Artif Life Robotics (2002) 6:73–77

ORIGINAL ARTICLE

Michita Imai · Tetsuo Ono · Hiroshi Ishiguro

Robovie: communication technologies for a social robot

Received and accepted: September 21, 2002

Abstract ATR Media Information Science Laboratories has developed a humanoid-type robot that can work in our daily life and fit naturally into human society. This robot will be a platform for developing various types of service robots, such as cleaning robots, security patrol robots, and entertainment robots, based on a rich communication ability.

Key words Human–robot interaction · Social robot · Robovie

1 Introduction

A new type of robot has been developed that appears to work well in the living spaces of humans. This new robot, named Robovie, is different from the types of robots working in factories. In particular, Robovie requires skills for daily communication with humans when participating in human society. It was developed as an everyday robot to investigate the functions necessary for communication. This article describes some problems of communication between a human and a robot through an explanation of Robovie.

For a robot to participate in human society, it has to be able to communicate with people naturally while carrying out its tasks. In other words, the robot must not only obey commands from users, but must also generate requests to ask people to solve problems it cannot deal with by itself. Such bidirectional communication is vital if the robot is to succeed in human society and play a significant role. To date, however, no one has proposed a method of communication between humans and robots while also considering robot participation in human society.

M. Imai (✉) · T. Ono · H. Ishiguro
ATR MIS Laboratories, 2-2-2 Souraku, Seika, Kyoto 619-0288, Japan
e-mail: michita@ayu.ics.keio.ac.jp

This work was presented, in part, at the Sixth International Symposium on Artificial Life and Robotics, Tokyo, Japan, January 15–17, 2001

An ordinary robot has the following features.

- Master–slave relationship, where a person gives the robot commands and the robot obeys them.
- Code-model communications, where each command used between the person and the robot has a static meaning.
- Task-oriented design, where the robot's behavior is designed to carry out given tasks only.

In short, the robot is designed as a tool and communicates with people as a tool. For example, a cleaner robot is designed with behaviors and commands only for cleaning.

From another perspective, the design theory of tool robots is insufficient for developing new types of robots capable of performing activities in the living spaces of humans; it does not consider that a person might be requested to do something by a robot. Almost no one would be aware of the robot's requests as defined by its programmer when he or she encounters the robot for the first time by accident. In short, to work in the living spaces of humans, the robot must have the ability to communicate independently of the ordinary command set. Moreover, the robot must be able to vary its role in human society, because it may encounter an event not related to a given task.

Further to the above discussion, this article proposes an everyday robot named "Robovie." The problems of the master–slave relationship, code-model communication, and task-oriented design come from the lack of a relationship between the human and the robot. Robovie achieves a new type of human–robot communication by developing a relationship with a person via physical interactions. Robovie has the features listed below.

- *Peer.* Robovie achieves bidirectional communication with a person by developing a dynamic relationship with him or her.
- *Mutual mind-reading.* The person and Robovie can communicate with each other by inferring the other's communicative intention based on the relationship developed between them.
- *Everyday behavior.* Robovie can perform everyday activities (autonomous battery-charging function and

autonomous behavior) for basic interactions in human society.

The remainder of this article is organized as follows. Section 2 describes a crucial element of human–robot interaction in human society. Section 3 describes the mechanisms of Robovie, and explains the communication process between a person and Robovie. Section 4 concludes the article with a summary.

2 Requests from a robot

Bidirectional communication between a person and a robot is an important function if the robot is to participate in human society. In the development of Robovie, we conducted a psychological experiment [OI00] where the robot requested experimental subjects to perform a task. Before explaining the details of the experiment, we describe the results. The results indicated that the relationship between the subject and the robot was a crucial factor in determining whether the subject would obey the request from the robot. The rest of this section gives a brief explanation of the experiment. In the experiment, an autonomous mobile robot asked the subject to perform a task after suddenly appearing in front of the subject (see Fig. 2). The request message was "Please move the trash can!" The message was generated with a speech synthesis system.

The experiment investigated the effects of the relationship between each subject and the robot on the request from the robot. We employed the migration of a computer graphic (CG) character to develop the relationship between the subjects and the robot. The display of a mobile PC (upper left-hand side of Fig. 1) showed the CG character. In addition, the robot (lower right-hand side of Fig. 1) could also display the CG character. In the first step of the experiment, the subjects interacted with the CG character displayed on the mobile PC. In this step, the subjects came to form a relationship with the CG character. In the next step, the CG character disappeared from the display of the mobile PC and appeared on the display of the robot. Through this migration of the CG character, we gave the subjects a relationship with the robot.

