Waseda-SSSA Joint Research for Human and Humanoid Robot Interaction

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Abstract. This paper describes the Waseda University-SSSA joint research for human and humanoid robot interaction by using the ISDN between Japan and Italy. The last few years have been characterized by the continuous development of information and communication technologies, robotics technologies, and home automation technologies. The number of application areas for such technologies is increasing, especially in fields rather outside the pure industrial scenario, often identified as "service applications." These are healthcare, public service provisions, social services for disadvantaged citizens, technical aids for promoting the independence of disabled and elderly people and many others. With this joint research, Scuola Superiore Sant'Anna and Waseda University, starting from the current availability of several mechatronic prototypes in their research laboratories, intend to validate different telecommunication tools for the remote control of mechatronic systems by demonstrating the feasibility and potential benefits deriving from the integration of such technologies.

1 Introduction

“Humanoid Robot” was a dream of not only the kids but also the robotics researchers. In addition, the robotics has been becoming the key technologies for the natural and smooth interactions between the humans by using telecommunication technologies and/or mechatronics technologies. The last few years have been characterized by the continuous development of these two technologies, such as information and communication technologies, robotics technologies, home automation systems and so on. The number of application areas for such technologies is increasing, especially in fields rather outside the pure industrial scenario, often identified as "service applications (Dario et al. [1])." These are healthcare, public service provisions, social services for disadvantaged citizens, technical aids for promoting the independence of disabled and elderly people and many others (Tanie [7]).

Generally speaking, it can certainly be stated that there is a generalized expectancy for new emerging technologies to improve the quality of life of all citizens in the upcoming "Information Society," where remote access to distributed resources and services will be guaranteed to all citizens by telecommunication networks.

This research between Italy and Japan in Figure 1 originates from the assumption that in order to really achieve a significant improvement in the quality of life of all citizens, not only information data, but also different entities such as sensations, emotions and actions should be remotely accessible and transferable over telecommunication networks. In other words, a fully sensitive, cognitive and physical interaction of humans with the remote environment should be guaranteed, at least in certain specific situations, e.g. to remotely take care of a child or of an elderly person living alone.

To this aim, the need for integrating telecommunication and mechatronic technologies, the tools that provide transmission of data, sensations and actions, becomes a major priority for interested researchers.

With this joint research, Scuola Superiore Sant'Anna and Waseda University, starting from the current availability of several mechatronic prototypes in their research laboratories in Figure 2, mostly deriving from relevant national and international programs, intend to validate different telecommunication tools for the remote control of mechatronic systems by demonstrating the feasibility and potential benefits deriving from the integration of such technologies.

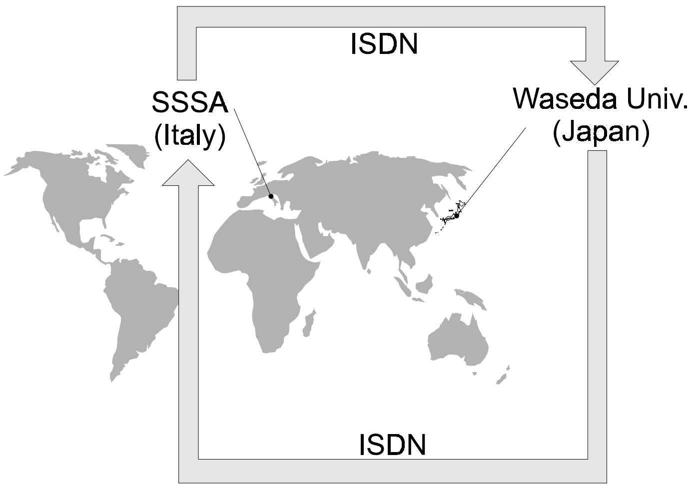


Fig. 1. Italy and Japan

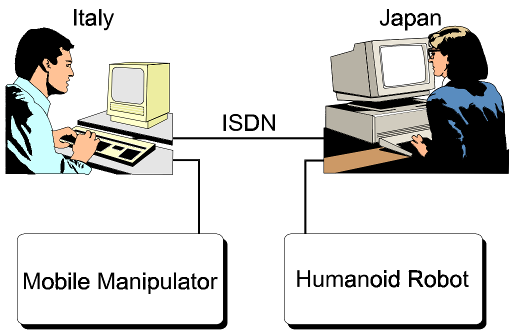


Fig. 2. System configuration

2 Objectives

The objective of this joint research is developing and validating telecommunication tools for the remote control of mechatronic systems such as manipulators, mobile bases, vision systems, auditory and home automation systems, and humanoid robots.

