Hand-Raising Robot for Promoting Active Participation in Classrooms

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Abstract. In Japanese school classrooms, it is important to promote hand-raising, because this motion reflects active participation in the classroom. In this study, a hand-raising robot is proposed. A prototype of the robot was developed based on typical hand-raising motions, which were measured in a separate experiment. In addition, experiments were conducted and the results suggest that fast, straight, and high hand-raising is the most favorable, and that the robot with the hand-raising is effective for promoting active participation in classrooms and enhancing student enjoyment when answering questions.

Keywords: Embodied interaction · Hand-raising · Motion analysis · Classroom

1 Introduction

In typical Japanese school classrooms, the teacher will lecture by standing at front of a room. Students listen while sitting at their desks. Hand-raising is a kind of arm motion, which is used by a student as a way to communicate intent to teachers or other students in such classrooms.

Hand-raising is very important [1, 2] because the motion reflects active participation in classrooms [3], and bodily motions are essential for interactional elements in communication [4]. Nevertheless, some students hesitate to raise their hands [5], and there are very few studies suggesting methods to help encourage students to raise their hands. In this study, a robot that imitates human hand-raising to promote active classroom participation was developed and evaluated through experiments.

2 Concept of the Hand-Raising Robot

The hand-raising robot's structure and appearance is designed to simulate a human arm and hand. It rests on students' desks, and can raise its "hand" in the same way a human does [6]. Figure 1 shows the concept behind promoting active student participation in the classroom. The robot raises its hand when students activate it.

Using the hand-raising agent makes it easy for hesitant students to indicate their intention in class. In addition, the robot provides a good example to students of the

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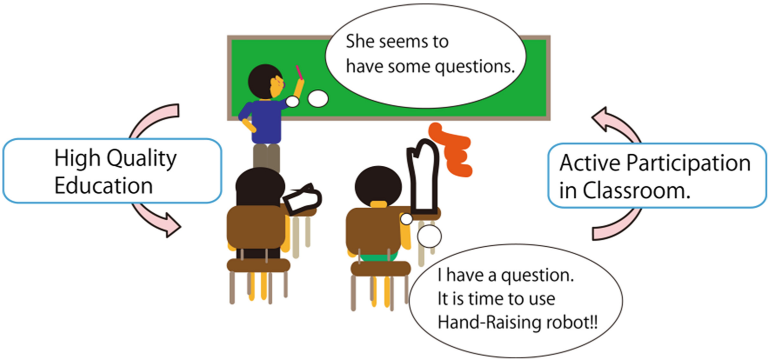

Fig. 1. Concept for promoting active participation in the classroom

proper way to raise one's hand and for how to actively participate in classroom activities.

3 Measuring Student Hand-Raising

3.1 Purpose and Method of the Measurement

To determine the robot's motion, the authors attempted to simulate the motion of real students. Nevertheless, studies with such measurements could not be found. Therefore, the authors conducted an experiment to measure this motion.

The experimental environment was a room that imitates a classroom, with a large screen at the front. Figure 2 shows an example of the measurement scene. A mock classroom was visible to participants on the screen, along with some general-knowledge questions. Participants were asked to sit and answer questions after raising their hand. The participants were university students between 18 and 25 years old (16 males and 16 females). The experiment was recorded by a video camera (SONY HVR-A1 J) and a motion-capture system (VICON MX) at 100 Hz.

3.2 Cluster Analysis of the Hand-Raising Motion

Some patterns of the motion were found in the results of the measurement. A ward-method cluster analysis was conducted in order to classify the motions. From observing the participants raise their hands, three values were chosen as parameters, as seen in Fig. 3. The speed was estimated by moving the distance of the fingertip marker in ten frames. The angle represents the maximum angle of the elbow, and it was estimated by the position of the upper-arm marker and the lower arm marker. The height refers to the ratio of the height of the fingertip marker in each trial to the highest point for each participant.

