Positioning a virtual teacher in an MR physical task learning support system

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ABSTRACT

Most of the existing physical tasks learning support systems do not show the task's physical motion in the real world. Because of this, a physical task learning support system showing a 3D virtual teacher model in the real world using mixed reality was developed. Our primary contribution is proving that the virtual teacher model's position and orientation has a direct effect on the learning process where some settings are more comfortable for the learner than others. Two experiments were conducted to find the effect of the virtual teacher's position and orientation. The first experiment used to narrow down the large number of possible positions, while the second experiment conducted to evaluate the positions that resulted from the first experiment and to compare them to the results from previous related research. Our experiments show that the virtual teacher's close side view is the optimal view in such physical tasks learning support system that includes hand moving.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User/Machine Systems—*Human factors*; H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces—*valuation/ methodology, training, help, and documentation*

General Terms

Experimentation, Human Factors.

Keywords

Virtual Reality, Mixed Reality, Physical Tasks Learning, Human Computer Interaction

1. INTRODUCTION

Physical task learning support systems that utilize VR (Virtual Reality) and/or MR (Mixed Reality) technology is actively researched. Using the actual equipment in the real environment in physical task's learning is known to be very effective. Consequently, many researches on supporting physical task's learning in such environment using sensors and VR has been conducted [17] [14].

There is also research on utilizing VR technology for task learning or work support. For example, there are a great amount of research has been conducted on systems for teaching body movements [18] [13] [6] [16] [4]. These systems present a virtual teacher to the learner so the learner can mimic the teacher's physical movements. Other examples are systems that show related information according to the current place in the real world [15] [11]. On the other hand, MR is able to support tasks in the real world, and it is able to realize user interfaces that are more adaptive to user behavior compared to that of VR [3].

Taking this into consideration, using MR is thought to be suitable for supporting physical task learning. Thus we have developed a task learning support system using MR. Our system visualizes a 3D virtual teacher model in the real world that presented in front of the learner. The system also interacts with the learner by tracking his movements. In this paper, we discuss the 3D virtual teacher's positions and orientations and find the best setup that leads to the optimum effective learning in such mixed reality systems.

2. RELATED WORK

2.1 VR-based Task Learning Support

There have been various researches on VR-based skill/task learning support. In the case of the VR-based operation training system by Ohsaki et al., a virtual work environment was built in the virtual space [14]. VR-based dance training system by Nakamura et al. shows a 3D dance example in the virtual world [13]. Sport skill acquisition support system by Honjo et al. shows examples in a head mounted display (HMD) [6]. Full body Tai Chi training environment was built by Chua et al. to improve the physical training task [4].

The virtual world is useful because it can provide a unique environment which might be difficult to realize in the real world. On the other hand, any real world physical objects used have to be built in the virtual world as well, which might be difficult to achieve [3]. MR techniques have been applied to overcome this problem. In the study of the presentation position for a body motion in a VR-based motion learning system, both a teacher model motion and a learner motion were displayed on the same HMD screen [9]. In this condition, it is easier to mimic the motion when more axes between the teacher model body and the learner body are aligned.

2.2 MR-based Task Support

The work support for machine operation and the work support for design in industrial field have been researched using MR. Augmented Reality (AR) Power Plant Maintenance overlays task instruction to the place of maintenance through a HMD [11]. Space Design helps designing 3D objects that are projected on a desktop with a stylus pen [5]. As a collaborative work support between distant places, sharing an object and sharing the manipulations to the object between the places have been researched [2]. In MR-based tasks support, virtual objects and instructions are overlaid in the physical world. Task support using the physical equipment is possible. Gestural learner interfaces are also easy to use [3].

2.3 MR-based Task Learning Support

Different from the MR-based task support, feedback information to the learner is needed in the MR-based task learning support systems [17]. Visualization of a recorded task in MR space is an example of a MR-based task learning support system. This proposes efficient task review by visualizing the manipulation record, position record, and the video of a target object together [12]. However, this is to support reviewing the task, not to support the task itself. This also does not give real time feedback information.

3. VIRTUAL TEACHER'S POSITION SPECIFICATION

In this research, the task's motion is presented by a 3D virtual teacher model displayed in front of the learner in the real world. There are various elements for describing such tasks like posture, position, order, rhythm, consumed time, etc... This research deals with posture, position, and task's order. The task of pushing buttons on a desk in a predetermined order was chosen as the model task. This model task represents a simple and generic physical task.

