Emotional Expression of Personified Objects Using IoT Avatar Device

Tetsuro OGI*[1], Toshihiko CHIBA*[2] and Yuki KIDA*[3]
*1, *2, *3 Graduate School of System Design and Management, Keio University
4-1-1 Hiyoshi, Kohoku-ku, Yokohama 223-8526, JAPAN
ogi@sdm.keio.ac.jp, chiba.space@keio.jp, ykida@keio.jp

Abstract
The use of avatar robots placed in the real world has been attracting attention as a method of providing remote services. This study aims at developing IoT avatar technology that turn various objects exist in the real world into avatars by attaching IoT devices to them. In order to communicate smoothly with an object, it is necessary for the remote user to feel becoming the object and for the local user to feel the object as a personified avatar. The evaluation experiment showed that by expressing emotions using LEDs attached to IoT device, local users feel the personality in the object and can communicate with the object like a communication between humans.
Keywords: IoT avatar, avatar robot, emotional expression, remote communication

1 Introduction
In recent years, avatar robots have often been used as a method for users in remote locations to communicate with or provide services to users in the real world. For example, the avatar robot "newme" is used to guide customers at airports, and the avatar robot "OriHime" is used by disabled people to serve customers at cafes [1][2]. In the previous research, it is shown that when using avatar robots, the remote users feel as if they are transferred to the robot and having a conversation, but the local users feel as if they are having a conversation with the robot in front of them, not the remote users [3]. Therefore, avatar robots can be used effectively in situations where the remote user can provide detailed services as themselves, and the local user can interact with the robot without hesitation unlike humans' communication.

However, since current avatar robots are expensive and use space, there are some problems with costs and space when introducing a lot of avatar robots in the real space. Therefore, in this research, we are developing IoT avatar technology that use various objects exist in the real world as avatars [4]. In this method, in order for local users to communicate smoothly with the avatarized objects, it is necessary for the remote user to feel as if he or she has been transferred to the object, and for the local user to feel that the object in front of him or her is personified like a humanoid robot. In this paper, we investigated methods for personifying objects, particularly methods for expressing emotions of objects, in order to realize IoT avatars.

2 IoT avatar
2.1 Concept of IoT avatar
IoT avatars aim to turn real world objects into avatars by attaching IoT devices to them. **Figure 1** shows the concept of IoT avatar. Basic design requirements for IoT avatar devices are a camera function as eyes, a microphone function as ears, a speaker function as a mouth, and a communication function with remote users. In general, though the functions of avatars include expressing user's motion, in the case of IoT avatars, motion expression is not considered, because the objects in the real world are used as avatars. In addition, in order to make the object itself be felt like an avatar, it is necessary to make the IoT device attached to the object as small as possible so that it does not have a presence.

Next, in order for the local user to feel the object with the IoT device as an avatar, it is important for the remote user to feel become the object and behave like the object. The effect of avatars that the user feels become an avatar and behave

like an avatar is generally known as the Proteus effect. In the world of metaverse, it is known that the user feels dumbbell lighter when using a muscular avatar, and the user behaves more aggressively in negotiations when using a tall avatar [5][6]. Since the Proteus effect was seen not only for humanoid avatars but also for non-humanoid avatars such as dragon or fire, it is thought that the Proteus effect can be seen for the objects used as IoT avatars [7][8]. In order to use the Proteus effect, it is necessary that the users become aware of their own appearances of the avatars, and for this purpose, methods such as placing mirrors in the virtual world are often used. In the case of IoT avatars, though it is difficult to use mirrors because the objects already exist in the real world, it is necessary to give feedback to the users that they are the objects in some way and make them aware of their own appearances.

Therefore, in this system, methods such as allowing the user to see part of his/her own figure by looking around the image captured by a 360-degree camera through the HMD, modulating the user's voice into a robotic voice and feeding it back to the user through the speaker, and using objects that physically interact with the local user as avatars in order to utilize the Proteus effect effectively. In addition, we aimed to make the objects in front of the local user be felt like human with personalities by expressing their emotions.

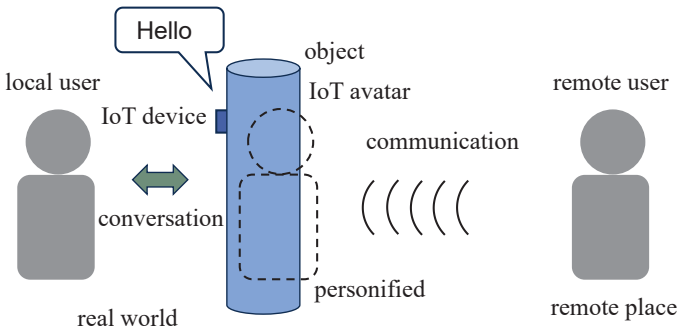


Fig. 1 Concept of IoT avatar

2.2 System configuration of IoT avatar

Figure 2 shows the IoT avatar device developed in this study. This device uses the single-board computer Raspberry Pi 4 Model B and is composed of a 360-degree camera (Entaniya, VR220), a mini USB microphone, a mini bluetooth speaker, and LEDs (Pimoroni, LED SHIM) for expressing emotions. The device was constructed small, with external dimensions of 92mm x 63mm x 38mm, and the case was created with PLA material by using a 3D printer.

