TelesarPHONE
- Communication Robot based on Next Generation Telexistence Technologies -

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TELEsarPHONE is a conceptual prototype of mutual- telexistence system, designed for a face-to-face tele-communication via robots. Thanks to the development of telexistence techonologies. We can have feelings that we are present in several real places and can work and act. However, those people in the place where someone telexists using a robot see only the robot but they can't feel that the person who presents. To solve this problem, the new prototype of a telexistence master-slave system for remote manipulation experiments is being designed and developed. And we apply RPT (retro-reflective Projection Technology) system to TELEsarPHONE system. In the TELEsarPHONE system, the face and the breast of the slave robot TELESAR II is covered by retro-reflective material. To provide the feeling of existence, the real-time image of the operator is projected onto there. Peeping from the RPT projector.

1. INTRODUCTION

Telexistence[1-3] is fundamentally a concept named for the general technology that enables a human being to have a real-time sensation of being at a place other than where he or she actually exists, and being able to interact with the remote environment, which may be real, virtual, or a combination of both. It also refers to an advanced type of teleoperation system that enables an operator at the control to perform remote tasks dexterously with the feeling of existing in a surrogate robot working in a remote environment. We proposed the concept of Telexistence in 1980 and have been working for the realization of the concept and application to the robotics, design and communication. And finally we have realized al prototype system "TELEsarPHONE " and exhibited it at the Prototype Robot Exhibition of EXPO '05 in Aichi.

2. CONCEPT OF TELEsarPNONE SYSTEM

TELEsarPHONE is a conceptual prototype of mutual-telexistence system, designed for a face-to-face tele-communication via robots. Almost a quarter of a century have past since our first idea and concept of telexistence was proposed, and it is now possible to telexist in the remote environment and/or virtual environment with a sensation of presence. We can have feelings that we are present in several real places and can work and act. However, those people in the place where someone telexists using a robot see only the robot but they can't feel that the person who presents. It is useless to use TV display on board the robot to show the face of the user. It would be just comical and far from reality.

In the history of communication, communication method has been developing, telephone is a communication method by phone (or sound) and television is communication by vision. In the next generation of communication method is communication by existence. This is our final goal.

To realize above concept, the new prototype of a telexistence master-slave system for remote manipulation experiments is being designed and developed. The robot built for this system is called "TELESAR II." In this project, we focus on producing human-like, realistic movement of TELESAR II. TELESAR II has bath arms and both hands and a head. It is important that master can present an exact force to an operator and slave has contact safety with human in a remote environment. Impedance control type master-slave we adopted can realize an exact presentation of force. Moreover, we can realize contact safety with human on slave, because slave has sufficient compliance by impedance control.

To control the slave arm, we developed the master arm of TELESAR II. For the reason that an operator can gesture smoothly, this arm has 6 degree of freedom structures to free an operator's elbow. To control the redundant degree of freedom of the anthropomorphic slave arm, we put a small orientation sensor on the operator's arm. Moreover, this master arm is made light and impedance control is applied so that an operator doesn't feel a big burden.

Important factor to feel the existence of an operator is not only motion of the operator but also visual image of the operator. The robot is painted with retro-reflective material and can act as screens for HMP (Head Mounted Projector). So the robot is seen as if it is the operator by the projection of real image of him or her on it with a sensation of presence. (See Fig.1)

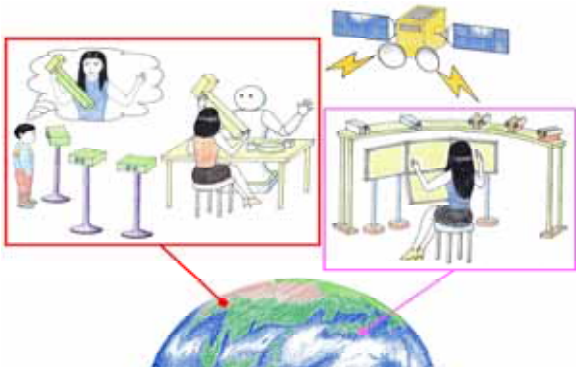

Fig.1 Conceptual Image of TELEsarPHONE

3. DESIGN OUTLINE OF TELEsarPHONE SYSTEM

The TELEsarPHONE system is composed of 4 sub-systems, slave robot TELESAR II, master cockpit, 3-D display system for cockpit and RPT system. (Fig.2,3)

