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A vision-based motion-speed instruction method. Application to motion learning of underarm throw.

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Abstract: When we learn our body motions with the physical exercises such as dances and sports, The learner, by him/herself, shall evaluate the correctness of the imitation in his/her movements. Therefore, we have developed a human-interface for instructing motions instead of instructors. The system was implemented with two functions. The first function is to evaluate the learner's movements. The second function is to correct the learner's motion using visual information. With these two functions, the learner can learn highly skilled motions in sports and dances by oneself. However, when instructing dynamic motions, we have to take into considerations not only postures but also speeds and accelerations. In this paper, aiming at providing a solution for the kind of motion speed instruction tasks, we proposed a vision-based system that is specifically designed for showing motion speed information to learner, and applied to an underarm ball throwing action. That is, while throwing before release, based on the online motion information, i.e., the velocity and position, the system predicts the after-release ball trajectory, and shows the trajectory to the learner in real-time. It is expected that, with the help of the predicted trajectory shown in real-time, the learner becomes to be able to adjust his/her motion in accelerative or declarative ways, and, thus, he/she masters the appropriate motion speed for hitting the reference. As a result of the instruction experiment, the proposed motion instruction system has feasibility as a practical tool for on-line motion speed

1. INTRODUCTION

How do we learn our body motions with the physical exercises such as dances and sports? While visually observing the expert's movements, we repeatedly practice in order to imitate expert's movements. Thus, vision-based motion learning methods, so-called, teach-by-showing, conversely learn-by-observing methods, would be typical ways of learning human boy motions. However, this process contains a fatal flaw in learning quality. It is that the learner, by him/herself, shall evaluate the correctness of the imitation in his/her movements. Even if the learner judged the movements correct, it may be actually incorrect movements. The misunderstanding may falls into a wrong motion acquirement. Thus, instructors who observe and correct the learners' movements are very important for learners to avoid such misleading. Therefore, we have developed a human-interface for instructing motions instead of instructors. The system was implemented with two functions. The first function is to evaluate the learner's movements. The second function is to correct the learner's motion using visual information. With these two functions, the learner can learn highly skilled motions in sports and dances by oneself.

In previous studies, we had developed a motion instructing system that visually teaches static postures using a motion-capturing suit and a head-mounted display. By using this system, we had instructed static poses of yoga [1] and pantomime [2].

However, when instructing dynamic motions, we have to take into considerations not only postures but also speeds and accelerations. For example, to enhance the correctness in ball throw toward a goal position (see Fig.1).Can you predict the trajectory of a ball from this picture? It must be impossible because, for the prediction, we need the ball velocity vector information together with the position at the release time.

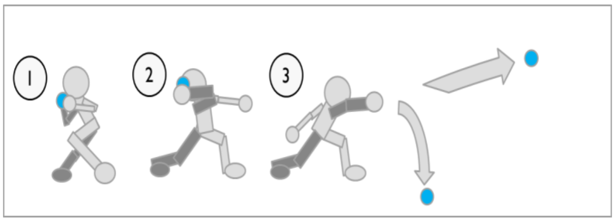


Figure 1 Ball throw toward a goal position

In previous studies, [3] and [4] utilized muscular power representation together with the postures. In this system, learners are assumed to align with the muscular power of reference motions. However, this system has a problem that we cannot perceive and control muscular powers quantitatively. In this sense, the muscular powers are not necessarily an effective way in motion monitoring.

Therefore, we recognized the importance of direct monitoring of the speed information. As for the speed information monitoring, there were various studies .