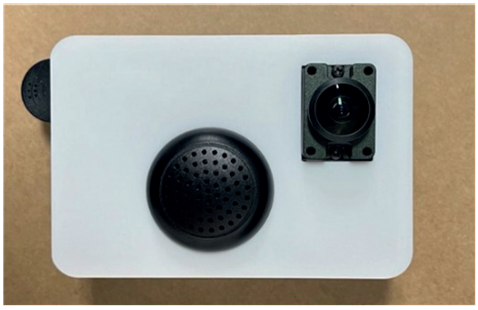


Fig. 2 IoT avatar device

Figure 3 shows the system configuration of the communication environment using the IoT avatar device. WebRTC (Web Real-Time Communication) was used to send and receive video and voice data between the IoT device and the remote user. WebRTC enables video, sound and data communication between web browsers using low latency P2P communication. In this system, we implemented a communication program via WebRTC by using NTT Communications' SkyWay SDK between the IoT avatar device and the HMD of Meta Quest 3 used by the remote user. On the remote user

side, the 360-degree video sent from the IoT avatar device is texture mapped in real time onto a virtual sphere using A-Frame, a WebVR framework, allowing the remote user to freely look around the 360-degree video. **Figure 4** shows an example of what a remote user sees when an IoT device is attached to a whiteboard. In addition, the voice of the remote user is modulated to sound like a robot's voice using a voice converter (Roland Voice Transformer VT-4), and it is sent to the IoT avatar device and is also output from the speaker on the remote user's side. It is known that modulated voice feedback gives users of avatar robots a stronger sense of becoming the robots rather than being themselves [9].

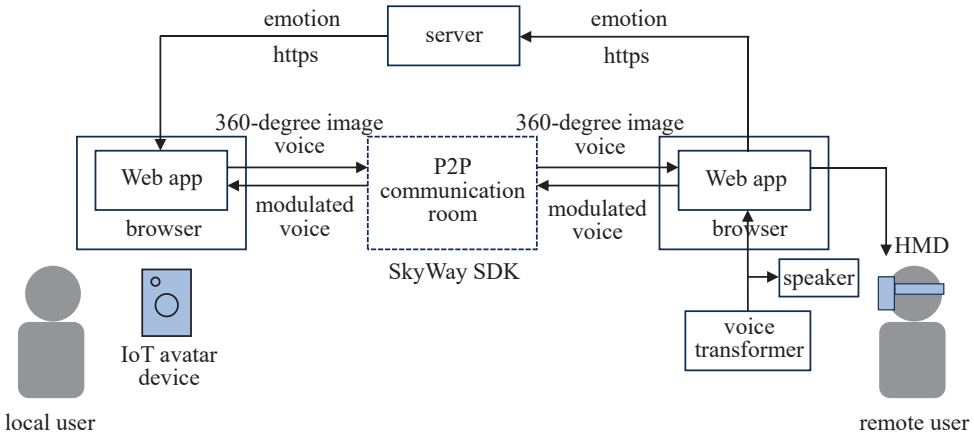
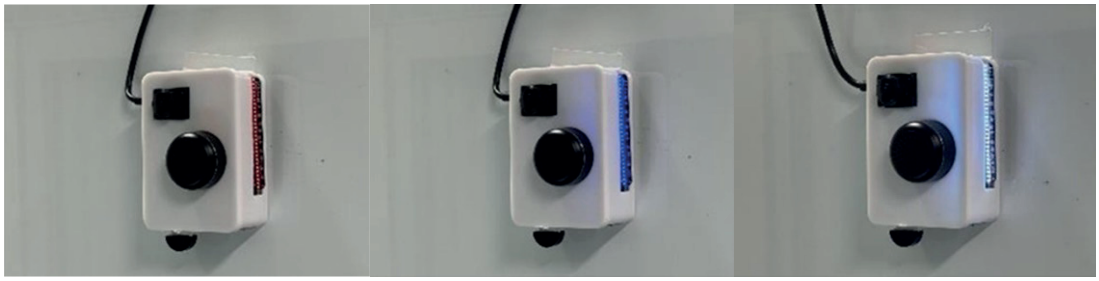