Appropriate feedback information is important for effective and smooth task learning [17]. In the conventional task learning by a real teacher, the teacher observes the learner and intervenes when the learner makes a mistake. To realize such interactive information feedback to the learner, sensing learning task or their progresses can be seen in VR based learning support systems [17] [14] [13]. This is applicable to the MR-based learning support systems as well. In our research, the task learning and its progress were sensed using motion tracking system. The processed tracked data was used to provide the learner with feedback information. The virtual teacher model was presented according to the learner's motion. This realizes a kind of interactivity in the real world.

The virtual teacher's position and orintation is known to be influential to the task understanding in VR-based systems [5]. Because the virtual teacher model is presented over the real world in the MR condition, its position and orientation are just as important in the VR condition. However, the best position and direction has not been known yet. To investigate the appropriate presentation of a teacher model, the relative position between a learner and the teacher model will be described next.

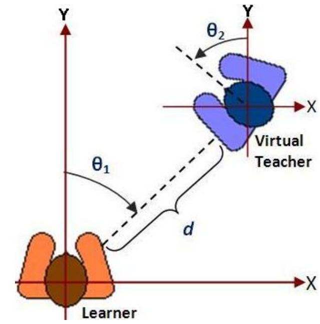

Figure 1: Virtual teacher position model

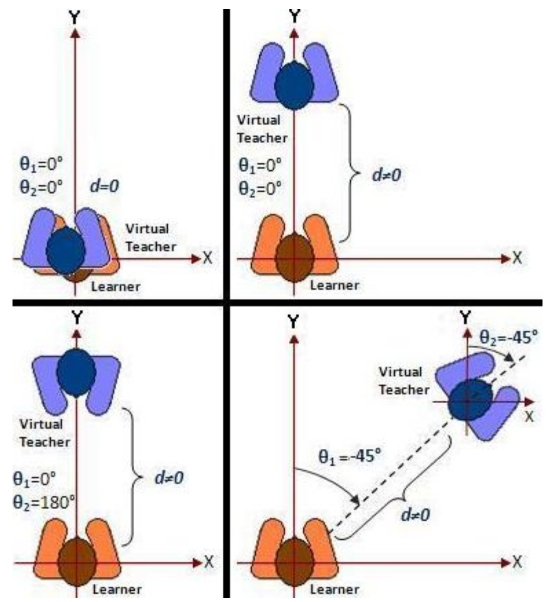

Figure 2: Examples of virtual teacher's positions

Let $\boldsymbol{d}$ be the distance between the virtual teacher model and the learner. Let θ_1 be the angle between the front direction of the learner and the teacher model. Let θ_2 be the orientation angle of the teacher model from the front (**Figure 1**).

In our research, we assumed that the size and height of virtual teacher model presentation will appear to the learner as a normal real person size and same height. Only the upper part of the teacher's view was displayed in order to focus the view on the important parts, which in our experiments are the hands. The relative position between the learner and the virtual teacher model can be expressed by the parameters $\boldsymbol{d}$, θ_1 , θ_2. Knowing that the maximum human's horizontal view angle is about 200^o [10]. From this, $-100^o < \theta_1 < +100^o$ considered the natural constraints. Examples of relative positions of the teacher model are shown in **Figure 2**, where the learner is located at the origin.

4. NARROWING DOWN THE POSSIBLE VIRTUAL TEACHER'S POSITIONS

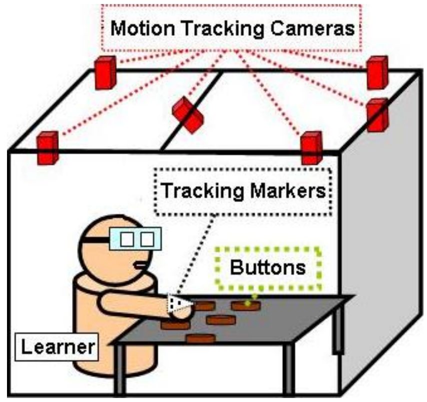

Figure 3: The physical workspace of our MR learning support system

4.1 Objective

The virtual teacher model's position may vary within the mentioned limits ($\boldsymbol{d}$, θ_1, and θ_2). For the learner, the best virtual teacher's position and orientation that leads to the optimum learning is not yet known. Therefore, this preliminary experiment was conducted to narrow down the possible virtual teacher's positions.

