

Educational System with the Android Robot SAYA and Field Trial

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Abstract— Communication robots are hard to interact with humans autonomously in everyday environment due to lack of intelligence even though robots can perform certainly only in limited environments and limited situations. However, since intelligence of robots is handled by an operator, tele-operated robots are useful to investigate functions required for robots and effects of robots in real-environment. This paper proposes an educational system with a tele-operated android robot that has human-like appearance. The developed android robot, named SAYA, is able to express human-like facial expressions and performs some communicative functions with its head and eye movements, and it is utilized as a roll of a teacher in the proposed educational system. In addition, SAYA's utterances and behaviors are controlled remotely by an operator so that it is able to not only conduct the class but also interact with students. A field trial was carried out at an elementary school, and SAYA conducted the class concerning the principle of leverage as a topic of science classes while interacting with students. Also, how it affected students' interest and motivation was investigated. As results, the trial verified that some students became interested in science class more than before the trial, and its positive effects in educational field, especially elementary schools, were verified.

Keywords—android robot; remote class system; educational robot; field trial; human-robot interaction

I. INTRODUCTION

In the last decade, various kinds of robots which offer services in daily environment through interactions with humans have been developed and studied. In the near future, robots are expected to be able to offer not only physical supports but also informative and emotional supports. For that purpose, it is very interesting to investigate what kinds of functions, mechanisms, and intelligence are required for robots, and investigate how robots should interact with human in daily environment. Thus, many kinds of communication robots have been developed and applied to not only laboratories but also our daily lives [1]-[6]. For example, the pet-type robot, named AIBO [1], was commercialized around ten years ago, and it can act in our living space. A seal type robot was also developed as a mental therapy robot and its effectiveness for elderly people was verified by being utilized in nursing-care facilities [2]. These kinds of animal-type robots interact with humans emotionally by performing endearing movements. On the other hand, humanoid robots have been developed, which have

human-like properties such as a head and arms to express more human-like behaviors. Thus, in humanoid-type robot researches, they utilize bodily movements such as gestures, nodding, eye-orientation, and facial expressions as non-verbal behaviors to interact with humans naturally [3]-[7]. For example, Robovie [3]-[5] interacts with humans and offers informative services by utilizing its human-like physical structure, and it was actually used at real-environment such as a train station, a museum, and an elementary school. However since intelligence technologies for robots are still impractical, robots cannot interact with human autonomously even though they can perform effectively in limited environments or limited situations. On the other hand, it is expected that tele-operated robots are applicative as an interface of telecommunication system rather than autonomous robots because their intelligence is handled by human operator. That is, in tele-operated robot, an operator enables a robot to interact with human by controlling robot's behaviors and utterances remotely without advanced intelligence technologies.

In this paper, a remote class support system is proposed as a one of applications of telecommunication system in which a robot is used as an interface. Especially, android type communication robot SAYA [8][9] which has human-like appearance is utilized in the proposed system, and it can interact with humans with human-like body movements such as facial expressions, head movements, and eye-orientation. Actually, Sakamoto et al. [10] verified effectiveness of the tele-operated android robot on conveying presence of a human who was in different place rather than existing media such as a speaker or a video-conference system. To investigate its effectiveness for children in elementary schools is also interesting, because children were interested in learning with a robot and they were motivated to learn a foreign language as shown in previous research [5] in which the robot interacted with children by speaking only English. Hence, the remote class support system with the android robot SAYA is also expected to contribute to children's motivation to learn. Thus, a science class is conducted for children at an elementary school with the proposed system to investigate its effectiveness on children's interest and motivation through this trial.

The structure of this paper is as follows. In Section 2, the android robot SAYA and its communicative functions are introduced. Section 3 describes the system structure of the

