A Collaborative Movement Instruction System Using Virtual Environment

Kazuhiko SEKI, Junichi HATAYAMA, and Hideki MURAKOSHI

Tokyo Metropolitan Institute of Technology Department of Electronic System Engineering

6-6, Asahigaoka, Hino City, Japan 191-0065

e- mail: seki@ml.ec.tmit.ac.jp

Abstract - This paper proposes a collaborative movement instruction system using virtual environment. The system consists of a monitor, USB cameras, and PCs. We implement a virtual studio as 3 dimensional computer graphics in the PC. Avatars of a learner and a partner are displayed in the virtual studio on the monitor. Moreover, a mirror is installed in front of the learner and the partner in the virtual studio. The learner can recognize movements of the learner and the partner. The mirror reduces area of learner's blind spots. We implement and evaluate the collaborative movement instruction system using virtual environment. We confirm that learners can learn collaborative and synchronizing movements efficiently.

I. INTRODUCTION

By the progress of computer networks, many movement learning systems are proposed, developed, and utilized. They are required on many fields such as physical education in the school and training without instructors at home. Since many of movement learning system are based on text contents, it is difficult for learners to learn movements. Especially, implicit knowledge such as form and synchronizing movement is difficult to learn. We developed the movement instruction system for table tennis which is consists of a monitor, cameras, and a PC [1]. USB cameras capture movements of a learner and an instructor. They are overlapped and displayed in the virtual environment as 3 dimensional computer graphics on the monitor. So a learner can learn forms of smashing. However, the system did not support to learn to synchronize movements. It is important for many collaborative movements such as dance, aerobics to synchronize movements with partners.

This paper proposes a collaborative movement instruction system using virtual environment. The system consists of a monitor, USB cameras, and PCs. We implement a virtual studio as 3 dimensional computer graphics in the PC. Avatars of a learner and a partner are displayed in the virtual studio on the monitor. The learner can recognize movements of the learner and the partner. Consequently, the learner can learn to synchronize movements with the partner. Moreover, a mirror is installed in front of the learner and the partner in the virtual studio. The mirror reduces area of learner's blind spots.

Cameras of the system capture learner's movement by using $\forall$-Space Software. $\forall$-Space Software can detect coordinates of arbitrary objects from the color-feature on

the picture that is captured by USB cameras. Therefore, the system can capture movements of learner without special equipments such as optical sensor and magnetic sensor.

We implement a collaborative movement instruction system using virtual environment and evaluate the system by experiments. As a result, we confirm that learners can learn collaborative movements and synchronizing movements efficiently.

The system overview is explained in section II. The procedure of learning movement using the system is explained in section III. The display of movements and mirror images is explained in section IV. Section V describes experiments and the results. And section VI is the conclusions of this paper.
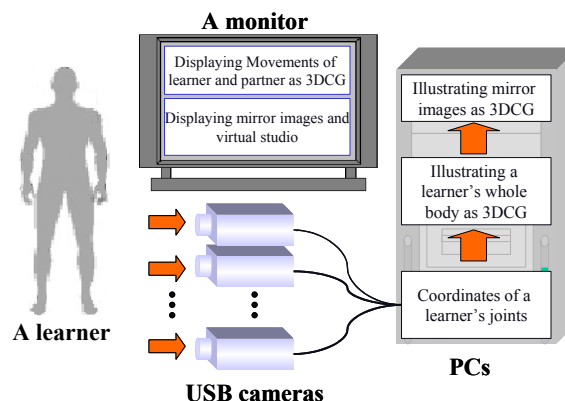

Figure 1. The system overview

II. THE SYSTEM OVERVIEW

The system overview of learning a collaborative movement is illustrated in Figure 1. The system consists of the USB cameras, PCs, and a monitor. We implement a virtual studio as 3 dimensional computer graphics in the PC. Avatars of a learner and a partner are displayed in the virtual studio on the monitor. Moreover, a mirror is installed in front of the learner and the partner in the virtual studio. A learner learns to synchronize movements of the partner by looking avatars of learner and partner on the monitor, and a movement of learner is captured by the USB cameras. The captured picture is sent to $\forall$-Space Software in a PC. $\forall$-Space Software can detect coordinates of arbitrary objects from the color-feature on the picture that is captured by USB cameras. The coordinates of waist, shoulder, elbow, wrist, leg, knee, ankle, and head of the learner are detected from picture by using $\forall$-Space Software in the PC. Therefore, the learner puts markings of different clarified color on these detecting points. The coordinates in PCs

are sent to another PC. Angles of the learner's joints are computed from the coordinates of these detecting points in the PC. By the angles, the learner's avatar in the virtual studio is illustrated as 3DCG in the PC. Moreover, by reversing the angles to the mirror, a mirror image of the learner in the virtual studio are illustrated in the PC. In the same way, the partner's and a mirror image of the partner in the virtual studio is illustrated as 3DCG in the PC by beforehand-detected coordinates. The avatars and the mirror images are displayed on the monitor.

