Development of dementia care training system based on augmented reality and whole body wearable tactile sensor

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Abstract— **This study develops a training system for a multimodal comprehensive care methodology for dementia patients called Humanitude. Humanitude has attracted much attention as a gentle and effective care technique. It consists of four main techniques, namely, eye contact, verbal communication, touch, and standing up, and more than 150 care elements. Learning Humanitude thus requires much time. To provide an effective training system for Humanitude, we develop a training system that realizes sensing and interaction simultaneously by combining a real entity and augmented reality technology. To imitate the interaction between a patient and a caregiver, we superimpose a three-dimensional CG model of a patient's face onto the head of a soft doll using augmented reality technology. Touch information such as position and force is sensed using the whole body wearable tactile sensor developed to quantify touch skills. This training system enables the evaluation of eye contact and touch skills simultaneously. We build a prototype of the proposed training system and evaluate the usefulness of the system in public lectures.**

I. INTRODUCTION

The burden of caring for elderly people whose cognitive function has declined due to dementia has rapidly increased in hospitals and nursing facilities. Care for elderly dementia patients is difficult and thus there is a shortage of caregivers and nurses. Such care also leads to exhaustion and burnout among staff and greatly decreases the physical function of the patients themselves. To tackle these issues, a multimodal comprehensive care methodology called Humanitude [1] has attracted much attention for the care of elderly dementia patients. Humanitude mainly consists of four care techniques: eye contact, verbal communication, touch, and standing up. Although some reports have shown that Humanitude is quite effective in suppressing the behavioral and psychological symptoms of dementia (BPSD) in patients and makes it possible to provide nursing care safely, calmly, and effectively, the training of the various techniques used in Humanitude simultaneously is very difficult. To overcome this problem and facilitate the use of Humanitude not only in hospitals and care facilities but also homes, we have been developing a system for the quantification of care skills and an effective training system for Humanitude using information technology [2][3].

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In this paper, we discuss measurements of the eye contact and touch skills used in Humanitude and propose a training system for Humanitude based on augmented reality (AR) technology. We built a whole body wearable tactile sensor to measure touch skill during a care action. To quantify touch skill, we need to measure the position and force of a touch applied to a patient's body by a caregiver. The sensor consists of conductive fiber sheets and a capacitance measurement circuit. The proposed training system for Humanitude uses HoloLens (Microsoft) and a soft doll equipped with the tactile sensor. To imitate the interaction between a patient and a caregiver, we superimpose a three-dimensional CG model of a patient's face onto the head of the soft doll using AR technology. The gaze direction, blinking, and facial expressions of the patient are dynamically controlled. The eye contact between the patient and the caregiver is detected and evaluated on-line. The position and force of a touch applied by the caregiver are measured by the whole body wearable tactile sensor.

II. HUMANITUDE

Humanitude is a multimodal comprehensive care methodology for dementia patients developed by Gineste and Marescotti [1]. This methodology consists of four main techniques, namely, eye contact, verbal communication, touch, and standing up, and more than 150 care elements. Several studies have reported that the cost efficiency of introducing Humanitude is around 20 times higher than that of care without it because of a 40% decrease in the use of psychotropic drugs and the number of care staff who leave [4]. One study [5] reported a case series for three dementia patients and showed that the duration of the behavioral and psychological symptoms of dementia (BPSD) decreased from 25.0%, 25.4%, and 66.3% for conventional care to 0%, 0%, and 0.3% for Humanitude, respectively. Humanitude has been introduced in more than 600 hospitals and nursing homes in Europe and has recently become popular in Japan. In the past three years, more than 2,600 people in Japan have undergone Humanitude training, which includes more than 30 training sessions.

