

Tele-Existence Robot Technology

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What is Tele-Existence?

Is it possible for a human operator to control a robot remotely and at the same time feel that he is present at the task site?

In other words, the robot performs the task on behalf of the operator but with the actual task situation being fully sensed and understood by him. As necessary, the operator's actions are transmitted for the robot to reproduce and the operator experiences the sensation of performing the work directly. This highly advanced tele-operation technology for controlling robots is called tele-existence.

In tele-existence, an anthropomorphic robot is placed at a remote site and an information transmission communication channel is established between human and robot. The operator's movements and physical status are sensed and transmitted to the robot via this communication channel. The transmitted signals directly control the robot's motor system to reproduce the exact movements of the operator in its artificial eyes, neck, hands, legs, and feet. Information picked up by the artificial sensory organs of the robot are transmitted back to the operator via the communication channel to the operator's sensory organs.

Take vision for example. Whichever direction the operator looks, the robot will look in the exact same spot. The operator will see on his retinae the image seen by the robot, in exactly the same manner as it would be seen by a human in the same position. If the operator were to bring his arm in front of his eyes, he would see the robot's arm being brought into his field of view in exactly the same relative position as his own arm.

With this kind of technology, humans can perform tasks via robots at a distance yet maintain close contact with objects and distant surroundings and apply their experience to the situation. Objects touched by the robot are also felt by the operator as tactile stimuli. Tasks can be performed with the same sense of touch as if objects are actually being handled.

Tele-existence technology also goes beyond the scope of the human senses. Radiation, ultra-violet rays, infrared, micro waves, ultrasonic waves, and ultra low frequency information picked up by the robot sensors can also be utilized. For example infrared information picked up by the robot sensors can be converted in to visible light on the operator's display. As the display gives a realistic sensation of presence, tasks can be performed in the dark yet with the illusion that it is light.

This super-sensory information can also be superimposed on the normal visual display. This is not the standard two-dimensional superimposition but is three-dimensional.

For example, by adding distance to the location of an object, spatial images are displayed. The image that was originally seen is withdrawn, and only the changed portions are displayed.

Principles of Tele-Existence and Means of Realization

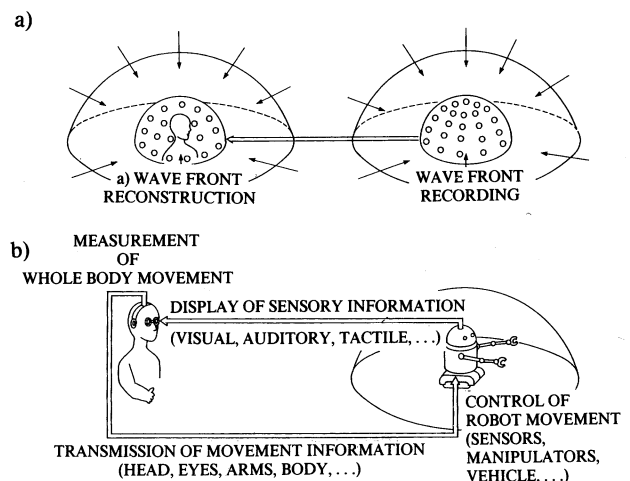
The basic configuration of the tele-existence system is shown in Figure 1. Vision will be used as an example to explain the make-up of the display which gives the sensation of presence.

In order to faithfully reconstruct the wave front, an enclosed curved surface is created as shown in Figure 1 (a). Wave fronts which strike the enclosed curved surface are recorded at multiple points upon it. This information is transmitted to the operator where the wave front is reconstructed from the reproduction device on top of a similar enclosed curved surface surrounding the operator. However with this method, in order to reconstruct the original scope of the environment, an extremely large recording/reproducing device is necessary which at this stage cannot be made.

The concept of the reconstruction method of the environment by the tele-existence system based upon robot technology and human senses is shown in Figure 1 (b).

Human vision is based on the images formed on each retina. These images change in real time in accordance with head and eye movements. On the basis of these two images the brain reproduces a three-dimensional world and causes objects to appear in their actual locations. Consequently in the tele-existence system, human head and eye movements are detected in real time and are reproduced accurately in the movement of the robot's head and eyes. By transforming the two images picked up by the robot's "eyes" to an image that can be seen by the human retinae, an image can be seen as if the operator were observing the object in the exact same position as the robot. Images picked up by the robot

Fig. 1: Principle of Tele-existence: a) Reconstruction of wave front; b) Display with sensation of presence using robotic technology



produces a realistic three-dimensional world in the human brain so that to the operator it appears as if he is actually looking at the object directly in person.

