Alter-Ego Interface Technology

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Abstract

A communication style in which robots serve as alter egos to represent our own bodies in distant locations is being considered for future wireless network services. As a step in that direction, research is under way on telerobots that execute commands sent from an operating interface such as cell phones and humanoid robots that convey human gestures and facial expression according to signals from human bodies. Here we describe a human interface for these alter-ego robots and a new communication style that is made possible by such humanoid robot mediators.

1. Concept of the alter-ego interface

1.1 From intellectual communication to bodily communication

Communication by mail conveys meaning by written characters. That may result in misinterpretations of the message and cause unintended disagreements that do not occur in verbal communication on the telephone, in which a person's feelings can be expressed by tone of voice. Mental activity is based on intellect, emotion, and volition, so smooth communication between people cannot be achieved if emotion is not conveyed sufficiently. The images presented by videophones and the avatars of virtual reality (VR) systems convey the user's semblance and posture, so a sense of the user's virtual movement and feeling can be achieved in cyberspace. However, that still leaves something lacking in the conveyance of feeling in human communication. If, in addition to voice, video, and data, it were possible to remotely convey real bodily sensation that supplements the expression of emotions as well as the user's ambience and body movement by the actual body of a robot, then it might be possible to establish a bodily communication style that can bring emotions more into play.

Communication involves more than the simple transmission of information: a person's intentions and feelings are also conveyed when we communicate. Here, we use the term alter-ego interface for this new style of robot-mediated communication that involves remote operation [1] and conveyance of gestures by a robot avatar that has an actual body for expressing your bodily sensation and remote vision that allows you to change your point of view in a remote location via a camera on the robot.

In future data communication, we believe there will be a need to shift toward communication in which there is more processing of body information in addition to intellectual recognition such as pattern recognition and understanding, which focus on data transmission.

1.2 Non-dissociative communication

The basis of communication is the sharing of "now and here", which is to say the sharing of a space and time. Although the development of data communication technology in the 20th century has basically followed the Shannon-Weber model, that model originally dealt with information theory that concerned the transfer of information without any consideration of human beings. Human communication, however, involves an inseparable element that cannot be explicitly manifested, so effective human communi-

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cation is difficult with such separation in the transfer of information. According to Miwa et al. [2], communication in a living society is not accomplished by information that is separated from the self; rather, communication that does not separate self from other is normal, and media technology that takes into consideration gestures that convey implicit information is needed. In communication between remote locations, it is generally difficult to create a space that is shared by the communicating parties, so a state in which one is dissociated from the other party arises.

If a communication system that supports the communicability of body movements could be introduced, then non-dissociative, co-creative communication in which context is shared by the communicating parties could be achieved [3]. We have investigated various methods for achieving the sharing of time and place that accompanies bodily coherence, including a new cell-phone-based human interface that employs a humanoid robot mediator and a new gesture interface that employs biological signals.

2. Steps in the evolution of the alter-ego interface

The steps in the evolution of the alter-ego interface assumed when considering hand-held or wearable terminals as terminals for robot operation are shown in Fig. 1. The first step is 'human remote operation' (tele-operation), in which work instructions are given to a colleague at a remote location via a hand-held videophone. That will be followed by tele-operation of home appliances by cell phone and will evolve further to the implementation of robot tele-operation by a human operator.

There will be not only the simple remote operation of armed and legged robots by master-slave*1 arm control, but supervisory control, in which the robot is given instructions for performing tasks on the command level and then executes the tasks semi-autonomously. We believe that we will soon reach the stage of developing multiple intelligent robots that have a high degree of autonomy and engage in wireless communication to collaborate on tasks autonomously.

*1 master-slave: Master-slave manipulator system consists of two identically shaped manipulators. An operator controls the slave manipulator at the remote location by handling the master one beside him.