III. DEVELOPMENT OF WHOLE BODY WEARABLE TACTILE SENSOR

In this section, we describe the developed whole body wearable tactile sensor for measuring the position and force of a touch applied to a patient's body by a caregiver. Two methods are considered to be used to obtain the touch information. In the first method, a sensor glove that can measure finger tactile pressure [6] and a motion capture system [7] are used. The timing and pressure are measured by the sensor glove and the touch position is estimated from the patient's posture and the hand position of the caregiver measured by the motion capture system. The two sensor systems (tactile sensor and motion capture) must be synchronized, making this method complex.

In the second method, a distributed tactile sensor worn by the patient is used. Since the position and force can be measured by a single sensor, the system is simple and easy to use. However, conventional force distribution sensors such as BPMS (Nitta) [8] or pliance (novel GmbH) [9] are quite expensive and difficult to cut or fold, making them difficult to use in a training system at care facilities or homes. A piezoelectric fabric sensor [10], pressure sheets using carbon microcoils [11] and conductive ink [12], and carbon nanotube elastomers [13] have been proposed. However, these sensors are small and thus cannot cover the whole area of a patient's body.

In this study, we developed a wearable tactile sensor that covers the whole body (arms, legs, and torso). The touch skill of a caregiver is quantified through the visualization of the force applied to the patient's body.

A. Tactile sensor based on conductive fiber sheets

We built a whole body wearable tactile sensor that consists of conductive fiber sheets and capacitance measurement circuits. Figure 1 shows a conductive fiber sheet with conductive fibers (Tsuchiya Inc.). By stacking two conductive fiber sheets, the force applied to the sheets can be measured by reading the difference in capacitance between the two sheets. Since this sensor is made from fiber sheets, it can be easily cut and folded to fit the shape of a body. The tactile sensor consists of square sensor cells. The minimum size of a sensor cell (maximum resolution) is 10×10 mm^2. By connecting several sensor cells, the resolution ranges from 10×10 mm^2 to 30×30 mm^2.

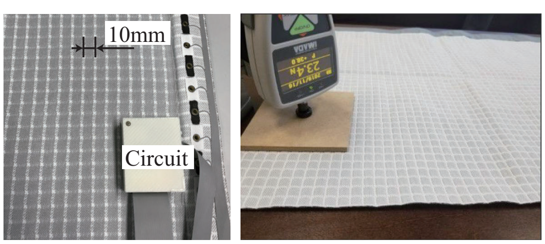


Fig. 1. Conductive fiber sheets (Tsuchiya Inc.) and sensor calibration by a force gauge

Next, we built a whole body wearable tactile sensor by forming the conductive fiber sheets into a shirt and pants. Figure 2 shows the components of the whole body wearable tactile sensor. This sensor consists of six tactile sensor sheets and capacitance measurement circuits. The sensor data are transmitted to a PC via Bluetooth and a wire. The numbers of sensor cells are 5,754 in total, which are 1,282 for body, 1,320 for two arms, and 3,152 for two legs. The resolution is 20×20 mm^2 and the sampling rate is 3.5Hz for whole sensor cells.

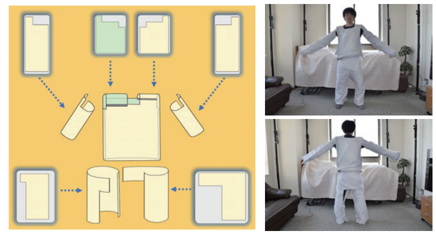


Fig. 2. whole body wearable tactile sensor

Figure 3 shows sensor values for various forces measured by a force gauge (Fig. 1). It is clear that the sensor cell has non-linearity and the measurement range is about 0.1 to 500 N or more.

