IoT Avatar: Turning Various Objects into Avatars

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Abstract. This research proposes an IoT avatar to communicate with users by representing various objects in real space as avatars. The IoT avatar is realized by attaching an Internet-connected IoT avatar device to various objects to turn the object into an IoT avatar. A remote user controls the IoT avatar itself via an IoT avatar device. In this research, a prototype was developed, and its effectiveness was evaluated through evaluation experiments. The results suggest that users who communicate with the IoT avatar generally feel that the IoT avatar has a personality and can communicate with the IoT avatar as if it were a person. In addition, it was found that remote users communicating via the IoT avatar can communicate as if they were the object itself.

1 Introduction

With the advancement of IoT (Internet of Things) technology, it has become possible to exchange data with various objects in our surroundings via the Internet. As a result, IoT is now being integrated into various commercial products and services. Specifically, it has been mainly used to acquire data using sensors to analyze and monitor the surrounding conditions of the IoT products or to operate them by sending signals from a remote location.

On the other hand, recent research on IoT is more comprehensive than sending and receiving sensor data and remote control. Still, it also extends to effective interaction between IoT devices and the people around them [1–3]. In particular, voice user interfaces have attracted attention [4–6]. As a precedent, smart speakers such as Amazon Echo and Google Home can interact with surrounding IoT devices through voice commands given by the user. Additionally, as part of research on IoT devices providing information through speech, there is research on the use of multiple IoT speakers [7]. This research developed a system in which IoT speakers are attached to various objects in real space, and these objects speak and present information. Evaluation experiments in this case have shown the effectiveness of information presentation using voice with multiple IoT speakers.

However, to more accurately understand user requirements and flexibly provide information according to the situation and context, the objects themselves must be able to communicate with the user as if they were people rather than just presenting information as speakers.

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Therefore, we aimed to make avatars of various objects in real space so that the objects themselves can communicate with users as people do. In other words, we propose an IoT avatar that turns various objects into avatars themselves. This research aimed to develop an IoT avatar, and a prototype was developed. Its effectiveness was evaluated through evaluation experiments.

2 Concept of IoT Avatar

The IoT avatar proposed in this research culminates from the realization that various objects in real space can be turned into avatars, enabling communication between the objects and the people around them. Figure 1 shows an example of a use case for the concept. For example, when users are working on a design while using a whiteboard, the whiteboard can talk to them and discuss and generate ideas together. In addition, the door talks to the user, enabling communication about relevant topics, such as room usage and identification. The functions of the IoT avatar are realized by attaching IoT avatar devices connected to the Internet to various objects, and a remote user controls the IoT avatar itself via the IoT avatar device. The IoT avatar use case shown in Fig. 1 is just one example. Still, it is expected to be used in a wide range of other applications as an avatar for various objects in shopping malls, train stations, airports, and other places where people gather.

Other techniques for using avatars in real space include robot avatars [8–10]. In a robot avatar, a robot with a physical entity is used as an alter ego for remote communication. However, when using robot avatars at various remote locations, many robots must be deployed at each remote location. In contrast, the IoT avatar has the advantage that the objects in the place can be used as avatars.

