A System for Practicing Formations in Dance Performance Supported by Self-Propelled Screen

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ABSTRACT

Collapsed formation in a group dance will greatly reduce the quality of the performance even if the dance in the group is synchronized with music. Therefore, learning the formation of a dance in a group is as important as learning its choreography. However, if someone cannot participate in practice, it is difficult for the rest of the members to gain a sense of the proper formation in practice. We propose a practice-support system for performing the formation smoothly using a self-propelled screen even if there is no dance partner. We developed a prototype of the system and investigated whether a sense of presence provided by both methods of practicing formations was close to the sense we really obtain when we dance with humans. The result verified that the sense of dancing with a projected video was closest to the sense of dancing with a dancer, and the trajectory information from dancing with a self-propelled robot was close to the trajectory information from dancing with a dancer. Practicing in situations similar to real ones is able to be done by combining these two methods. Furthermore, we investigated whether the self-propelled screen obtained the advantages of dancing with both methods and found that it only obtained advantages of dancing with projected video.

General Terms

Human Factors, Experimentation, Performance

Keywords

Formation dance training, Mobile robot, Projector

1. INTRODUCTION

Improving physical expressions and the sense of rhythm in dance performances has attached attention in recent years due to the increase in child dancers and dance studios. Even beginners in dance gain more opportunities to perform dances in groups. When dancing in groups, collapsed formation will greatly reduce the quality of dance performance, even if the choreography is synchronized with the music. Therefore, it is very important to keep formation in group dances. It is also important to be aware of keeping the proper formation and moving smoothly into the next formation to perform professional level group dances. However, it is difficult to obtain the sense of a proper formation if some member of the dance cannot participate in practice. The presence of a person dancing next to someone affects his/her performance and senses.. When dancing in groups, training to do the formation is an important element as well as learning the choreography.

There have been various approaches that have supported learning of the choreography. There have been methods of learning skills using motion capture technology[1, 2] and inertial sensors have been employed[3]. This researches has verified what kind of support is effective to enable the choreography to be practiced. They also research has also been done on the ways to display model dances and on visualizing the differences between model dances and one's actual movements.

However, there has not been any previous work that has focused on training to do formations. Therefore, we propose a system of training to do formations when there a member is about using a self-propelled robot to provide the presence of the missing member. We project an image of the dancer onto a self-propelled screen in this system that can move as quickly as the dancer, making the other dancers feel as though they were dancing with the missing dancer. Furthermore, we evaluate which method of practicing formations gives the closest feeling of dancing with an actual dancer.

The remainder of this paper is organized as follows. Section 2 outlines related work and Section 3 enumerates methods of practicing formations, explains system requirements, presents the results, and provides considerations into evaluating the methods of practicing formations. it also describes the design of our system. Section 4 explains the system implementation and Section 5 presents the results we obtained from experiments and considerations into the methods of evaluation. Section 6 presents our conclusions and plans we have for future studies.

2. RELATED WORK

Various methods of having humanoid-robots dance have recently been developed because of advances in robotics-related technologies [4, 5, 6, 7, 8]. Xia et al. have shown that algorithms can automate the task of choreographing robot dances to allow them to dance without detailed human planning [9]. Nakaoka et al. has developed a system for robots to perform dance motions acquired from human dancers [10]. However, the robots using these methods cannot choreograph their movements or more as smoothly as human beings. In addition, various autonomous robots that can dance with humans have been developed. For example, the partner ballroom dance robot(PBDR) [11] developed by Kosuge et al. has a variety of mechanisms to achieve the necessary movements required in ballroom dancing. After receiving forces and moments in three dimensions from a 6-axis force sensor built into it, the computer in PBDR controls its movements based on ballroom dance steps that have been stored in it in advance. Therefore, the robot can feel the direction that the dance partner wants to lead and estimate the partner's steps. Nakamura et al. proposed a system were students learned the choreography and the amount of translation efficiently by following a robot equipped with an image display [12]. However, these training systems focused on ballroom dancing, and targeted beginners. These systems did not consider that people made vigorous movements like those in street dancing in groups. The presence of a person dancing next to them in a performance will have various effects on partners. Therefore, people can not usually succeed in dancing by learning the choreography to translate dances.