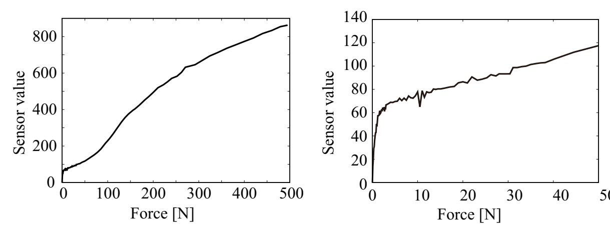


Fig. 3. Sensor values for various forces

Figures 4 and 5 show the force distribution measured by the whole body wearable tactile sensor when a Humanitude instructor and a trainee give a posture change motion for a patient. In these figures, yellow and blue areas indicate high and low forces, respectively. In Fig. 4, it can be seen that the Humanitude instructor uses not only the hands but also the upper arm to lift the patient's body. The instructor did not grasp the patient's leg but pulled behind the thigh with the right palm. On the other hand, the trainee grasped a back of the knee and applied strong force. Figure 6 shows the force measured by the cell that indicates the maximum force during the contact. The left figure shows the force applied by the left hand of the Humanitude instructor and the right figure shows the force by the left hand of the trainee. As shown in this figure, the Humanitude instructor lifted the thigh more gently compared with the trainee.

IV. Training system for Humanitude based on AR technology

The methodology of Humanitude consists of four main techniques and more than 150 care elements. Therefore, learning Humanitude requires much time. To train care techniques effectively, the quantification of care skills performed by trainees is crucial. However, it is almost impossible to directly attach many sensors to a dementia patient. Therefore, a training doll is sometimes utilized in the role of a patient, but the interaction between a patient and a caregiver, which is important for Humanitude, cannot be simulated using this system. Instead of a doll, a person can imitate a dementia patient during training. However, in Humanitude, the face of

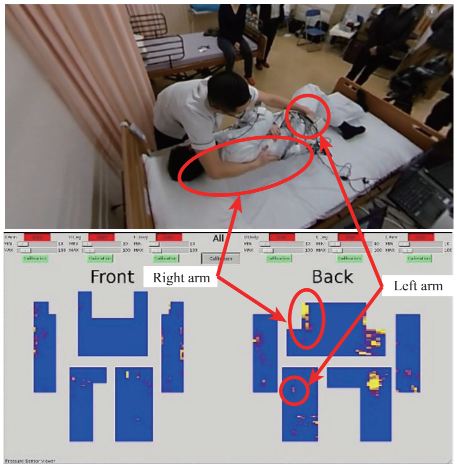


Fig. 4. Sensor measurement of posture change by a Humanitude instructor

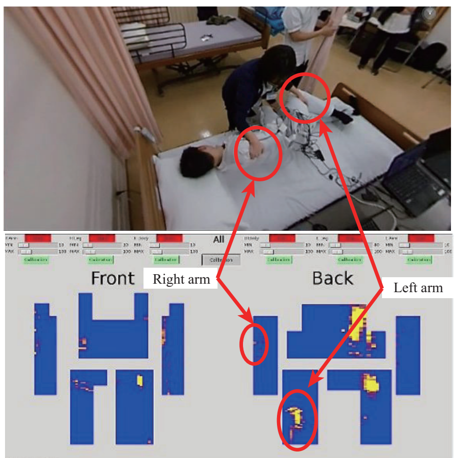
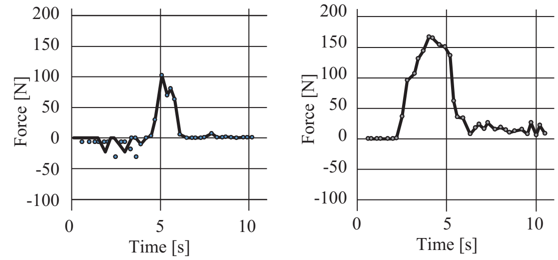


Fig. 5. Sensor measurement of posture change by a trainee

the caregiver must be placed quite close to the patient's face (< 200 mm) and the caregiver has to keep eye contact with the patient for as long as possible, which is quite unnatural in daily life. Therefore, the person playing the role of the patient needs special skills and thus has to be trained.