Figures 2 and 3 show the results of the experiment. The subject in Fig. 2 was given a relationship with the robot based on the migration of the CG character. As a result of the migration, the subject obeyed the request from the robot naturally and moved the trash can. The subject in Fig. 3 was not given a relationship with the robot because the CG character did not migrate to the robot's display. As a result, without the migration, that subject ignored the request from the robot which had suddenly appeared.

These results suggest that forming a relationship between a person and a robot is crucial for the robot's ability to successfully request the person to do something.

3 Robovie

Robovie was developed to investigate human–robot interaction in terms of the development of a relationship. The

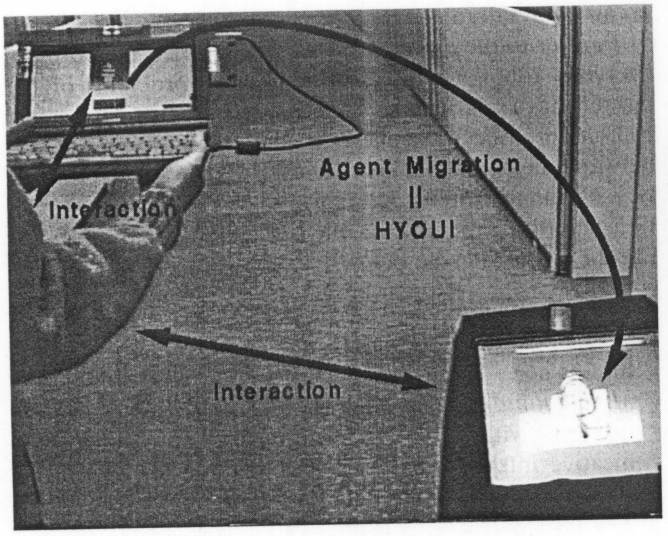

Fig. 1. Migration of a relationship by migration of a CG character

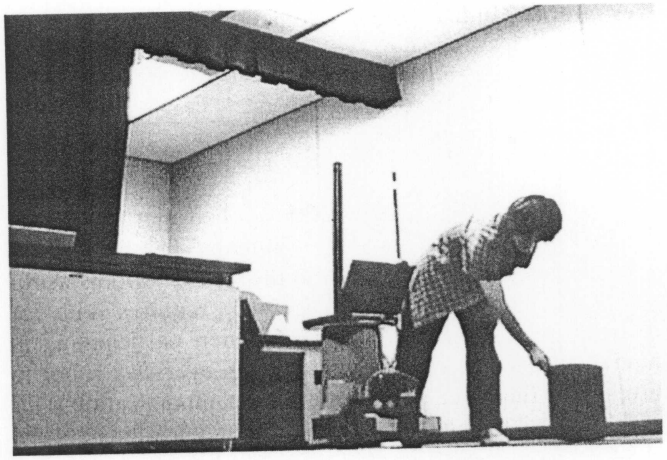

Fig. 2. Subject who could understand the request from the robot

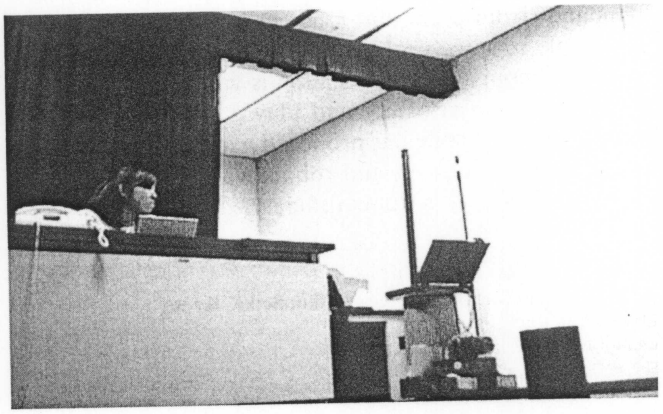

Fig. 3. Subject who could not understand the request from the robot

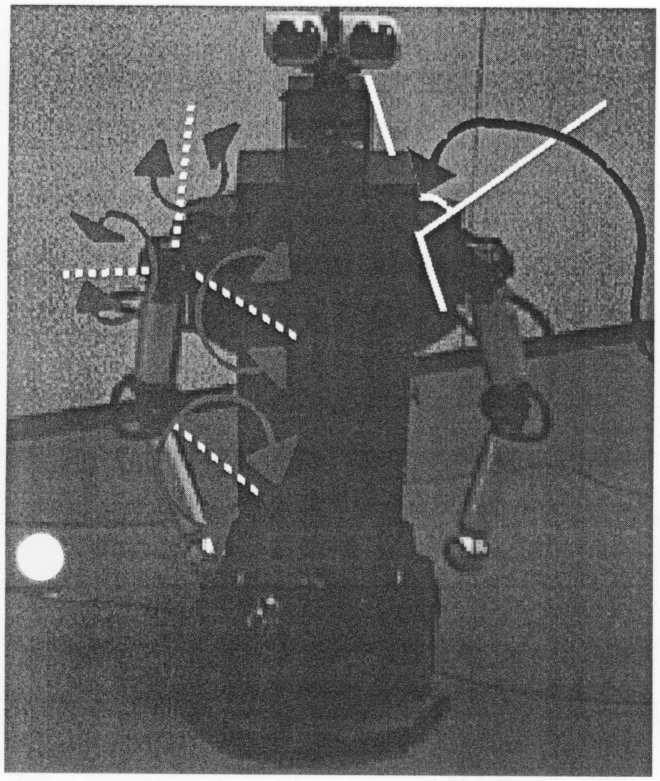

Fig. 4. Everyday robot "Robovie"

upper part of Robovie consists of one head and two arms like a human body, and Robovie develops a relationship with a person through its physical representation. The lower part of Robovie is a mobile base with two wheels and one caster. Figure 4 is a photograph of Robovie. The arms of Robovie have four degrees of freedom, enabling the hands to move like human hands. In addition, since the points fixed on the arms bend toward the front of Robovie, it is e for the arms to reach the front part of Robovie. Because of the movement range of the arms, Robovie can generate gestures more naturally. In addition, the head has three degrees of freedom to move like a human head. Table 1 shows Robovie's other specifications.

