Using Robots for the Study of Human Social Development

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Abstract

We built a child-like humanoid, *Infanoid*, and a small creature-like robot, *Keepon*, by which we investigate human social development, especially of interpersonal communication. The approach we take here includes (1) to implement on the robots psychological models of social development, (2) to observe how human children interact with the robots through various social actions like pointing at and showing objects. These two sides are complementary: findings from the observation will then be used for upgrading the robots' structure and function, thus forming an elaboration cycle. This position paper introduces our research project, *Epigenetic Robotics*, in which we do both implementation and observation in order to provide a promising and productive field of synergy for exploring the developmental mechanism of human communication.

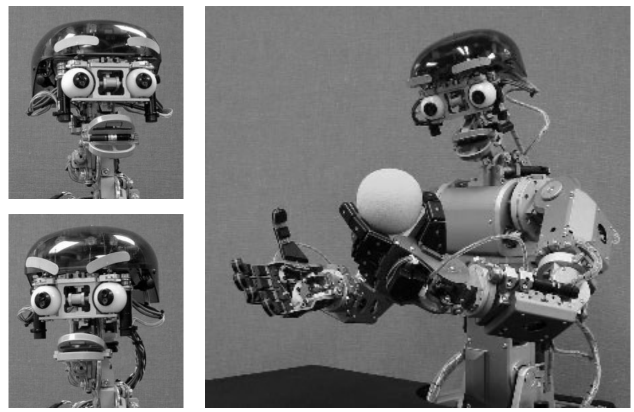


Fig. 1 *Infanoid*, the attentive and emotive humanoid.

Fig. 2 Eye-contact and joint attention with *Infanoid*.

Introduction

Developmental Robotics is a newly emerging approach to modeling and building autonomous artificial intelligence with the human-level adaptability to the physical and social environment. This interdisciplinary field is expected to provide both developmental psychologists and AI/robotics researchers with the linkage between theories in the laboratories and practices in the field (Breazeal 2000; Zlatev 2001). The most of the early efforts were, however, just trying to transfer the psychological and neurological findings onto robotic platforms in rather ad hoc and restricted settings. In order to create the synergistic effect, AI/robotics should make more influence on developmental psychology.

In this paper we introduce our research project, *Epigenetic Robotics* (Kozima 2001), with an emphasis on utilizing our robots in psychological research. Since we are interested in human social development, especially of interpersonal communication (Kaye 1982; Trevarthen 2001), (1) the cognitive models we implement on the robots have to be evaluated in the real social environment with human interactants, (2) from that evaluation we need to investigate the underlying mental mechanism of human social communication, and (3) we would like to contribute the research outcomes to the pedagogical and clinical fields (Dautenhahn 1999), from where we have had a great influence. Based on the motivations above, we built the robots and use them for investigating how humans, especially children and babies, perceive and act on (and finally relate to) the robots.

Building Robots

To get started, we built a child-like humanoid, *Infanoid*, and a small creature-like robot, *Keepon*, which are capable of primordial embodied communication with humans, especially children and babies, respectively.

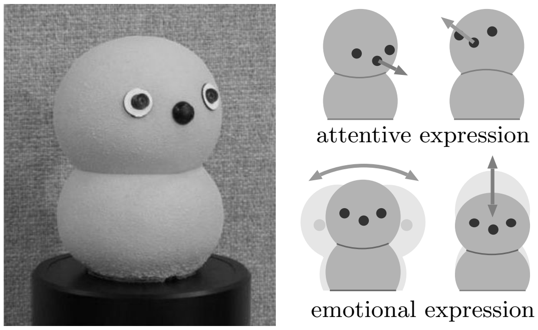


Fig. 3 *Keepon* and its expressive functions.