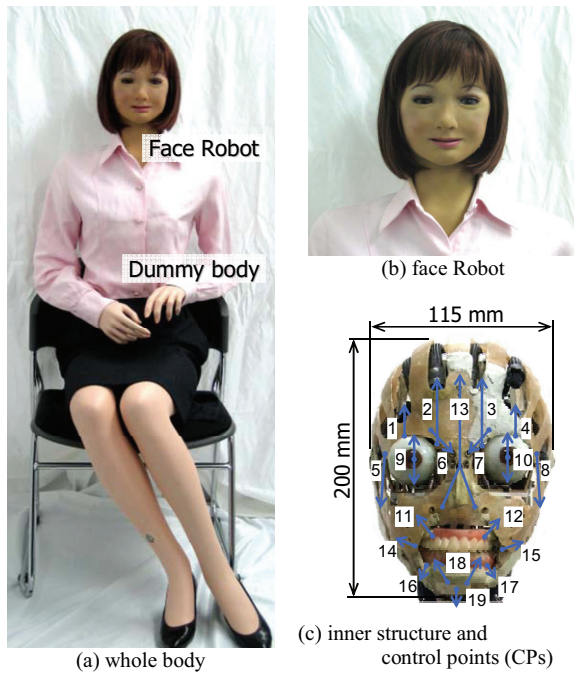


Figure 1. Android Robot SAYA

remote class support system with SAYA and the detailed content of the class. In section 4, detailed procedure of a field trial and its results are presented. In final section 5, the contributions of this research are discussed, and this paper is concluded.

II. ANDROID ROBOT SAYA

Fig. 1 shows SAYA which has been developed as one of android-type communication robots. The face robot [9][11] is mounted on a dummy body and it is highly realistic appearance. SAYA is also used as an interface of receptionist system at a university [8], which equips a speech dialogue function and some non-verbal communicative functions such as facial expressions, head movements, and eye-orientation.

A. Facial Expressions with the Face Robot

In human face-to-face communication, facial expressions are said to play a very important role as one of non-verbal communication [12]. Facial expressions are expected to contribute to realize smooth communication between humans and robots. Therefore highly realistic face robots that resembles to human-like face have been developed, and it can express facial expressions [9][11]. Almost all related studies of producing facial expressions are based on “action unit” that is defined in FACS (Facial Action Coding System) [13]. Action units express motions of mimic muscles as 44 kinds of basic motions, and there are 14 action units to express 6 typical facial expressions. Referring to these studies, 19 control points and their directions on the face robot are modeled as shown in Fig. 1(c). By combining movements of control points, various facial expressions are realized with the face robot. Fig. 2 shows examples of 6 typical facial expressions of the face robot, and the face robot succeeded in achieving high correct recognition rate of these facial expressions in previous study [9].



Figure 2. Examples of SAYA's facial expressions

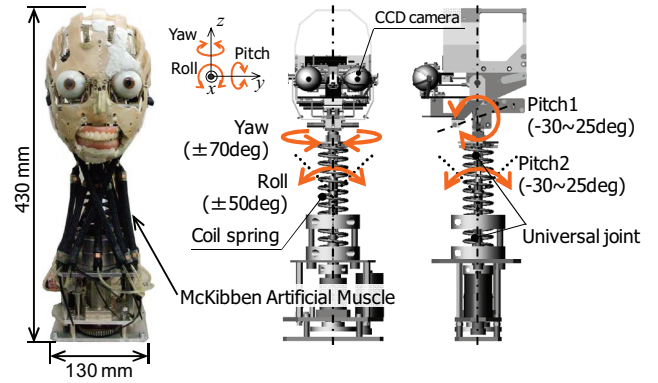


Figure 3. Mechanical structure of SAYA

In the face robot, McKibben artificial muscles are utilized to actuate control points. Since it is small, lightweight and flexible, it can be distributed to curved surfaces of the skull like human muscles.

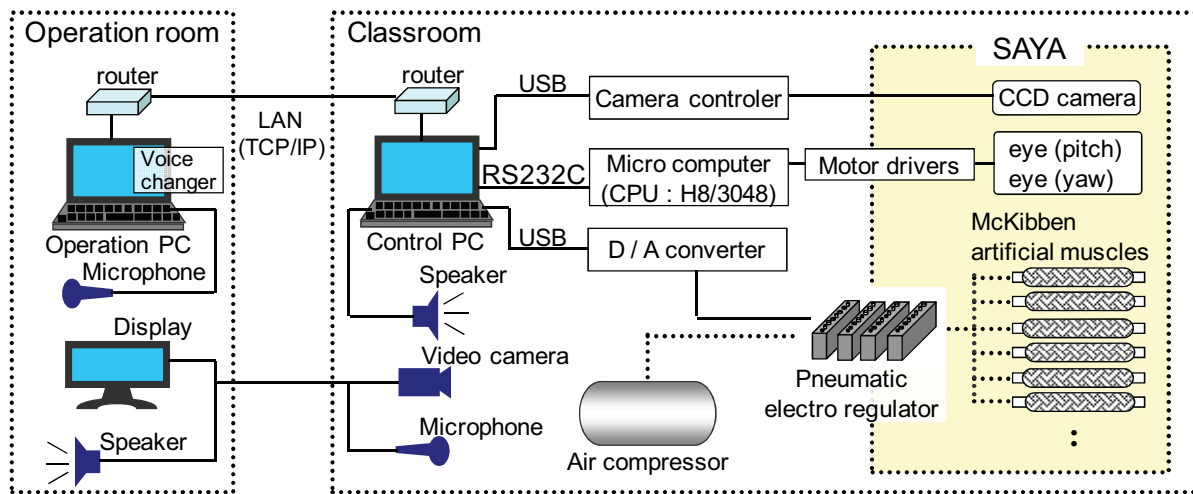
The facial skin is formed with soft urethane resin to mimic the texture of human facial skin.

