PAPER

DanceUnisoner: A Parametric, Visual, and Interactive Simulation Interface for Choreographic Composition of Group Dance

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SUMMARY Composing choreography is challenging because it involves numerous iterative refinements. According to our video analysis and interviews, choreographers typically need to imagine dancers' movements to revise drafts on paper since testing new movements and formations with actual dancers takes time. To address this difficulty, we present an interactive group-dance simulation interface, *DanceUnisoner*, that assists choreographers in composing a group dance in a simulated environment. With DanceUnisoner, choreographers can arrange excerpts from solo-dance videos of dancers throughout a three-dimensional space. They can adjust various parameters related to the dancers in real time, such as each dancer's position and size and each movement's timing. To evaluate the effectiveness of the system's parametric, visual, and interactive interface, we asked seven choreographers to use it and compose group dances. Our observations, interviews, and quantitative analysis revealed their successful usage in iterative refinements and visual checking of choreography, providing insights to facilitate further computational creativity support for choreographers.

key words: *Choreography, Choreographic composition, GUI-based interaction, Group dance*

1. Introduction

Street dance is a popular dance style, and dancers often compete with each other and give unique artistic performances in official competitions. The competitions are held as onsite events with audiences, often recorded and broadcasted on TV shows and online. Break dancing is a prominent example of street dance. It was adopted as an official sport in the 2018 Youth Olympic Games in Buenos Aires [1] and was selected as a candidate for inclusion in the 2024 Olympics in Paris [2]. Competitions can employ a variety of rules depending on the number of dancers. For instance, the International Dance Organization categorizes competitions into "solo," "duo," "crew" involving 3 to 7 dancers, "formation" involving 8 to 24 dancers, and "production" involving 25 dancers or more [3].

To win, choreographers must compose an appealing dance performance well before the competition. However, the composition process becomes more challenging when the performance involves more dancers. For choreographers, it would be ideal if dancers could instantly learn a choreography they came up with and perform it without any mistakes. Then, the choreographers could focus on making iterative refinements to the choreography without significant interruptions. In reality, dancers cannot always gather at one place at one time; they need to spend a certain amount of time learning a choreography and the intention behind it, and they often have difficulties performing it. As a result, the choreographer usually needs to rely on a set of conventional analog devices—sheets of pen and paper—to make iterative refinements without the actual dancers.

The goal of our work is to support the creativity of choreographers of group dances with the computer, enabling choreographies to be composed and iteratively refined without dancers present. We analyzed existing group-dance videos and interviews with expert choreographers to uncover design principles that effectively support creativity and determined that there needs to be a group-dance simulation interface that is parametric, visual, and interactive (Section 2). These findings led us to develop *DanceUnisoner*, a tool that allows the choreographer to choose, edit, arrange, and combine videos of a single dancer with a dedicated user interface and simulate a group dance performance (Figure 1; Section 4). In creativity, the cycle of imagination and its implementation is important [4–7]. Our system supports the imagination in the creative process and makes the process of the cycle from imagination to implementation more efficient.

The main contributions of this work are threefold:

(1) Through interviews with choreographers, we clarify that three design principles—*parametric*, *visual*, and *interactive*—could be used to support their creativity.
(2) On the basis of (1), we propose and implement a novel interface for easily adjusting the various properties of dancers, such as the position and size of every dancer and the pattern and timing of every movement.
(3) Based on our user study, we provide insights on the process of composing a choreography with the support of computers.

2. Design Process

We aim at providing efficient computational creativity support for choreographers. Toward this goal, we need to understand

Manuscript received March 3, 2023.

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DOI: 10.1587/transinf.E106.D.1

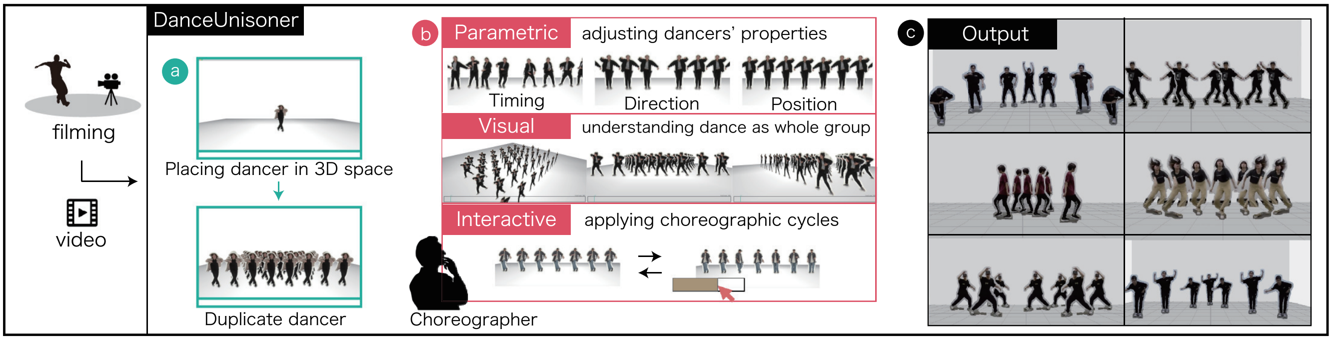

Fig. 1 *DanceUnisoner* allows choreographers to simulate group dances by placing and duplicating excerpts from recorded dance videos in 3D space (a). We designed it according to three principles informed through our video analysis and interviews (b). We observed that all seven participating choreographers could effectively utilize it to compose group dances in their respective styles (c).

the current workflow for composing choreographies. We first investigated the typical patterns appearing in choreographies for group dancing by reviewing dance videos available online. We also conducted interviews with choreographers in regard to their workflow. In this section, we describe the findings and discuss the design principles we figured out for establishing computational support.

2.1 Current Workflow of Choreographic Composition

To investigate common choreographic patterns, we analyzed a set of 94 highly-ranked videos available on YouTube and interviewed seven choreographers about their own processes for choreographing group dances.