Robovie moves around and avoids obstacles by using ultrasonic distance sensors. In addition, with its skin sensors it can notice when a person touches it. It has two cameras with stereo-vision in its head to find a battery station. The back of Robovie has an omnidirectional vision sensor, which captures the panoramic scene around Robovie in one shot. The omnidirectional vision sensor is mainly used by Robovie to find its location by comparing the current captured image with previously captured images. In addition, Robovie has a speech synthesis system and a recognition system to communicate with people via vocal messages.

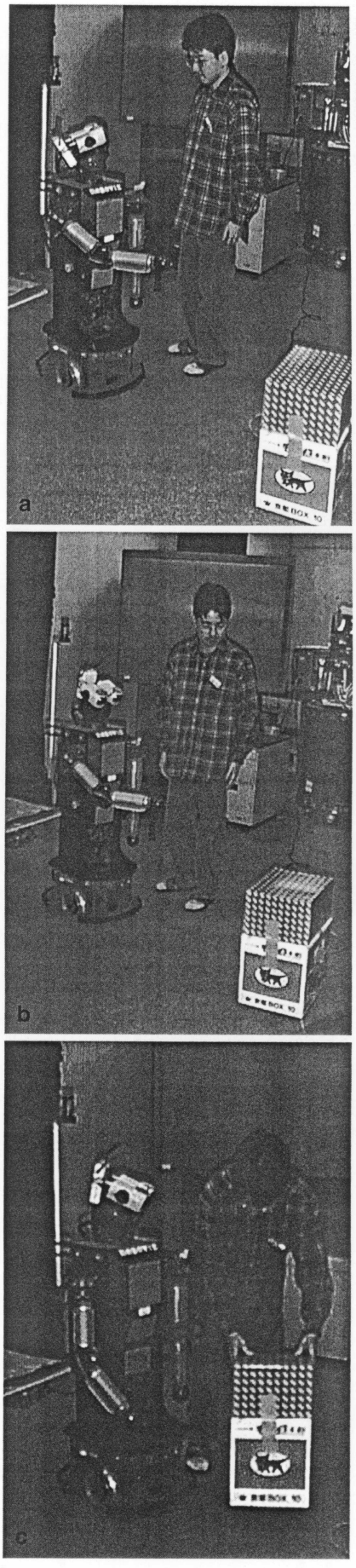

Fig. 5. Communication with gaze behavior. **a** Gaze manifestation toward a person. **b** Gaze manifestation toward a box. **c** The person moves the box in response to a physical representation and a vocal request

Table 1. Specifications of Robovie

Size	*H* 114 cm × *W* 52 cm × *D* 50 cm
Weight	39 kg
Maximum movable speed	1.6 m/s
Maximum arm speed	200°/s
Battery specification	DC 12 V, 21 Ah
Movable time	3.5 h
Movable base specification	2 wheels (drive), one caster
Minimum height from ground	3 cm
Cameras	Sony EVI-G20 × 2
Ultrasonic distance sensors	24 units
Omnidirectional vision sensor	1 units
Hand sensors	Switch type × 2 units
Skin sensors	Touch sensor × 16 units
Arm motors	Harmonic drive DC motor ×8 units
Head motors	Harmonic drive DC motor ×3 units
Computer	K-6-II 400 MHz HDD 6 GB SDRAM 128 MB Video capture board
Communications	Wireless LAN

3.1 Communication based on a relationship between a human and a robot

Robovie achieves communication by forming a relationship with a person with the hardware described above. The crucial methodology for developing the relationship is physical representation.