One of the systems has an off-line learning function that the learner can compare reference speed with his speed after operation [5]. Another system provides the motion correction information to learners so that learners adjust their motion speed either more or less faster in real-time [6]. However, there has not been seen any research on a systems that shows learners the difference of the present speed from the reference one. In this paper, aiming at providing a solution for the kind of motion speed instruction tasks, we proposed a vision-based system that is specifically designed for showing motion speed information to a learner. That is, while throwing before release, based on the online motion information, i.e., the velocity and position, the system predicts the after-release ball trajectory, and shows the trajectory to the learner in real-time. It is expected that, with the help of the predicted trajectory being shown in real-time, the learner becomes to be able to adjust his/her motion in accelerative or declarative ways, and, thus, he/she masters the appropriate motion speed for hitting the goal.

2. PROPOSED METHOD

2.1 Reference motion

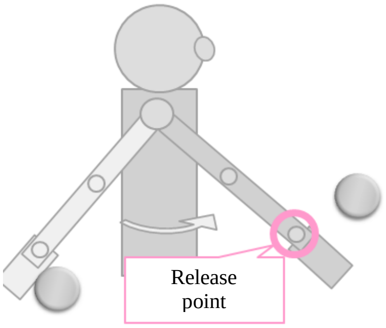


Figure 2 Example of a simple underarm throw motion

In this paper,, a simple underarm throw operation was examined. The underarm throw motion is a 1-DOF shoulder joint inward rotation, i.e., the flexion, where both an elbow and wrist joints were fixed so as not to bend.

2.2 Proposed display systems

Next, we considered the ways of presenting the velocity differential to a learner. We took the following points into considerations.

・The learner can react in real time.
・The learner can perceive the velocity differential.

Then, we thought up the following four presentation methods.

a. Ghost display
b. Speed meter display
c. Color display
d. Trajectory display

For all the display systems, the velocity difference is calculated by the following formulas, and is represented in either a desktop-PC monitor or a HMD by the ways to be described in the followings.

$$v_{e(t)} = v_{l(t)} - v_{r(t)} \quad \cdots\cdots\cdots\cdots(1)$$

v_e : Velocity difference
v_r: Reference velocity
v_l: Learner's velocity
t : Present time ($t = 0$ at the motion start time)

a. Ghost display

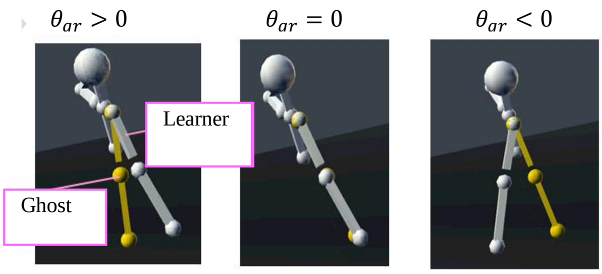


Figure 3 Ghost display system

While the learner's arm graphic being displayed, a ghost arm graphic is additionally displayed in proportion to the velocity difference of a ghost representing the reference motion, from a learner. The displayed ghost's shoulder joint rotation angle, θ_{gr}, is given by

$$\theta_{gr(t+1)} = \theta_{l(t)} - k_g e_{v(t)} \quad \cdots\cdots\cdots\cdots\cdots\cdots(2)$$

θ_{gr} : Ghost's shoulder joint rotation angle (reference)
θ_l : Learner's shoulder joint rotation angle
k_g : Feedback gain for ghost display

The learner can learn a reference velocity by controlling his/her muscles so that the learner's arm graphic may lie on top of a ghost one.