2.1.1 Video Analysis

To collect group-dance videos, we searched the phrase “group street dance” on YouTube and chose the top 137 videos. Of these videos, we removed 36 that could not be regarded as dancing, such as those that were interviews or audio only, and checked a total of 101 videos. These 101 videos consisted of dance performances on a stage for competitions and for entertaining people (78 videos), video works for promoting dance groups or choreographies (12 videos), improvised street-dance performances (5 videos), flash mobs (3 videos), practice scenes in a studio (2 videos), and a number of people having fun dancing outdoors in their own way (1 video). We then excluded the five improvised videos and one video of people dancing outdoors from the analysis because these videos did not fit the purpose of this paper of supporting the creation of group dance choreography. We finally set 95 videos for analysis.

Although we had difficulty counting the number of dancers for 13 of the videos, other dance performances consisted of 3 to 22 dancers. Moreover, we observed several common characteristics of group dance among those videos including various street-dance genres:

Choreography synchronization. In all of the dance videos, we confirmed that there were shots in which multiple dancers simultaneously performed to the same choreography.

Front-focused performance. In 89 out of the 95 videos, dancers performed assuming that the audience could watch them from the front. The exceptions include large-scale flash mobs, dance performances on the street, and solo dance performances surrounded by an audience.

Crossing. In 75 out of the 95 videos, there were various formation-transition scenes, such as dancers moving to another formation while crossing each other.

Flipping of choreography. In 66 out of the 95 videos, we observed multiple dancers performing flipped choreography, such as symmetric choreography centered on the middle of the stage.

Shifting timing of movements. In 41 out of the 95 videos, there were moments where each dancer performed the same movements but their start time was different. We could see that the choreography seemed to be propagating to the next dancer. We also observed that the number of dancers dancing tended to increase.

In summary, the video analysis revealed representative techniques used in choreographic compositions. However, while this analysis suggested techniques that should be covered in the computational support, the actual process used by choreographers to compose group dances was still unclear. To further understand the workflow of choreographers, we conducted interviews. We interviewed both professional and amateur choreographers who had experience with choreographing group dances to find out how they do so.

2.1.2 Interview with Choreographers

We interviewed a dance instructor with more than 9 years of street-dance experience and experience with group-dance composition, and 6 amateur choreographers (each with 3, 4, 7, 9, 9, and 16 years of dance experience) who belonged to a university dance club and had experience with group-dance composition. We asked 7 choreographers in total about their workflow from choreographic composition to group-dance performance. The participants volunteered to participate in the interview. We conducted the interviews in Japanese, and the translation was conducted by the first author. From the comments obtained, we found that the choreographers

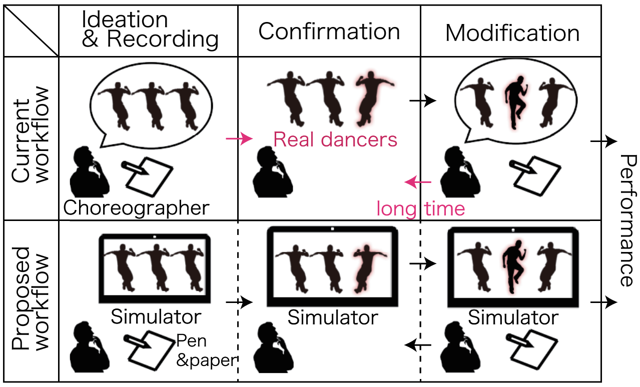

Fig. 2 (Top) Current workflow for composing choreography. It involves iterative refinement process that includes asking dancers to gather and learn modified version for confirmation, and thus, often takes long to get to final performance. (Bottom) Workflow with the proposed system. Simulator can simulate group dance and allows choreographers to create, record, confirm, and revise group dances faster.

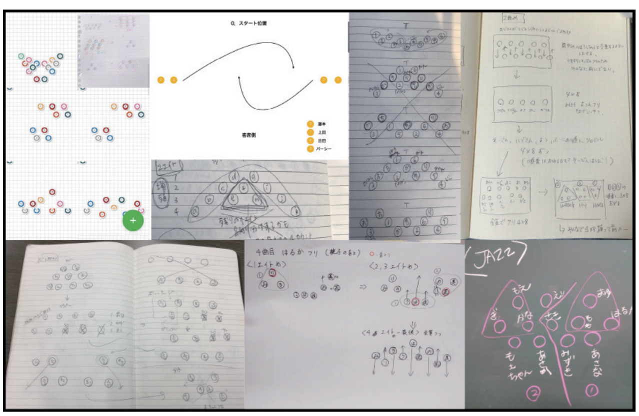

Fig. 3 Notes for visualizing choreography that we collected. They were recorded in various formats: paper, blackboard, and simple drawing software. Overwritten cross marks (rejection marks in Japanese culture) indicate trial and error in composing group dance.

proceeded with the workflow shown at the top of Figure 2. Each part of the workflow is explained below.

Ideation and Recording. Choreographers decide upon a musical piece and compose the dance performance. When composing a dance, each choreographer uses various methods, such as imagining the dance while listening to the musical piece, trying to dance to the piece, searching for dance videos that use the same piece and referring to them, deciding upon movements while talking with dancers, and so on. In common with all choreographers, they visualize information such as the movement of dancers on paper or simple drawing software (e.g., Keynote), as shown in Figure 3, and organize and record them.

Confirmation. Since just imagining on paper is not enough, the choreographer confirms the created choreography by watching dancers perform the piece. To do so, not only do the choreographers have to watch the performance, but they also film the dance to review it with the dancers or have others in to observe.

Modification. The choreographers then correct any problems that were noticed. For example, if dancers do not move smoothly, or they collide or overlap with each other, the choreographers adjust the choreography. Moreover, to compose an appealing dance performance well, the choreographers adjust the balance of various properties such as the position, direction, and size of the dancers, as well as the pattern and timing of every movement in a group dance. After correcting the problems, the choreographers return to the *Confirmation* step and repeat both steps until they are satisfied.

One of our unique findings was that, as mentioned in the *Ideation and Recording* step, the choreographers compose the positions and movements of the dancers by visualizing choreographic information on paper. If dancers are waiting near the choreographers throughout all steps, the choreographers can confirm the dance they composed, correct it, and then quickly move on to the *Confirmation* step again. However, choreographers cannot easily arrange for such a situation. From one interviewee, "*We cannot confirm the choreography until the next meeting,*" and in some cases, "*We have to wait until a week later.*" That is, we found that the choreographers took too much time going back to the *Confirmation* step from the correction phase because they had to wait for the dancers to gather again.