B. Eye and Head Movements

Figs. 1(b) and 3 show the internal structure of the face robot. There are 2 DOF for eye movements. Two eyeballs are linked mutually and two DC motors move both pitch and yaw rotations of eyeballs. In addition, a small CCD camera is mounted to the inside of an eyeball to obtain images of SAYA's view point. The eye orientation is also able to be controlled by extracting human skin color region from image of the CCD camera so that the face robot can track a human.

There are 4 DOF for head movements. In order to mimic flexible neck movements of a human cervical spine, we utilize a coil spring in the neck part. Furthermore, the center of rotations for pitch rotation (“Pitch1”) and yaw rotation are set in the base of the head part. The forward and backward motions are realized by combining the head rotation (“Pitch1”) and the neck bending (“Pitch2”). The roll-rotation, both pitch-rotations (“Pitch1” and “Pitch2”) and the yaw-rotation are also actuated by McKibben artificial muscles as shown in Fig. 3.

We use electro-pneumatic regulators for controlling contraction of McKibben artificial muscle.



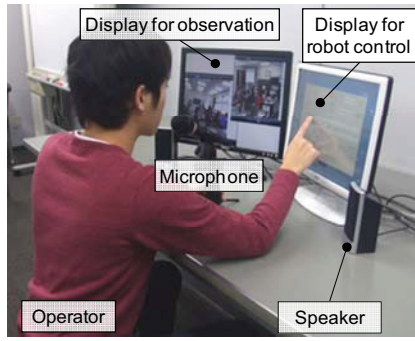


Figure 6. Operation room

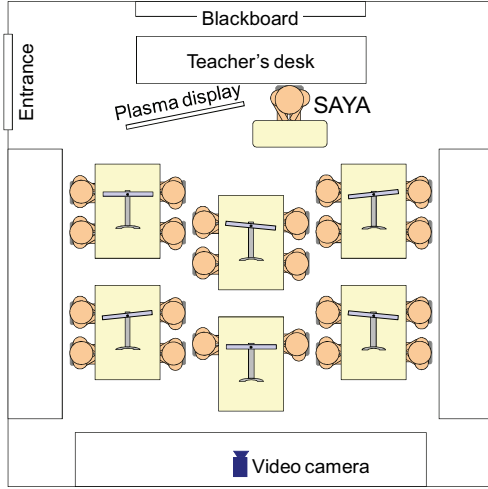


Figure 7. Experimental environment

part (a), there are some icons to change teaching materials that are displayed to a screen or a display. In part (b), lines that the operator should say are displayed in the text boxes. In part (c), there are many icons that are corresponding to robot's behaviors such as facial expressions, eye and head movements. An operator can easily control the robot by clicking these icons with a mouse or a touch panel as shown in Fig. 6.

D. Content of Science Class

The principle of leverage is adopted as a topic of the science class for elementary school students. This topic is said to be difficult for students because it contains both mathematical elements and experimental validations. In order to create teaching materials, science textbooks that are generally used in elementary schools are referred.

Table 1 shows the flow of the science class concerning the principle of leverage. First of all, self-introduction of the android robot SAYA is performed, and the class is opened. Then, SAYA explains the theory and mechanical advantages of leverage with some slides. In this scene, three important points of leverage are introduced. That is, a pivot point, a point of effort, and a point of load are explained. SAYA then shows familiar examples of leverage that are seen in our daily lives. For example, scissors, bottle-opener, tweezers, and so on are shown. After that, SAYA lets students experiment for discovering or confirming the principle of leverage with an experimental lever kit, and students are able to experience the