III. PROCEDURE OF LEARNING MOVEMENTS

The procedure of learning collaborative movement using the system is as follows.

1) A learner looks at the sample collaborative movement on the monitor until can understand simply.

2) The leaner performs the collaborative movement, looking movements of the learner and the partner, the mirror images of the leaner and the partner movement. It displayed the leaner and the partner as 3 dimensional computer graphics, the mirror image, and the image of viewpoint from the learner's head on the monitor. By looking these images, the learner learns to synchronize movements. The learner repeats learning a collaborative movement in the virtual studio until the learner can understand sensuously.

3) After the learner learned a collaborative movement, actually performs in the real world with the partner who learned a collaborative movement using this system.

IV.THE DISPLAY OF MUTUAL MOVEMENTS AND MIRROR IMAGES

We can capture colors by using ∀-Space software for capturing learner's movements with USB cameras. Therefore, the system can capture learner's movement without special equipments such as optical sensor and magnetic sensor. ∀-Space software is shown in figure 2. In the figure2 ∀-Space is capturing the hat. ∀-Space software is the software that can detect objective coordinates from the color-feature of the arbitrary objects on the picture that is captured by USB cameras.

The detecting points are illustrated in Figure 3. It is captured the detecting points that are waist, shoulder, elbow, wrist, leg, knee, ankle, and head (A1-A14 of Fig. 3) in this system. Therefore, a learner wears marking of different clarified color on these detecting points.
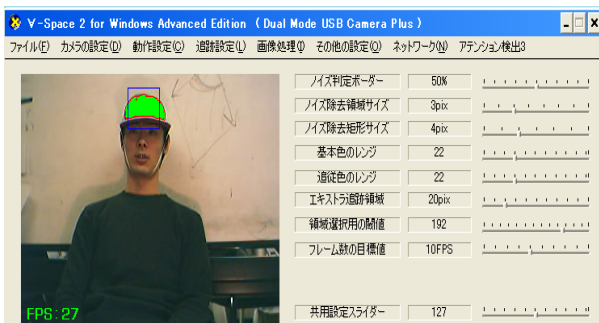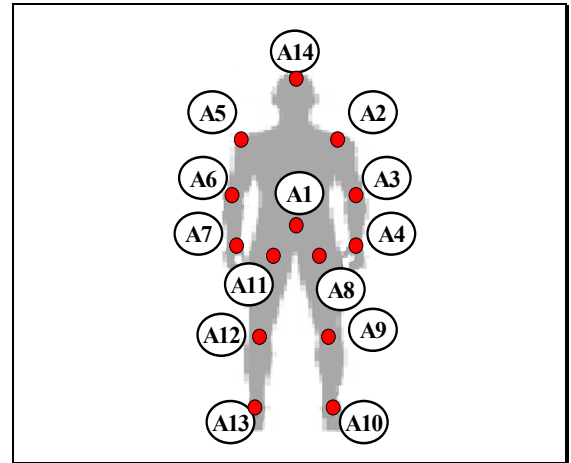

Figure2. ∀-Space software

Figure 3. The detecting points

A. *The cameras position*

The cameras position of the system is illustrated in Figure 4. It is necessary to fully separate the distance of USB cameras from the front, right side, left side with one USB camera to detect the coordinates of learner's joints. If it is not large space, it will become impossible to learn a collaborative movement in the virtual studio. Then, the upper half of the body and the lower half of the body are respectively captured in the system. A learner can perform a collaborative movement in the limited space. Two USB cameras are installed in the front, the right side, and the left side. A camera is installed over learner's head. It is detected a learner's position by using this camera. Seven cameras are installed to detect the coordinates of a learner's head and joints.
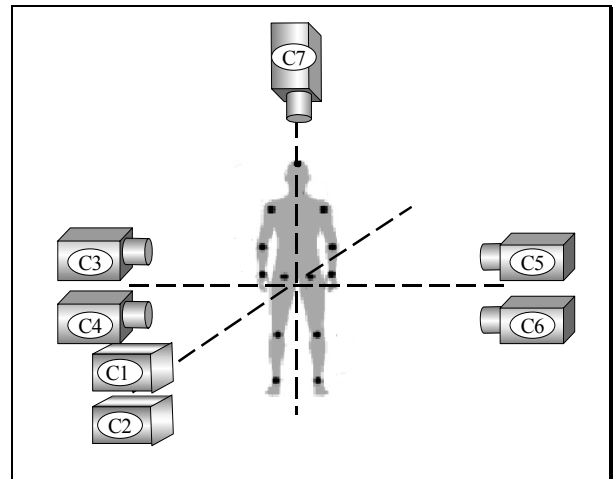