There are methods that support the learning of skills using motion capture technology [13, 14, 15], inertial sensors, and field of the virtual reality [16]. Furthermore, Microsoft developed for a new type of motion controller for games called KINECT. Much game software for learning dance has been released. It is possible to obtain the position of joints in the body in real time, and identify the movements of the entire body with KINECT [17]. If users can learn useful skills in the real world while playing video games through a more sophisticated virtual experience, this will greatly change the importance of video games. Deng et al. proposed an interactive dancing game [18] in which a virtual character memorized one's dance moves in advance, and a virtual avatar was linked to one's real time movements when dancing together on a screen. By comparing the virtual character to one's avatar, he/she will be able to know if he/she is making the same moves, and enjoy learning the choreography.

There are large numbers of studies that have supported the learning of dance choreography. However, there have been no studies that have focused on supporting the practice of dance formations. This paper proposes a training system that focuses on dance formations.

3. SYSTEM DESIGN

3.1 Methods of Practicing Formations

People in the normal practice of dance and look at a mirror while practicing. Three possible approaches when dancers are lacking in practicing formations have been enumerated below.

- Methods of dancing by watching reference videos previously created
- Methods of learning the distance dances and the absence of dancers by projecting them onto a wall
- Methods of feeling as if dancers are absent using a self-propelled screen that can move quickly like a person

We adopted methods of using a self-propelled robot that we anticipate the strongest existence.

3.2 System Requirements

Although the related work that has been described so far has been to primarily support the learning of choreography and generating it, this paper proposes practicing support with an emphasis on formation. The necessary conditions to be included in a system to practice formations are given below.

- The self-propelled robot moves smoothly like humans do and moves exactly to the same position as the dancer.

The changing of formations will be disrupted if the robot does not move smoothly. In addition, even though practice involves learning of appropriate distances, we will obtain an insignificant sense of distance if the robot is not able to move like a human.

- The self-propelled robot makes it feel like one is actually dancing with a dancer.

It is necessary to share information that is obtained when dancing with actual dancers, such as whether the choreography is synchronized or not, by providing a being that is close to an actual dancer. The most necessary requirement for a system is to practice formations when there is a lack of dancers by providing the presence of a missing dancer using a self-propelled robot.

3.3 Preliminary Experiment on Methods of Practicing Formations

We evaluated which method was close to dancing with an actual dancer for each method of practicing formations (Figure 1). The subjects were nine dancers who had experience in dancing for more than three years. The subjects learned the choreography for approximately 12 seconds that consisted of three times eight beats after checking a reference video. This choreography contained three elements that were considered to be greatly influenced by the presence of the others.

- Intersection: Front and back intersection
- Approaching: Quickly approaching to the dancer
- Parallel translation: Moving while maintaining distance of side-by-side

Three experiments were carried out to compare the sense of dancing with a partner.

The dancer in Experiment 1 danced alone while looking in a mirror. We controlled OMNIKIT2010 (Figure 2) with a wireless-controller attached to make the dancer feel as if the missing dancer was there in Experiment 2. We learned the appropriate distance between the missing dancer