2.1.3 Questionnaire of dancers

We further conducted a questionnaire survey with dancers regarding how they perceive such workflows, especially about how they are instructed in the process of composing of the group dance. We asked 28 dancers with more than 3 years of street-dance experience who belonged to a university dance club and had experience with a group dance performance. The participants volunteered to answer the questionnaire. As the result, 16 out of 28 participates answered that they had experiences they received paper-based explanations about the composition of the choreography, and 8 out of 28 participates answered that they had received video-based explanations about it. Also, one dancer mentioned that it was easier to understand the choreography of a group dance if they received a video "*where I can see the movements from both front and back, shot in a place with mirrors.*" In addition, one dancer commented, '*When the choreography required each dancer to move at different timing for each beat, it was difficult to dance because the timing was different from the other dancers and there was no sample.*" We found that when dancers learn group dance choreography, it is important to visualize the overall image of the choreography clearly.

2.2 Design Principles

In the previous sections, the analysis of existing dance videos showed four common characteristics found in choreography for group dances. The interviews showed that the choreographers used pen and paper to visualize, organize, and record their choreography and that the choreography ideation, recording, confirmation, and modification cycles took too much time. In addition, we revealed that such visualization would often be too poor for dancers to learn the choreography. These findings conversely suggest that we can leverage computers to free choreographers from the workload of such tedious and time-consuming tasks (see the bottom of Figure 2) as well as helping dancers learn choreography. For this aim, on the basis of the knowledge obtained in the previous section and the knowledge of the first author, who has more than 10 years of street dance experience (mainly breakdancing), we created the following three design principles.

Parametric. To express crossing, choreography flipping, and the timing of shifting, choreographers can adjust the balance of various dancer properties such as the position, direction, and size of every dancer and the pattern and timing of every movement in a group dance in sync with the beat.

Visual. Choreographers can intuitively understand a whole front-focused group dance. This is also helpful for dancers who learn the composed choreography afterward.

Interactive. Choreographers can quickly and easily apply iterative cycles of ideation, recording, confirmation, and modification through an interface.

A system that meets the above principles will allow choreographers to refine their iterative process more efficiently, which will lead to more time spent on creative tasks such as choreography and composition of group dance.

3. Related Work

Our preliminary interviews revealed three principles required for supporting choreographers with computers. However, we acknowledge that some studies have proposed systems for supporting choreographic composition. To situate our work, we review related work, especially highlighting that the requirements have not been well supported yet.

3.1 Choreographic Composition Support Tools

Many support tools for choreographic compositions have already been proposed, and Alaoui et al. [8] compiled these pieces of research. COMPOSE [9], Animate Tokens [10], Life Forms [11], and CorX [12] were presented in the first half of the 1990s and then expanded into various research directions, such as one work using a motion capture system [13] and one using a stylus pen and tablet [14]. Carlson et al. [15, 16] proposed tools that support choreography analysis by visualizing Laban efforts [17]. These systems employ visualization with a stick man or simple polygon human. It is desirable to visualize a dancer with an appearance similar to that of an actual dancer, where choreographers can grasp the subtle differences of the choreography.

Compared with single-dance choreographic composition, there is relatively little research focusing on group-dance choreographic composition. Schulz et al. [18] proposed authoring environments for dance performances that use movement information obtained from a motion capture system. Choreographers can compose choreography by dragging and dropping movements selected from prepared choreography lists onto a timeline. Moreover, they can easily compose a group dance by setting the dancer positions displayed in 2D with a mouse. Furthermore, the system displays the results with character animation, which allows choreographers to confirm the choreography in 3D. A similar system using a motion capture system, DanceDesigner [19], was released. While not including dancers displayed with character animation, this system allows choreographers to transform the movements of dancers into textual instructions for dancers. They can also check dance videos shot from the front and a path plan including the dancer's positions. The above systems are suitable for the purpose of preserving and editing detailed choreographic compositions and visualizing group dance choreography. However, in terms of efficiency for the iterative cycles of ideation, recording, confirmation, and modification, a motion capture system is not suited for repeated trial and error done for the many choreographic-composition steps in a limited amount of time. Without a motion capture system, though it has been possible to obtain movement information from general-purpose devices such as smartphones equipped with a depth sensor recently, these types of devices have difficulty accurately capturing movement information since many errors can be included depending on the dancer's posture.

Some systems focus on methods for moving and changing the formations and positions of dancers on a simulator. Systems that operate with Kinect [20] and gamepads [21] have been proposed. While looking at a group of dancers visualized on screen, users of these systems can control the formation with their own body gestures or check the positions of the dancers in 3D by moving the virtual camera with the gamepad. Given that, we propose a GUI-based interface with a trackpad that can not only control multiple dancers at once as in the above system, but also graphically displays the positions of dancers by duplicating boards (billboards) on which a solo-dance video is pasted and place.

3.2 Video Editing and Broadcasting

We are inspired by projects designed to support video editing and broadcasting. Video editing methods [22] that display dances in 3D by using depth data have been proposed. Kurihara et al. [23] proposed a video editing system that can express group dance in 3D by showing colored 3D point clouds generated by combining depth information obtained from Kinect and RGB color information. Ohta et al. [24–26] proposed a real-time 3D video transmission technology with a simplified 3D model consisting of a single plane on which 2D athletes extracted from multiple cameras are pasted. We presume that such techniques would also be useful for choreographic situations that choreographers imagine the dance. That is, they can visually understand the movements and positions of dancers in 3D by using multiple flat planes on which 2D athletes extracted from an RGB camera are pasted.

Some video editing tools that use the synchronization of audio and image tracks of videos have also been proposed.

Truong et al. [27] presented QuickCut, which can help in quickly creating narration videos. Leake et al. [28] proposed a system for efficiently editing video of dialogue-driven scenes. Tsuchida et al. [29] developed an automatic system for editing multiple dance videos. Some content-based editing techniques that use content synchronization have also been proposed. Rubin et al. [30] proposed a transcript-based speech editing tool and also presented UnderScore [31], which automatically refines, aligns, and adjusts speech and music. PodCastle [32] provides an interface that enables users to easily correct speech recognition errors. In this paper, our proposed system will utilize the synchronization between the audio and images (dance video shots) of videos to enable editing in beat units, which have a close relationship with dance movements.

