Agents on Robots: Mixed Reality Robots with Changeable Appearances depending on the Situation

Wataru Kodama[1], Nagisa Munekata[1], and Testuo Ono[1]

[1]Graduate School of Information Science and Technology, Hokkaido University

Abstract: This paper presents a communication system between humans and character agents, Agents on Robots (AoR), which combines the ability of expressions of character agents with the presence of robots. This system attaches an AR marker on mobile robots and allows users to communicate with CG agents through a Head Mounted Display (HMD). In our experiments, we compared the difference of impressions between AoR and communication robots which have the same surface appearance. As a result, we found the item "Activity" for AoR in the questionnaires to be statistically higher than that for a robot. This result support usefulness of our proposed system.

1 Introduction

Studies of network robots which combine ubiquitous networks and robots have been actively researched. These systems can be classified into three categories [1], [2]. First, "Visible-type" robots have bodies and behave physically in the real world [3]. Second, "Virtual-type" robots search and show information over the display. Third, "Unconscious-type" robots are installed everywhere, sensing human behavior and offering suitable information. These types combine robotic technologies with the ubiquitous network ones, which are able to realize highly sophisticated communication much like human-human dialogue. However, there are problems that users may not naturally communicate with these robots. Because users may not understand the unified support structure of this system, making it difficult to notice what kind of support users can receive from the robots.

Here we show the related study appropriate to solve these problems, called the ITACO system [4]. The idea of this system is that character agents who have users' information migrate between media, such as smart phones, domestic appliances and so on. This system can offer support based on the situation. Moreover, a user can recognize that the agents are the same before and after migration. The user may easily recognize unified support with any type of robots if we apply the ITACO system to network robots.

We propose a suitable robot system for the ITACO system, and we use humanoid agents because it can communicate nonverbally. Humanoid agents can be classified into two categories, "robot agents" and "character agents". Those agents have good and bad points. First, robot agents can physically behave in the real world, for example moving anywhere, grabbing something and so on. But this good point restricts smooth movement and ability of expressions of robot design. Furthermore it is difficult to popularise them because these robot agents have operation and maintenance costs. On the other hand, character agents can behave freely and naturally on displays, and operation and maintenance costs are relatively cheap. In addition, through augmented reality, it is possible to display virtual-type robots in the real world. In recent years, there are many studies of agent interaction over smart phones or Head Mounted Displays (HMD) using augmented reality [5], [6]. However, this method needs to recognize a marker, limiting the range of movement of the agent. Therefore, we develope "Agents on Robots (AoR)", which is an agent interaction system which uses HMDs and mixed reality technology.

2 AoR System

This system attaches an AR marker on mobile robot (Fig. 1), and allows a user to communicate with CG agents via HMDs (Fig. 2). This system consisted of two layers, the robot layer and the character layer (Fig. 3), combining the good aspects of both layers. It has an agent's merit which is the free expression of character without physical limitation, and a robot's merit which is the presence of character being there with the user.

Additionally, this system has other good points, for instance, its ability to change agents' appearance depending on the situation using the information of sensors such as a depth sensor, and a camera, etc., on the robot. Moreover, although the range of movement is limited in the conventional AR agent system, the proposed system allows the agent to move anywhere. For


Fig.1. AoR, Robot layer


Fig.2. HMD

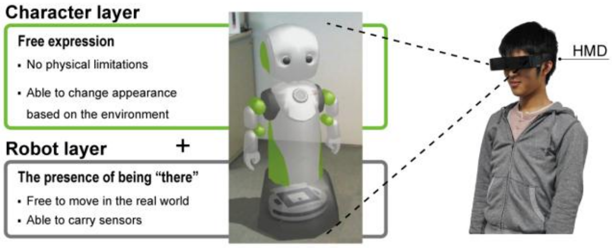

Fig.3. Construction of AoR

example, it is possible for the agent to call from behind the user.

3 Experiment

We set three conditions to compare the impressions of AoR and that of normal robots. First, we compared Groups 1 and 2 in such a way as confirm the influence of the HMD, and, second, we compared Groups 2 and 3 with both agents having the same appearance (Fig. 4).

Group 1. No-HMD, Robot interaction
Group 2. HMD, Robot interaction
Group 3. HMD, AoR interaction


Fig.4. AoR (left) and robot (right) seen via HMD

3.1 Environment

We will now briefly describe the construction of AoR. In the Robot layer, the robot in the experiment is Roomba made by iRobot Corporation. In the character layer, to display character agents, the CG character agents' appearance is made with Metasequoia, and the agents' motion is made with MikuMikuDance. For the HMD we used a HMZ-T1H made by SONY, and we fixed a web camera (68.5 degree wide angle) to the front of the HMD. On the other hand, in condition 1 and 2, the robot is a Robovie R3 made by Vstone. In the experiment, we adopted a Wizard of Oz approach for the agents' movement, which the experiment cooperator operated by remote control. Group 1 had 5 participants, and Group 2 and 3 had 6 participants. The results of the participants who became unwell during the experiment are excluded.