Six clusters were extracted. A dendrogram and examples of the motion are shown in Fig. 4. Table 1 shows the parameter samples for each cluster. Cluster A is

Fig. 2. An example of measuring hand-raising

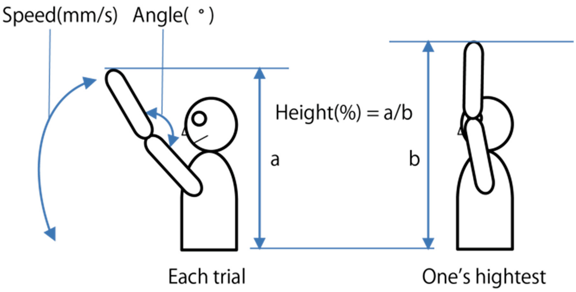

Fig. 3. Parameters for analyzing hand-raising motions

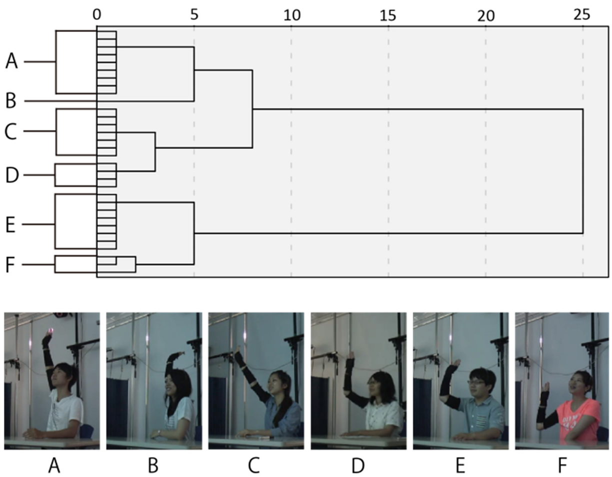

Fig. 4. Classification of hand-raising motions and examples of each cluster

Table 1. Parameter examples of each cluster

Cluster	Height (%)	Speed (mm/s)	Angle (°)
A	90.6	2796.0	174.3
B	92.3	4710.9	162.5
C	79.2	2347.3	171.1
D	75.0	1776.0	114.4
E	70.0	2234.9	110.0
F	47.3	2452.2	51.6

comparatively high, with the second-fastest hand-raising. The angle of the elbow in this cluster is straight. Cluster B is the highest and fastest hand-raising. The angle of the elbow in this cluster is also straight. Cluster C has straight elbows, and medium speed and height. Clusters E and F are flexed hand-raising. Cluster D contains diverse motions, making this cluster difficult to interpret.

These clusters can be regarded as typical examples of the hand-raising motion of Japanese students. From each motion, the authors received different impressions. Authentic motion from the hand-raising robot is desirable to foster a positive image for others. Therefore, the authors decided to use the motion from all clusters with the exception of cluster D, as candidates for the motion of the hand-raising robot. These candidates were compared and evaluated in an experiment described below. Finally, the motion was chosen from this experiment, and implemented in the hand-raising robot.

4 Development of the Hand-Raising Robot

A prototype for the hand-raising robot was developed. The robot was implemented with the concept of hand-raising and the five clusters of hand-raising motion. Figure 5 shows an overview of the hand-raising robot and its control system, and Table 2 shows the size, and provides detailed specifications. The shape of the robot is an imitation of a human arm, with three degree of freedom (3DOF). The robot has three servomotors as drive parts for joints in the shoulder, elbow, and wrist that can rotate in a vertical

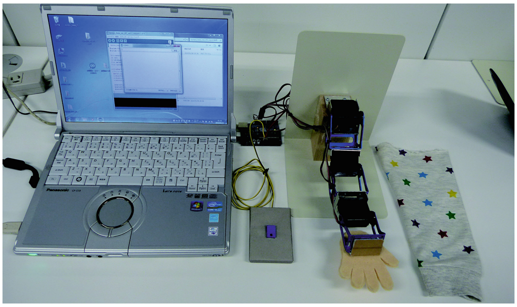

Fig. 5. Overview of hand-raising robot prototype and its control system

Table 2. Size and elements of the hand-raising robot

Size	Width65 × height 122 × depth 280(mm)
Servo motor	VS-S092×J
Control board	Arduino UNO SMD R3
Power	DC 5 V
PC	panasonic CF = S10

direction. The actual size of the robot is approximately half that of an adult human arm. It was designed to be smaller in order to set it on top of a desk in a classroom. In addition, Arduino is used to control the robot's motion, and servomotors can be operated with software or with a physical button connected to the robot.