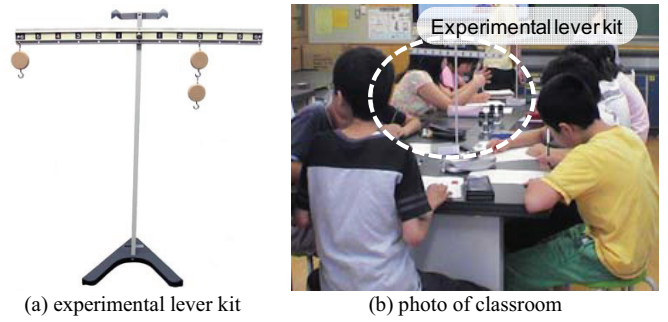


Figure 8. Photos of experimental environment

TABLE I. THE FLOW OF SCIENCE CLASS CONCERNING THE PRINCIPLE OF LEVERAGE

Scene	Contents
1	Self introduction of SAYA and opening the class.
2	Lecture on basic theories and mechanical advantages of leverage.
3	Lecture on familiar examples of leverage in daily lives.
4	Experiments for discovering and confirming the principle of leverage.
5	Conclusion of the class.

balancing theory of leverage. Finally, SAYA summarizes its talk and closes the class.

IV. FIELD TRIAL AT AN ELEMENTARY SCHOOL AND EVALUATION

A. Setting

A field trial at an elementary school was conducted to verify effectiveness of the developed educational system in actual educational fields. The trial was carried out after school, and it took about one hour. 22 students who were 10-11 years old and belonged to the fifth-grade class participated.

Fig. 7 shows experimental environment. We used a standard classroom, and we put SAYA on the front of the room as the role of a teacher. A plasma display was also put on the front of the room to display teaching-materials, and a video camera was put on the rearward to let the operator monitor the classroom. In addition, there was an experimental lever kit on each desk every four students as shown in Fig. 8.

Four students per a desk were made to sit on assigned positions. The position of each student had defined so that the operator could identify each student, and he could let SAYA look at a student and call a student's name individually.

B. Experimental Procedure

At the first, an experimenter let students sit down in assigned positions. He then explained the flow of this trial briefly and asked students to answer a brief questionnaire. After that, he exited the room and the operator began the science class by controlling SAYA. The science class was conducted along the scenario that had prepared based on content described in Table I. During the class, the operator sometimes talked to students. That is, the operator asked some questions or gave cautions and advices to students through



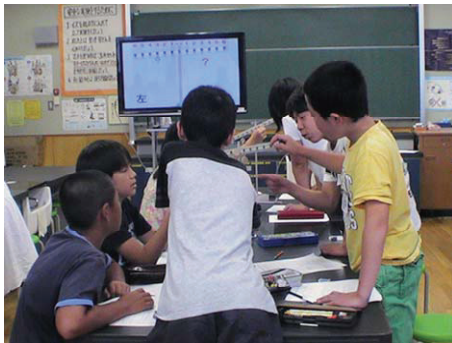
(a) SAYA explained to students and they concentrated on SAYA's talk



(b) SAYA looked at a student



(c) students raised their hand and attempted to answer a question



(d) students discovered and confirmed the principle of leverage through the experiment with experimental lever kit

Figure 9. Scenes of the field trial in the elementary school

SAYA. After the class, the experimenter asked children to answer a questionnaire.

Fig. 9 shows scenes of the field trial in the elementary school. Fig. 9(a) shows the scene in which SAYA gave explanations about the leverage along the scenario, and

TABLE II. QUESTIONNAIRE AND RESULTS OF Q. 1 TO Q. 12

Questionnaire		Result (ave. (s.d.))
Q.1	Are you interested in science and technology?	1.00 (0.87)
Q.5		1.36 (1.00)
Q.2	Do you prefer science classes?	0.73 (1.08)
Q.6		1.45 (0.74)
Q.3	Are you interested in robots?	1.09 (1.15)
Q.7		1.36 (1.09)
Q.4	Are you interested in a class conducted by robots?	1.27 (0.94)
Q.8		1.50 (0.96)
Q.9	Were you able to concentrate on the class more than usual?	0.55 (1.30)
Q.10	Was the class easy to understand?	1.45 (0.86)
Q.11	Do you want to participate in the class again if you have opportunity?	1.09 (1.23)
Q.12	Did SAYA answer you correctly? (yes / no)	yes: 17, no : 5

students concentrated on hearing SAYA's talk and paid attention to the screen. SAYA sometimes looked at students and asked some questions as shown in Fig. 9(b). Fig. 9(c) shows the scene in which students raised their hand and attempted to answer a SAYA's question. In class, students experimented for discovering and confirming the principle of leverage with the experimental lever kit as shown in Fig. 9(d).

