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Designing a Robot as Communication Media
–The Effect of Head and Body Movement on Co-Present's Impression–

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Abstract

We have been developing robots as communication media. This paper focuses on the latest development named GestureMan 2. We used ATLAS which was developed at ATR to control the robot in proportion to a remote person's walking and head movement. Our experiment with the system showed that co-present persons got better impression on the robot when it was controlled with a conventional joystick. From this result, we noticed that for this kind of robot to have an affinity to people, not only its figure but also its motion should be properly designed.

1 Introduction

When a video mediated communication system is used, participants occasionally "encounter difficulties in making sense of each other's conduct even when undertaking seemingly simple actions such as pointing to objects within a particular environment ([1], p.121)"

Our idea to challenge this problem is to use a robot as communication media. For example, in order to assist remote pointing, we have developed a remote control laser pointer named the GestureLaser[4]. Then we mounted it on a mobile robot named the GestureMan [2]. However, the system could not perform pointing as well as people do in co-existing situation. One of the main reasons for this problem is lack of resources that clearly shows a remote person's (a person who remotely controls the robot) orientation and frame of reference. In order to alleviate this problem, we developed a new robot that has clearer resources to indicate orientations. Then, we have conducted an experiment to control the robot in proportion to a remote person's motion.

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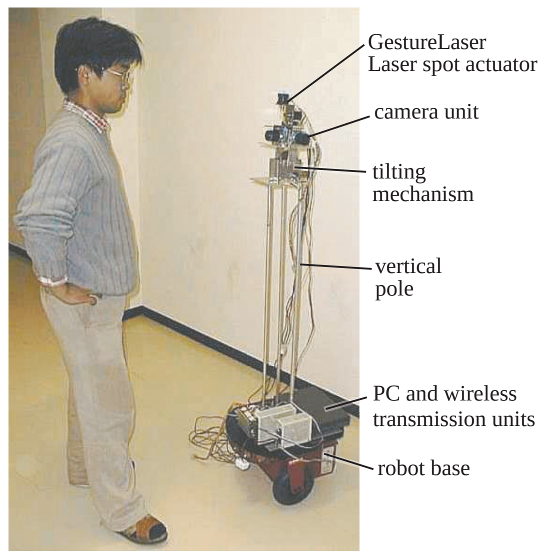

Figure 1: GestureMan

In this paper, based on the experiment, we will discuss how the head and body movement of a robot affect a co-present's (a person who co-exists with the robot) impressions on the robot. Also we will try to elicit some design implications for a robot as communication media. In the next section we start from describing our previous robot named GetureMan. Then, after introducing a newly designed robot: GestureMan 2, we describe our experiment to control the robot in proportion to a remote person's body motion. Finally, we will discuss the results of the experiment.

2 GestureMan

GestureMan (fig. 1) consists of a robot that can move around a remote domain. It has three cameras and a laser pointer on its top. In a remote domain, a remote person sits in front of a three screen system. (fig. 2). A

Figure 2: Three screen system

remote person moves the robot by a joystick. The laser pointer is controlled by a mouse and pressing the mouse button makes the laser dot brighter. This is a way of distinguishing movement of the laser dot from pointing with it. Participants speak to each other via wireless headsets and microphones.

Through the experiment we could recognize some problems of GestureMan [1]. In this paper, we focus on the following problems:

- A red dot of the laser pointer appears apart from the robot and there is not enough resource to determine where the remote participant is looking at. Therefore, sometimes it is hard to find the red dot in the environment.
- Since the laser spot is kept turned on, it lies on the surface of an object. Thus a local participant occasionally misunderstands that the remote participant is keep discussing on that particular object.

These problems occur because, as it can be imagined from figure 1, GestureMan has a little clue to tell where a remote participant is orienting to. Then it was suggested that the following considerations might be relevant to the design and development of an improved system:

- Provide participants with the ability to determine the location, orientation and frame of reference of others;
- Provide resources through which participants can discriminate the action of others which involve shifts in orientation and reference to the space and a range of objects, artifacts and features.

In the next section, we'll introduce our new system that aims to alleviate these problems.

3 GestureMan 2

We designed a new robot that has more resources to show a remote person's orientations than the GestureMan. We named he new robot GestureMan 2 (Fig. 3).

3.1 Head and Body Design

Three-camera unit is mounted at the head of the robot. Each lens has 60 degrees of horizontal field of view thus a remote participant can get 180 degrees of horizontal field of view in total.