Fig. 3 System configuration of IoT avatar system

Fig. 4 Example of scene viewed by remote user

2.3 Emotional expression

In this study, we considered the method of emotional expression by IoT avatar devices in order to give objects a personality. In the study by Sugiyama et al. on illuminating clothing of robot, it was shown that red light evokes emotion of anger and blue light evokes emotion of sadness in the user [10]. Therefore, we attached LEDs to the IoT device and used a method of flashing the LEDs in red, blue and white according to the emotion of anger, sadness and normal, as shown in **Fig. 5**. At this time, since the flashing of light make users feel a biological rhythm, the flashing of LEDs was controlled according to the change in heart rate due to emotions, so that the white light flashes 60 times per minute in normal, the red light flashes 120 times per minute for anger, and the blue light flashes 30 times per minute for sadness. The LEDs were attached to the side of the device and illuminated the object as indirect light, in order to express the emotion of the object to which the IoT device is attached, rather than the emotion of the IoT device itself. In the future, we aim to sense the emotion of the remote user and control the LEDs automatically, but in the prototype, we used a method in which when the remote user selects the emotion they want to express, a command is sent to the IoT device to flash the LEDs.



red blue white

Fig. 5 Flashing of LEDs in red, blue and white

3 Evaluation experiment

3.1 Experimental method

By using the developed IoT avatar device, an evaluation experiment on personifying expression of objects was conducted. In the experiment, the IoT avatar device was attached to a whiteboard, and the experimenter acted as a remote user and talked with subjects in front of the whiteboard in the conditions of using LEDs and without using LEDs that express emotions. The experimenter encouraged the subjects to draw pictures on the whiteboard, and intentionally expressed his emotions of anger and sadness according to the way of drawing and the drawn pictures. The remote user's emotions were shown to the subjects by the speaking style in conversation and by the flashing of the LEDs.

The experiments using and without using LEDs were conducted in random order, and after each experiment, subjects were asked to answer the questions in the questionnaire shown in **Table 1**. Q1 and Q2, Q3 and Q4 were paired questions, and subjects answered each question using a 7-point Likert scale (1: Strongly disagree, 2: Disagree, 3: Slightly disagree, 4: Neither, 5: Slightly agree, 6: Agree, 7: Strongly agree). **Figure 6** shows the experimental scene.

Table 1 Questionnaire asked in the evaluation experiment

Q1. I felt I was talking with the object
Q2. I felt I was talking with the remote user
Q3. I felt a change in emotion of the object
Q4. I felt a change in emotion of the remote user
Q5. I felt the object was personified
Q6. I felt the personality in the object
Q7. I felt like I was communicating with a human

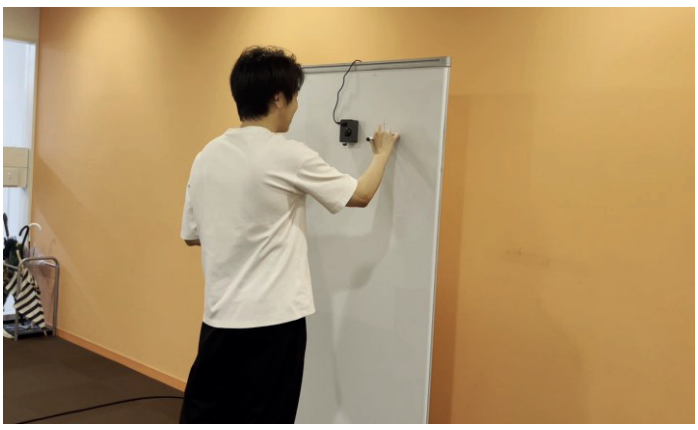


Fig. 6 Experiment using a whiteboard as an IoT avatar

3.2 Experimental results

Figure 7 shows the results of the questionnaire for 10 subjects. Comparing the answers to Q1 and Q2, there was a tendency that by using LEDs, the local users felt less they were talking with a remote user and more they were talking with the object itself, though no significant difference was shown in t-test. And comparing the answers to Q3 and Q4, it was shown that by using LEDs, the local users felt more of a change in the emotion of the object than without using LEDs ($p < 0.05$), and they felt the change in the emotion of the object rather than a change in the emotion of the remote user ($p < 0.05$). Furthermore, the answers to Q5, Q6, and Q7 showed that the subjects felt whiteboard was personified to some extent regardless of the use of LEDs, but by using LEDs, a tendency that the subjects felt more personality in the whiteboard and felt more human-like communication was conducted was shown though there was no significant difference.

Namely, it is considered that these results showed by using LEDs to express emotions of the object to which the IoT avatar device was attached, the local user felt more personality of the object and conducted more personified communication with the object.