3.3 Choreographic Communication

The creation of choreography also has a social aspect between the choreographers and dancers communicated via choreography. Some studies have examined the ways that choreographers and dancers interact with technology. Studies [33, 34] done through art activities and studies [35,36] aimed at design done collaboratively through technologies between people involved in various genres have been conducted. Additionally, Hsueh et al. [37] examined how interactive visual systems can support choreographic composition. Felice et al. [38] stated that tools for supporting choreographers in the creative process should enable them to visualize and manipulate their ideas and share them with dancers and collaborators. We anticipate that our work can complement the previous findings through its observation of how choreographers compose group dance using the proposed system.

4. DanceUnisoner

4.1 Prototype Implementation

We built a prototype system according to the design principles (see Section 2.2). The interface is shown in Figure 4. We introduce the functions of the prototype system below.

4.1.1 Input data

The prototype system uses three kinds of input data: a musical piece used for a group-dance performance, a dance video in which a single choreographer or a single dancer dances along the musical piece, and an image of the background used in filming the dance video of a single dancer. It does not require a special device such as a motion capture system or depth sensor. Choreographers simply film themselves dancing to a piece by using a simple RGB camera like the one attached to a smartphone. The background behind a dancer can be removed by subtracting an image of the background from the video. The image of the background can be prepared by cutting out an image from a dance video in which dancers do not appear. All input data was designed to be prepared easily.

4.1.2 Pre-processing

Using the audio of the input musical pieces, the prototype system automatically trims segments in which the music is played in the dance video and choreography appears. Specifically, we use landmark-based audio fingerprinting [39] to automatically detect a musical piece's starting position in a dance video. We then cut it out as a video of one dancer within the period of time length specified by the choreographer from that start position. After that, the human region corresponding to the dancer is cut out in each frame of that dance video by subtracting the background image.

4.1.3 Group-dance display method

To display a group dance by combining videos in which a single dancer dances, the prototype system can be used to duplicate boards (billboards) on which a solo-dance video is pasted and place (i.e., copies and pastes) the duplicated boards on the floor throughout 3D space. Through loop playback of all videos in sync with the music, the prototype system enables multiple dancers to be visualized as if they are dancing at the same time. An example is shown in Figure 5. This method is easier to implement than displaying dancers such as computer animated 3D characters and is suited to choreographic composition since choreographers can easily compose a group dance while imagining the visuals of an actual group dance such as the swaying of and texture of clothes.

4.1.4 Adjustment GUI

Focusing on the parametric aspect of choreography composition (i.e., the number, position, appearance, and movement of dancers), which is important in composing group dances, the prototype system provides a simple GUI such as a slider and 2D pad (see Figure 4) that can be used to adjust those properties. The choreographer can change the number and positions of the dancers with simple GUI-based operations. Moreover, the dancers can be flipped by horizontally, and the timing of movements can be shifted in units of video frames. Additionally, in group dances, the choreographer often creates choreography to which dancers perform the same movement shifted one beat (as suggested in Section 2.1); therefore, the prototype system makes it possible to shift the timing of dancers' movements in beat units according to the positions of the dancers (shifting by 1, 2, or 4 beats can be selected).

4.2 Interview with Expert

To arrange the functions necessary for composing group dances, we asked an expert choreographer with 18 years of hip-hop dance experience to use the prototype system and to allow us to interview her about the functions that needed to be improved or added.

Fig. 4 Interface window. Choreographer can adjust in real time elements (dancer position, size, and timing of movements) that should be considered when composing group dance while overviewing whole choreography.

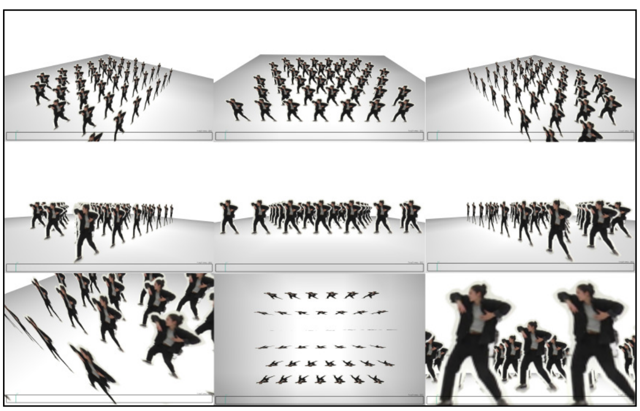

Fig. 5 An example of displaying dancers placed in 3D space.

The interview took 3 hours. For the first hour, the choreographer received an explanation on how to use the prototype system, and she then imagined and composed a group dance based on a musical piece that had 32 beats (4 beats × 8 measures in four-four time), where the term "beat" denotes a quarter note. After the choreographer organized the choreography, we shot her dancing to that choreography. We imported the video into the prototype system, and the choreographer then visualized the group dance in 3D space by using the system. For the remaining two hours, we interviewed the choreographer regarding which functions should be improved and what functions are required while asking how a group dance is usually composed. The choreographer was compensated ¥15,000 (JPY) for taking part in the interview.

Through the interview, the choreographer expressed her pleasure with each of the functions built in accordance with each of the three design principles. In particular, for the design principle *interactive*, from the viewpoint of composing a group dance efficiently and quickly, the choreographer positively commented *"I can see the whole choreography even if all dancers have not gathered, so I feel like the choreographing speed will become significantly faster [...] I feel like I can make a choreography in half the time."* However, the choreographer pointed out that one function needs improvement and one function is missing.

4.2.1 Fine-grained timing control

The choreographer requested that we allow for finer settings regarding the dancer properties along the timeline. The prototype changes the properties for an entire section of an input dance video. For example, if the choreographer shifts one beat against the timing of the movements of a dancer, that dancer always dances shifted one beat while the video is playing. However, it is rare for the dancer properties to not change during an entire section of choreography. Although the choreographer agreed with the current functions, such as the simple GUI based on the design principle *parametric*, she commented that *"If I could set the choreography finely, I wouldn't feel bothered re-filming the video or changing the properties,"* and we determined that the choreographer needed additional functions to be able to set properties with a finer granularity along the timeline.