Present Status of Research

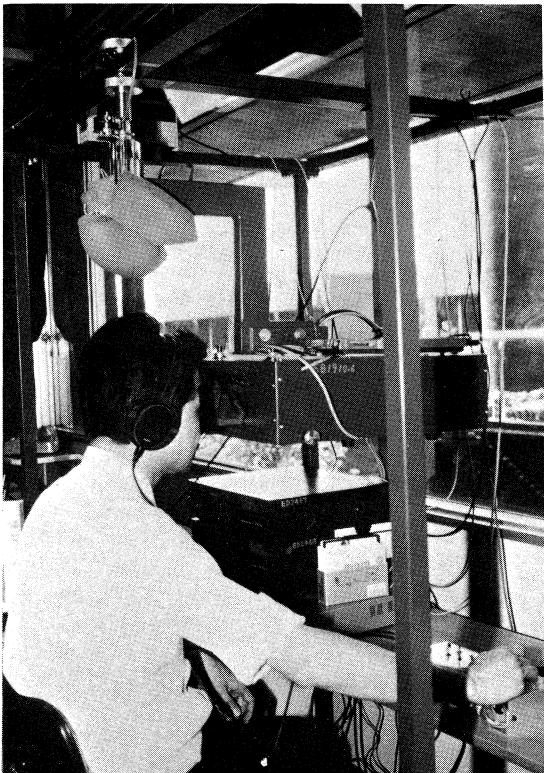
Research and development on tele-existence technology commenced from the 1983 Fiscal Year at the Mechanical Engineering Laboratory. Research to date has centered on the design of the visual display system. Recently an experimental tele-robotic system was developed to confirm the fundamental concepts of the tele-existence system.

An important aspect of this system is the sensation of presence that is created, as if the operator were making observations at the location in person. One of the secrets to the sensation of presence is in the two television cameras on the robot which have been adapted to accommodate the human visual dimension. The two images picked up by the cameras are transmitted to the control room via radio waves. The images pass through the three-dimensional image processor attached to the operator's head and are seen by each eye. Based on human vision characteristics, the robot's field of vision unfolds in front of the operator's eyes as a three dimensional full color image with sounds being heard stereophonically.

The operator starts, speeds up, and steers the robot with a lever at his fingertips while viewing the three-dimensional image and listening to the stereophonic sound which give a good sensation of presence. The television cameras on the robot move left or right in accordance with movements made to the left or right by the operator. (Refer to photograph 1(a).) The above information passes through a wireless modem.

In a test run on the outside pavement of the Mechanical Engineering Laboratory, it was confirmed that even on paths with obstacles, the robot can be remote controlled with sensations similar to driving a car.

Photograph 1(a): Head-Linked Stereo Display



The superiority of the tele-existence display (three-dimensional) to a conventional screen display — has been confirmed in regards to the time required to reach the destination, and how the obstacles were avoided (Refer photograph 1(b).)

With the current device a little energy needs to be exerted by the operator to turn the neck. However, research is progressing towards the development of a device where the head can be moved freely without the wearer being aware of it. This will be incorporated in the next experimental model.

Tele-Existence Applications

Applications of the tele-existence technology include manufacturing plants, dangerous and hazardous environments (oil refinery complex, etc . . .), inspection/repairs in atomic power plants, space and ocean exploration, repairwork/construction, rescue work, restoration work, cleaning, construction, agriculture and fisheries, health and welfare, police work, investigation, leisure, substitute test pilot driver.

Tele-Existence Research

Tele-existence is a research and development program which is being conducted at the Man-Machine Systems Division of the Mechanical Engineering Laboratory as a part of the National Large Scale Project, "Advanced Robot Technology: JUPITER". This program is an eight-year project (from F Y 1983 through F Y 1990) and aims at the establishment of tele-existence system technology and seeks its application to various areas.

References

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- ² S. Tachi and H. Arai, "Study on Tele-existence (II) Three-Dimensional Color Display with Sensation of Presence," Proceedings of the '85 International Conference on Advanced Robotics (ICAR), Tokyo, Japan, September 9-10, 1985 (North Holland Publishers), pp. 345-352.
- ³ S. Tachi, "Human-Robot Systems in the Third Generation Robotics," Invited Lecture, The Australian Academy of Technological Sciences, Melbourne, March 4, 1987.

Photograph 1(b): Prototype Mobile Tele-Vehicle I