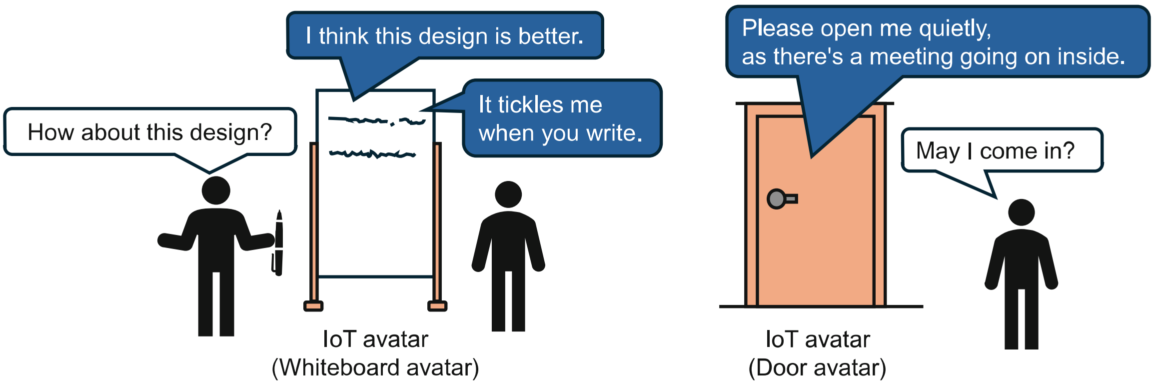

Fig. 1. An example of the IoT avatar use case

3 Design of IoT Avatar

In this research, we developed an IoT avatar device, as shown in Fig. 2, to realize the above-mentioned IoT avatar concept. The IoT avatar device comprises a Raspberry Pi 4 model B, a small Bluetooth speaker (Wireless Ultra Mini Speaker), a 360-degree camera

(VR220 Camera), and a small USB microphone. The IoT avatar device has dimensions of 92 mm in length, 63 mm in width, and 38 mm in height, and its body was fabricated using PLA material with a 3D printer. By attaching this IoT avatar device to various objects, the object itself can be realized as an IoT avatar. In addition, a remote user communicating via the IoT avatar controls the IoT avatar in an immersive environment using an HMD (Meta Quest 3).

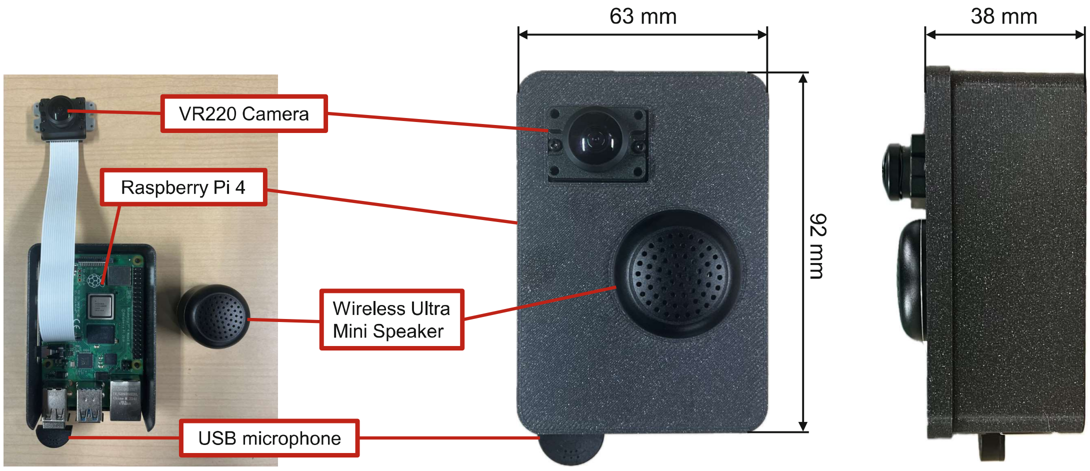

Fig. 2. IoT avatar device

Figure 3 shows the remote communication method by IoT avatar devices. This system adopted WebRTC (Web Real-Time Communication) for real-time remote communication. WebRTC is a technology that enables audio, video, and data communications between browsers. This system used SkyWay (NTT Communications) [11], a WebRTC platform SDK, for real-time remote communication between IoT avatar devices and the HMD.

Specifically, we created web applications for communication to use the SkyWay SDK for real-time remote communication between the IoT avatar device and the HMD. First, as shown in Fig. 3, the IoT avatar device and the HMD each open a web application in their browsers. The web application programs are stored on the server and loaded by the browsers of the IoT avatar device and the HMD via HTTPS communication. The communication between the IoT avatar device and the HMD is implemented using P2P communication for low latency. Next, IoT avatar devices and HMDs can communicate with each other in real time via a P2P communication room created by SkyWay SDK using their respective web applications.

Regarding the actual system process, the voice and 360-degree images acquired by the IoT avatar device are delivered to the web application on the HMD side via a P2P communication room. The voice is output from the HMD's speaker. As for the images, 360-degree images sent from the IoT avatar device were attached to the celestial sphere using A-Frame (WebVR open-source framework) implemented in the web application on the HMD side. This created an immersive image viewing system on the HMD. On the HMD side, only the remote user's voice is acquired by the HMD's microphone using a web application, sent to the IoT avatar device, and output by the IoT avatar device's speaker.