b. Speed meter display

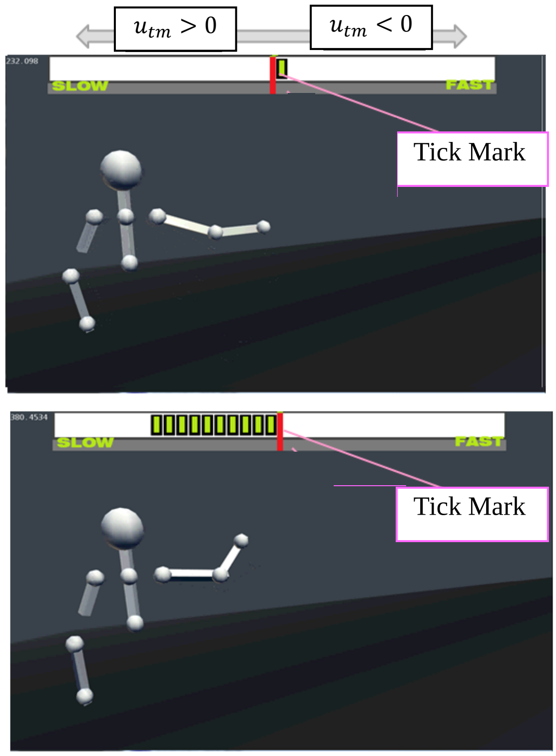


Figure 4 Speed meter display system

In the meter display system, a velocity differential is represented in the quantity of the tick marks. The quantity of the tick marks, u_{tm}, is given by

If the learner's motion is too fast, the tick marks increase to the right, which suggests the learner to move his/her arm more slowly., On the contrary, if, vice versa, the tick marks increase to the left, this system suggests the learner to move his/her arm faster.

c. Color display system

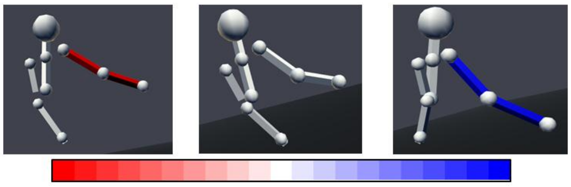


Figure 5 Color display system

The color display system represents the velocity difference by color. If the brightness of the color shows deep, the velocity difference is large. The RGB color intensites, *r*, *g*, *b*, are given by

If $v_{e(t)} > 0$

$$\begin{cases} r_{(t+1)} = 255 \\ g_{(t+1),} b_{(t+1),} = 255 - k_c v_{e(t)} \end{cases} \quad \cdots\cdots\cdots(4)$$

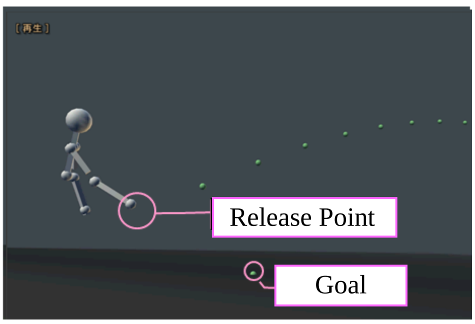
If $v_{e(t)} < 0$

$$\begin{cases} b_{(t+1)} = 255 \\ r_{(t+1),} g_{(t+1),} = 255 - k_c v_{e(t)} \end{cases} \quad \cdots\cdots\cdots(5)$$

k_c : Feedback gain for color dispay
r, g, b : RGB intensity values

If model's arm changes its color to red, this system informs the learner to move his/her arm faster. While, if the model's arm color is blue, this system inform learner to move his/her arm more slowly.

d. Trajectory display system



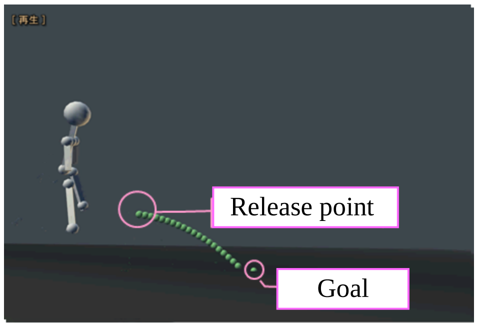


Figure 6 Trajectory display system

While throwing before release, based on the online motion information, i.e., the velocity $v_{l(t)}$ and position $\theta_{l(t)}$, the velocity vector $\vec{v}_{(t_{RP})}$ at the release point t_{RP} is assumed: in this paper, the magnitude of the velocity vector $\vec{v}_{(t_{RP})}$ at the release point t_{RP} is assumed to be identical to the present velocity $v_{l(t)}$, and the throwing direction is assumed to be given as a known unit vector $\vec{n}_{(t_{RP})}$. That is,

$$\vec{v}_{(t_{RP})} = \vec{n}_{(t_{RP})} v_{l(t)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots.\cdots(6)$$

Next, assuming a free-fall motion with the initial velocity $\vec{v}_{(t_{RP})}$, the trajectory display system calculates the after-release ball trajectory and shows the trajectory to the learner in real-time.

