Geminoid
- Tele-operated Android of an Existent Person -

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Abstract

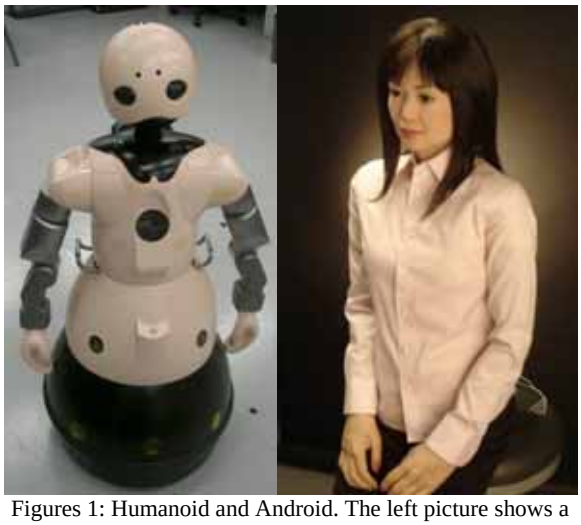
Androids are testbets for studying human-robot interaction. They enable us to compare the developed robot technologies and humans in a direct manner. Especially, they can be used for verifying cognitive and psychological hypotheses. And then the verified hypotheses are applied for improving the androids. This tight connection between robotics and cognitive science is called *android science*.

The developed androids so far, however, are not enough for various cognitive tests. Especially, they lack abilities for long-term conversation. In order to compensate this problem, we need to consider high-bride systems in which a human and the android are integrated. The integrated system is called *geminoid*. Geminoid is a new category of robot. It is a tele-operated android of an existent person. By using the geminod, we can tackle to the unsolved problems and extend the framework of android science.

Appearance and behavior of interactive robots

Why are we attracted in humanoids and androids? The answer is simple. It is because of our tendency to anthropomorphize non-human things. We, humans, always anthropomorphize targets of communication and interaction. Therefore, we expect much with humanoids. In other words, we find a human itself in the humanoid. Recently, re-searchers' interests in robotics are shifting from traditional studies on navigation and manipulation to interaction with the robots.

The human-robot interaction study has been neglecting an issue. That is "appearance v.s. behavior problem." The interactive robots that have been developed thus far are non-android types. Evidently, the appearance of the robot influences the impressions of the subjects, and it is a very important factor in the evaluation of the interaction (See Figure 1). There are many technical reports that compare robots with different behaviors; however, thus far, the appearance of the robots has not been focused upon. Although there are many empirical discussions on very simplified static robots such as dolls, the design of a robot's appearance, particularly to make it appear a humanoid, has always been a role of industrial designers. This is a serious problem for developing and evaluating interactive robots. The appearance and the behavior are tightly coupled, and the results of the evaluation change with the appearance.



Figures 1: Humanoid and Android. The left picture shows a humanoid Eveliee P1 in Osaka University based on WAKAMARU that was developed by Mitsubishi Heavy Industry Co. Ltd.; and the right one shows an android Repliee Q2 developed by cooperation with KOKORO Co. Ltd. in Osaka University.

Android Science that bridges science and engineering

One of the methods to tackle to the neglected issue is to develop a very humanlike robot, i.e., an android, and use it for studying human-robot interaction. The right figure of Figures 1 shows the developed android. The android has 42 air actuators for the upper torso, excluding fingers. In the development, we have determined the positions of the actuators by analyzing the movements of a real human by using a precise 3D motion capture system. The actuators can represent the unconscious movements of the chest due to breathing in addition to conscious large movements of the head and arms. Furthermore, the android has a function for generating facial expression that is important for interactions with humans. Place acknowledgments (including funding information) in a section at the end of the paper.

The development of the androids requires contributions from both Robotics and Cognitive Science. In order to realize a more humanlike android, knowledge from human science is necessary. This new framework is called *android science* [1, 2]. Thus, android science is an interdisciplinary framework between engineering and cognitive science. Robotics attempts to build very humanlike robots based on the knowledge from cognitive science. Cognitive science

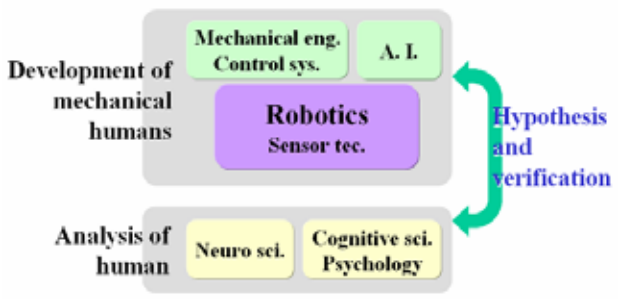


Figure 2: Android science

employs the robot for verifying hypotheses for understanding humans (See Figure 2).

In the past, robotics research used knowledge from cognitive science, while research in cognitive science utilized robots. However, the contribution from robotics to cognitive science has not been adequate; since appearance and behavior could not be separately handled, non-android type robots were not sufficient as tools of cognitive science. We expect that this problem can be solved by using an android that has an appearance very close to a human. On the other hand, robotics research based on the cues from knowledge in cognitive science faces a similar problem since it is difficult to clearly recognize whether the cues pertain solely to robot behaviors, isolated from their appearance, or the combination of its appearance and behaviors. In the framework of android science, androids enable us to directly share knowledge between the development of androids in engineering and the understanding of humans in cognitive science.