4.2 System Design

An MR learning system was built to perform this experiment [7]. The system physical workspace is shown in **Figure 3**. Six NaturalPoint Optitrack^{TM} (FLEX: V100) optical motion tracking cameras are placed above a table. These cameras detect the markers that are placed on the learner's hand. Three markers placed at vertices of a small triangle are used as a hand tracking markers to accurately capture the hand's location and direction. The virtual teacher model is presented to the learner by a head mounted display HMD (VUZIX® iWear VR920). The used HMD resolution is 640x480 pixels. Five buttons of 10cm in diameter and 5cm in height were placed on a table in two rows. The space between the buttons is 12cm and the space between the two rows is 9cm. These buttons represent simple push buttons and they do not contain any sensor or mechanism. Pushing the buttons is a generic example of a physical task. In our system, pushing the correct button will be determined by tracking the learner's hand movement over the buttons.

A motion capture program written in **C#** receives the motion data from the cameras and processes it. This program used to determine which buttons the learner pushed and sends the data to the MR system. The MR system is responsible for managing the motion tasks to be displayed to the learner through a HMD. A **C++** program was developed to render the real scene, which received from the webcam that are placed on the HMD, and the generated 3D virtual teacher. While the virtual teacher performs the tasks, the program receives the user's action data from the motion capture system and decides whether the learner's action was correct or not. **Figure 4** shows the MR system components in detail.

4.3 The Virtual Teacher's Appearance and Motion

In a recent research, The men's decisions were found to be strongly affected by certain appearance aspects of the virtual avatar appearance while women's decisions were not [8]. Another study found that attractiveness (and gender) has an effect on the way that virtual interactions occur on both sides [1]. Therefore, to minimize any effects of the virtual teacher model's appearance on the task performance, a plain cylindrical 3D model was used as shown in **Figure 5**. The experiment teacher task's motion used in the system was built using a sequence of sub-motion units. Each sub-motion unit, which shows the virtual teacher model pushing one of the buttons by his right hand, was prepared in advance by tracking and recording a real person's motion while he performing these actions. This was done to create a realistic and smooth motion. Finally, the sub-motion units were combined in a random sequence to create different tasks. The 3D virtual teacher's model was animated by the free software RokDeBone2.[1]

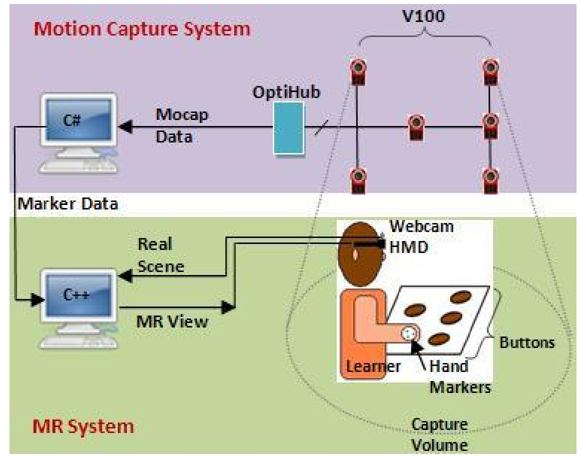

Figure 4: MR system components

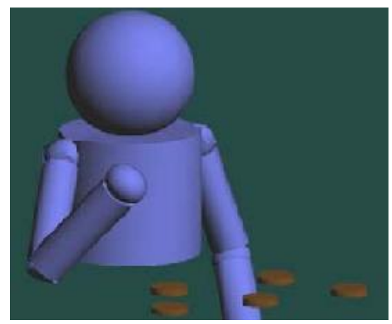

Figure 5: The 3D virtual teacher's appearance

4.4 Procedure

The 3D virtual teacher model performing some hand moving tasks was presented to the learner at various positions through HMD. A total of **120** positions were suggested for the evaluation process, where 3 conditions of $\boldsymbol{d}$ (0m, 1m, 2m), 7 conditions of θ_1 (0^o, $\pm30^o$, $\pm45^o$, $\pm60^o$), and 8 conditions of θ_2 (0^o, $\pm45^o$, $\pm90^o$, $\pm135^o$, 180^o) was considered for this experiment. **Figure 6** shows these positions where the learner is located at the origin. Each position was rated