In detail, the main goals of the research are as follows:

– To establish a strong co-operation link by means of joint research and experimental activities in the field of mechatronics and telecommunications between Japan and Italy;
– To demonstrate the feasibility and outline the potentiality of integrated applications of the mechatronic and telecommunication technologies in Figure 3 (tele-robotics, network robotics, etc.);
– To develop and extensively test a cross-border, distributed platform for validation of such technologies in Japan and Italy;
– To enlarge the opportunities for validation of existing mechatronic technologies for service applications in different, real-life conditions and with different typologies of end-users (e.g. cultural and social backgrounds);

- To allow fertile exchange of know-how and of non-confidential documentation between participating laboratories, so to favor continuous improvement and enrichment of existing systems and prototypes;
- To identify new possible areas of application for mechatronic and telecommunication technologies, and to create guidelines for the development of novel prototype systems for service and medical (Dario et al. [2]) / dental (Takanobu et al. [6]) applications.

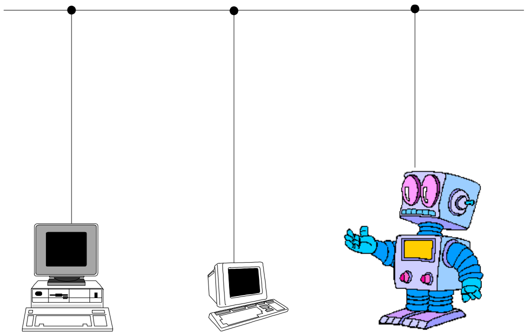


Fig. 3. Network correspondence humanoid robot

3 Italy and Japan Sites

This research is a joint research with the ARTS lab in Italy and HRI (Humanoid Robotics Institute) in Japan, both are doing the researches related to the robotics, bioengineering, and medical systems. Details of these two laboratories' researching robots are shown here to clarify the exact target of this research.

3.1 Italy

In Italy, the Advanced Robotics Technology and Systems Laboratory (ARTS Lab.) of Scuola Superiore S. Anna (Pisa, Italy) will supervise the research. The ARTS Lab will take care of the development and/or adaptation of all the technologies that will be used in the framework of this research, and of the establishment of the network arrangements for guaranteeing proper communication via the selected telecommunication media.

3.1.1 Site details

Involved demonstration sites that will be theaters of possible local and cross-border experiments and validation sessions are:

- Centro Auxilia at Casa Angela, Livorno, Italy. This center, a nursing home for severely disabled people, hosts a validation center for telecommunication and mechatronic technologies that was established by SSSA in 1995. The Centro Auxilia includes a small mechanical and electronic workshop, a public point for the assistance of the disabled (selection and adaptation of commercial aids, etc.), and a laboratory for validation of novel technical aids resulting from SSSA research activities. The site is also comprised of a full-scale demonstration environment for a home automation system, including the TIDE-MOVAID (Guglielmelli et al. [4]) mobile robotic unit.
- The EQUALITY Service Center, Livorno, Italy. The local authorities of Livorno established this Service Center with the direct support of the ARTS Lab in 1996 in the framework of the European project TELEMATICS-EQUALITY (Tele-services for All). The center features a number of facilities for public provision of telecommunication services (e.g. tele-work, tele-shopping, etc.) to all citizens, and especially to disabled, elderly and other disadvantaged citizens. It will be fully operative in the beginning of 1997.
- The Centro Servizi of Peccioli is a novel service center for elderly people currently being established in the town of Peccioli (Pisa, Italy). It aims at co-radiating a number of direct and tele-services for the integrated home care of non-autonomous people.

Additional sites could be identified during execution of the research according to specific requirements and/or special prescriptions for planned experimental activities.