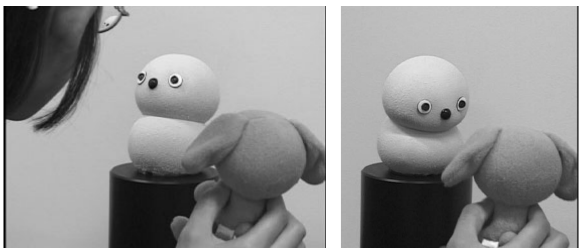
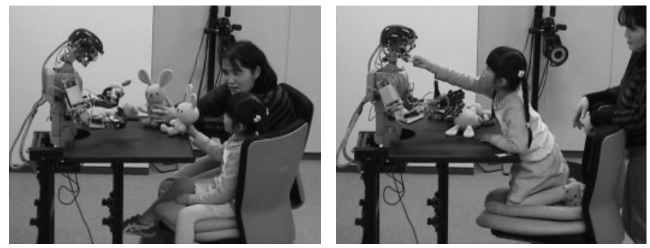


Fig. 4 *Keepon* gazing at a face and then at a toy.

(a) Showing a car (left) and giving a rabbit (right).



(b) Playing with agents/objects (left) and feeding (right).

Fig. 5 Children interacting with *Infanoid*.

Infanoid — An Upper-torso Humanoid

Infanoid, shown in Fig. 1, is an upper-torso humanoid robot which is as big as a 3- to 4-year-old human child (Kozima 2001, 2002). It has 29 actuators (mostly DC motors with encoders and torque sensing devices) and a number of sensors arranged in the relatively small body. It has two hands capable of pointing, grasping, and a variety of hand gestures; it also has lips and eyebrows to produce various facial expressions, like surprise and anger, as shown in Fig. 1, left.

The head of *Infanoid* has two eyes, each of which contains two different color CCD cameras for peripheral and foveal views; the eyes can perform saccadic eye movements and smooth pursuit of a visual target. The video images taken by the cameras are fed into a cluster of PCs for real-time detection of human faces (for eye-contact, as shown in Fig. 2, left) and a primordial form of joint attention (as shown in Fig. 2, right) by reading the human's face direction to a third object. From the microphones at the ears, *Infanoid* hears human voices and analyzes the sound into a sequence of phonemes. By feeding the phoneme string with the extracted pattern of fundamental frequency, *Infanoid* performs vocal imitations while sharing attention with the interactant.

Keepon — Not a Toy nor a Human

For psychological experiments with younger children, we built another robot, *Keepon* (Kozima 2003). Comparing with *Infanoid*, which has human-like sophisticated structure and function, *Keepon* is a small (12cm in height, 8cm in diameter), soft (made of silicone rubber), creature-like robot, as shown in Fig. 3, left. It can perform only two kinds of motion, as illustrated in Fig. 3, right: (1) expressing its *attention* by orienting its face to a certain target in the environment, and (2) expressing its *emotional states*, such as pleasure and excitement, by rocking its body from left to right and by bobbing up and down. Keepon is connected by wireless links to a remote PC, from which a human operator or a computer program controls the motion. Although its appearance is quite simple, *Keepon* has two color CCD cameras and one microphone at the nose tip, which provide almost the same audio-visual capabilities as those of *Infanoid*, as shown in Fig. 4.

Observing Interaction with Children

We carried out a series of observations of child-robot interaction, where normal children and mentally challenged children played with our robots almost without any experimental constraint.

Interacting with Infanoid

Fourteen normally developing children (about 5 years old on average) interacted with *Infanoid* (Kozima 2003). The robot ran in Automatic Mode, in which it alternates between eye-contact and joint attention with pointing; if necessary, a remote operator made adjustments to the robot's attention (e.g. direction of the gaze and bodily posture). First, each child was seated alone in front of the robot, without having been given any prior knowledge about the robot. About 3 to 4 minutes later, the child's caregiver (usually mother) came in and sat next to the child. Interaction continued until the child get tired or bored; on average, each child had an interaction of about 30 minutes.

We found from the observations that each child's ontological understanding of *Infanoid* changed with the progress of the interaction in the following manner.