[1]http://www5d.biglobe.ne.jp/ ochikko/rokdebone.htm

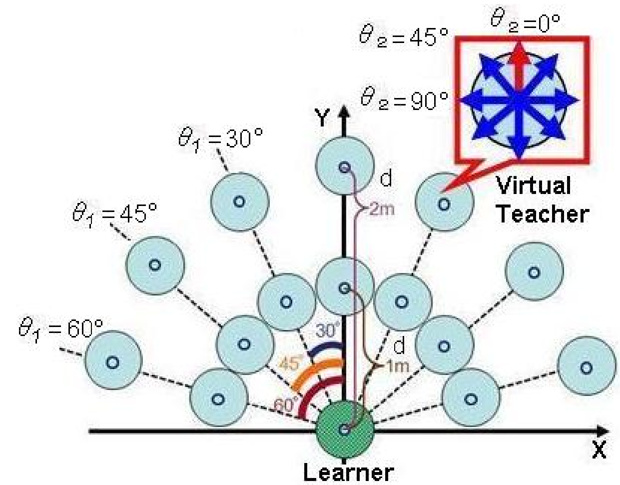

Figure 6: The 120 evaluated positions in the preliminary experiment

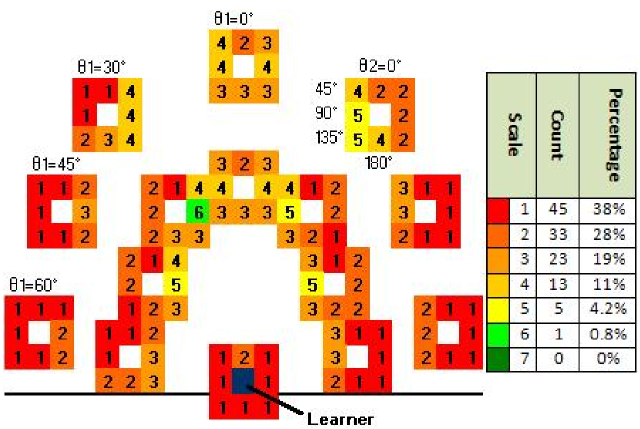

Figure 7: Highly evaluated positions

in a 7-point Likert scale by two evaluators separately. The evaluators were two male graduate students. After watching the task which consisted of 10 sub-motion units for each position, they evaluated the positions based on how comfortable and easy they felt mimicking the task of pushing the buttons. The scale was 1-"very confusing", 2-"confusing", 3-"somehow confusing", 4-"neither", 5-"somehow clear" 6-"clear", and 7-"very clear". After the evaluation process is completed, the average was calculated and the highly evaluated positions were decided.

4.5 Result

The positions' average evaluation distribution is shown in **Figure 7**. The positions that were rated 4 or more out of 7 are shown in **Figure 8**. As for the distance $\boldsymbol{d}$, half of the highly evaluated positions were close to the learner (9 positions out of 19). As for the teacher's direction angle θ_1, many of the highly evaluated positions were in front of the learner, but not exactly front (5 positions at 0^o, 11 positions at $\pm30^o$, 3 positions at $\pm45^o$). As for the virtual teacher's orientation angle θ_2, the side view of the 3D teacher model is seems to be preferred (6 positions at $\pm45^o$, 10 positions at $\pm90^o$, 2 positions at $\pm135^o$, 1 position at 180^o).

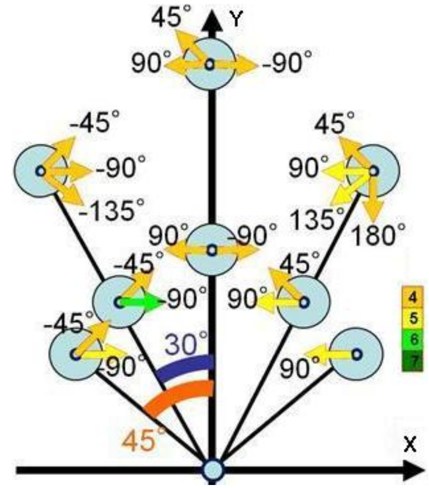

Figure 8: Highly evaluated positions

Figure 9: Learner's view

5. FINDING THE OPTIMUM VIRTUAL TEACHER'S POSITION

5.1 Objective

The objective of this experiment is to investigate the optimum virtual teacher model's position that yields the highest learning performance in a mixed learning environment. The selected virtual teacher's positions in this experiment are based on the one determined from the previous narrowing down experiment plus some positions resulted from previous VR studies.