3.1.2 The MOVAID system

The MOVAID system (Dario et al. [3]) is composed of a distributed robotic system, including a mobile robotic unit and two fixed workstations, and of dedicated interfaces for standard kitchen appliances. In this section, technical descriptions of the MOVAID system's components are given.

The MOVAID mobile unit is composed of a four-wheel mobile base supporting a robotic arm and hand. On the first link of the arm, a pan-tilt head supporting two TV cameras and a DLPS (Distributed Local Positioning System)-based auto-localization system is mounted. The mobile base is also equipped with a ring of ultrasound sensors for obstacle detection, and is partially covered by a tray for object transportation. The docking system is also mounted on the rear lower part of the mobile base. The mobile unit structure is modular so that the vehicle can be used on its own as a mobile platform, or the arm can be mounted on a different support (a table or a wheelchair).

The vehicle used as a mobile platform for the MOVAID system is the Electric Pedestrian (by INSERM - Unité 103, Montpellier, France). The Electric Pedestrian, re-designed to give it a warmer and more pleasant look, is a four-wheel vehicle with two steering front wheels and two driving rear wheels. The batteries for the energy supply of the system are located on the forepart of the vehicle.

The MOVAID arm is the DEXTER arm, and it has been derived from the prototype realized by Scienzia Machinale s.r.l. (Pisa, Italy) for URMAD system. It is an 8-DOF robotic arm especially aimed at operating in unstructured environments. The redundancy in its kinematic structure facilitates dexterous manipulation, enables the arm to be configured for work at various heights above the ground, and allows the arm to fold so that its work envelope can be minimized.

The arm end-effector is a three-fingered gripper developed by Scienzia Machinale s.r.l. (Pisa, Italy) in the MARCUS project. The Marcus Hand is a two-degree-of-freedom prosthesis possessing great gripping capability in terms of number of graspable objects, and its size and grip force. A passive mechanical compensator allows it to fit its prosthesis kinematic configuration to the object, and the reduction gears of the thumb and fingers are equipped with an irreversibility mechanism that make it possible to maintain its grip force even though the motors are powered off. Force sensors are mounted on the fingertips of the three fingers in order to control the force of the grip.

The MOVAID head, developed at the University of Genoa, is a pan-tilt device (2-DOF) supporting a binocular TV camera system. The head is located on the top of the first joint of the arm, and includes a small platform for supporting the DLPS localization system.

The DLPS localization system developed at the University of Genoa allows the mobile base to compute its absolute position and orientation in the house environment. It is an active positioning system for indoor applications in a multi-robot environment using a modulated light beam. The system is composed of two parts: an on-board rotating unit, and a set of active beacons distributed over the operating area (located on the walls at suitable heights). The rotating unit transmits a rotating and modulated beam of light (red laser), and it has an omnidirectional infrared receiver. The active beacons are little boxes that receive the beam of light transmitted by the rotating unit and return its identification code. The returning messages of each beacon are processed in order to reconstruct the position and orientation of the robot.

The mobile robotic unit can dock to a fixed workstation through a special docking system composed of a special connector for the transmission of power and data, and of a 2-DOF mechanical support allowing connection even at low positioning accuracy. The docking system has been designed so that the female part, the one fixed to the workstation, occupies very little space. The docking system is also used despite the uncertainties of the absolute localization system used on-board. These uncertainties are due to errors in the positioning of the beacons, accuracy of the rotating part and accuracy of the odometry.

An Ethernet radio link allows bi-directional data flow between the fixed workstations and the mobile base when the robot is undocked. Through the radio link, the fixed workstations send commands to be executed by the mobile base, while the mobile base returns the result of the command executed and the images acquired by the TV cameras.

The hardware architecture of the mobile unit is composed of two PC racks connected by a serial link. The on-board resources are distributed onto the two racks, one of which communicates with the fixed workstations through the Ethernet link (either radio or physical, through the docking connector). On the first rack are allocated the electronics for the base, hand and US control. On the second rack, the one with the radio link, are also allocated the hardware for the control of the arm and of the head systems and for the acquisition of the images.

The hardware architecture of the mobile unit and existing components are shown in Figure 4 and Figure 5. Some photographs are given in Figure 6 of the MOVAID mobile unit in the demonstration environment where it is being validated.