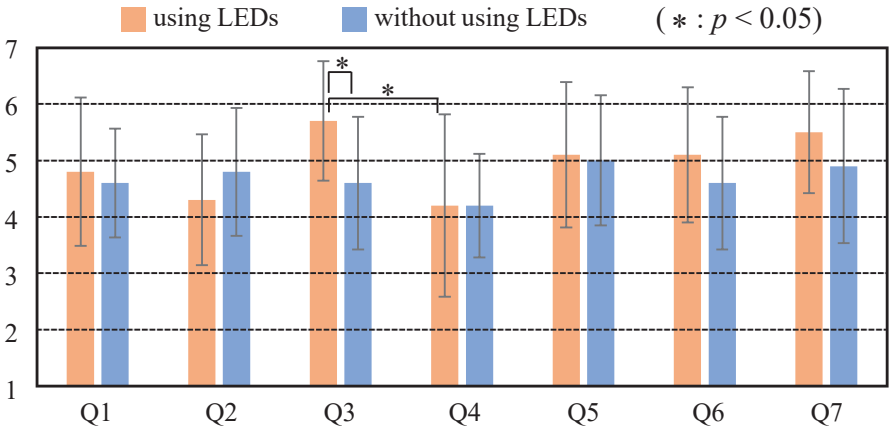


Fig. 7 Results of evaluation experiment

4 Conclusions

In this study, IoT avatar technology that allows a remote user to use any object that exists in the real world as an avatar was developed. In order to achieve smooth communication between local user and the IoT avatar, it is important that the remote user feels becoming the object and that the local user who is confronted with the object feels that the object is personified. In particular, this paper showed that by attaching LEDs to the IoT avatar device and expressing the remote user's emotions, the local user feels more personality in the object and can communicate with the object like a communication between humans.

In the experiment, a simple method in which a remote user selected the emotion he or she felt to control the LEDs on the IoT avatar device was used, but in the future, a method of automatic emotion detection and expression can be considered by introducing emotion detection AI technology that estimates user's emotions from the user's facial expressions and voice in conversation. In this case, we also need to investigate how the remote user feels about becoming an object through emotional expression. In addition, in order to provide services to local users who move widely, a future challenge will include realizing continuous communication between local users and IoT avatars by having the remote user move among multiple IoT avatar devices.

Acknowledgment

This research was partially supported by JKA promotion funds from AUTORACE (2024M-549),

References

[1] Fukabori, A., Kajitani, K.: ANA AVATAR, Journal of the Robotics Society of Japan, 36, 10 (2018), 663 (in Japanese).

[2] Takeuchi, K., Hatada, Y., Yamazaki, Y., Yoshifuji, K.: Empirical Studies on Remote Customer Service using Telepresence Robot “OriHime” by People Who Have Difficulty Going Out, IPSJ Digital Practice, 5, 2 (2024) (in Japanese).

[3] Ogi, T. and Kida, Y.: Human Relationship Felt in Communication Using Tele-immersion Avatar Robot, The 20th International Conference on Machine Design and Production (UMTIK 2024) (2024), 101.

[4] Kida, Y., Chiba, T., Kinoshita, T., Mikami, A., Yakoh, T. and Ogi, T.: IoT Avatar: Turning Various Objects into Avatars, The 27th International Conference on Network-Based Information Systems (NBiS 2024) (2024), 398.

[5] Sumida, K., Ogawa, N., Narumi, T. and Hirose, M.: Proteus Effect of a Muscular Avatar on Weight Perception in Virtual Reality, 25th Annual Conference of VRSJ (2020) (in Japanese).

[6] Yee, N. and Bailenson, J.: The Proteus Effect: The Effect of Transformed Self-representation on Behavior. Human Communication Research, 33, 3 (2007), 271.

[7] Oyanagi, A., Narumi, T., Lugrin, J., Ando, H. and Ohmura, R.: Reducing the Fear of Height by inducing the Proteus Effect of a Dragon Avatar, Transactions of the Virtual Reality Society of Japan, 25, 1 (2020), 2.

[8] Kida, Y. and Ogi, T.: Evaluating How Psychological Senses and Physical Motions Are Affected by Avatar Shapes in A Non-immersive Environment, Artificial Life and Robotics, Springer (2024).

[9] Ogawa, N., Baba, J. and Nakanishi, J.: Investigating Effect of Altered Auditory Feedback on Self-representation, Subjective Operator Experience, and Task Performance in Teleoperation of a Social Robot, Proceedings of the CHI Conference on Human Factors in Computing Systems (2024), 1.

[10] Sugiyama, T. and Kanoh, M.: Investigating Emotional Expressivity in Robots Wearing Light-Emitting Clothing. AHFE International Conference, AHFE Open Access, 117 (2023).

Received on January 20, 2025
Accepted on January 14, 2025