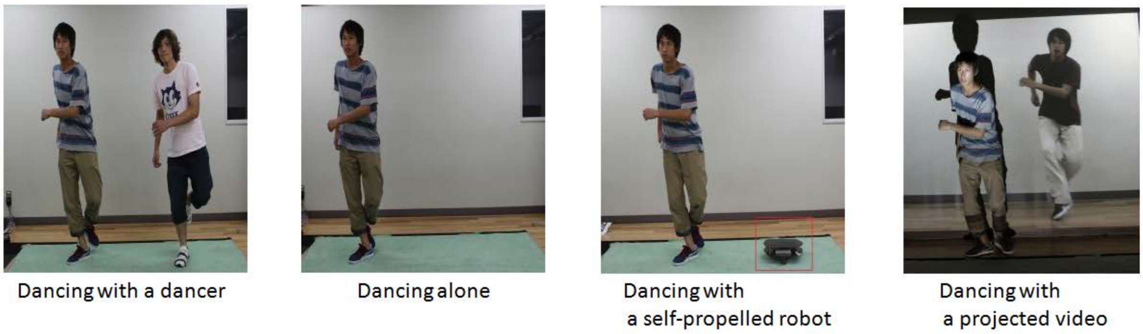

Figure 1: Each method for practicing formations

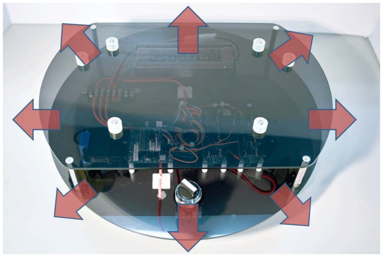

Figure 2: OMNIKIT2010

Table 1: Question items

Question 1	Was it close to the sense that you get when you dance with a dancer, when you intersect?
Question 2	Was it close to the sense that you get when you dance with a dancer, when you quickly approach to a dancer?
Question 3	Was it close to the sense that you get when you dance with a dancer, when you move while keeping the distance of forming ranks?
Question 4	Was it easy to do the choreography, and the movement?
Question5	Was it easy to learn the sense of distance?

while checking a video of the dancer projected onto the wall through the mirror in Experiment 3.

All subjects danced the choreography involving three times eight beats for 12 times in total, i.e. three times each for experiments 1, 2, 3 and dancing with a dancer. We saved the location information obtained from a depth camera every time we finished dancing the choreography that consisted of three times eight beats. We used Microsoft Corp's Kinect as the depth camera. The five question items (Table 1) took into consideration three elements including the choreography. All subjects evaluated the methods in five stages. In addition, free-comments were provided as a reference.

3.4 Results of the Experiment

Figure 3 plots the trajectories of movements for Subjects 1 and 2, Table 2 lists the results from a questionnaire, and Table 3 summarizes the average distances.The time at some point for the method of dancing with a dancer was termed Ti. The time at some point for the other was termed Tj. The maximum number of data for the method of dancing with a dancer was termed N. The maximum number of data for the other method was termed M. The two-dimensional positions of subjects were termed (Xi, Yi) and (Xj', Yj'). We calculated the average distances as Ave' using the following algorithm:

Source Code 1: Calculating the average of distance

```
S=0;
for (m=0;m<3;m++){
 for (n=0;n<3;n++){
  for (i=0;i<N; i++){
   Min=∞;
   for (j=0;j<M; j++){
     if (Min>|Ti−Tj|){

      Min=|Ti−Tj|;  X'=Xj';  Y'=Yj';
     }
   }
  Di=sqrt((Xi−X')^2+(Yi−Y')^2);
  S+=Di;
  }
 Ave+=S/N  ;
 }
}
Ave'=Ave/(3*3)  ;
```

We considered which method was closest to the sense and movement of dancing with an actual dancer based on the results obtained from an evaluation questionnaire.

For Question 1, in which the distributions of respondents were identical between methods, we assessed the difference between averages by using one-way analysis of variance (AN OVA). As a result, we found no significant differences ($p = 0.112 > 0.05$). However, the ratings were the highest when the subjects danced with the self-propelled robot. The reasons were considered to be as follows. When dancing with the projected video, subjects paid too much attention to the video. Moreover, depth was hard to perceive from the projected video. When dancing alone, it was difficult for subjects to establish the sense of distance because there was nothing next to them to match the movements and depth was hard to perceive from the mirror. When dancing with the self-propelled robot, the distance between the robot and the subjects made it easy for them to learn because they did not have to worry about colliding with the robot. One subject answered that it was easier to establish the sense of distance than when dancing alone. Another subject who answered that it was easier to establish the distance dancing alone said that they already had a clear image of intersect-