4.2.2 Path planning

The prototype interface cannot be used to plan the movement paths of dancers. Since the interface places a dance video in 3D space, choreographers are allowed to experiment with both left-and-right and back-and-forth movements. However, these movements cannot be easily edited on the prototype system. From comments such as *"When dancers dance for the first time, they face problems such as colliding into each other and movements not reaching the designated position,"* the system must avoid such problems by making it possible to confirm and edit choreography including its movements in advance.

We refined the prototype system into DanceUnisoner† on the basis of the comments from the interview. Three modes, *Setup, Dancer Parameters,* and *Position 2D Map,* were added as a result of the improvements besides *Formation* mode, which allows users to change the number of dancers and their position as the prototype system does.

4.3 User Workflow

We introduce the user workflow of DanceUnisoner. The choreographer first films themselves dancing to their choreography while imagining the choreography as a group dance. We pre-process the captured video into a form that can be used with DanceUnisoner in the same way as the prototype system.

When a choreographer launches DanceUnisoner, *Setup* mode is displayed. In this mode, to set the position of the dancers on the z-axis in 3D space, the choreographer can manually add depth information to the videos shot by adjusting the depth slider (see Figure 6). This makes it possible to display and move dance videos in 3D space. The choreographer adjusts the depth information by using the GUI so that the movements displayed look as much like the actual movements of a group dance as possible.

The choreographer then explores the initial formation of dancers. *Formation* mode has the same functions as the prototype system, and the choreographer can easily adjust the number of people and design a formation. *Position 2D Map* mode shows the layout of the dancers' positions as seen from above (i.e., overhead view). The choreographer can freely move and set the positions of the dancers with a mouse.

After setting the initial formation of dancers, the choreographer switches from *Position 2D Map* mode to *Dancer Parameters* mode. In this mode, the choreographer can edit dancers' properties such as the kinds of choreography (pre-shot dance videos with different choreography), flipping, and shifts in beats. The choreographer can compose a group dance while constantly switching between *Position 2D Map* mode and *Dancer Parameters* mode.

We give details on the functions of DanceUnisoner in the next section.

4.4 Implementation

We modified DanceUnisoner based on the improvement (Section 4.2.1) and missing point (Section 4.2.2) that the choreographer pointed out in the previous section. We implemented DanceUnisoner using openFrameworks 0.9.8 and conducted the operation check on macOS Sierra.

4.4.1 Setup

In *Setup* mode, the choreographer can manually set depth information, which is difficult to estimate with only RGB video. On the interface window shown in Figure 6, dancers are displayed translucently for overviewing the movements of the whole video at every four beats of the musical piece. Moreover, the top right part of the screen shows an overhead view of the dancers' positions, and that view displays the dancers' movement trajectories for eight beats in 3D space.

When the music starts playing, the main dancer begins to dance. The choreographer can set the depth information of the dancers by moving the depth slider on the upper right side of the window (see Figure 6) up and down according to the main dancers' movements. The choreographer can also increase the level of detail of the movements by clicking the line chart that is displayed on the timeline of the interface.

Furthermore, in the original input video, dancers become smaller if they move to the back away from the camera, and their left and right movements become shorter. Similarly, when moving toward the camera, they become bigger, and the left and right movements become longer. Therefore, the choreographer can adjust these differences by controlling the slider on the interface.

4.4.2 Position 2D map

The *Position 2D Map* mode allows the choreographer to assign and confirm dancer positions from an overhead view. The choreographer can select groups of dancers by clicking and dragging a rectangular selection box comprised of triangles over dancers. They can then change the dancers' positions by dragging the rectangle (see Figure 7). This mode also allows the choreographer to rearrange selected dancers in a formation such as a circle or a triangle that fits the size of the designated rectangular area with a single button. The choreographer can enlarge and reduce the formations by using the 2D pad. They can also apply beat shifts and flips (if the dancer is facing to the right, we can flip them so that they face to the left) to the selected dancers like with the prototype system functions.

4.4.3 Path Planning

This mode also allows the choreographer to register the destination the choreographer lets the dancers move to. The choreographer can use the registered formation in *Dancer Parameters* mode, which will be explained in the next paragraph, and let dancers move to the designated destinations. This function enables the dance video to visually imitate the movements dancers make when walking in 3D space, solving the *Path Planning* problem mentioned in Section 4.2.2.

4.4.4 Dancer parameters mode

To set properties with a finer granularity along the timeline than the low granularity mentioned in Section 4.2.1, this mode allows the choreographer to adjust the properties per beat. First, the choreographer selects the dancer that the choreographer wants to adjust with the slider labeled *Dancer ID* at the top left of the interface (see Figure 8). By dragging a mouse pointer across the rectangular frames at the top of

† https://youtu.be/sMYKIA6DSJQ

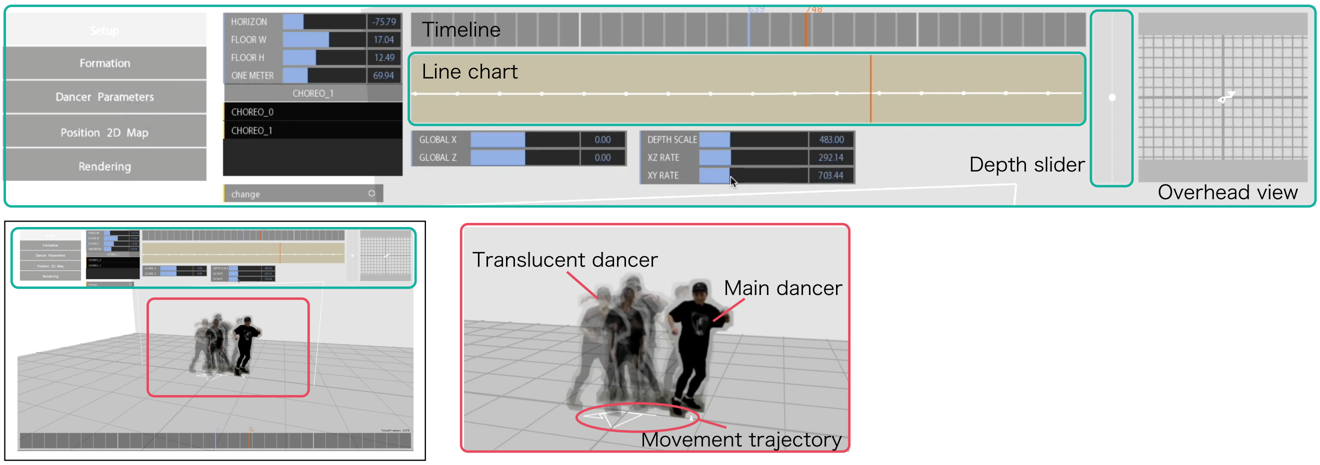

Fig. 6 *Setup* mode. Choreographer can manually set depth information of dancer's movements, which allows them to edit movements of dancer in two dimensions. Prototype system did not support editing of this information.