To solve these problems, we constructed a training system that realizes sensing and interaction simultaneously by combining a real entity and AR technology (Fig. 7). This system consists of a soft doll equipped with a whole body wearable tactile sensor (see Section 3) and a head-mounted AR display (HoloLens, Microsoft). The virtual face of a patient, with eyes that gaze and blink, is generated and superimposed on the head of the soft doll using AR technology. The caregiver can see the facial expression of the patient through the AR display. Eye contact can be detected if we assume that the facial direction of the caregiver coincides with the direction of the head-mounted AR display. In addition, the caregiver can touch the surface of the doll's body and get tactile feedback. The position and force of the touch are measured by the whole body wearable tactile sensor on the doll. Therefore, we can quantify the eye contact and touch skills of a caregiver using the proposed training system.



(a) Humanitude instructor (b) Trainee

Fig. 6. Force applied by the left hand of the Humanitude instructor and the left hand of the trainee to the patient's thigh and the back of the knee

Note that the training system based on AR technology was originally developed by Exawizards Inc.

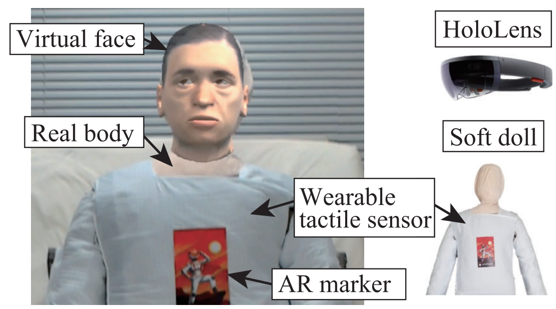


Fig. 7. Training system for Humanitude using a virtual face and real body

A. Evaluation of touch skill using whole body wearable tactile sensor

In order to quantify the touch skill of Humanitude, the whole body wearable tactile sensor was attached to the body of the soft doll (Fig. 7). In Humanitude, a caregiver should touch a patient's body as softly as possible and never hit or grasp the body. In addition, the caregiver should start the touch at the patient's arms or back and then move the touch position slowly from the back to the front of the patient's body. With the whole body wearable tactile sensor, we can measure the position and force distribution of the touch applied by a trainee and evaluate the quality of the touch skill.

To evaluate touch skill, we developed the decision tree from observations of the care actions of expert caregivers. For example, the instructor does not touch the front of the patient's body, but initially touches the back and the shoulder gently. Thus, we divided the touch sensor on upper body into 10 parts, and determined the positive and negative parts to be touched. The proper force applied to the patient is also measured through the demonstration by the instructor. In most cases, the instructor touched the patient's arm with less than 8 N and body with less than 2 N, and we determined the threshold to be 8 N and 2 N, respectively. Also, the instructor spreads his/her fingers and touches the body over a large area, so contact areas are also included to determine touch skills (> 5000 mm^2). According to the decision tree, if the contact position, the force, and the contact area are appropriate, the message "Excellent!" is displayed in the AR display in real time, as shown in Fig. 8. However, if not, the warnings such as "Please touch the patient's back", "Please touch a wider area", or "Too strong!" are displayed.

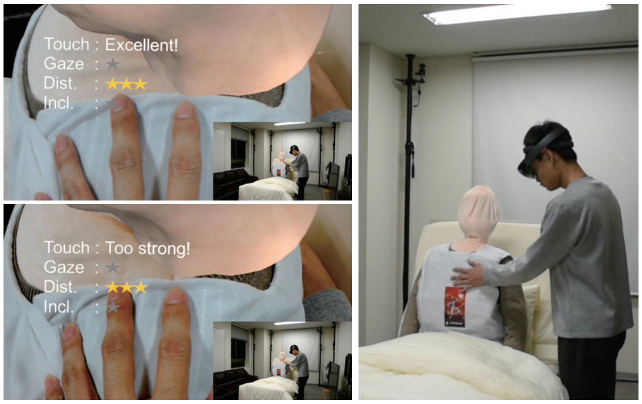


Fig. 8. Touch skill instructions

B. Evaluation of eye contact skill using head-mounted AR display

As mentioned, the face of the patient is generated and superimposed on the head of the doll using a head-mounted AR display. This allows virtual interaction between the avatar of the patient and the caregiver. The eye direction, blinking, and facial expression can be controlled using the training system. The facial model in this system was developed using the open-source software MakeHuman[14]. The blinking and changes in eye direction of the avatar occur randomly. However, once eye contact with the caregiver is established, the avatar keeps eye contact as long as the caregiver keeps looking at the patient's eyes.