Three-camera unit is covered with a white helmet so that it looks like a head. Also two ears and a visor are attached to a helmet. In this way the head gives local participants a clue where the middle camera is orienting

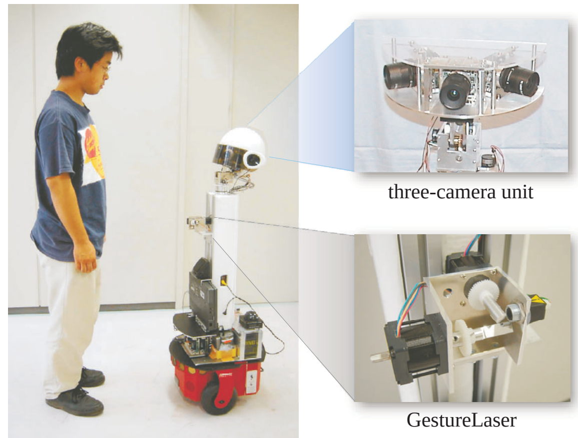

Figure 3: GestureMan 2

to. Pan and tilt motion of the head are enabled by two motors at the neck. In this way, the robot can show both body orientation and head orientation independently. In order to clearly express body orientation shoulder-like shapes are attached to the body.

3.2 GestureLaser

GestureLaser is a remote control laser pointer that was developed by the authors [4] and it is attached to the robot's body. A remote participant controls the laser spot by a mouse. The laser beam is emitted only when a left mouse button is pressed. Otherwise the laser is turned off completely.

3.3 Control the Robot by Human Motion Tracking

For the robot head of the Gestureman 2 to be an effective resource for communication, it should be controlled to accommodate a remote person's intention to look at objects in an environment. We used a joystick to control a head of previous GestureMan. Although a joystick worked quite well, it is clear that a robot head does not move as frequently as people do. Therefore, we decided to control the robot by tracking motion of a remote person.

Figure 4: ATLAS

For this purpose, we used a locomotion interface named ATLAS developed by ATR [3]. It is a treadmill-like locomotion interface. A user can get the sensation of walking on flat ground or on a slope. We mount a CCD camera with an infrared light filter and an infrared lamp in front of the treadmill. The relative positions of the small IR reflection markers attached to each ankle of a user are measured by a video-tracking system (OKK QuickMug) and determines the speed of the belt of the treadmill. When a user steps sideways, the whole system turns to compensate for the user's walking direction. Using the ATLAS, we can control the robot's forward, backward, and turning motion in response to a remote person's walking action. Forward motion speed is determined in proportion to a remote person's walking speed.

We also use a head mounted display (HMD) with a magnetic position sensor. A magnetic sensor enables to control the robot's head in proportion to a remote person's head motion. An HMD shows an image captured by a three-camera unit. However, we used only the middle camera among three cameras because the HMD is only capable of showing one video signal at the same time.

The GestureLaser is controlled by a small handheld track ball unit. We did not control the laser in proportion to a remote person's arm motion because a remote person do not have to keep his/her hand up when he/she wants to keep pointing at a certain object.

For voice communication, a remote person wears a headset. A co-present wears a wireless microphone to transmit his/her voice to a remote person. A remote person's voice can be heard from a speaker imbedded in the robot's head.

4 Remote Guide Experiment

We have conducted a preliminary experiment to examine the effect of using ATLAS as an user interface for a remote person.

4.1 Experiment Design

The GestureMan 2 resided in a room at the University of Tsukuba and the ATLAS was installed at ATR. Two sites were about 400km apart and the Japan Gigabit Network (JGN) was used to transmit audio/video signal and robot control commands.

At the university, six posters that explains different research topics were posted in the room. These research topics were categorized into two research areas, i.e. virtual reality and tele-conferencing and each area consisted of three posters. A remote person at ATR controlled the robot and guided a co-present (subject) to posters to explain about research topics. When each session started, a co-present chose one course which seemed to be more interesting for him/her.

We compared two control modes; joystick mode and ATLAS mode (Fig. 5). Only the middle camera of the robot was used for both modes. 10 university students served as co-present for each mode. On the other hand, only one researcher of ATR served as the remote person. As a reference, we did the same poster session under the face-to-face setting. The same researcher of ATR actually came to the university and guided 10 subjects.

For later analysis, all the sessions were video taped and questionnaires were given to all subjects.