5.2 Use Scenario

Before the system starts, the learner wears a HMD and puts the markers on his/her hand. When the system starts, it displays the 3D virtual teacher model overlaid the physical space as shown in **Figure 9**. The teacher model demonstrates the task's physical motion. The learner will learn by mimicking the teacher's motion. The system has the ability to recognize whether the learner's motion is correct or not by tracking the learner's hand position using motion tracking cameras and comparing the hand location to the buttons' location. If the learner's motion is correct, the system carries out the next task's unit. If the learner's motion is incorrect, the system re-presents the same task's unit again. The system architecture is shown in **Figure 10**.

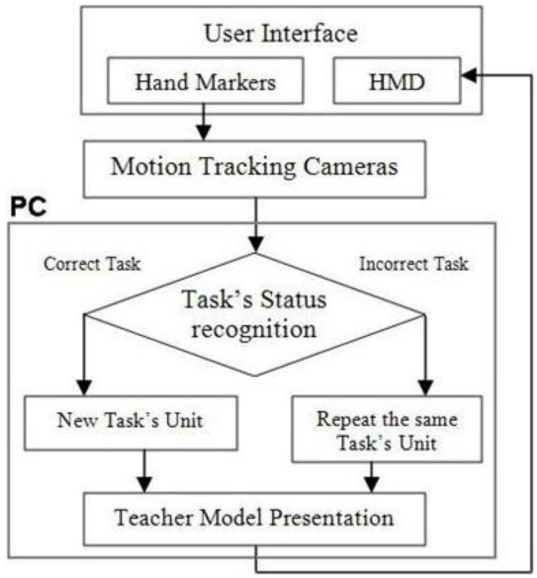

Figure 10: System architecture

5.3 Procedure

In this experiment the learners were asked to finish the task of correctly mimicking the 3D virtual teacher model's motion as fast as possible. The teacher model was displayed at each candidate position in one condition. The participants in this experiment were comprised of 10 graduate students, 4 females and 6 males. Because the participants used this system for the first time, it was expected that the participants would get accustomed to the system after a while. To avoid this effect, a practice session(s) of mimicking a task motion using the system was conducted first. The order of the conditions was also randomized for each participant in the experiment. The participants took a rest for 15 seconds between the conditions. The error rate and the task's completion time were measured for each of the conditions.

5.4 Virtual Teacher Positions

The highly evaluated positions resulted from the narrowing down experiment were considered and reduced to 8 conditions by combining some locations -conditions 1 to 8- (**Figure 11**). Conditions 1 (d=1m, θ_1=45^o, θ_2=−60^o), 2 (d=1m, θ_1=−45^o, θ_2=60^o), 3 (d=1m, θ_1=30^o, θ_2=−60^o), and 4 (d=1m, θ_1=−30^o, θ_2=60^o) were selected to investigate the effect of changing the position. Conditions 5 (d=2m, θ_1=30^o, θ_2=−60^o) and 6 (d=2m, θ_1=−30^o, θ_2=60^o) were selected to investigate the effect of the distance. Conditions 7 (d=1m, θ_1=0^o, θ_2=90^o) and 8 (d=1m, θ_1=0^o, θ_2=−90^o) were selected to study the effect of teaching from the side view. For comparison purposes; conditions 9 (d=1m, θ_1=0^o, θ_2=0^o), 10 (d=1m, θ_1=0^o, θ_2=180^o), and 11 (d=0m, θ_1=0^o, θ_2=0^o) were considered as a result of a previous related research; they were positively evaluated in VR environment [9].