Let us summarize major research issues in android science here. The issues in Robotics are as follows

- Development of the very humanlike appearance with silicon
- Development of the humanlike movements
- Development of the humanlike perception by integrating with ubiquitous sensor systems.

On the other hand, the issue in Cognitive Science is "conscious and unconscious recognition." The goal of android science is to realize a humanlike robot and find the essential factors for representing human likeness. How can we define human likeness? Further, how do we perceive human likeness? It is well known that a human has conscious and unconscious recognition. When we observe objects, various modules are activated in our brain. Each of them matches the input sensory data with the human models; and then they affect on reactions. A typical example is that even if we recognize a robot as an android, we react to it as a human. This issue is fundamental both for the engineering and scientific approaches. It will be an evaluation criterion in the development of the android, and it provides us cues for understanding the human brain mechanism of recognition.

Bottleneck of robotics

The developed android shown in Figure 1 enables us various cognitive tests, however it is still limited. The bottleneck is long-term interaction by talking. Unfortunately,

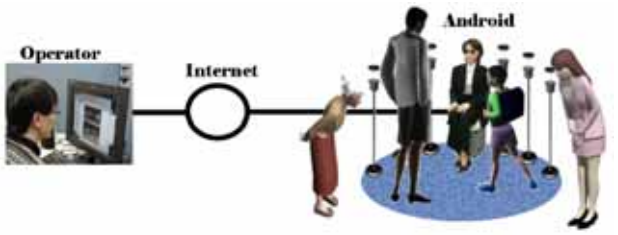


Figure 3: Tele-operated android

the AI technology for developing humanlike brains still limited and we cannot expect humanlike conversation with robots.

A method for solving this problem is to develop a hybrid system using tele-operation techniques. If the operator talks through the Internet, the android can have long-term conversation with people.

When we see humanoids, we usually expect to have humanlike conversation with them. However, the technology is very behind of the expectation. The development of the technology takes time and it is rather our final goal in robotics. In order to arrive at the final goal, we need to use possible technologies and understand deeply on what a human is. Our solution for this problem is to integrate the android and tele-operation technologies as shown in Figure 3.

This approach also develops practical application of androids. If we access to the android locating in a distant place, we do not need to go their. By using it, we can exist at the distant place.

Studies on existence of the person

For compensating the bottleneck, we have developed a *geminoid*. Geminoid is a new category of robot. It is a tele-operated android of an existent person. Figures 3 show myself and the geminoid.

After developing this prototype system, we have encountered several interesting phenomena as follows.

- When I saw the static geminoid, it was like a mirror. However, when it naturally moved, it was not myself although we have copied my movement. This means we do not objectively recognize our unconscious movement by ourselves.
- While I operate the geminoid with the interface system, I unconsciously adapt my movements to the geminoid's movements.
- Both of me and the visitor can quickly, less than 5 minutes, adapt to the conversation through the geminoid. The visitor recognizes the geminoid as me while talking each other. This is string entrainment, especially for people who know me well.
- When the visitor tough to the Geminod, I get a feeling to be toughed. The system does not provide sensor feedbacks. But, by looking at monitor and interacting with the visitor, I get the feeling.

By using the gemioid, we can have long-term conversation for explaining these phenomena and extend the framework of android science. In the previous works in android science, we focused on human likeness. In addition

Figure 3: Myself, the geminoid, and the tele-operation system. The geminoid has been developed in ATR Intelligent Robotics and Communications Laboratries.

to that, we can study on existence of the person. The questions are

- What is the difference between my existence recognized by myself and my existence recognized by others?
- What is invariant of my existence between them?

These questions are related to a simpler question whether my conscious and my body can be separate. By using the geminoid, we can tackle to these issues and deeply and systematically understand humans.

Our current challenges are as follows:

Tele-operation technologies for complex humanlike robots: It is necessary to study the method to tele-operate the geminoid in order to convey existence/presence, which is quite different with traditional tele-operation for mobile robots and industrial robots in the complexity. We are studying a method to autonomously control an android by transferring motions of the operator measured by a motion capturing system. We are, also, developing methods to autonomously control eye-gaze and humanlike small and large movements.

Synchronization between speech utterances sent by the tele-operation system and body movements: The most important technology for the tele-operation system is synchronization between speech utterances and lip movements. We are investigating how to produce natural behaviors during speech utterances. This problem is extended to other modalities, such as head and arm movements. Further, we are studying effects on non-verbal communication by investigating not only synchronization of speech and lip movements, but also facial expressions, head and even the whole body movements.

Psychological test for human existence/presence, so called *Sonzai-Kan* in Japanese: We are studying the effect of transmitting Sonzai-Kan from a remote place, such as participating to a meeting instead of the person himself. Moreover, our interest is to study what existence/presence is through cognitive and psychological experiments. For example, we are studying whether the android can represent authority of the person himself by comparing the person himself and the android.

Conclusion

Our purpose to develop the geminoid is to study on Sonzai-Kan by extending the framework of android science. The scientific aspect is to answer the questions how humans recognize human existence/presence. The technological aspect is to realize a tele-operated android that works on behalf of the person accessing from a distant place. This will be one of the practical networked robots that is realized by integrating the Internet and robots.

References

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