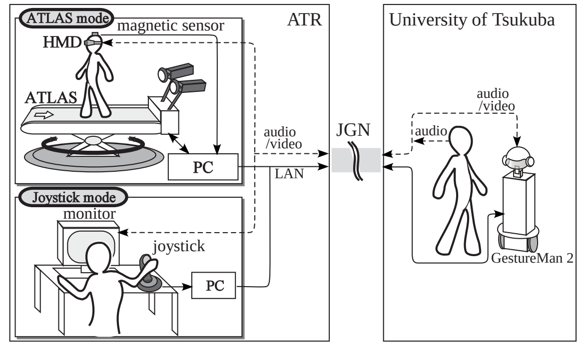

Figure 5: Overview of the experiment

4.2 Result

Before the experiment, our hypotheses to this experiment were as follows:

- ATLAS mode was superior for a co-present in recognizing where a remote person was looking at.
- A co-present had better impression on the robot when it was controlled in ATLAS mode because its head and body motion were natural.

In this section we will discuss the result of the experiment based on the video analysis and questionnaires.

Behavior analysis

During the experiment, a remote user moved the robot from one poster to another. Posters were intentionally placed so that the robot should move from one side to the other side of the room. A remote person turned the GestureMan's head to look back and forth between posters and a co-present just like people commonly do when they are co-existing (Fig. 6).

These kinds of attitudes of the robot were observed in both control modes. We counted the number of this kind of head turns and it turned out that the head was turned less often during the joystick mode (Fig. 7).

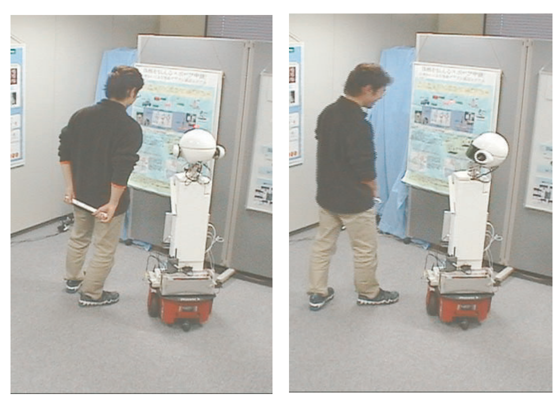

Figure 6: An example that robot turned its head.

When the robot roved, however, it moved faster during joystick mode compare to ATLAS mode. Figure 8 shows the average time that the the remote person waited for a subject. Negative numbers indicate that a

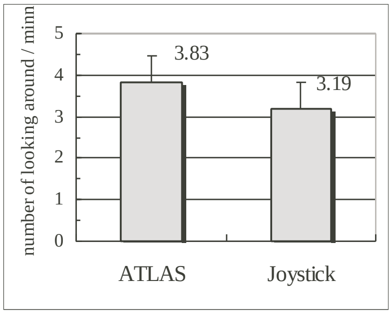

Figure 7: Number of head turns per minute.

subject waited for the remote person. Steel-Dwass test showed that there was statistically significant difference ($p < .05$) between each mode.

This result was mainly due to the difference of parameter setting between ATLAS mode and joystick mode. For instance, the maximum speed of the robot was diminished due to the software limitation. Although this result was quite opposite from our expectation, we are now interested in how this difference of motion affected subjects' impressions on the robot.

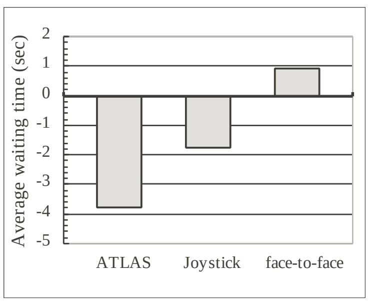

Figure 8: Average time to wait for the robot.

Questionnaire

After the session, we asked each subject to answer three kinds of questionnaires. First one (table 1) asked the overall impressions on the robot. Second and third one (table 2) asked the impressions on the robot's head and body motion respectively. Please notice that we called the robot as "guide" in this questionnaire.

Firstly after the session, subjects answered 27 items in questionnaire 1 using a 5-point scale ranging from 1 (not at all) to 5 (very much). Then, subjects answered questionnaire 2 and 3. There were 16 adjective pairs (opposite in meaning) in each questionnaire and subjects chose responses from 5 point scale.

In case of the questionnaire 1, Wilcoxon rank sum test showed that there were significant differences ($p < .05$) in item 1, 2, and 24 (printed in bold face in table 1). For instance, joystick mode was preferable in terms of affinity, dependability, and fatigue.