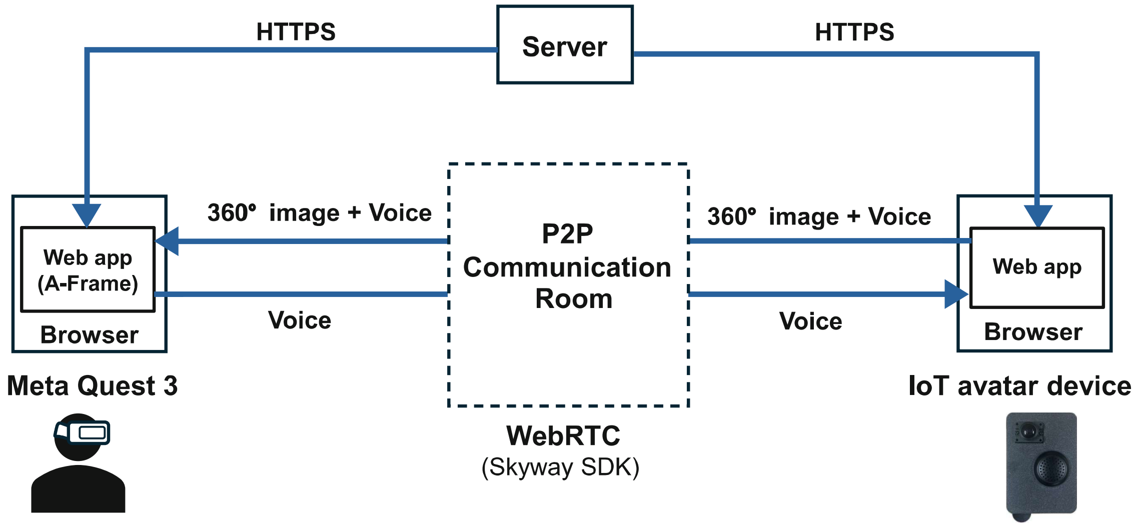

Fig. 3. Real-time remote communication method for this system

4 Evaluation Experiment

In this experiment, a whiteboard and a door, which many people in university facilities use, were selected as objects to become IoT avatars. The following two evaluation experiments were conducted on 10 participants to evaluate the system's effectiveness.

- Experiment (1): Participants face and communicate with IoT avatars.
- Experiment (2): Participants communicate with a local person near the IoT avatar via the IoT avatar.

4.1 Experimental Environment and Method

As for Experiment (1), participants face the IoT avatar and communicate with it, while the experimenter (remote user) in another room wears an HMD and communicates with the participant via the IoT avatar. Figure 4 shows scenes of a participant in Experiment (1). In the case of the whiteboard, participants were asked to communicate with the whiteboard while writing freely on it. The experimenter pretended to be a whiteboard and communicated with the participant. For example, the experimenter spoke as if pretending to be the whiteboard, e.g., "It tickles me when you write with a pen." In the case of a door, participants were asked to communicate with the door by knocking on the door and turning the doorknob. Similarly, the experimenter communicated with the participant while pretending to be the door, speaking, for example, "It hurts if you knock too hard." The experiments on the whiteboard and door were conducted in random order.

As for Experiment (2), the participant communicates with the experimenter via the IoT avatar, with the experimenter near the IoT avatar. In this case, the participants wear an HMD and communicate with the experimenter near the IoT avatar via the IoT avatar from another room. Figure 5 shows a scene of a participant in Experiment (2). In the case of a whiteboard, participants were asked to pretend to be the whiteboard and communicate with the experimenter. The experimenter communicated with the whiteboard while writing freely on it. In the case of a door, participants were asked to pretend to be the door and communicate with the experimenter. The experimenter communicated with the door by knocking and turning the doorknob. Also, in Experiment (2), the experiments on the whiteboard and door were conducted in random order.