Figure 4. The cameras position

B. *The display of mutual movements*

The method of displaying mutual movement as 3 dimensional computer graphics is as follows. Using USB cameras (C1-C6 of Fig. 4), it is detected the coordinates of the points (A2-A13 of Fig. 3) that are marked by different clarified color.

The vectors of x-y plane (The front body is captured C1 and C2 of Fig. 4) and z-y plane (The right half body is captured C3 and C4 of USB cameras, and the left half the body is captured C5 and C6 of USB cameras) detected from the relative coordinates of portions. These portions are the upper arm, the forearm, upper thigh, and

lower thigh. The angles of vector are respectively detected from these vectors in these portions. It is space vectors by using these angles in these portions. Detecting axis of rotation and rotation angles from space vectors and downward vector that is perpendicular to x-z plane, we can construct movement of each part.

A learner's right upper arm is shown Figure 5. The learner's right shoulder angle is detected from the vector that is computed from relative coordinates (A5, A6 of Fig. 3). The learner's shoulder angle from the front is θ_1, and the learner's shoulder angle from the right side is θ_2. The each component of the spatial vector is as following formula (1).

$$
\begin{aligned}
x &= \sin\theta_1 \\
y &= \cos\theta_1 \\
z &= \frac{\sin\theta_1}{\sin\theta_2}\cos\theta_2
\end{aligned}
\tag{1}
$$

We call this vector A-vector. It is prepared the vector which the component is (0, −1, 0). We call this vector B-vector. In order to construct the learner's right upper arm, it is necessary to compute the axis of rotation and the rotation angle. The axis of rotation is following formula (2) using outer product of A-vector and B-vector.

$$
\mathbf{A} \times \mathbf{B} = (z, 0, -x)
\tag{2}
$$

The rotation angle is following formula (3) using outer product of A-vector and B-vector and using inner product of A-vector and B-vector.

$$
\theta = \tan^{-1}\frac{|\sin\theta|}{\cos\theta}
\tag{3}
$$

This rotation angle is more precise in nearby 0 degrees than the rotation angle that is computed from the inner product of A-vector and B-vector.

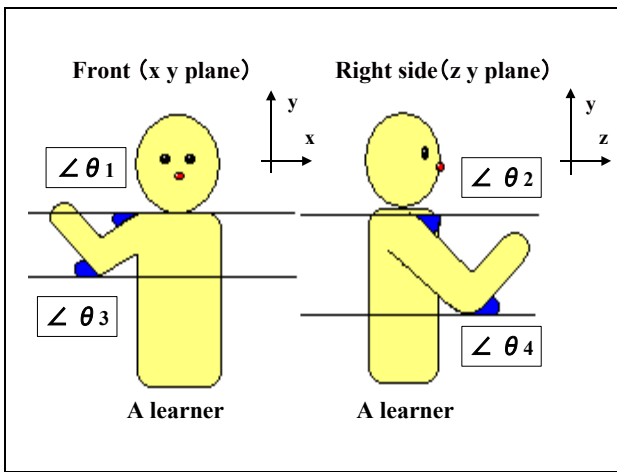We can display mutual movement by combining these constructed parts.

Figure 5. A learner's right upper arm

C. *The learner's position*

The learner's initial position is that a leaner begins learning in the real world. The learner's position (position of the body) in the virtual studio is calculated from the distance of an overhead USB camera (C7 of Fig. 4) using the coordinates on marking of the head (A14 of Fig. 3). The learner's moving distance in the virtual studio is calculated from the distance of an overhead USB camera (C7 of Fig. 4) by using the moving coordinates on marking of the head (A14 of Fig. 3). And the learner's position in the virtual studio is calculated the distance of USB cameras (C2, C4, C6 of Fig. 4) using coordinates on marking of learner's waist (A1 of Fig. 3) when the learner bends the waist.