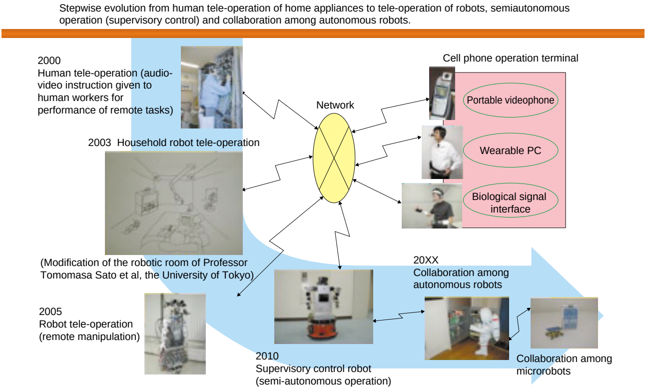

Fig. 1. Steps in the evolution of the alter-ego interface.

3. Humanoid robot mediated communication style

3.1 Dialog mediated by a robot that can introduce emotions

We have performed virtual experiments for conducting dialog via a network in which robot terminals are placed at the two locations [4]. Those experiments revealed some demerits of such systems, including the feeling of resistance to the appearance of a living face on the robot, the sense of incongruity arising from the fact that the robots were not life-sized, and insufficient bodily sensation due to the absence of a feeling of substance of the robot body and the robot's lack of emotion and body movements and lack of inertia. One merit, on the other hand, was the enjoyment of two-way, real-time robot-mediated communication. To solve the problems revealed in those experiments, we constructed the experimental platform for full-size humanoid robots for use in mediating communication shown in Fig. 1 [5]. The external appearance and specifications of the robots are presented in Fig. 2.

3.2 Transmission of gesture information to a full-size humanoid robot by EMG signals

To convey the operator's own wrist and finger gestures to the humanoid robot in front of him, which serves as a human interface for relaying the information via a network to the remote humanoid robot, we are contriving a method in which electromyogram (EMG) signals are detected on the operator's skin and processed for pattern recognition. One of us (A.H.) has already achieved control of five fingers and ten joints of a robot hand by detecting the electrical signals from muscles on the skin surface at the place where a person wears a wristwatch and performing pattern recognition on the signal data with an artificial neural network [6]. That system also employs the method mentioned above. Furthermore, for arm and shoulder movements, we achieved recognition of three of the six degrees of freedom (DOF: the number of axes of rotation of the robot joints) from EMG signals detected by skin surface electrodes placed on the upper arm (2) and shoulder (3) on both sides of the body (Fig. 3). The recognition is now being extended to six DOF by employing a new method of signal processing.

For the detection of human movements in a mobile environment, a wearable data collection system in which sensors are mounted on clothing, such as a data suit, can be considered for the detection of human movements in a mobile environment. For the detection of EMG signals, however, it is effective to attach electrodes at just some of the points on multiple muscles, so it is possible to embed skin-contact electrodes in items worn on the body such as bracelets or joint supporters. Furthermore, this approach is not affected by the restrictions of other methods, such as motion capture by a camera that is at a distance from the person. In recent years, active electrodes that incorporate preamplifiers have enabled stable, low-noise detection of EMG signals at the skin surface in ordinary indoor and outdoor environments or in vehicles.

3.3 Three communication modes for using a humanoid robot

We propose three modes for communication medi-

Entire body	31 DOF	Head	3 DOF
Fingers of one hand	6 DOF × 2	One eye	2 DOF × 2
One arm	6 DOF × 2		

Mounted on a mobile platform equipped with infrared sensors
Multiple multi-colored LEDs on face
Exterior is 3D optically cured plastic with some aluminum parts

Fig. 2. Constructed full-size humanoid robots.

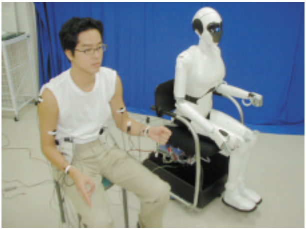

Fig. 3. Operator and humanoid robot.

ated by a humanoid robot.