In case of questionnaire 2, Wilcoxon rank sum test showed that there were significant differences ($p < .05$) in item 11 and 15 (printed in bold face in table 2). For instance, head movement in joystick mode was more lovable and natural compare to ATLAS mode. There were no significant difference in any items in questionnaire 3.

Table 1: Extracts from questionnaire 1 (overall impressions).

1.	**Did you feel affinity to the guide?**
2.	**Did you think the guide was dependable?**
3.	Did you feel the guide was lovable?
4.	Was the robot's roving clumsy?
5.	Was it easy to follow the guide?
12.	Were you irritated by the red dot?
15.	Were you aware of the guides gaze?
16.	Was it easy to recognize where the guide was looking at?
17.	Was it easy to project where the guide was aiming at?
24.	**Were you tired?**

Table 2: Extracts from questionnaire 2 and 3 (head/body impressions)

1.	sensitive ⇔ dull
3.	quick ⇔ slow
8.	safe ⇔ dangerous
11.	**lovable ⇔ hateful**
13.	good ⇔ bad
15.	**natural ⇔ artificial**

5 Discussions

First of all, we could not prove our hypothesis that the ATLAS mode is superior for a co-present in recognizing where a remote person is looking at. In this paper, however, we focus on the effect of a robot's head and body movement on co-present's impressions on the robot. Especially we are interested in clarifying why joystick mode was superior in terms of impressions.

Co-presents thought the robot was more dependable during joystick mode. As shown in figure 8, during face-to-face mode, the guide ("remote person" in other modes) arrived at the next poster to be explained before co-presents. Thus we could assume that subjects felt the guide was dependable when he always led subjects. Therefore, we think that subjects felt the robot was less dependable during the ATLAS mode because they had to wait for the robot longer compare to the joystick mode.

In terms of the robot's head, subjects thought that its movement was more lovable and natural during the joystick mode. We are going to discuss some reasons for this from the aspects of the frequency of head rotation, head rotation angle, and head rotation speed.

At first, as shown in figure 7 the head moved more frequently during the ATLAS mode. However, this figure shows only major movement of the head. Actually, during the ATLAS mode, there were much more small and frequent movement in response to the remote person's actual head movement. Of course this kind of motion was not seen during joystick mode.

For this experiment, only the center camera of the three-camera unit was used. Its field of view is 60 degrees horizontally and 45 degrees vertically and it is of course much narrower than human eyes. Therefore, in order to look at a certain object via the robot, a remote person had to turn the robot's head more than a people normally does. Especially when the remote person wore HMD, he tended to look at an object at the middle of his field of view and this made the motion of the robot's head unnaturally large. On the other hand, when the remote person was using the joystick, he tended to stop turning the robot's head soon after the object appears at the edge of the monitor. Thus, during the ATLAS mode, the robot's head tended to turn much larger than the joystick mode.

In case of the ATLAS mode, the maximum rotation speed of the robot's head was faster than the joystick mode in order to catch up with the motion of the remote person's actual head motion. On the other hand, in case of the joystick mode, the maximum speed was reduced due to the controllability. As the robot's head turned faster, it made larger noise from gears. Thus, during the ATLAS mode, the robot's head turned faster with more noise compare to the joystick mode.

In summary, the robot's head turned more gently during the joystick mode compare to the ATLAS mode. We are assuming that these were the main reasons why subjects got better impressions on the joystick mode. It is quite interesting that simpler head motion during the joystick mode made subject feel that it is more natural. We can assume that such motion seemed to be "natural" for that kind of robot design. We can also assume that the difference of the head motion led to the difference of affinity and tiredness.

Another interesting result about the head movement is that although the robot's head during ATLAS mode tended to direct more precisely toward objects, it did not make any difference to items from 15 to 17 of the questionnaire 1.

This is still a preliminary experiment and we cannot clearly conclude that which factors are dominant for the results of subjects impressions. However, our previous study and results in this paper gives us following design implications;

- The robot should provide resources for a co-present to determine a remote user's orientation.
- However, it may not be necessary for such resources to precisely direct to a certain object.
- It is important to design how fast, how much, and how often such resources to be moved.

6 Conclusions

We have developed robots as communication media named GestureMan 2. We controlled the robot in proportion to a remote person's walking and head motion. Our experiment with the system indicated that for this kind of robot to have an affinity to people, not only its figure but also its motion should be designed properly.

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