Table 2: Results from a questionnaire

	Question 1		Question 2		Question 3		Question 4		Question 5	
	Average	Variance	Average	Variance	Average	Variance	Average	Variance	Average	Variance
Alone	2.0	1.6	1.7	0.4	2.1	1.2	3.8	1.7	1.4	0.2
Robot	3.0	1.1	2.7	2.2	2.6	1.8	2.0	1.6	2.6	1.1
Projector	2.0	0.7	3.2	0.8	3.4	1.1	4.1	0.8	2.9	0.3

Table 3: The average of the distance between method of dancing with a dancer in each method

The subjects number	1	2	3	4	5	6	7	8	9
Dancing alone	207	185	353	415	363	320	570	337	281
Dancing with a self-propelled robot	202	203	469	360	278	196	481	257	317
Dancing with a projected video	254	218	532	552	306	256	280	237	469

ing, making it easy to imagine where the other dancer was while dancing alone.

For Question 2, in which the respondents were identically distributed between methods, we assessed the difference between the averages by using ANOVA. As a result, there was a significant difference ($p = 0.026 < 0.05$). Moreover, we assessed the difference between the averages for the methods by using a Scheffe test. As a result, there were significant differences between when subjects danced alone and when they danced with the projected video ($p = 0.028 < 0.05$). In conclusion, the method of dancing with the projected video obtained a closer sense of dancing with an actual dancer than the method of dancing alone. Additionally, the rating was the highest as a number when subjects danced with the projected video. The reasons were considered to be as follows. When subjects moved laterally, depth did not matter so they tried to match the projected video through the mirror. It was easy for them to retain the appropriate distance because they did not have to worry about the colliding with another dancer or the robot. When dancing with the self-propelled robot, it could only move at a constant speed making the robot move irregularly. Because of that and the robot not being tall enough, the subjects had to pay attention to their feet to avoid stepping on the robot. However, variance was high when subjects danced with the self-propelled robot. Therefore, some subjects awarded them more points. The reasons were that the subject felt like he/she was actually dancing with another dancer because the robot actually approaching them made them aware of the distance between them. The difference in the evaluations appeared because the robot sometimes moved smoothly since it was manipulated with a controller. When dancing alone, subjects were not able to learn the sense of being approached because there was nothing coming up to them. Also, subjects did not know how far they should move. For these reasons, the ratings were low.

For Question 3, in which the distributions of the respondents were identical for the methods, we assessed the difference between the averages by using ANOVA. As a result, there were no significant differences ($p = 0.090 > 0.05$). However, the ratings were also the highest when subjects danced with the projected video. This occurred for the same reasons as those in Question 2. When dancing alone, the ratings lowered because of the reasons mentioned in Question 2 and because the subjects paid less attention to theirs footsteps without the other dancer. However, Question 3 was rated higher than Question 2. This is because that while intersection and approaching were big movements parallel translation was a smaller movement and the subjects felt more anxious when they took big steps alone. When dancing with the self-propelled robot, the robot was there as a reference for dancing, so there was little difference between parallel translation and approaching. As a result, the ratings for Question 3 were roughly equivalent to those for Question 2.

For Question 4, in which the distributions of respondents were identical for the methods, we assessed the difference between the averages by using ANOVA. As a result, there was a significant difference ($p = 0.003 < 0.05$). Moreover, we assessed the difference between the averages for the methods by using a Scheffe test. As a result, there were significant differences between when subjects danced with the self-propelled robot and when they danced with the projected video ($p = 0.024 < 0.05$). In conclusion, the method of dancing with the projected video obtained a closer sense of dancing with an actual dancer than the method of dancing with the self-propelled robot. The ratings were also the highest as a number when the subjects danced with the projected video. The ratings were different for the method using a projector and dancing alone even though they were similar in that neither had anything next to the subject. The reason for this is that it was easier to dance because the subject was able to establish the sense of distance throughout the experiment as mentioned in Question 5. Moreover, it was easy for the subjects to dance and to gain the sense of dancing with a dancer because they could check the projected video through the mirror. When dancing alone, the variance in evaluations was high and the evaluations were polarized. Subjects who evaluated it highly strongly thought that they were able to make big movements and engage in choreography because they did not have to worry about collisions. Subjects who evaluated it lowly strongly thought that it was difficult for them to learn the choreography because they did not have a role model.