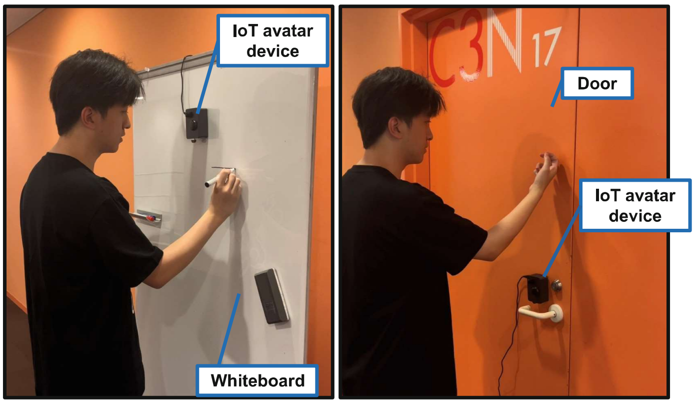

Fig. 4. A participant in the experiment (1).

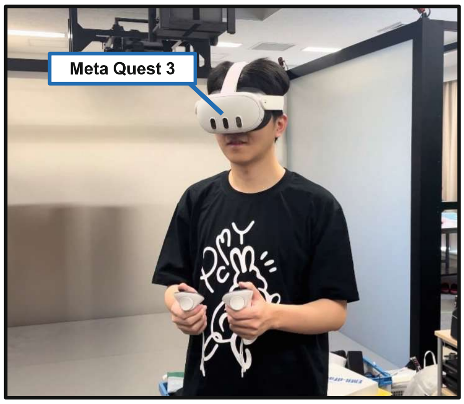

Fig. 5. A participant in the experiment (2).

4.2 Evaluation Method

In Experiment (1), participants answered the questionnaires in Table 1 at the end of each whiteboard and door experiment. The questionnaire was rated on a 7-point Likert scale (1: Strongly disagree, 2: Disagree, 3: Slightly disagree, 4: Neither, 5: Slightly agree, 6: Agree, 7: Strongly agree).

Similarly, in Experiment (2), the participants answered the questionnaire in Table 2 on a 7-point Likert scale at the end of each whiteboard and door experiment.

Table 1. Evaluation questionnaire for the experiment (1).

Q1. I felt I was communicating with the object itself, not the remote user
Q2. I felt I was communicating with the remote user, not the object itself
Q3. I felt the object itself had a personality
Q4. I felt it easy to communicate
Q5. I want to use this system

Table 2. Evaluation questionnaire for the experiment (2).

Q1. I felt the object itself was communicating with the other person, not myself
Q2. I felt I was communicating with the other person, not the object itself
Q3. I felt as if I was becoming the object itself
Q4. I felt it easy to communicate
Q5. I want to use this system

5 Results and Discussion

5.1 Results and Discussion of Experiment (1)

Figure 6 shows the results of the whiteboard and door in Experiment (1). First, we compare the results of Fig. 6 to see whether the participants felt they were communicating with the object itself (Q1) or the remote user (Q2) when they faced and communicated with the IoT avatar.

Comparison of Q1 and Q2 on the whiteboard and Q1 and Q2 on the door by t-test was not significant (whiteboard: $p = 0.878$, door: $p = 0.110$). Regarding the mean values, Q1 and Q2 were almost the same in the case of the whiteboard, while Q1 was rated higher than Q2 in the case of the door. The high Q1 rating for the door is because the participants had many opportunities to directly touch the door with their hands, such as knocking, tapping, and grasping the doorknob. The door was speaking in response to these actions.

The results of Q1 and Q2 show that when communicating with the IoT avatars developed in this research, participants felt a sense of communicating with the objects themselves. At the same time, a sense of communicating with a remote user was not absent. One of the factors causing this result can be the voice of the IoT avatar. In this experiment, the voice of the experimenter (remote user) was directly output as the voice of the IoT avatar. Therefore, the mean value of Q2 is above 4, which results in the participants feeling somewhat communicating with the remote user. Thus, the following approach would be to change the experimenter's voice using a voice changer, etc. For example, it is expected that changing the voice to one like a robot or an animated character will increase the sense of communicating with the object itself rather than with the remote user. Further, the mean value for the item 'Q3: whether the participants felt the personality of the object itself' was over 4.5, indicating that they felt that the IoT avatars had a personality. From these results, the concept of communicating like a person with the object itself as the avatar is considered to have been realized.

Finally, 'Q4: whether participants felt the ease of communication' and 'Q5: whether the participants wanted to use the system' showed positive results, with the mean values for both the whiteboard and the door exceeding 5. In other words, the results suggested its effectiveness in terms of ease of communication and desire to use this system.