(1) Synchronous chat mode

In this mode, two persons at remote locations chat in real time via a network, and gestures are sent via the network to each person's alter-ego humanoid robot, which is located near the other person and reproduces the gestures. This is the same form of communication as chatting on a personal computer. In this mode, the movements of the master are transferred to a humanoid robot that operates in slave mode. This form of two-way real-time communication using two tele-existence*2 robots is called the synchronous chat mode.

(2) Asynchronous mail mode

This mode is similar to e-mail exchanged on computers, and so is called the asynchronous mail mode. A person's voice and gestures are conveyed to the humanoid robot at that person's location and transferred via a network to a remotely located humanoid robot, which reproduces the voice and gestures. However, the information transfer is not done in real time; rather, the receiving party plays back the transmission at a convenient time.

(3) Autonomous response mode

The third mode employs what might be called an intelligent humanoid robot that responds autonomously to a person's inquiry or utterance. For example, the humanoid robot might autonomously interpret the message "Tell Mr. 'So-and-so' 'something-or-other'," and autonomously convey the gestures involved in the message via the network to the humanoid robot at the recipient's location according to the content of the message. This mode could conceivably also be used locally, without a network.

Another form in which the autonomous response mode could be used involves connection via the network to a large-scale intelligent engine or natural language processing database located at a remote center.

4. Future issues

4.1 Extension of human interface technology to sense of force and sense of touch, and development of a humanoid robot that possesses our five senses

A deeper understanding of signal processing technology for the EMG signals at the skin surface for use as human interface technology in transferring gesture data to a humanoid robot will allow the detection of human finger pressure and joint tension. Application to a bracelet-type wearable terminal as well as to the robot-human interface is also being investigated. Ultimately, it will be necessary for a robot that acts as one's alter ego to posses our five senses and present or transmit the sensory information to the other person. Electrical tactile display technology and sensing technology are also future topics that we are grappling with.

*2 tele-existence(or tele-presence): Tele-existence is an advanced type of teleoperation system which enables an operator at the remote controls to perform remote manipulation tasks dexterously with the feeling that he or she exists in the remote environment where the robot is working.

4.2 Artificial intelligence

Robot technology and artificial intelligence research are, ultimately, two sides of the same coin. Artificial intelligence based on signal processing is seen as having come to a temporary impasse, but the ultimate problem that cannot be avoided in the future is the artificial construction of intelligence, knowledge, and consciousness in a robot that has an actual body and is equipped with sensors and actuators [7].

4.3 Alter-ego robot using EEG and MEG measurement

The ultimate human interface for transferring our own intentions to an alter-ego robot is thought transfer, in which we simply think of an action and it is transferred to the robot [8]. A human intention to perform a movement involves the generation of a series of voluntary movement operations by the motor cortex, pre-motor cortex, and other parts of the brain: a process that requires a complex time structure. That process produces signals that can be detected on the scalp in the form of minute preliminary electric and magnetic field variations mixed with the background brain wave patterns [9]. Although it is currently technically difficult to do pattern recognition on those signals in real time, control of a remote alter-ego robot by a magnetoencephalogram (MEG) human interface using superconducting quantum interference device (SQUID) measurements via a network and receiving sensory feedback by various methods (for example, electrical stimulation of the median nerve or the inner ear, or magnetic stimulation of the brain) is not merely a futuristic dream.

5. Conclusion

We have proposed a promising communication style for the future that employs full-sized humanoid robot mediators acting as communication terminals.

Even if intelligence is not achieved in the humanoid robot, a life-size humanoid robot operated on a master-slave basis will still enable telecommunication that involves embodiment in an actual physical body, which has not been possible with previous types of communication terminals. We believe that this is a very significant development.

Even though the teleportation of a physical body that we see in science fiction is an impossibility, virtual teleportation through the mediation of a humanoid robot is a real possibility.

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Akira Hiraiwa passed away on July 10, 2003. We deeply appreciate his contribution to this article and sincerely express our condolences to his family (Editorial board).