For Question 5, in which the distributions of the respondents were identical for the methods, we assessed the difference between the averages by using ANOVA. As a result, there were significant differences ($p = 0.002 < 0.05$). Moreover, we assessed the difference between the averages in for the methods by using a Scheffe test. As a result, there were significant differences when subjects danced alone and when they danced with the projected video ($p = 0.006 < 0.05$). In

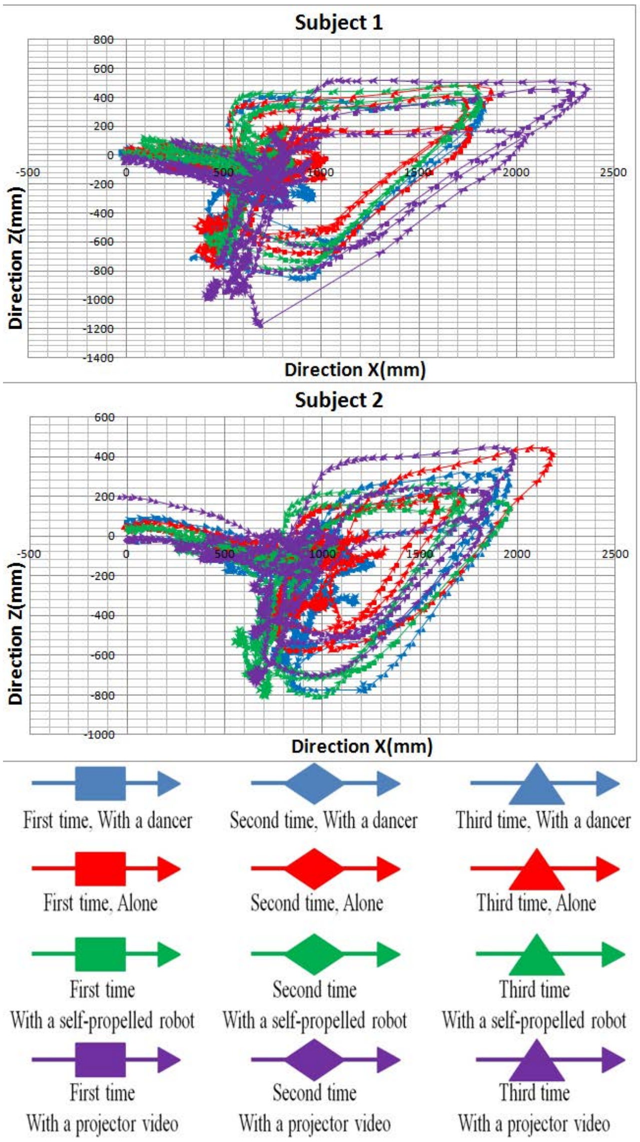

Figure 3: Trajectories of movements of Subject 1 and 2

conclusion, the method of dancing with the projected video provided a closer sense of dancing with an actual dancer than the method of dancing alone. Additionally, the ratings were the highest when subjects danced with the projected video. It was easy for subjects to established the sense of distance throughout in the case that the evaluations of Questions 2 and 3 were high even if it was difficult for them to established the sense of distance. The ratings were low when they danced alone. It was difficult for them to established the sense of distance because there were no references for the dancer. When dancing with the self-propelled robot, the evaluations were polarized reflecting the evaluation results in Questions 2 and 3.