It is expected that, with the help of the predicted trajectory shown in real-time. The learner becomes to be able to adjust his/her motion in accelerative or declarative ways, and, thus, he/she masters the appropriate motion speed for hitting the goal.

3. EXPERIMENTS

3.1 Discussing issues

We carried out some psychophysical experiments to evaluate the effectiveness of the proposed display systems. In this experiment, we ask for examinees to answer their subjective rating values with respect to the following issues.

1. Has the presentation been easy to perceive how much your motion velocities are deviated from the reference ones?
2. Have you enjoyed yourself when using the displaying method?
3. Haven't you felt stress?

3.2 Experimental devices

We used a binocular-type 3-D range finder, i.e., XtionPro which was made by Asus Corp (see Fig.7).

Figure 7 Xtion Pro: appearance (left), a captured range image (right)

3.3 Visual presentation program

An example of the visual presentation is shown in Fig.8. In the experiments, the upper-half- body model was employed.

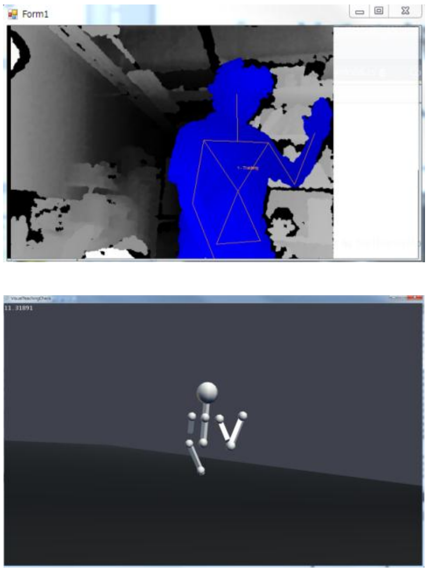


Figure 8 Visual presentation: an extracted human skeleton (top), created CG image based on the extracted human skeleton 3-D information (bottom)

3.4 Experimental result

The comments answered by the subjects with respect to the display systems were as follows.

Ghost display

・The CG images were just shown by the rectangular parallelepiped, and, therefore, I felt unclear in the discrimination of whether ghost model has overlapped or not.

. I felt disturbed in deciding an action of either acceleration or deceleration because the ghost responded to learner's motion too sensitively.

Speed meter display

・I felt disturbed in deciding an action of either acceleration or deceleration because the scale either increased or decreased too frequency.

・I suffered much stress in decreasing the quantity of the tick marks, i.e., in adjusting my arm velocity to the reference one .

Color display

・It was hard to notice the color change.

・I didn't feel much fun in this system because the color representation was too low-keyed.

・I feel tired in my eye when trying to detect the change in color.

Trajectory display

・ It was easy to perceive the appropriateness of my arm-motion speed by observing the predicted after-release trajectory.

・I felt fun in aiming at the goal position while changing trajectory.

As a result, almost all the people approved the trajectory display system among the four display systems. Two reasons are considered for the approval as in the followings. One reason is that the learners were able to learn as if they played a game. The other reason is that the learners were able to know in advance about what is going to happen.

4. CONCLUSIONS

We had thought up four kinds of motion display systems. Next, we had evaluated their performance through some psychophysical experiments, and confirmed that the trajectory display system was best performing among them, and it is considered to have a potential ability to meet our objective.

In the future, we are directed to evaluate the display system in learning under throw motion

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