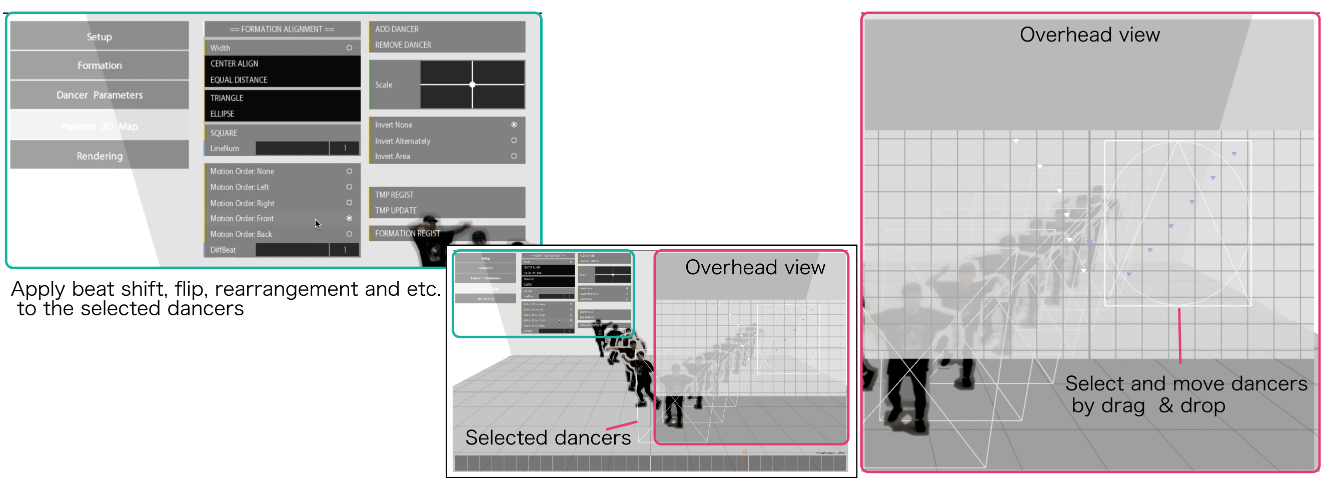

Fig. 7 *Position 2D map* mode. The choreographer can arrange the dancers' position.

the interface window, the choreographer can designate the beats that the choreographer wants to adjust.

5. User Study

The goal of our work is to support choreographers' creativity by providing an efficient choreographic process with computers. To investigate how DanceUnisoner can contribute to choreographers and whether the system makes the choreographic process more efficient, we asked seven choreographers to choreograph group dances by using the proposed system. We recruited 7 participants (2 males and 5 females) who had between 4.5 to 18 years of dance experience (average = 10 years). Their experience covered a variety of dance genres such as locking, hip-hop, popping, breaking, house, jazz, waack, and ballet dance. One of them was the same choreographer who participated in the above interview.

We conducted the user study in a meeting room with an area of about 6 m × 9 m. Participants could move freely in the room, which had chairs and tables. Each participant used DanceUnisoner, and it ran in openFrameworks 0.9.8 on a MacBook Pro (Retina, 15-inch, Mid 2015). The study was conducted for each choreographer and lasted for five days. The participants were compensated ¥15,000 (JPY) for taking part in. We conducted the interviews in Japanese, and the translation was conducted by the first author.

5.1 Task

Each participant simulated two group dances of seven dancers in DanceUnisoner. They choreographed to the same musical piece that had a duration of 32 beats (4 beats × 8 measures in four-four time), at a tempo of 90 beats per minute. To have the participants use the distinct functions of *DanceUnisoner*, we asked them to compose a group dance that included the following four elements.

- Back and forth movements.
- Left and right movements.

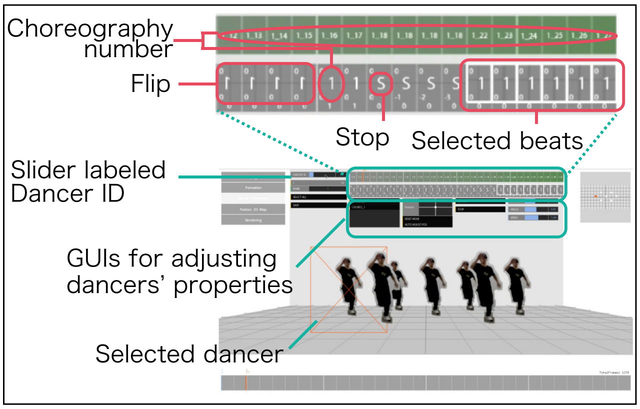

Fig. 8 *Dancer parameters* mode. Choreographer adjusts dancers' properties (stop, flip, etc.) for each beat. "Stop" is written with *S*, and "flip" is represented by reversed numbers (numbers mean difference in beats). When choreographer inputs video, choreography number is assigned to every beat of video. Choreographer then shifts timing of movements on basis of this number.

- Flipping of choreography horizontally.
- Shifting of the timing of movements.

5.2 Procedure

The participants performed the following five activities. Completing all activities took about 3.5 hours. Participants took a short break between activities.

5.2.1 Explanation (15 min)

In order for the participants to understand what functions are included in DanceUnisoner, we gave a verbal explanation of about 15 minutes to them while actually operating the interface.

5.2.2 Composition and filming (30-50 min)

The participants first imagined the choreography of a group dance as per usual. While composing the dance, we provided them with pen and paper, which they were free to use. At the end, we filmed them dancing as an element for constructing the choreography.