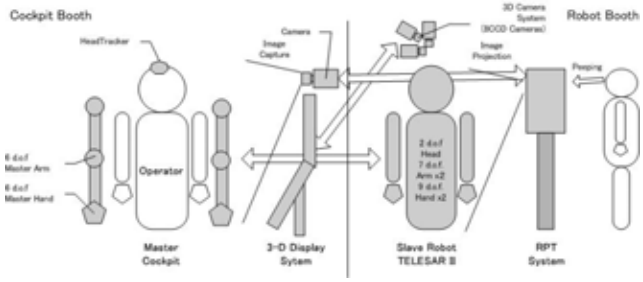

Fig. 2 System Outline

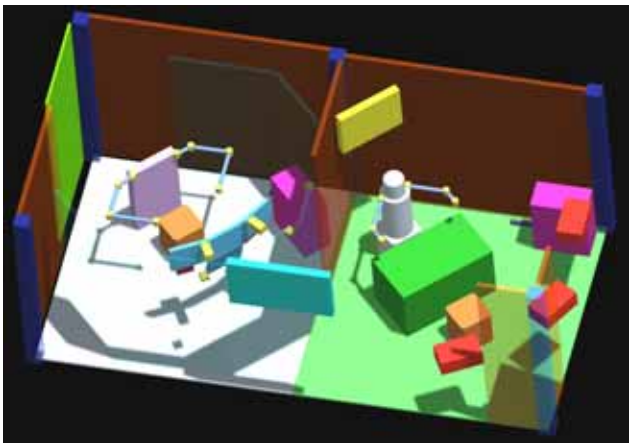

Fig.3 System Layout
(left: Cockpit Booth / right: Robot Booth)

The slave robot TELESAR II has 2 DOF head, which can rotate pitch and roll axes. There are 2 CCD Cameras for stereoscopic inside its head. (Not used in Aichi-Expo) The motion of the head is synchronized with motion of operator's head, which measured by head tracker of Master cockpit. TELESAR has not only head but also both arms, and both hands. The operator can control these arms and hands easily, because the motion of the operator‘s hands/arms are measured by master cockpit and are the synchronized with TELESAR's.

Head, right/left arms and right/left hands are composed master-slave systems individually. In the case of autonomous robots, system needs hard computation to avoid crash of each arms/hands or body. But in the case of telexistence robot, system needs no collision detection. The operator calculates it unconsciously. This is very remarkable factor of telexistence system.

The most distinctive feature of TELEsarPHONE system is RPT (retro-reflective Projection Technology) system. In our laboratory at the University of Tokyo, a newtype of visual display is being developed called, which uses retro-reflective material as its projection surface. The retro-reflective surface works as a special screen. Under the RPT configuration, a projector is arranged at the axial symmetric position of a user's eye with reference to a half-mirror, with a pinhole placed in front of the projector to ensure adequate depth of focus. In the TELEsarPHONE system, the face and the breast of the slave robot TELESAR II is covered by retro-reflective material. To provide the feeling of existence, the real-time image of the operator is projected onto there. Peeping from the RPT projector. According to the safety restrictions of AICHI EXPO, we demonstrate by using fixed type HMP, but we also developed wearable HMP.

If there are enough space and money, we will construct the 3-D Display system by immersive wide-angle screen system. But we don't. So In AICHI EXPO, we decide to use simple 3-D Display system. The system consists of four 3-D displays (17inch Lenticular type) arranged in front, left, right and bottom (like T-shape). Because of lenticular, the operator can see stereoscopic without any glasses. And 3-D camera system is located above the TELESAR II (not ON head). Because the display system is fixed, camera system should be fixed. If we want use stereoscopic camera located on eye poison of TELESAR II, the operator must wear HMD (Head-Mounted Display), which hide the operator's eyes, it makes a poor communication. The 3-D camera system consists of four couple of CCDs (totally eight CCDs). Each couple of camera is for front, right, left and bottom view. Each of captured images by those cameras are translated to respective displays. The system provides approximated first-person's view for the operator.

