ is the transformation matrix from the local coordinates defined by $\mathbf{p}_{example}\left(w(t)\right)$ to the global coordinates defined by $\mathbf{p}(t)$; and $+$ and $-$ denote the sum and difference between the horizontal positions and directions, respectively. The posture on the example motion is then translated and rotated based on $\mathbf{q}(t)$. In addition, by using inverse kinematics, the foot position is fixed while the foot is supporting to prevent the foot from sliding.

In addition, when the difference between the initial direction of the character and that of the locomotion path is greater than a threshold (30 degrees), the character performs a turning motion before starting to walk. In the same way, when the difference between the terminal direction of the character and that of the locomotion path is greater than the same threshold, the character turns at the end of the walking motion. We prepared several turning motions from which the system chooses the appropriate one based on the turning angle. If the user wishes to make the character turn at some point during locomotion, the locomotion should be split into several units.

The user can create an initial locomotion and place it on the timeline as a motion unit. Thereafter, the user can edit the

Figure 8. Example of the path in the synthesized motion.

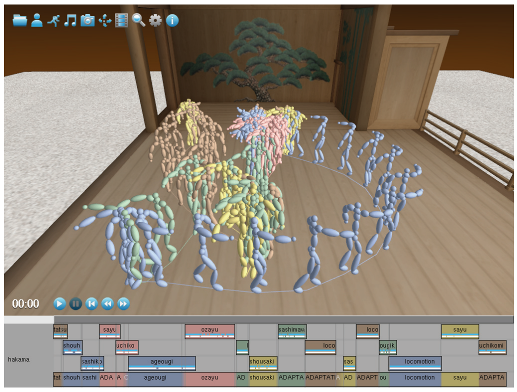


Figure 9. Example of postures in the synthesized motion.

locomotion path, which is defined by a number of control points. Each control point has a horizontal position and horizontal direction, which can be controlled through the same interface as the control of the initial position and direction (Figures 6 and 7). However, the first control point cannot be controlled through this interface as it is determined from the terminal position and direction of the previous motion. The user can also add and delete control points.

The locomotion path is represented as a quadratic curve based on the control points using a Hermite function. The directions of the initial and terminal points are computed from the position of the adjacent points since specified directions are used to control the turning angle before and after locomotion.

F. *Additional Functions*

Our system also has functions to visualize the synthesized motion. The path of the entire synthesized motion can be drawn on the floor as shown in Figure 8. The colors of the segments of the path represent the corresponding motion segments on the timeline. The synthesized motion can also be drawn as a series of stick figures as shown in Figure 9. These functions are useful when a user wishes to understand the movement of an entire Noh dance.

The system can also render the synthesized animation and create a video file so that the created animation can be viewed on standard video players. The user can specify an audio file of a vocal song and arrange the timings of the motion units according to this based on the Noh dance notation.

V. Evaluation and Discussion

The accompanying video is available on the author's web site: *http://www.cg.ces.kyutech.ac.jp*

To evaluate our system, we created several animations of Noh dances including *Yuya*, *Oimatsu*, and so on. The generated animation of *Yuya* is included in the accompanying video as well as a demonstration of our system. As described in Figure 1 and Section III.A, *Yuya* is about 3 min in length and consists of 14 pattern-type and three locomotion-type motion units. Figures 8 and 9 show the path and postures of the synthesized motion. Note that the path in Figure 8 basically matches that in Figure 5. This means that our system reproduces the overall performance written in the Noh dance notation well.

We compared the synthesized motion with the reference motion, that is, the captured motion of the entire play of *Yuya* given by the same professional Noh performer. Since the synthesized motion roughly matches the reference motion on the whole, we can say that our system reproduces the Noh performance well.

However, we observed some artifacts during the transitions between sequential motions. When the postures in two successive motions are slightly different (e.g., the right arm is raised in both postures, but at slightly different heights), unnecessary movements for posture transition (e.g., changing the height of the right arm) are generated, because the motion synthesis method tries to reproduce the postures of both motions as closely as possible even when a smooth transition is preferable. On the other hand, when the postures in the motions are very different, quick movements for posture transition are generated, because the transition time period is given as a fixed parameter in the motion synthesis method when there is sufficient time for transition. To address these artifacts, certain extensions to the motion synthesis method are required.

Other problems that we observed relate to locomotion generation. Although our locomotion module basically works well for generating non-Noh-style locomotion, we found that it is not capable of generating natural-looking Noh-style locomotion for the following reasons. First, in Noh-style locomotion, turning and walking are not clearly separated. The performer can turn while walking a few steps. Although turns of this type are observed in non-Noh-style locomotion, they are much clearer in Noh-style locomotion. This type of turning motion cannot be generated by our current locomotion module. Secondly, the walking speed is not constant in Noh-style locomotion. Initially it is slow, becoming gradually faster. Sometimes it slows during a long walking sequence when the performer changes direction. In fact this type of speed control during walking is one of the important characteristics of a Noh performance. At this point, our locomotion module generates walking motion at a constant speed. This may be regarded as a small difference but it is a significant problem according to professional Noh performers and researchers. Improving our locomotion module to realize these characteristics of Noh-style walking is one of our important future works.

Another noticeable problem is the motion of the fan held by the character. In the synthesized animations, the fan frequently penetrates the character's body. Moreover, the fan sometimes faces the wrong way. Although the motion of the hand is captured in our motion data, this is not enough to control the direction of the fan, because the performer can change the manner and direction of holding the fan slightly or sometimes greatly during the performance. To address this issue, we need to capture the motion of the fan and reflect it in the motion clips. This is a future work, as well as realizing manipulation of the fan (e.g., opening and closing) during motions as indicated in the Noh dance notation.

There are also some issues regarding the user interface. For locomotion-type motion units, the user is expected to give a specific path of locomotion based on the Noh dance notation. This requires knowledge of the Noh performance. It would be helpful for users if we could develop a method for determining the locomotion path automatically based on only the descriptions in the Noh dance notation.

In terms of time efficiency, in our experiments it took only about 20 min to create the animation of *Yuya* for non-professional users. For comparison, we asked a semi-professional animator to create a similar animation using an existing animation system MotionBuilder [20] with the same motion clips. It took him about 6 h to create the animation and moreover, the locomotion parts are not well reproduced because of the difficulty of creating locomotion using MotionBuilder. However, in terms of the quality of the animation, the artifacts at transitions were not present in this case, because the animator edited the blending period and method manually. Considering that our system requires much less time and knowledge, it is very efficient especially for people who wish to visualize Noh dance notation easily.

VI. Conclusion

In this research, we developed a practical easy-to-use authoring system for creating Noh dance (*shimai*) animations based on Noh dance notation (*katatsuke*) by using our smart motion synthesis method [1]. We showed that our system can be used to create Noh dance animations efficiently even by users who do not have much knowledge of motion editing and experience with using animation systems.

Our future work includes conducting more practical user tests to see if our system can assist researchers, learners, and teachers of Noh dance. As discussed above, improving certain features of our system, including the motion synthesis method, locomotion generation, handling the motion and manipulation of the fan, and the method for automatically determining the locomotion path, is also future work. As explained in Section I, the ultimate goal of our research is to identify how professional performers move their bodies by analyzing the differences between the synthesized motion and the motion captured from a professional performer. We see our system as a promising tool for realizing this goal.

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