5.2.3 Training (30 min)

So as to familiarize themselves with controlling the interface, the participants practiced simulating the group dance in DanceUnisoner with pre-prepared videos while imagining the choreography in their heads. We answered any questions on how to use DanceUnisoner during the practice. During this activity, we pre-processed the recorded videos and made DanceUnisoner ready for use.

5.2.4 Simulating choreography (60–90 min)

The participants simulated the choreography imagined in their heads in DanceUnisoner by using the videos shot during the second activity. We stayed near participants so that we could answer questions whenever they did not understand how to use the interface. For this activity, pen and paper were also available.

Fig. 9 Pick-up screen shots of the output videos that the participants created.

5.2.5 Interview (30 min)

We asked participants what the benefits are of using DanceUnisoner, what functions are convenient, and what functions are essential.

After all participants completed the above activities, we shared the output videos created by each participant among the participants. To predict how using DanceUnisoner may affect communication between choreographers and dancers (via a choreography), we collected comments regarding the question: *"When you watched the videos created by other participants from a dancer's point of view, were there any points of concern or improvement?"*.

Here, we recorded the interface windows while the participants used DanceUnisoner and logged the participants' interaction with it. We also recorded the voices of the participants in the interviews and gathered the pieces of paper used in composing and simulating group dances. We anonymized the data, and we refer to participants as P1-P7.

5.3 Results

We confirmed that all participants successfully simulated their imagined choreography. Some of the output of the participants is shown in Figure 9. Moreover, we received various positive comments from all participants: *"Easy to imagine because I can see the video with my real eyes," "Convenient," "I understand the impressiveness of group dance," "It is good to be able to confirm the music, composition, and choreography at the same time," "I can notice the subtle difference of movements," "most functions are essential," "I can see what I visualize in my head with the video."*

5.3.1 User feedback

Looking at the feedback in terms of the efficiency of choreographic composition, we found that three participants (P2, P6, and P7) kept on changing the choreography while adjusting the group dance simulation. P6 commented, *"When I felt that this part includes few [formation] movements, I added a plus alpha [forth and back movements] to the choreographic composition."* As this participant simulated a group dance with the system, the participant noticed and supplemented the parts that lacked formation movements. We found that DanceUnisoner made it possible to confirm choreography in a way that could not be done without dancers and allowed the participants to modify their compositions. P7 said, *"As I use the system [DanceUnisoner], I can notice things that I never thought of in my head and put them on paper."* The simple GUI of DanceUnisoner allowed them to easily change the properties of dancers, so they could check various patterns instantly. This feature may make it easier to notice new patterns in choreography. P2 commented, *"I got inspiration from seeing the actual movements of dancers [on DanceUnisoner]."* The gap between imagination and simulation possibly affected the participants' creativity. DanceUnisoner could not only accelerate the confirmation and modification cycles of choreography as we expected but could also affect their creativity.

Four participants (P1, P3, P4, and P5) focused on using the system to modify a group dance they were imagining in their head. They mainly used the interface to confirm their choreography and did not change their overall composition style. P1 said *"I will first make the choreography based on music and then use this [DanceUnisoner],"* and P4 also said, *"I do not think I will change how I compose choreography [...] need a mirror and earphones [...] I may use it [DanceUnisoner] as a tool for confirming and sharing choreography."* What they had in common is that they modified their choreography while visually checking the choreography in DanceUnisoner after creating a group-dance simulation.

5.3.2 Quantitative analysis

To examine the effectiveness of DanceUnisoner, we analyzed the operation logs from the user study, as shown in Table 1. EX year indicates the number of years of dance experience. Since one choreography log of P1 was not taken, a dash is displayed in the respective boxes.

The logs revealed that the formation function was most frequently used. The range of group dances that could be expressed is narrowed when using only the original movements in the input video, so the choreographers struggled to compose a variety of group dances. In addition to the movements of dancers, the path planning function mentioned in Section 4.4.2 was essential as we learned from the interview with the professional (in Section 4.2).

We found that the flip function was the second most frequently used function. Four participants (P3, P4, P6, and P7) commented that this function was most convenient. When composing group dance, choreographers have many opportunities to flip choreography as can be seen from the video analysis in Section 2.1.1. We can say that this function is essential when designing a system similar to the current one.

Table 1 The operation logs of DanceUnisoner. The number of operations in which each function was used is displayed.

id	EX year	time (min)	film	flip	stop	beat shift	formation
P1	7.5	31	1	0	9	58	28
		15	2	–	–	–	–
P2	8	10	2	24	0	0	0
		11	4	8	0	0	28
P3	17	32	1	24	0	0	56
		55	1	0	14	86	66
P4	18	11	1	0	8	4	0
		15	1	48	0	0	28
P5	4.5	14	1	56	0	0	84
		20	1	24	18	13	14
P6	6	36	3	4	0	0	21
		31	2	28	0	0	30
P7	7.5	60	2	24	13	8	80
		22	1	26	0	0	56

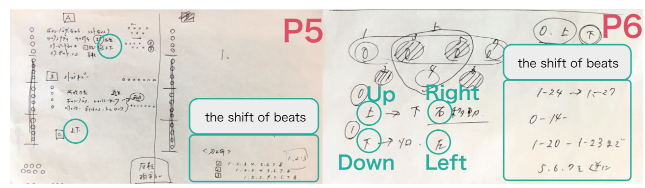

Fig. 10 Papers written by P5 and P6.

Moreover, when using the beat shift and stop functions, the time spent on composing group dance was relatively longer than when not using it. The functions might have confused the participants since the parts of the choreography were skipped or the positions were shifted from the original position when the beat was shifted. For beat shift and stop functions, a clearer interface would be required.

To summarize, we found that all choreographers were able to simulate their choreography by using DanceUnisoner and appreciated its dedicated support for choreographic composition. Moreover, we found that three choreographers not only accelerated the making of iterative refinements to their choreography but also had their creativity stimulated by the system.

6. Discussion

To facilitate further computational support for choreographers, we describe insights gained through feedback from the participants of the user study.