3. DETAILS OF SLAVE ROBOT "TELESAR II" AND MASTER COCKPIT

3.1 Master-Slave Arms[4]

From the viewpoint of simplification of function and control, high rigidity, small inertia, and the fact that the power to be applied to the operator's hand is along at most 6 axes, we designed the master arm to specialize in the power presentation function in these 6 axes, and also made its mechanism 6-DOF. (Fig. 4)

Since the measurable movement of the master arm that follows the operator's hand has 6 DOF, we decided to use a new lightweight posture sensor composed of two acceleration sensors to measure the final DOF, which is

critical to identifying the posture of the operator's whole arm, including his or her elbow.

Altogether, the mechanism serves as a master system with 7 DOF for measurement of the arm's posture, and 6 DOF for power presentation. Since the posture sensor is very light compared with mechanical restraints on the operator's elbow, the sensor enables much freer movement of his or her arm without any undesirable load on it.

Moreover, since the master arm has less than 7 DOF, it achieves power presentation with high rigidity and stability.

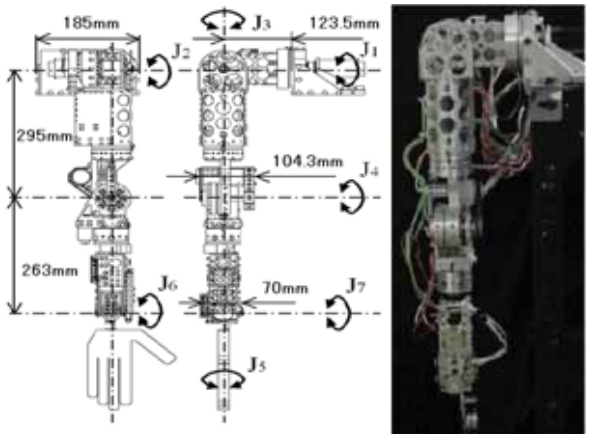

Fig.4 Slave Arm (right: structure left:overview)

As described above, we should leave the motion of the operator as unrestrained as possible in telexistence. Therefore we adapted an exoskeleton-type mechanism for the master arm. Although the master arm does not necessarily need an exoskeleton-type structure to present forces along 6 axes, it has a mechanism similar to the human body in general, and it always follows human motion. So, we decided to use the structure because we considered that it could be widely adapted for movement of an operator with minimal size requirements, which is an essential characteristic to correspond to a human's various actions in everyday life. In our system, the number of degrees of freedom in the master arm is less than that of a human arm, so it is impossible for the master arm to follow an operator's whole arm completely, and it introduces the possibility of mutual interference between the human arm and the master arm.(Fig. 4)

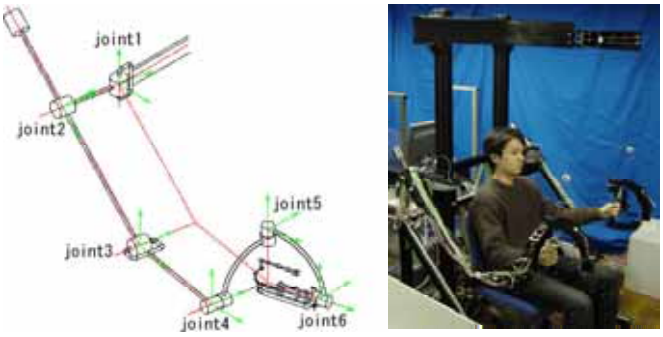

Fig.4 Master Arm (right: structure left: overview)

3.3 Master-Slave Hands[5]

We have developed a new type of master-slave hand to improve these disadvantages. (Fig.5,6) Our master hand has two features as follows.

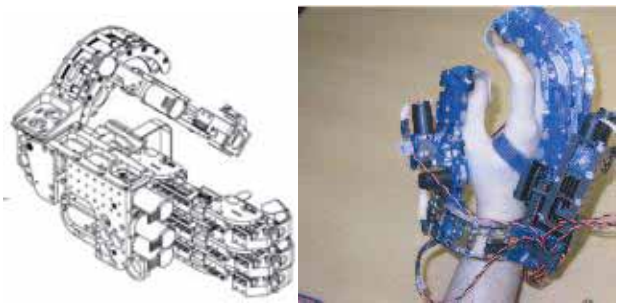

Fig.5 Master Hand (right: structure left:overview)

Fig.5 Slave Hand

One is the compact exoskeleton mechanism of the master hand's finger contrived to cover wide workspace of an operator. Possible ways to place an exoskeleton mechanism are to place it over (parallel joint) or beside (coaxial joint) an operator's finger. To place it over the operator's finger, there is a problem that master finger disturbs the motion of the operator's finger when the finger is bent. However, to place it beside an operator's finger is difficult, because there is little space to place it. To solve this problem, we propose "circuitous joint" that coincides joint axis of the master hand with that of the operator by extending the link length in proportion to the joint angular displacement (Fig.7).