D. *The mirror images*

The mirror images of a learner and a partner in the virtual studio are shown Figure 6. In order to illustrate mirror images of a learner and a partner in the virtual studio, it is reversed direction of computed vector's z-y plane to z-axis. Moreover, it is installed semitransparent walls. The room is like mirror room.
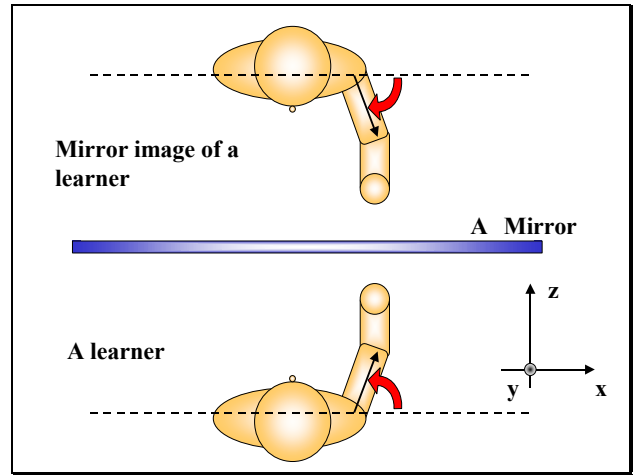

Figure 6. The mirror images

V. EXPERIMENT AND RESULTS

A. *Experiment*

A collaborative movement of the system is stagedrill that is performed simple change of the formation with music. Stagedrill is called the marching that is performed on the stage [2]. Moreover, the movement of the partner who performs collaborative movement and the sample collaborative movement was measured by a unit of 10 times, and detected the average of the coordinate on each point in each time.

Five sets of subjects used the system and learned collaborative movement according to procedure of learning movement.

After the leaner learned the collaborative movement, the questionnaire was carried out, because the impression of learners is important for this system. The questionnaire has five questions.
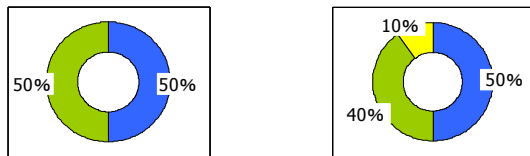1) Could you sensuously understand partner and own position?
2) Could you sensuously understand partner and own movement?
3) Could you learn to synchronize movements?
4) Could you similarly perform collaborative movement in the space after learning in the virtual
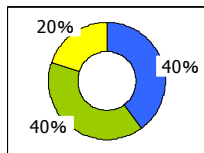
environment?

5) Did using of this system raise the learning conation? Learner answers the questions by number 1 to 5.
   (5: Excellent, 4: Good, 3: Fair, 2: Bad, 1: very Bad)

B. *Experimental results*

The experimental result for this system is shown in Figure 7. As the result of impression, the rate that learners answered "Excellent", and "Good" is 100% of the question 1), and 90% for the question 2), and 80% for the question 3), and 90% for the question 4), and 100% for the question 5). It shows that a collaborative movement instruction system using virtual environment is effective for learning system.

1) Could you sensuously understand partner's and own position?

2) Could you sensuously understand partner's and own movement?

3) Could you learn to synchronize movements ?
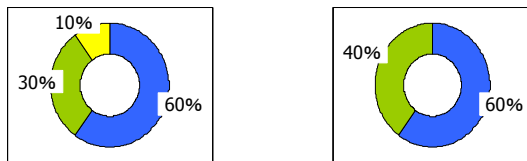
4) Could you similarly perform collaborative movement in the real space after learning in the virtual environment?

5) Did using of this system raise the learning conation?

5pt 4pt 3pt 2pt 1pt

Figure 7. Result of the question

VI.CONCLUSION

This paper proposed the collaborative movement instruction system using virtual environment. The system consists of a monitor, seven USB cameras, and PCs. We implement a virtual studio as 3 dimensional computer graphics in the PC. Avatars of a learner and a partner are displayed in the virtual studio on the monitor. Moreover, a mirror is installed in front of the learner and the partner in the virtual studio. We implement the system and evaluated by experiments. As a result, we confirmed the validity of the improvement in the learning conation.

The system has two problems. First, Seven USB cameras were installed to detect coordinates of a learner's joints in this system. It takes time and effort for learners to install and prepare the USB cameras. Second, a monitor is installed in front of a leaner. In short, the learner cannot learn movements unless the leaner is looking the front. The next challenges of our study are to reduce the number of the USB cameras and to learn with looking any directions by using head-mounted displays (HMD).

REFERENCES

[1] Junichi Hatayama, Hideki Murakoshi, Toru Yamaguchi:"A Movement Instruction System Using Virtual Environment" ISIS 2003, Sep.25-28, 2003, pp70~73

[2] Noboru Kunihisa, "Marching drill teachers' manual " ATN Inc, ISBN4-7549-4329-5 C3073