6.1 Using DanceUnisoner Together with Pen and Paper

Participants were free to use pen and paper while using DanceUnisoner. All choreographers except for P2 wrote floor plans (diagrams that represent spatial trajectories, as seen in Figure 10) by using symbols such as circles and arrows. In addition, as shown in Figure 10, P5 and P6 wrote words recalling the functions of the system, such as inversion, left, right, top, and bottom. They seemed to take advantage of the functions of DanceUnisoner by writing the shifts of beats and expressing differences in the choreography with numbers and colors. Three participants (P3, P5, and P6) wrote characters and short sentences. P5 commented, *"I think it will be [more] convenient if I can add words [...] if I can write points [on DanceUnisoner],"* and asked for functions for adding words.

6.2 Difference in Number of Shots

We observed three major patterns in how the participants used the input video.

(1) The participants simulated a group dance with only one video of a single dancer dancing.
(2) To change how the dancers looked, the participants danced to the same choreography multiple times.
(3) The participants shot multiple different choreographies to obtain necessary shots.

For item (1), five participants (P1, P3, P4, P5, and P7) composed a group dance with one video. P7 regarded the dancer as a controllable object that can represent choreography and said that she wanted to rotate the dancer with the interface instead of taking multiple video shots.

Regarding item (2), since DanceUnisoner can only capture video shot from the front, P2 danced to the same choreography twice to simulate the choreography as shown from the back. P2 and P5 commented, *"dance video shot from behind"* is necessary to make it *"easy to learn choreography."* As for P4, she requested that *"inversion is not only left and right but also back and forth,"*, and we confirmed that there exists choreography that is difficult to express by using only video shot from the front.

For item (3), three participants (P1, P6, and P7) increased the number of shots of different choreographies to adjust elements that cannot be changed by DanceUnisoner, such as height differences between dancers.

To summarize, by regarding the dancer as a controllable object that can represent choreography, the interface could be expanded to offer more ways of expressing a composition. Moreover, we could design the interface to be able to automatically generate a dancer's back from video shot from the front and to allow the choreographer to modify the dancer's posture directly in the video.

6.3 Large-scaled Group Dance Choreography

After creating the choreography, all participants mentioned that DanceUnisoner would be particularly beneficial to the choreographer who composes a group dance with a large number of dancers. The participants commented about the number of people, 10 to 40 dancers, and P4, P5, and P6 commented about 20 dancers.

Five participants (P1, P2, P3, P4, and P7) mentioned that they could visualize large-scale choreography, even with a large number of dancers, for which there are *"few opportunities for all members to gather"*. In particular, P4 commented that even if there were a lack of dancers, the choreographer could compose a group dance with the regular number of dancers by duplicating the dancers with *DanceUnisoner*.

Four participants (P2, P3, P4, and P5) said that DanceUnisoner would help to "communicate" the "image" of a composition to dancers. The larger the number of dancers, the harder it becomes for the choreographer to imagine how the dance group looks. The participants pointed out that it would be useful to practice choreography with an output video that can be regarded as the goal. Also, from the viewpoint of teaching, P2 and P4 commented that the interface seemed useful in "understanding" the choreography of group dances comprised of a large number of dancers.

6.4 Sharing Output Videos Among Choreographers

P5 noted that choreographers could share DanceUnisoner among themselves to avoid problems when sharing choreography. Also, P7 mentioned that she wanted to register an excellent choreographic composition into DanceUnisoner and analyze the formation movements and the choreography on the interface rather than watching the video.

DanceUnisoner has the potential to provide opportunities to receive advice and modification from other choreographers through the sharing of choreographies. As future work, it is beneficial to extend DanceUnisoner to allow choreographers to share, analyze, and polish their compositions, resulting in more varied choreographies. For example, DanceUnisoner could store shared choreographies in a library so that choreographers can reuse them for a different musical piece. This confirms our design principles that were partially informed by the survey in Section 2.1.3.

7. Limitations and Future Work

Despite the affirmative responses from the participants, there are some limitations with DanceUnisoner. First, DanceUnisoner demands dance skills of the choreographer since it uses video of them dancing. When the choreographer does not have enough skills, they would need to ask another dancer to dance for the video. Even if the choreographer could dance, they might not be able to imitate other dancers' styles and also their appearance. To address this issue, it would be helpful to develop a function that can support a model of dancer's individual characteristics and apply it to dances.

Second, DanceUnisoner has a limitation with the 2D billboard on which a solo-dance video is pasted. As discussed in the video analysis in Section 2.1.1, most dance performances are assumed to be seen from the front, but in some cases, the audience surrounds the dancers. Even if the choreographer using DanceUnisoner would want to check a performance from the side, they would barely be able to see the dancers because of the 2D billboard. To address this issue, a function of representing the dancers' movements and appearances in 3D space would be necessary. In addition, DanceUnisoner has difficulty representing dance performances in which some physical objects are used by dancers. To display dancers throwing a physical object like a ball, for example, a function of supporting such a 3D model would be necessary.

Third, although our user study illustrated the usefulness and creative aspect of DanceUnisoner, its generalization to other dance genres is left as future work since this paper targets the choreography of group dances in street dance genres. Further investigation on observing how choreographers in other genres (e.g., K-pop, salsa, and cheerleading) utilize DanceUnisoner would indicate areas of improvement. We know that DanceUnisoner cannot support every genre since some genres involve movements improvised by dancers during performances. Even a musical piece could be improvised (i.e., not pre-recorded). Such improvisational nature is out of the score of this research and is not supported by DanceUnisoner.

8. Conclusion

We have described DanceUnisoner that enables a single choreographer to easily compose, by leveraging videos in which a single dancer dances, group dance videos that look as if multiple dancers are dancing. We first investigated the current group-dance choreographic composition, figured out the existing group-dance composition issues, and determined design principles. Based on the design principles, we developed the prototype system and conducted a professional interview where an expert choreographer used the proposed interface on the system. On the basis of comments obtained from the interview, we improved the interface and built DanceUnisoner. To investigate how choreographers use DanceUnisoner, we conducted a user study with seven professional choreographers. We confirmed that all of them could simulate a group dance by themselves; in particular, three of them utilized the iterative refinement process, which cannot be done efficiently without DanceUnisoner.

Acknowledgments

This work was supported in part by JST ACCEL Grant Number JPMJAC1602, Japan.

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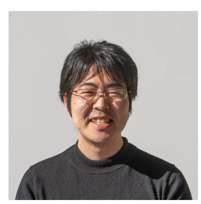

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