These results from Questions 2, 4, and 5 for which there were significant differences indicated that dancing with the projected video was the closest to dancing with a dancer.

Next, we investigated the trajectory information. Comparing each items of trajectory information simultaneously is the most advantages. However, the timing when data are collected differ for each trial because there must be a distribution for the intervals when data are obtained. Such differences will accumulate if we compare individually data collected from two different trails from the start. Therefore, we regard the average distance between the position of a model dancer on a time point and the position of a trial dancer on the nearest time point as the distance in time because we can minimize the error due to accumulation. The average distance data are calculated by comparing trajectory information where subjects danced with a dancer and trajectory information where they danced with another method for all combinations of three trials for the former and three trials for the latter. We could obtain nine distance data for each timing since the combination becomes nine, and we calculated the average for these nine data. Subjects whose average distances were the shortest in dancing with the self-propelled robot were observed for four of the nine subjects from of these experiments. Dancing alone was observed for three subjects, and Dancing with the projected video was observed for two subjects. Subjects whose average distances were the longest in dancing with the projected video were observed for five of the nine subjects. Dancing alone was observed for four subjects. The results revealed that the trajectory information on dancing with the self-propelled robot was the closest to the trajectory information of dancing with a dancer. However, we could not determine which method was best only from the results, i.e., closest to dancing with a human dancer.

When subjects danced with the self-propelled robot, it means that they were the most accurate in actual positioning. The reasons were considered to be as follows. There was nothing next to the subjects when they were dancing alone or dancing with the projected video. However, the self-propelled robot was next to the subjects when they were dancing with it. Therefore, subjects obtained appropriate trajectory information because they could use the robot as a marker. Moreover, the subjects'movements were restricted unconsciously so that they did not collide with the robot as they stated in their responses to Question 2.

3.5 System Functions

The results from the questionnaire suggested that dancing with the projected video gave the subjects a close impression of similarity in dancing with a dancer. The results from the trajectories suggest that the trajectory information from dancing with the self-propelled robot was the closest to the trajectory information from dancing with a dancer in reproducing the positions. Based on these facts, we propose the following system that meets the requirements described in Section 3.2. We summarized the proposed methods that meet the system requirements below.

First, the self-propelled robot could be controlled in small movements and was able to move in eight directions to move smoothly like a human being.

Second, the real-time position of the dancer could be obtained and corrected by Kinect to accurately reproduce the positions and the movements of the dancers. The direction of the robot was necessary to correct the position. We used the depth information from the screen to establish the direction of the robot. Moreover, we established the extent of shaking from the screen by using the six-axis motion sensor.

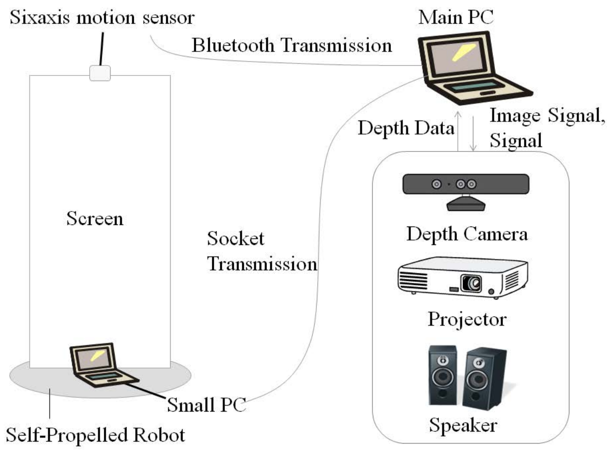

Figure 4: System Configuration

Finally, the self-propelled robot had to be equipped with a screen to project the image of the dancer taken previously to make it feel like the dancer was actually dancing with a partner. The screen had to face the same direction because the video was accurately projected onto the screen. Therefore, we corrected the direction using depth information.

By implementing a system that met these requirements, we propose a system that will make it possible to practice formations when there is a lack of dancers.