5 Impression Comparison Experiment for the Robot's Hand-Raising Motion

5.1 Purpose and Method of Comparison

An experiment was conducted to determine what type of motion is most impressive and suitable for the hand-raising robot.

Five arm motions were implemented in the robot, based on Clusters A, B, C, E, and F, extracted from the results of the measurements described above. Figure 6 shows an example of the robotic motion. The elbow angle, speed, and the positions of the fingertips were adjusted to correspond with human motion.

In addition to that, a 2DOF-version and a 1DOF-version of the motion were also implemented in the robot, if an equivalent impression is made with fewer degrees of freedom, it would be better to develop a more simplified robot. Figure 7 shows the 2DOF-version of the motion, using only the elbow and shoulder joint, and a 1DOF-version, with only the shoulder. Frontal views of the alternate versions were adjusted to coincide with the 3DOF version.

Finally, 15 motions were implemented in the robot, and these were evaluated by the participants in the experiment using a paired-comparison method. There were 10 participants (8 males and 2 females), and they were 21-25 years old. Each pair of motions with the same DOF were shown to the participants, and they were asked to choose the more impressive motion.

5.2 Comparison of Impressions with the Same DOF

The results of the paired comparison were analyzed, and summarized using the Bradly-Terry model, which represents the "preference" of each motion in a paired comparison based on the number of wins [7]. Figure 8 shows the Bradley-Terry model scores for the motions. The greater its score, the more impressive the motion was. Regardless of the DOF, a straight hand-raising motion (A, B, and C) made a better impression than flexed motions (E and F). In particular, the most impressive motion was from Cluster B

Fig. 6. Hand-raising motions from the pattern clusters

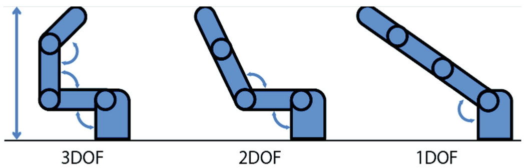

Fig. 7. Examples of motions with 3DOF, 2DOF, and 1DOF

in all DOFs. These results suggest that raising the hand high and quickly, and with a straightened elbow, is the most favorable.

In addition, the impressions of hand-raising were compared between different DOF in a separate experiment. The most impressive motion was always Cluster B, regardless of the DOF. More details for this experiment will be described in the presentation owing to limitations in space.

6 Evaluating the Hand-Raising Robot

6.1 Purpose and Method of Evaluation

An evaluation of the hand-raising robot was conducted. The purpose of the experiment was to confirm that the robot can, in fact, make it easier for students to raise their hands.

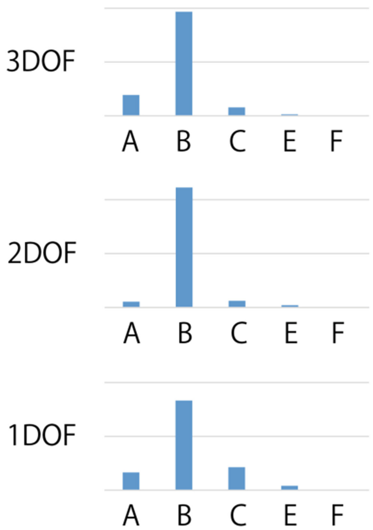

Fig. 8. Bradley-Terry model score for each motion

A situation where participants raised their own hand was compared with and one where they used the robot. 20 participants (10 males and 10 females) took part in the experiment; they were 18-23 years old.

Figure 9 shows the experimental environment and configuration. In the experiment, a participant sits at a desk upon which the robot is set. The robot was ultimately designed with the 3DOF version and motion implemented from Cluster B, because this was the most impressive motion in all DOFs. The robot was set to the right of the participant. An experimental scene is shown in Fig. 10.