The relative position of the faces of the patient and the caregiver is measured as shown in Fig. 9. The initial relative position is determined by detecting the AR markers on the body of the doll using the cameras on HoloLens. This initial calibration process was developed using the AR toolkit Vuforia[15]. After the initial calibration, precise calibration is conducted manually by applying a pinch motion to the AR model to precisely place the facial region on the head of the doll. Figure 10 shows the superimposed face and the actual body of the doll after calibration. Trainees can see the superimposed facial images on the head of the doll with HoloLens.

Figure 11 shows six facial expressions implemented in this system: happiness, anger, surprise, fear, and sadness. Each facial expression corresponds to the touch and the eye contact scores. When the eye contact is established, the happiness facial expression appears. On the other hand, if the trainee touches inappropriate position of the body such as the chest, the surprise facial expression appears. The angler facial expression is displayed when the trainee grasps or touches body strongly.

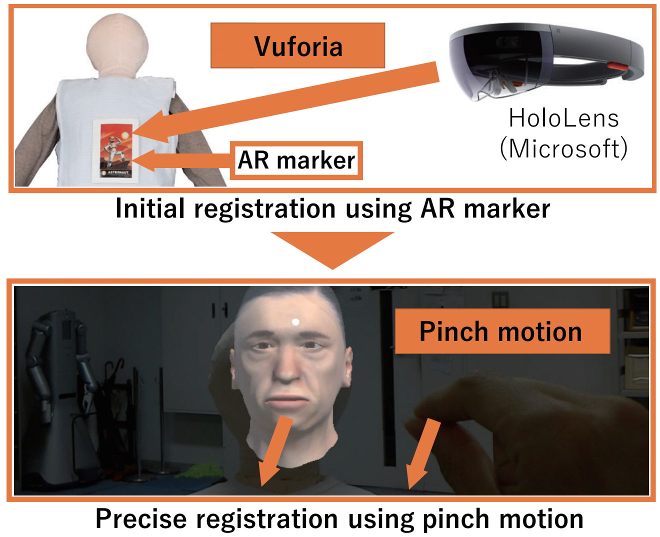


Fig. 9. Registration of facial image on a doll head [16][15]

Fig. 10. Superimposed facial image

We evaluated eye contact skill in terms of gaze, distance, and inclination, as shown in Table I. The scores are shown in the AR display as "Poor", "Good", or "Excellent".

TABLE I
EVALUATION INDICES

Index	Description
Gaze	Difference between eye directions of avatar and trainee
Distance	Distance between faces of avatar and trainee
Inclination	Relative angle between faces of avatar and trainee

1) Gaze score: HoloLens does not have a built-in eye tracking function. We thus assumed that the direction of HoloLens coincides with the eye direction of a trainee. The gaze score is assigned as "Excellent" if the direction of HoloLens remains toward the avatar's face and the eye direction of the avatar remains toward HoloLens. "Good" is assigned if the direction of HoloLens remains toward the avatar's face but the eye direction of the avatar does not remain toward HoloLens. "Poor" is assigned if neither direction is toward the target. The threshold for determining eye contact is 15 degrees and 25 degrees in the first and second experiments in Section V-B, respectively.