There is an overview of the design of the proposed system in Figure 4. The trajectory information and the choreography for the dancer as a reference were extracted and saved in advance. The robot was programmed to move based on these data. The robot's direction and position was corrected by obtaining the direction information of the initial position when the dancers were practicing, making it possible to practice formations when there was a lack of dancers. An overview of the procedure for the entire system is as follows.

(1) The choreography of a model dancer is captured on video. Simultaneously, the trajectory information of a dancer practicing is obtained with Kinect and saved.

(2) The self-propelled screen moves matching the video playback.

The position and direction are corrected based on the information obtained for these. Thus, the self-propelled screen is able to move to the designated position and to project the image onto the screen accurately even if the self-propelled screen deviates from the ordered movement because of changes in the environment. The sense of dancing with another dancer is obtained by looking at the video projected onto the screen of the model dancer and checking the choreography through the mirror. We will be able to obtain a feeling of being close to the presence of another dancer from the movements of the self-propelled robot based on the trajectory information of the dancer. The program for movement is adjusted so correction is minimized. The commands are sent to a small computer installed on the robot by using socket transmission.

We will be able learn the appropriate senses of dancing from dancing formations with a self-propelled screen in formations with absent dancers by using the system.

Figure 5: System appearance

4. IMPLEMENTATION

There is a photographer of the system being used in Figure 5. The OMNIKIT2010 made by Tosadenshi is a self-propelled robot with a screen and a small PC (VGN-UX90PS, Sony). The screen has a door to prevent the wind resistance. The main PC that calculates the three-dimensional position is connected to a depth camera (Kinect, Microsoft), a projector (MP522ST, BenQ), and a speaker (Computer Music-Monitor, BOSE).

We developed the application using C ♯, and the development environment was the Microsoft Visual Studio 2010. We will explain the functions of this application shortly. First, we start socket transmission between the small PC and main PC and serial communication between the six-axis motion sensor and main PC. Second, the application screen displays a distance from the self-propelled screen to the destination, the current progress of the program, the X value of the destination, and the Z value of the destination in real time.

The main PC calculates the S slope of the screen as the X-axis is a plane parallel to Kinect obtained with Equation (1). The self-propelled screen rotates so that S is close to zero. Therefore, the screen is parallel with Kinect. The depth of the left end toward the screen is termed Z_1. The depth of the right end toward the screen is termed Z_2. The horizontal width of these two points is termed X_{12}.

$$S = \frac{Z_2 - Z_1}{X_{12}} \tag{1}$$

Furthermore, the system returns the self-propelled screen to the destination automatically depending on the distance between the destination and the current location.

5. EXPERIMENT ON SELF-PRO PELLED SCREEN

5.1 Experimental Procedure

Next, we investigated whether or not the self-propelled screen obtained the advantages of these methods. The subjects were nine dancers who had experience dancing for more

Table 4: Question items

Question 1	Was it close to the sense of dancing with a dancer?
Question 2	Was it easy to learn the sense of distance?

Table 5: Results of the questionnaire

	Approaching			Parallel Translation			Intersection		
Experiment number	1	2	3	1	2	3	1	2	3
Question 1	1.7	3.5	3.1	1.8	2.9	3.1	2	3.3	3.1
Question 2	2.4	3.4	3.3	2.7	2.9	3.4	2.8	3.5	3.7

than three years. They learned three simple choreographies of approximately 8 seconds that consisted of two times eight beats after checking the reference video. These three simple choreographies corresponded to each of the three elements of intersection, approaching, and parallel translation, mentioned in Section 3.3. By investigating the three choreographies that contained each of the elements between methods, we could see the difference in effects for the methods in each of the elements.

The subjects in Experiment 1 danced with OMNIKIT2010 controlled by an attached wireless controller. The subjects in Experiment 2 danced while checking the video of a dancer projected onto the wall through the mirror. The subjects in Experiment 3 danced with the self-pro pelled screen that projected the video of the dancer. We considered that the sense of dancing was closest to the sense of dancing with a dancer because subjects could check the video of the dancer, and the trajectory information of dancing was close to the trajectory information of dancing with a dancer because subjects danced with the robot as a marker.