5.5 Result

In this experiment, the error rate for pushing buttons for all the conditions is shown in **Figure 12**. By calculating Scheffe's multiple comparison test we found that the error occurred in condition 9 was significantly different from the other conditions. In condition 9, looking at the back of

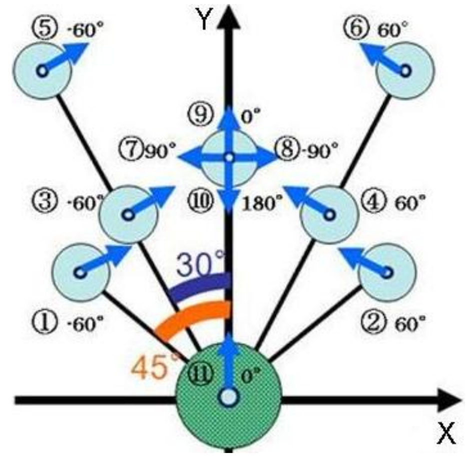

Figure 11: Eleven evaluated conditions in the experiment

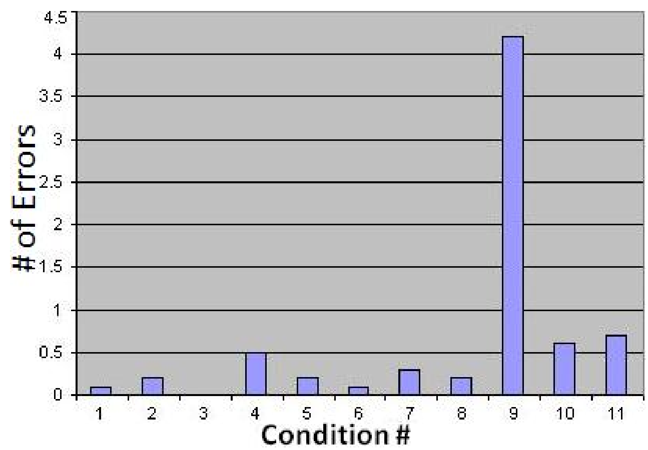

Figure 12: Errors by conditions

the teacher model did increase the error rate significantly because in this case, the hand motion was partially or completely hidden. The resulted data also proves that looking at the teacher's model from the side did minimize the error (conditions 1-8). On the other hand, condition 3 scored less error results comparing to condition 4 even though both represents a side view but from opposite angle. This because the experiment task's motion was recorded using the teacher's right hand only, where the hand's motion view was clearer for condition 3comparing to condition 4.

The task's completion time per condition is shown in **Figure 13**. By calculating Scheffe's multiple comparison test we found that the completion time consumed in condition 9 was significantly different from the conditions 3, 4, and 8. Looking at the back of the virtual teacher model also significantly increased the task's completion time. The conditions 3, 4, 7, and 8, that scored the shorter completion times, were the virtual teacher placed in front of the learner, were closer to the learner, and where the side-view of the teacher model made it so the hand motion's were easily recognized.

6. CONCLUSION

Our primary contribution in this paper is the investiga-

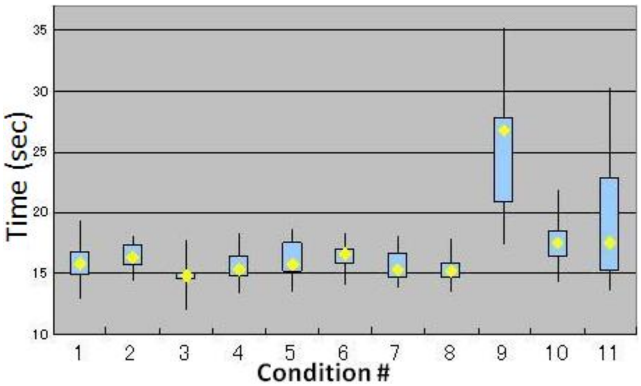

Figure 13: Task completion time by conditions

tion of the optimum virtual teacher's position and rotation that leads to the best learning outcome when mimicking the virtual teacher's motion in such an MR environment. The investigation process was done in two experiments. The first preliminary experiment was conducted to narrow down the possible 3D virtual teacher's positions. Depending on the preliminary experiment's result, the second experiment was conducted to find the optimum virtual teacher model's position that gives the highest learning performance. In order to do so, a physical task learning system that uses interactive MR virtual teacher was implemented. The system provides instruction in the real world which is different from that of VR-based systems. This system is expected to expand the domain of physical tasks to be learned because the learner can be located in front of the target physical objects when learning. The proposed system also provides real time interactive support of a physical task by tracking the learner's motion and giving him back feedback regarding the accuracy of the motions he mimicked. The experiments' results show that the 3D virtual teacher's close side view is the optimal view in such physical tasks learning support systems that includes hand moving.

7. ACKNOWLEDGMENTS

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