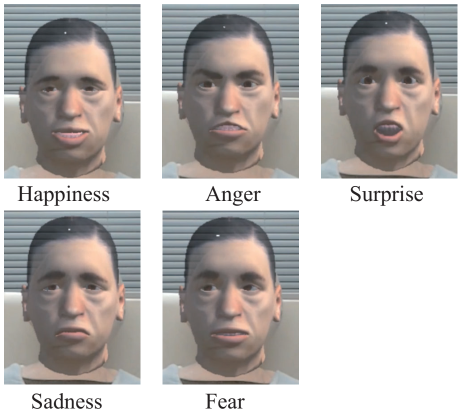


Fig. 11. Facial expressions

2) Distance score: The distance between the avatar's face and the trainee's face can be measured using the positioning tracking function of HoloLens. In Humanitude, it is recommended that the distance between faces be around 200 mm. "Excellent", "Good", and "Poor" are assigned if the distance is less than 300 mm, between 300 mm and 600 mm, and more than 600 mm, respectively

3) Inclination score: The inclination score is adopted from the concept of mutual facial position [2]. This score reflects the relative inclination angle between the faces of the patient and the caregiver. Observations of care actions by experts in Humanitude indicate that they keep the vertical direction of their faces parallel to the vertical direction of the patient's face, as shown in Fig. 12(a). In the developed system, in addition to the alignment of the vertical directions of faces, we introduce a score of the relative position (height) of faces, as shown in Fig. 12(b). The caregiver should look at the patient's face from the same height, and thus this score decreases if the trainee looks from above or below the patient's face. The sum of these two scores is the inclination score ("Excellent", "Good", or "Poor"). "Excellent", "Good", and "Poor" are assigned if the relative angle is less than 10 degrees, between 10 degrees and 20 degrees, and more than 20 degrees, respectively.

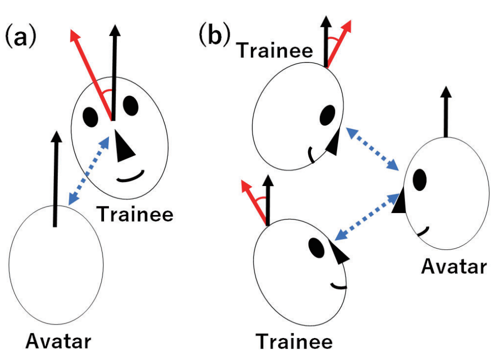


Fig. 12. Relative facial positions

C. Two training modes

We develop two kinds of modes for training Humanitude: free training mode and scenario-based training mode.

1) Free training mode: In this mode, a trainee performs care action freely and the evaluation score during the care action is displayed in AR display on-line. The obtained scores are displayed as a number of asterisks, as shown in Fig. 13, where one, two, and three asterisks correspond to "Excellent", "Good", and "Poor", respectively. In this mode, the care action of the trainee in daily work is evaluated from the viewpoint of Humanitude.

Fig. 13. Free training mode. Asterisks indicate each score.

2) Scenario-based training mode: In this mode, a trainee performs care action according to the instruction by the system. The scenario implemented currently is as follows:

1) The trainee approaches the patient (doll) from the left side along the arrow displayed on the HoloLens and establishes eye contact.
2) The trainee touches gently the patient's shoulder.
3) The patient changes his gaze to the right.
4) The trainee changes the standing position and catches the gaze again while touching the patient's shoulders.
5) The trainee rifts the patient's left arm to encourage standing up.

Figure 14 shows the images from the trainee's viewpoint. The scores of eye contact and gentle touch are displayed on the left corner of the display.

V. Training Experiment

Finally, we conducted training experiments of care skills of Humanitude. Firstly, Humanitude instructors used the developed care training system and we received valuable comments to improve the system such as the natural response of a dementia patient. After modifying the system according to the comments, 12 people tested the system. Six of them have dementia patients in their families.

A. Evaluation by instructors

Two Humanitude certified instructors, a medical doctor, and three trainees tried the developed system and evaluated the validity for the training of care skills. Figure 15 shows the experiment by the certified instructor. After the trials, we interviewed them and received various comments. Most of comments are positive, such as this system is very suitable for beginners since he/she has never experienced of keeping eye contact with the patients from such as a close distance.