All subjects danced the two times eight beats choreography for 36 times in total, 3 times each for experiments 1, 2, 3 and dancing with a dancer. We saved the location information obtained from Kinect every time we finished dancing in the choreography that consisted of two times eight beats. There were two question items (Table 4). All subjects evaluated the methods in five stages.

5.2 Results from Experiment

Table 5 summarized the results from the questionnaire. Table 6 lists the average distances between the method of dancing with a dancer in each method in approaching for the nine subjects. It also lists the average of the maximum width between the method of dancing with a dancer in each method in parallel translation for the nine subjects and the average maximum longitudinal width between the method of dancing with a dancer in each method in intersection for the nine subjects.

We considered whether or not the self-propelled screen would obtain the advantages of these methods based on the results obtained from the evaluation questionnaire.

We found for both Questions 1 and 2 that the evaluation of dancing with the self-propelled screen was close to the evaluation of dancing with the projected video. As a result, the self-propelled screen was able to obtain the advantages of dancing with the projected video for approaching, parallel translation, and intersection.

Next, the trajectory information needs to be considered.

Table 6: The average of the distance for 9 subjects

Experiment number	1	2	3
Approaching	109	63	128
Parallel translation	103	82	150
intersection	119	86	111

For Experiment 1∼3, the average value for dancing with the self-propelled screen was the highest of the methods. As a result, the self-propelled screen was not able to obtain the advantages of dancing with the self-propelled robot for approaching, parallel translation, and intersection. Furthermore, the values for dancing with the projected video was the lowest for all experiments, i.e., the position information on dancing with the projected video was closest to the position information on dancing with a dancer. The reasons for this were considered to be as follows. The choreography for this experiment was simpler and shorter than it was in the preliminary experiment for the methods of practicing formations. Therefore, the self-pro pelled screen was not able to play the role of a marker. We considered that the self-propelled screen would have been able to do it and obtain the advantages if the choreography had been longer and more complex.

In conclusion, the self-propelled screen was able to obtain the advantages of the projected video. However, it was not able to obtain the advantages of the self-propelled robot. The reasons for this were considered to be as follows. The self-propelled screen made it easier to do irregular motions by shaking the screen. Therefore, it gave subjects a greater sense of presence than necessary. Further, as the outer frame of the screen was made of aluminum, their fear of collision was stronger than that with the other methods because there was a possibility of injury. Furthermore, reliability with the self-propelled screen was low because subjects did not practice with it repeatedly. Therefore, they were not able to move with complete freedom.

The improvements we need to make to the methods are considered to be as follows. The self-propelled screen should move more accurately. We need to reduce the risk of the collision by attaching a buffer material to the screen to prevent injuries. Dancers should get used to dancing with the self-propelled screen by practicing with it repeatedly.

6. CONCLUSION

We proposed a system for practicing formations in dance using a self-propelled screen instead of an actual dancer. By dancing with a self-propelled screen, we were able to make people feel like they were dancing with the missing dancer. We investigated which method for practicing formations was closest to dancing with an actual dancer, and found that the distance between a dancer and his/her partner in a formation dance changed according to the methods used. The results from our experiments clearly revealed that dancing with a projected video in terms of human feelings, and dancing with a self-propelled robot in terms of the trajectory information were closest to the feelings and the movements of dancing with a dancer. Therefore, our system that combines dancing with a projected video and dancing with a self-propelled screen is valid.

We intend to make a self-propelled screen in the future that has excellent mobility and is lighter to make the movements of the self-propelled screen smoother. Moreover, using other sensors must be considered to obtain the appropriate trajectory information. More appropriate corrections need to be carried out for various situations to corrects positions and directions. When we have optimized the self-propelled screen, we intend to support the practice more complex formations with more than three dancers by using multiple self-propelled screens.

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