C. Questionnaire Investigation for Evaluation

In order to evaluate the developed educational system, the questionnaire was prepared to investigate how students' interest and motivation were affected through this experiment. Therefore, questionnaire investigations were conducted before and after the class. Tables II shows the questionnaire that consisted of 12 questions (Q.1 - Q.12). First 4 questions (Q.1 - Q.4) were used for the investigation before the class as the brief questionnaire, and last 8 questions (Q.5 - Q.12) were used after the class. Each question was evaluated on a scale of -2 to 2 except Q.12, where 2 is most positive evaluation. Only Q.12 was evaluated with "yes" or "no". Moreover, Q.1 and Q.5 (interest in science and technology), Q.2 and Q.6 (interest in science classes), Q.3 and Q.7 (interest in robots), Q.4 and Q.8 (interest in a class conducted by robots) are same question. Their results are compared to estimate the contrast of students' interest and motivation between before and after the experimental science class.

D. Questionnaire Results

Table II also shows averages (ave.) of Q.1 to Q.11, and numbers provided in parentheses are standard deviations (s.d.). The numbers of respondents who answered "yes" or "no" in Q.12 are also shown. In addition, Fig. 10 shows comparisons between Q.1 and Q.5, Q.2 and Q.6, Q.3 and Q.7, Q.4 and Q.8. In Tables II, we can find that students' interest and motivation were affected through this experiment. That is, evaluation

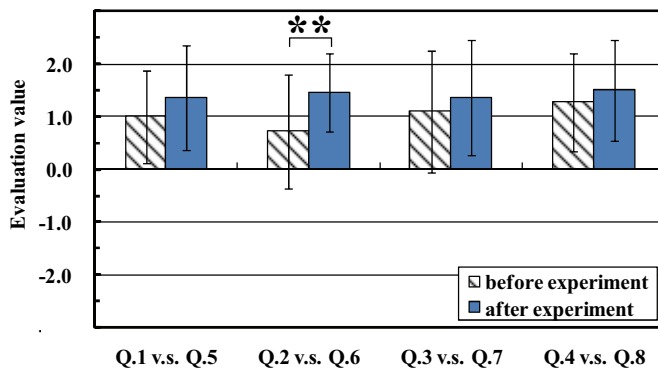


Figure 10. Comparisons between paired questions (Q.1 and Q.5, Q.2 and Q.6, Q.3 and Q.7, Q.4 and Q.8)

values of Q.1, Q.2, Q.3, and Q.4 are higher than values of Q.5, Q.6, Q.7, and Q.8 respectively. Wilcoxon signed-rank test was also applied to each pair, and its results are shown in Fig. 10. The results revealed a significant difference in the pair of Q. 2 and Q.6 ($p < .01$). Therefore, the class conducted with SAYA enhanced students' interest in science classes.

In addition, it is confirmed that concentration of students was low because evaluation value of Q.9 (concentration on the class) is relatively lower than those of other questions. The results of Q.10 and Q.11 indicate that students could understand SAYA's explanations and teaching materials easily, and students wanted to participate in the classes again. In Q.12, 17 of 22 students answered "Yes". That is, it is confirmed that the operator replied to them correctly through SAYA.

V. CONCLUSION

In this paper, a remote class support system was proposed as a one of applications of telecommunication system in which the android robot SAYA was used as an interface. SAYA has human-like appearance and can interact with humans with human-like body movements such as facial expressions, head movements, and eye-orientation. A remote control system of SAYA was also developed for the remote class support system, and this system allows an operator to control SAYA's behaviors and observe students' behaviors remotely. In addition, the principle of leverage was adopted as the topic of a science class, and the scenario of the class concerning that topic was made. Then, the science class with SAYA was carried out in an elementary school to investigate how the proposed educational system affects students' interest and motivation.

Results of field trial reveal that students came to like science class. That is, it is expected that this system enhanced students' interest in science classes. However, other students' interest and motivation (interest in science and technology, interest in robots, and interest in a class conducted by robots) were not affected significantly even though their evaluation values were higher than before the trial.

Our future work is to investigate how students' attributions (familiarity with robots, science classes, and science and technology) affect to changes of their interest and motivation through experience of the class conducted by SAYA. In addition, various topics of science classes will be prepared, and the proposed educational system should be compared with other existing media such as video-conference system. Also, it would be interesting to investigate contrasts between the proposed educational system and human teacher.

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