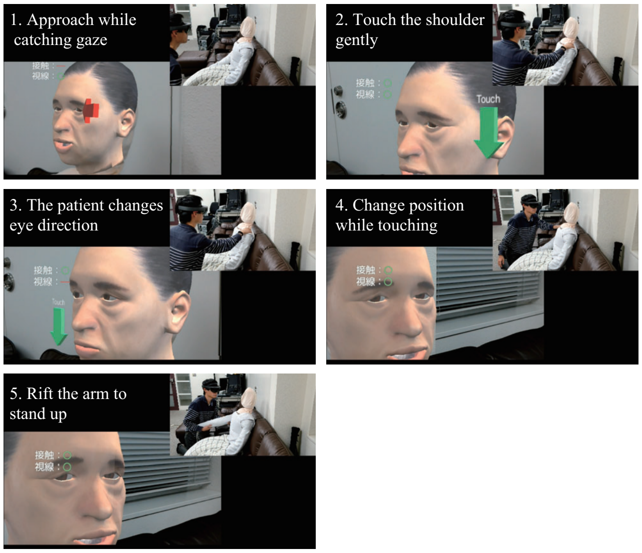


Fig. 14. Scenario-based training mode

They also said this system is useful for training hand-eye coordination, which is critical for Humanitude but hard to be trained by conventional voice instruction. On the other hand, instructors pointed out some weaknesses to be improved. For example, the facial expressions are very important to know the patient's emotion. The patients tend to maintain eye contact once the eye contact has been established.

Fig. 15. Trials by instructors

B. Training experiment by Humanitude trainees

According to the comments mentioned above, we improved the system so that the patient changes his facial expressions and keeps eye contact once the eye contact has been established as mentioned in Section 3.

After modifying the system, we tested the system in two public lectures for dementia care. 6 people participated the first public lecture. They have dementia patients in their families and care for them every day at home. In the second public lecture, 6 people who are interested in dementia care participated and tested.

Tables II and III show the results of interview after the training. The evaluation score and comments after the first public lecture was very harsh. This is because they could hardly catch the gaze of the patients due to the inappropriate threshold value for judging the eye contact. In the second public lecture, the threshold was adjusted so that the trainee can catch the gaze more easily. In addition, we revised the scenario so that the instruction can be understood more intuitively and the direction of approach is indicated by the red arrow. The evaluation score and comments after the second public lecture was greatly improved and the positive comments were increased.

TABLE II
IMPRESSION OF THE TRAINING SYSTEM OBTAINED BY THE INTERVIEW AFTER THE TRAINING

	1st	2nd
Naturalness (1:Low - 5:High)	1.8	3
Usefulness (1:Low - 5:High)	3.3	4.3

TABLE III
QUESTIONNAIRE RESULTS

Question	Votes ($\leq$ 6)	
Positive	1st	2nd
I could feel the eye contact	1	3
I could learn the face distance	1	5
I could learn how to catch gaze	0	2
I could learn how to touch gently	2	2
Negative	1st	2nd
I could not learn the eye contact	5	2
I could not feel the facial expressions	6	2
I could not learn the proper force	2	2
The field of view of HoloLens was narrow	4	4

Fig. 16. Training in public lecture

VI. CONCLUSIONS

In this paper, we proposed a whole body wearable tactile sensor for quantifying the touch skill used in Humanitude. In addition, we proposed a training system that combines an actual entity and AR technology. This system consists of a soft doll equipped with a whole body wearable tactile sensor and a head-mounted AR display. It realizes sensing and the interaction used in Humanitude simultaneously. We think the proposed system is suitable for beginners since the distance and the eye contact used in Humanitude are very special and have never been experienced for most of trainees. In future work, we will introduce the proposed training system to public lectures or courses of Humanitude at nursing schools. We will also perform comparative experiments before and after training to more carefully investigate whether the proposed system is sufficiently realistic and useful for actual training.

ACKNOWLEDGMENT

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