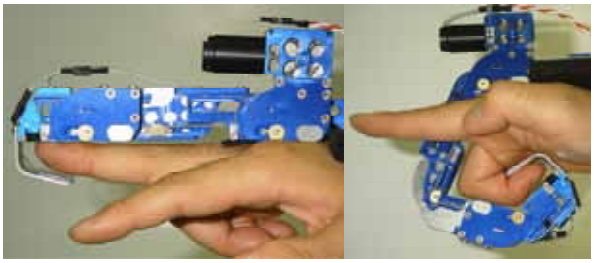

Fig.7 Master Hand (left: stretch right: bend)

The other is the encounter-type force feedback. Encounter-type device stays at the location of the object in the remote world and waits for an operator to encounter it. As shown in Fig. 8, our encounter-type master hand's finger

usually follows the operator's finger without contact. It enables him to touch nothing when the slave hand contacts nothing. When slave hand touches an object, master finger contacts the operator's finger and provides resistive force. Therefore, our master hand is able to provide both perfect unconstrained motion and natural touch sensation.

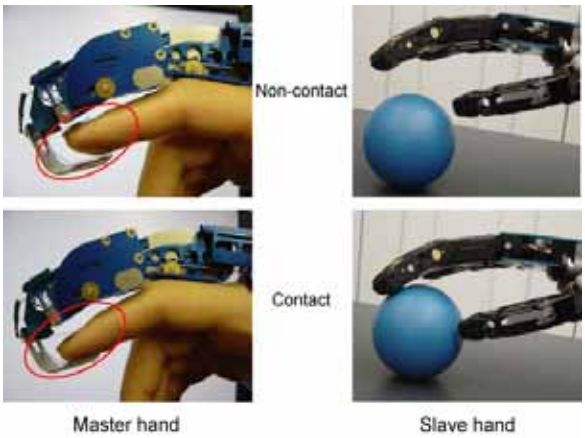

Fig.8 Encounter-type master-slave hand

4. DETAILS OF RPT SYSTEM

Fig.9 shows the principle of RPT system, a projector is arranged at the axial symmetric position of a user's eye with reference to a half-mirror, with a pinhole placed in front of the projector to ensure adequate depth of focus. [2][3]

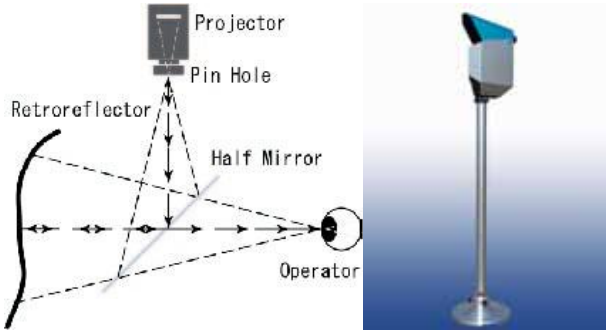

Fig.9 RPT (left: Principle right: overview)

The face and breast of TELESAR II is covered by retro-reflective materials. The ray comes from a direction reflect the same direction on the surface of retro-reflective material. Thanks to this characteristic, image is projected onto the surface of TELESAR II without distortion. And if we use many RPT projectors in different direction and project difference images, observer can see corresponding image. In AICHI EXPO we set up 3 RPT projectors in front, right side and center of these. Observers simultaneously see the front face, right face and slant face of the operator.

5. CONCLUSION

In this paper, we finally built up the prototype telexistence system. And we exhibited it at AICHI EXPO as "TELEsar PHONE." Fig. 10 shows overview of slave-robot TELESAR II and master cockpit.

Fig.10 right: TELESAR II,
Left: Master Cockpit (operator's view)

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Peeping from RPT projectors as shown in Fig. 11, visitors can see the real-time operator's image on the surface of TERESAR II's body.

Fig.11 TELSAR II
(left: normal view right: Peeping from RPT)

Until now, we have studied elemental technologies of telexistence. Now we are getting a clue for the next generation of telexistence. We will keep studying about essence of the telexistence.

6. REFERENCES

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