The classroom scene and general-knowledge questions were displayed on the screen at the front. Participants answered questions after raising their hand, either manually or with the robot. Participants then answered a seven-scale questionnaire to evaluate hand-raising, after answering six general-knowledge questions. After answering the questions, they answered a six-item questionnaire concerning their

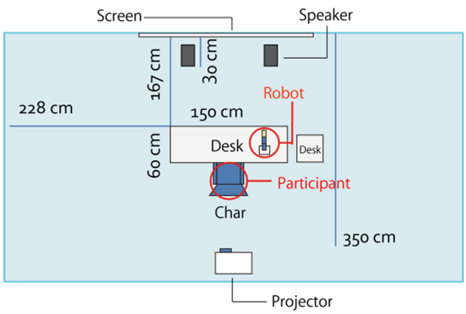

Fig. 9. Experimental environment

Fig. 10. Examples of manual hand-raising and robotic hand-raising

impressions with regard to the robot. Moreover, free descriptions of their thoughts were also gathered.

6.2 Results and Discussion

The results from the seven-scale questionnaire are shown in Fig. 11. A Wilcoxon signed-rank test was conducted in order to reveal differences between manual hand-raising and hand-raising using the robot, and these results are also shown in Fig. 11. Item 2 ("It was easy to raise my/the hand.") and Item 4 ("I felt there was an atmosphere of hand-raising.") show considerable differences at a significance level of 1 %. Item 3 ("I felt like raising my/the hand.") is even more different, at a significance level of 5 %. The hand-raising robot performed better for each item, with the exception of Item 1. These results indicate that the robot encourages hand-raising, and promotes active question answering.

The results from the six-item questionnaire about the participant's impressions of the robot are shown in Table 3. Approximately 80 % of the participants answered "yes" to Items 2, 3, and 6. This reveals that they felt positively toward the robot. In particular,

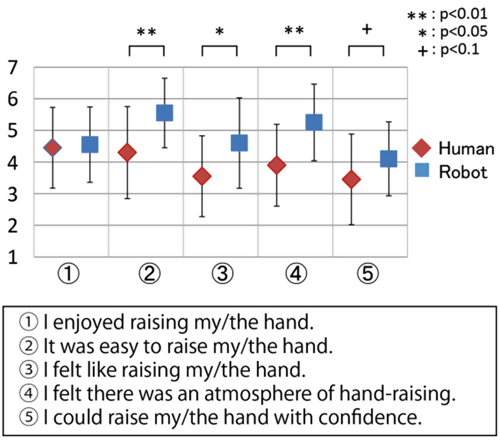

Fig. 11. Results of a seven-scale questionnaire to evaluate manual and robotic hand-raising

Table 3. Results of six-item questionnaire about impression of the robot

Item	Yes	No
1. I was happy that the robot was set on my desk	12	8
2. I enjoyed the classroom lecture	15	4
3. I enjoyed the answering questions	14	6
4. I felt that the robot was another me	6	14
5. I wanted to raise my hand alongside the robot	4	16
6. I felt affection toward the robot	16	4

Item 3 suggests that the robot enhanced their enjoyment in answering questions. This effect was supported by some of the responses provided in the free description.

However, approximately 80 % of the participants answered “no” to Items 4 and 5. Thus, the hand-raising robot was not regarded as an extension of the self. This is believed to be because the robot is a non-autonomous system that responds only to the user’s operation. Consequently, it was regarded as a tool, rather than a robot.

7 Conclusion

In this study, a hand-raising robot was proposed, and a prototype of the robot was developed based on typical hand-raising motions that were measured in an experiment. According to the experiment, hand-raising that is fast, straight, and high is the most favorable, and this was used in designing the robot’s motion. The consequences of this finding should not be limited to this prototype. It can be applied to any robot with arms.

In addition, an evaluation revealed that the robot is effective in promoting active participation in classrooms, while enhancing students’ enjoyment in answering questions. Hand-raising was studied observationally. Therefore, this study is especially significant to the promotion of hand-raising in an academic setting.

This study revealed the effect of a single robot used by only one person. However, a classroom is a complex communicative environment, with several students and teachers. Thus, in future research, the authors plan to investigate the effectiveness of the hand-raising robot in an environment with many users.

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