- Neophobia phase: For the first 3 to 4 minutes, the child showed embarrassment, not knowing how to deal with this *moving thing*. In fact, there was no reciprocal interaction, but just staring at the robot.
- Exploration phase: Next, by poking the robot and showing his/her hand or toys to the robot (Fig. 5 (a), left), the child started exploring what stimuli the robot could perceive and what action the robot could perform in response.
- Interaction phase: Finally, the child gradually got into the loop of social exchanges. For example, the child responded to the robot's pointing to a toy by handing it to the robot (Fig. 5 (a), right), as if he/she recognized the robot as a *mental agent* that has desire and likes/dislikes.

In addition, we observed a 6-year-old high-functioning autistic child interact with *Infanoid* (Kozima 2004a), where we found almost the same tendency in the progress of the interaction, except that the autistic child did not get bored even after 45 minutes intensive interaction with the robot. For details, refer to (Kozima 2004a).

We hypothesized that children change their ontological understanding of *Infanoid* in the following way. First, children recognize the robot as *a moving thing*; then, observing the robot's motion responding to various environmental disturbances, they recognize that the robot is *an autonomous, subjective system* that possesses attention and emotion as an initiator of the motion. Next, they find that the robot's response (in terms of attention and emotion) has a spatio-temporal relation with what they have done to the robot; then, they recognize the robots as *an intersubjective companion* with which they can exchange or coordinate their attention, emotion, and actions.

Interacting with Keepon

Twenty-three normally developing babies in three different age groups, namely 0-year-olds (from 6 months of age), 1-year-olds, and over-2-year-olds, interacted with *Keepon* together with their mothers (Kozima 2003). The robot ran in Manual Mode, where a remote operator controlled the robot's attentional and emotional expressions manually with the help of the images and sounds taken by the on-board and off-board cameras. The robot usually alternated between eye-contact (with the baby or the mother) and joint attention (to some toys on the floor); when the baby showed any meaningful response (touching, pointing, etc.), the robot made eye-contact and showed positive emotion by rocking and bobbing its body. Interaction continued until the babies showed any sign of fatigue or boredom; on average, each baby had an interaction of about 10 minutes.

We found from the observations almost the same tendency that we found the interaction with *Infanoid*; however each of the three age groups showed different

(a) Showing a rabbit (left) and soothing (right).

(b) Challenging the robot (left) and pretense play (right).

Fig. 6 Babies/children interacting with *Keepon*.

depths to which they deepened the level of the interaction.

- 0-year-olds: The interaction was dominated by tactile exploration using hands and mouth. The babies did not pay attention to *Keepon*'s attention.
- 1-year-olds: The babies showed awareness of *Keepon*'s attentional and emotional expressions. Some mimicked the robot's emotional expressions (by rocking and bobbing their bodies).
- 2-year-olds: They socially interacted with *Keepon*, by showing toys (Fig. 6 (a), left) for instance. When the robot's response was meaningful to the babies, they often soothed the robot by stroking its head (Fig. 6 (a), right).

We assume that the different ways each group took in the interaction reflect their ontological understanding of the robot.

Meanwhile, we also longitudinally observed 15 preschool children (2 to 4 years old) with developmental disorders (e.g. PDD and autism) interact with *Keepon* (Kozima 2004b). We placed Keepon in the playroom at a day-care center for children with special needs. The children, often with their parents and nursing staffs, could interact with Keepon spontaneously anytime during the remedial session (about 3 hours). Through a series of longitudinal observations for about five months (12 to 15 sessions for each child), we observed various types of change in the children's ways to interact with Keepon, each of which displays the distinctive characteristics of the child and his/her difficulties. The video record of the interaction that had taken from the view point of *Keepon* and its preliminary analysis are being used for planning and evaluating the remedial service. For details, refer to (Kozima 2004b).

Conclusion

We described here some of our preliminary attempts to utilize interactive robots for the psychological study of human social development. The child-like humanoid, *Infanoid*, and the creature-like robot, *Keepon*, are being used as (1) research platforms on which we implement and test our models of social intelligence and its development, (2) tools for psychological investigation, where the robots display various types of social actions to human interactants, and (3) a medium through which we contribute to the social needs in the pedagogical and therapeutic practices. These aspects of robot utilization are, of course, complementary ones; further knowledge exchange by which the researchers could share their seeds and needs is certainly important for the success of this interdisciplinary undertaking.

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