3.2 Design

We used the following procedures in the experiments. For Groups 2 and 3, which use HMD, the experimenter first explained to the participants how to use the HMD, and get the hang of it before the experiment. After that, the agent entered the room, and greet with a participant. Next, the experimenter instructed how to solve a dot-to-dot puzzle. After that, the agent communicated with the participant, and the experimenter left the room.

In this communication, first, the agent asked the date, letting the participant realize the agent can communicate. Second, the agent signaled the start and end of the task. Finally, the agent asked the participant about the picture drawn in the task. After those interactions, the experimenter entered the room again after the agent had left, and handed the participant a questionnaire.

3.3 Predictions and Evaluations

AoR is not only character but also robot, therefore characters can move anywhere. We think that noise of movement system gives the character the presence. Additionally, there is no difference of impression between this system and robots for participants when agents of AoR and robots appearances are same. However, time delay causes the uncomfortable mismatching between the sense of motion and the visual input for the user [7], therefore this effect may make participants' impressions worse.

Therefore, we investigate the possibility that the agents' impressions are effected by HMD. Now, we defined and studied three types impressions in the communication between agent and participant. First, "Familiarity" is whether participants like agent. Second, "Activity" is whether participants feel agent to be active. Third, "Reliability" is whether information of agent is accurate and reliable. We used the questionnaire method, especially the semantic differential scale method [8].

4 Results and Consideration

In the experiments, all participants followed the agent's requests, therefore we judged that communication was established. The results of experiments are Table 1.

Comparing results between Groups 1 and 2 (Fig. 5), as predicted, Group 1, which participants put on the HMD had worse impressions of the robot than Group 2, which participants didn't put it on, in impressions "Familiarity" ($p<0.05$) and "Activity" ($p<0.01$). These results may be interpreted a being caused by the difference in sight of looking through a HMD and looking with the natural eye. Especially, we thought HMD made participants' view narrow, and their motions were displayed late.

On the other hand, comparing results between Groups 2 and 3 (Fig. 6), as predicted, there was hardly any difference. In fact, when using HMD, the impression condition of AoR's "Activity" was better than that of a Robot's. We thought the result was caused by the difference of the smoothness of the motions.

Table 1. Results of experiments

	Familiarity	Activity	Reliability
Group 1	Mean = 5.3	Mean = 5.2	Mean = 4.0
	S.D. = 2.01	S.D. = 2.03	S.D. = 0.73
Group 2	Mean = 4.6	Mean = 4.2	Mean = 4.0
	S.D. = 1.76	S.D. = 1.75	S.D. = 2.42
Group 3	Mean = 5.1	Mean = 5.2	Mean=4.45
	S.D. = 1.43	S.D. = 0.64	S.D. = 0.99

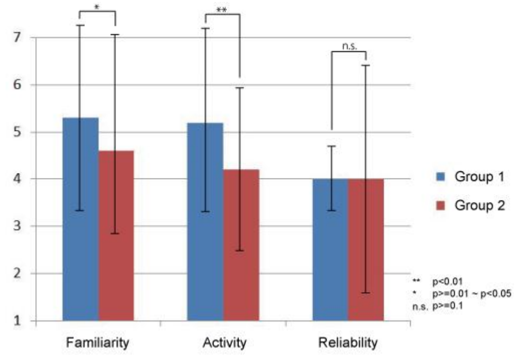

Fig.5. Difference of impression between Groups 1 and 2

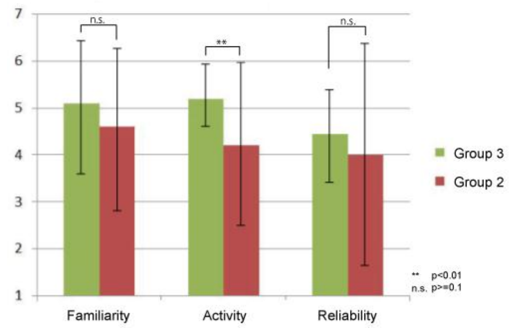

Fig.6. Difference of impression between Groups 2 and 3

5 Conclusion and Future work

This paper proposed AoR, a system combining a character's and robot's features, and investigated the differences of the impressions between AoR agents and robots that have the same appearance. In the results, the impression of robots by those participants in the Head Mounted Display (HMD) group was worse than those in the group with no HMD, when participants communicated with robot over HMD or not. Concerning communication with AoR agents and robots via HMD, the AoR group was better than the robot group in "Activity". Additionally, there was no difference between AoR agents and robots in "Familiarity" and "Reliability". These facts suggested that AoR was useful, and we may substitute this system for communication robots.

In future works, we'll propose applications for AoR where, for example, the agent's height is changed depending on the children's stature, or the robot is hidden by a picture which the same pattern as the floor, and so on. Additionally, considering this system has low costs, we will try to apply it as guides in museums, shopping streets etc.

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