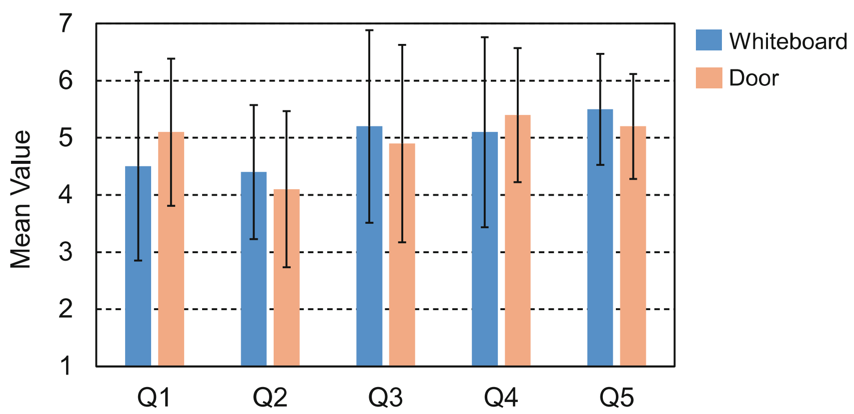

Fig. 6. Results of Experiment (1)

5.2 Results and Discussion of Experiment (2)

Figure 7 shows the results of the whiteboard and door in Experiment (2). From the results in Fig. 7, we compare whether the participants felt that the object was communicating with the other person (Q1) or whether they were communicating with the other person (Q2) when they communicated via the IoT avatar.

Comparison of Q1 and Q2 on the whiteboard and Q1 and Q2 on the door by t-test was not significant (whiteboard: $p = 0.320$, door: $p = 0.370$), respectively. Regarding the mean values, Q1 had a higher rating than Q2 for both the whiteboard and the door. The mean value for the item ‘Q3: Whether participants felt as if they had become the object itself’ was over 4.5, indicating that they felt as if they had become the object itself. Namely, the results show that when communicating via the IoT avatars developed in this research, the participants feel as if they have become the objects themselves, and the sense that the objects themselves are communicating with the other party is enhanced. Furthermore, ‘Q4: whether participants felt the ease of communication’ and ‘Q5: whether the participants wanted to use the system’ showed positive results, with the mean values for both the whiteboard and the door exceeding 5.

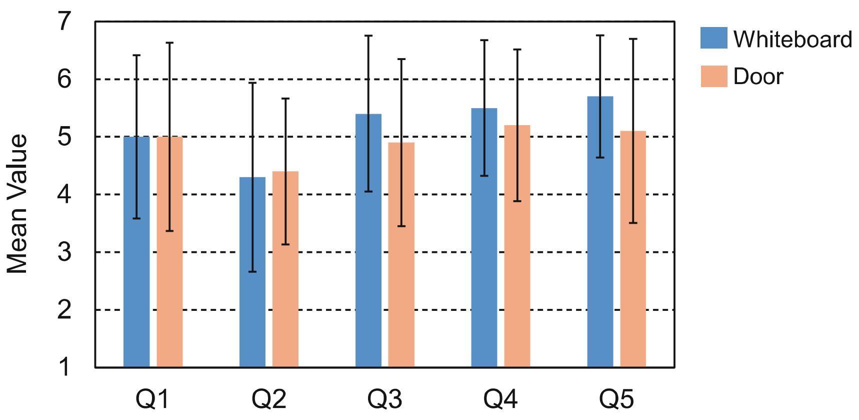

Fig. 7. Results of Experiment (2)

6 Conclusion

In this research, we developed an IoT avatar that can communicate with people around it by turning various objects in real space into avatars. In the current system, evaluation experiments suggest that users who communicate with the IoT avatar generally feel that the IoT avatar has a personality and can communicate with the IoT avatar as if it were a person. On the other hand, it was found that remote users communicating via IoT avatars have a sense of communicating with local users as if they became the object itself. In addition, its effectiveness in terms of ease of communication and the desire to use IoT avatars was confirmed.

In future work, improving and researching the voice of the IoT avatar is necessary to increase the sense of communication with the object itself. Furthermore, evaluating other use cases for the IoT avatar, including its implementation for various objects in various places where other people gather, is a prospect.

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