

Telexistence — from 1980 to 2012

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Abstract—Telexistence technology enables a highly realistic sensation of existence in a remote place without any actual travel. The concept was originally proposed by the first author in 1980, and its feasibility has been demonstrated through the construction of alter-ego robot systems such as TELESAR & TELESAR V, which were developed under the national large scale project on “Robots in Hazardous Environments” and the “CREST Haptic Telexistence Project.” A mutual telexistence system, such as TELESAR II & IV, capable of generating the sensation of being in a remote place in local space using a combination of an alter-ego robot and retro-reflective projection technology (RPT), has been developed, and the feasibility of mutual telexistence has been demonstrated. Thirty-two years of telexistence development are historically reviewed in this jubilee video.

INTRODUCTION

Telexistence is a fundamental concept that refers to the general technology that allows a human being to experience a real-time sensation of being in a place other than his/her actual location and to interact with the remote environment, which may be real, virtual, or a combination of both [1]. It also refers to an advanced type of teleoperation system that allows an operator at the controls to perform remote tasks dexterously with the feeling of being in a surrogate robot working in a remote environment. Telexistence in the real environment through a virtual environment is also possible.

Sutherland [2] proposed the first head-mounted display system, which led to the birth of virtual reality in the late 1980s. This was the same concept as telexistence in computer-generated virtual environments. However, it did not include the concept of telexistence in real remote environments. The concept of providing an operator with a natural sensation of existence in order to facilitate dexterous remote robotic manipulation tasks was called “telepresence” by Minsky [3] and “telexistence” by Tachi [4]. Telepresence and telexistence are very similar concepts proposed independently in the USA and in Japan, respectively. However, telepresence does not include telexistence in virtual environments or telexistence in a real environment through a virtual environment.

The concept of telexistence was proposed by the first author in 1980 [4], and it was the fundamental principle of the eight-year Japanese national large scale “Advanced Robot Technology in Hazardous Environment” project, which began in 1983, together with the concept of “Third Generation Robotics.” The theoretical consideration and systematic design procedure of telexistence were established through the project. An experimental hardware telexistence

system was developed and the feasibility of the concept was demonstrated.

In this jubilee video, the development of telexistence technology and telexistence systems is historically reviewed from 1980 to 2012.

HISTORY OF TELEXISTENCE

A. How Telexistence was Conceptualized and Developed

Our first report [5,6] proposed the principle of a telexistence sensory display and explicitly defined its design procedure. The feasibility of a visual display providing a sensation of existence was demonstrated through psychophysical measurements performed using an experimental visual telexistence apparatus.

In 1985, a method was also proposed for developing a mobile telexistence system that can be driven remotely with both auditory and visual existence sensations. A prototype mobile televehicle system was constructed and the feasibility of the method was evaluated [7].

B. Telexistence Manipulation System: TELESAR

The first prototype telexistence master-slave system for performing remote manipulation experiments was designed and developed, and a preliminary telexistence evaluation experiment was conducted [7-10]. The slave robot employs an impedance control mechanism for contact tasks. An experimental block-building operation was successfully conducted using a humanoid robot called TELESAR (TELEXistence Surrogate Anthropomorphic Robot). Experimental studies of the tracking tasks quantitatively demonstrated that a human can telexist in a remote environment through a dedicated telexistence master-slave system [8]. An experimental operation was successfully conducted in an environment with poor visibility using TELESAR and its virtual dual [11].

Based on the technology, telexistence into a humanoid biped robot was realized in 2000 under the “Humanoid Robot Project” (HRP) [12].

C. Mutual Telexistence: TELESAR II & IV

A method for mutual telexistence based on the projection of real-time images of the operator onto a surrogate robot using retroreflective projection technology (RPT) was first proposed in 1999, and the feasibility of this concept was demonstrated by the construction of experimental mutual telexistence systems using RPT in 2004 [13].

In 2005, a mutual telexistence master-slave system called TELESAR II was constructed for the Aichi World Exposition. Nonverbal communication actions such as gestures and handshakes could be performed in addition to conventional verbal communication because a master-slave manipulation robot was used as the surrogate for a human [14]. Moreover,

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a person who remotely visited the surrogate robot's location could be seen naturally and simultaneously by several people standing around the surrogate robot.

The mobile mutual telexistence system, TELESAR IV, which is equipped with master-slave manipulation capability and an immersive omnidirectional autostereoscopic 3D display with a 360° field of view, was developed in 2010 [15]. TELESAR IV is constructed from an immersive audiovisual system, TWISTER—an omnidirectionally mobile robot with a robot arm and hand—and projection of the remote participant's image on the robot by RPT.

Face-to-face communication was also confirmed, as local participants at the event were able to see the remote participant's face and expressions in real time. It was further confirmed that the system allowed the remote participant to not only move freely about the venue by means of the surrogate robot, but also perform some manipulation tasks such as a handshake and several gestures.

TELEXISTENCE AVATAR: TELESAR V

In telexistence, an operator can feel his/her slave robot as an expansion of his/her bodily consciousness and has the ability to move freely and control the slave robot in a similar way to his/her body movement.

In order to certify this concept in telexistence, the TORSO (TELESAR III) system, which can acquire visual information in a more natural and comfortable manner by accurately tracking a person's head motion with 6 DOF, was constructed [16]. TELESAR V, a master-slave robot system with a conjunction of 53 DOF for performing full-body movements, was developed in 2011. In addition, an operator can feel the fingertip haptic and thermal sensations when touching objects remotely. The TELESAR V system satisfies the following functions [17,18].

- (1) The operator can freely and independently move his/her head, upper body, and both arms and hands. In contrast, the slave robot's arms and hands follow similar movements with 53 DOF while maintaining 6-DOF arm endpoint accuracy.
- (2) The operator can have a clear wide-angle stereo view of the remote site with 6-DOF point-of-view robot vision accuracy. The operator also has the ability to perform binaural, bi-directional verbal communication.
- (3) The operator can grasp and manipulate objects in a similar manner to a human hand.
- (4) The operator feels fingertip haptic and thermal sensations when touching objects remotely.

CONCLUSION

Telexistence is a concept that allows humans to be emancipated from time and space restrictions and to be present at a "location" defined by inconsistent time and space or in a virtual space. Telexistence technology was historically reviewed over the period from 1980 to 2012.

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