The most important factor in the development of such a relationship is gaze behavior. In particular, the most important gaze behavior for developing a relationship is eye-contact between the person and Robovie (Fig. 5a). Robovie also employs gaze as another communication function, which is called attention manifestation. This function manifests the direction in which Robovie pays attention. Figure 5b shows Robovie manifesting its direction of attention toward the box.

Robovie can request a person to perform a task, such as asking "Please move this box!", by making eye-contact with the person and displaying attention manifestation toward the box (Fig. 5c).

In addition, Robovie has an autonomous battery-charging function. This function was implemented to allow us to investigate the process by which Robovie can acquire a dynamic role in human society. In short, Robovie can find a battery station and charge its battery automatically when the voltage level becomes low. Since Robovie is designed to work in the living spaces of humans without the aid of humans, it has its own life-cycle. As a result of this life-cycle, we can pursue research that investigates the communication functions necessary for dynamic role changes.

4 Conclusions

This article has described an everyday robot named Robovie. Before developing Robovie, we conducted a psy-

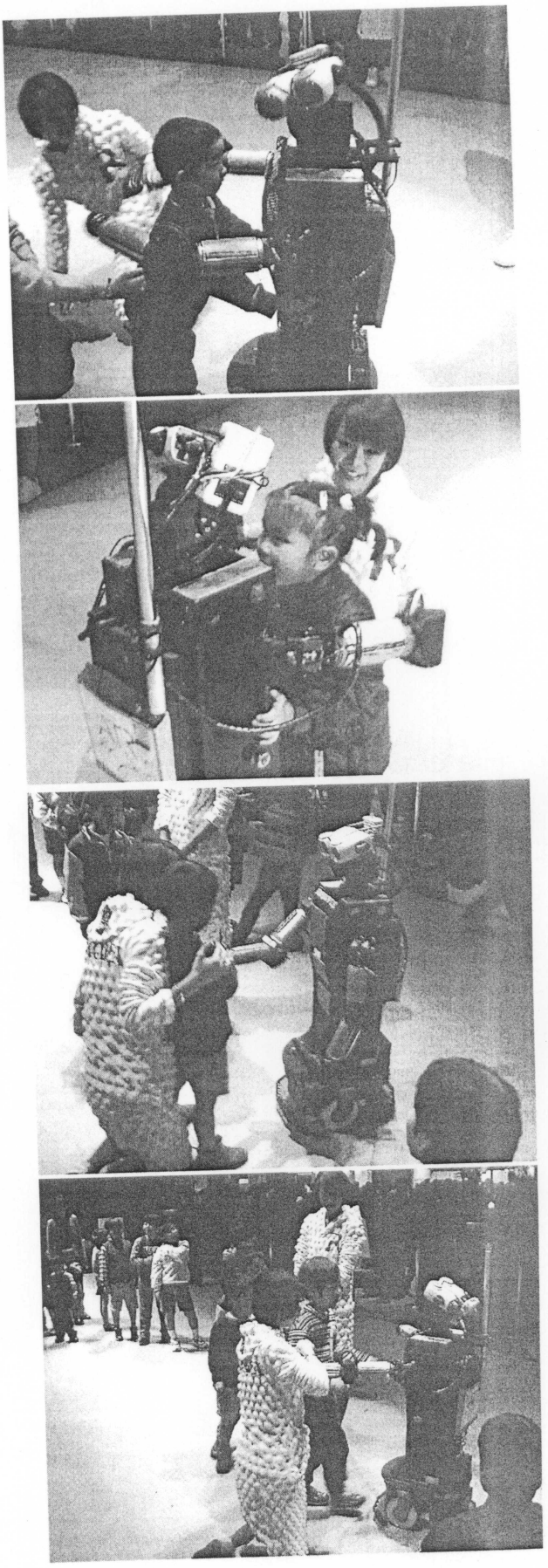

Fig. 6. Exhibition at ROBODEX2000

chological experiment to acquire knowledge about the interaction between a person and a robot. Our experiment suggested that verbal interaction alone was insufficient for bidirectional human–robot communication. The important factor in achieving such communication is the development of a relationship between the person and the robot. As a result, we gave Robovie a physical representation function to develop a relationship with people. At present, interaction with Robovie is being evaluated at several exhibitions, for example, ROBODEX 2000 (Fig. 6).

Acknowledgment This research was supported in part by the Telecommunications Advancement Organization of Japan. http://www.mic.atr.co.jp/~michita/everyday/

References

1. Ono T, Imai M (2000) Reading a robot's mind: a model of utterance understanding based on the theory of mind mechanism. In: Proceedings of AAAI-2000, pp 142–148