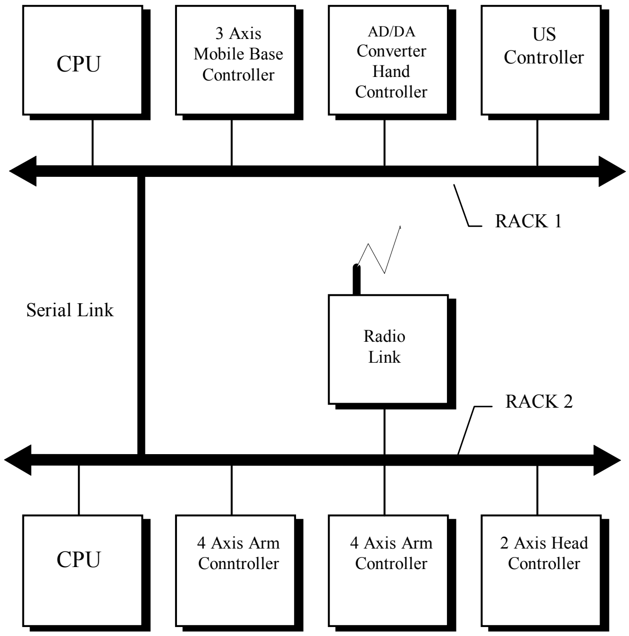


Fig. 4. The hardware architecture of the mobile unit

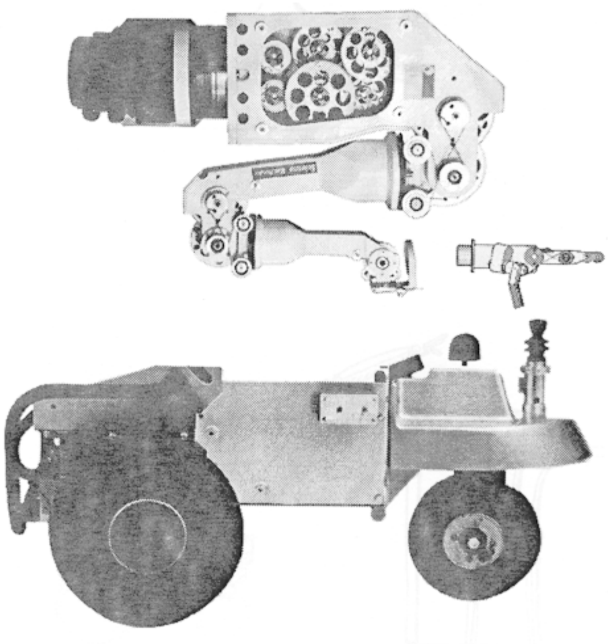


Fig. 5. Existing components

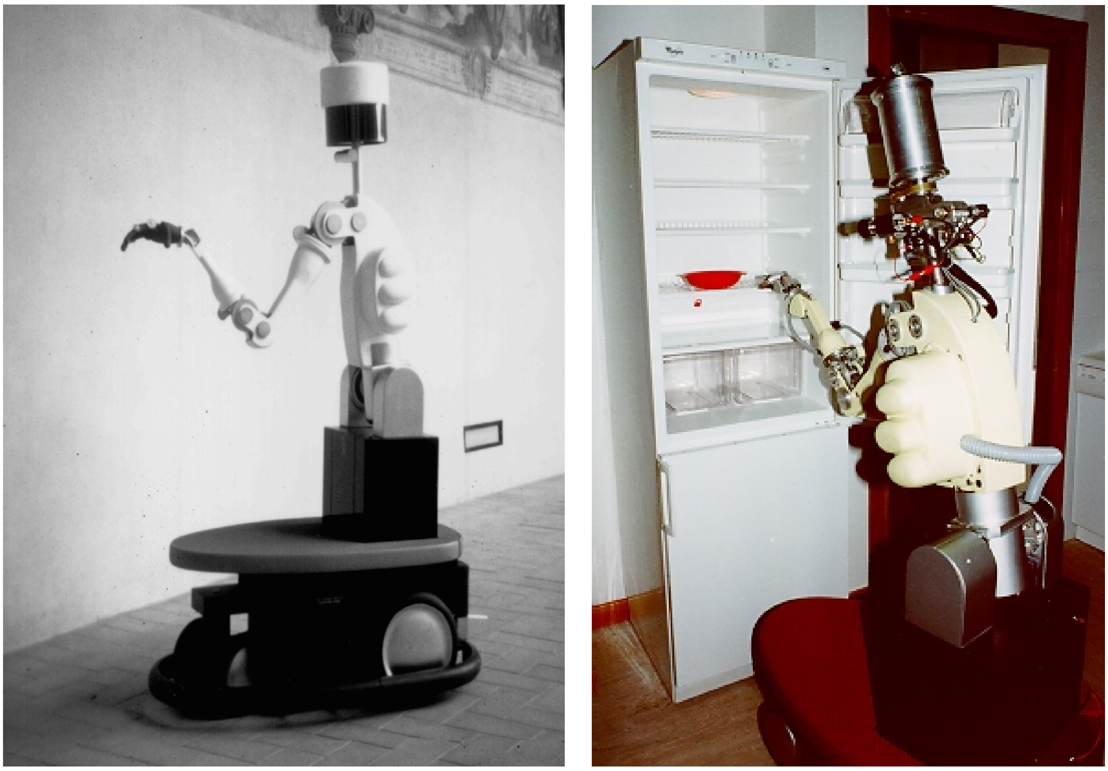


Fig. 6. The MOVAID mockup and prototype performing the typical tasks in the demonstrative environment

3.2 Japan

In Japan, Narita Laboratory and Takanishi Laboratory, both are included in Humanoid Research Institute, Waseda University (Tokyo, Japan) supervise this research. The HRI controls the robots in Italy via the ISDN media. This section deals with the Japanese site and humanoid robot WABIAN that is used in this remote operation.

3.2.1 Sites

The two sites, the HRI and ARTS laboratories, were connected via an ISDN line that enables people to contact each other using the videoconference system.

3.2.2 Humanoid robot WABIAN

This section describes the total and trunk mechanism of the humanoid robot WABIAN that is used for this experiment.

Total mechanism

The bipedal humanoid robot WABIAN (WAseda BIpedal humANoid) (Hashimoto et al. [5], Yamaguchi et al. [8]) is shown in Figure 7. The total weight is 107 [kg] and the height is about 1.66 [m]. It is made primarily of extra-super-duralumin and of GIGAS (YKK Corporation). An assembly drawing and a link structure of this robot are shown in Figure 8. As Figure 8 indicates, the lower-limbs have 6-DOF on the pitch-axis; the trunk has 3-DOF on the pitch-axis, roll-axis and yaw-axis; the upper-limbs have 14-DOF; the eyes and neck each have 2-DOF on the pitch-axis and yaw-axis; and the hands each have 3-DOF. The total active DOF is 35. In particular, the hip joint is an antagonistic driven joint using non-linear spring mechanisms. By using this drive system, it is possible to control the stiffness of the joint across a wide range.

15 AC servo motors and 16 DC servo motors are centrally controlled through I/O boards (D/A, A/D, and counter) by the control computer (PC/AT compatible CPU board). The control computer is installed at the back of the waist, and the

motor drive circuits at the top of the trunk. Thus, the only external connection to the robot is the power supply. This electrical configuration enhances WABIAN's walking and manipulating ability.

Trunk mechanism

The trunk of WABIAN can generate a three-axis moment with three DOF link mechanisms. This trunk mechanism generates a three-axis moment by swinging the upper-limbs around the yaw-axis using the yaw-axis actuator. The upper-limbs are linked to the yaw-axis actuator, which is installed at the top of the trunk. The pitch-axis and the roll-axis moments are generated by swinging the upper-limbs, the yaw-axis actuator, and the motor drive circuits around the pitch-axis and the roll-axis. By installing the yaw-axis actuator and motor drive circuits at the top of the trunk, and using its own weight to compensate for the pitch-axis and the roll-axis moments, the robot was able to generate a three-axis moment by the trunk without adding to the total weight of the robot.

Total system configurations are shown in Figure 9. Italy and Japan site were connected through ISDN 64 [kbps] line. In Japan, 10-base Ethernet cable connects the three computers those control the WABIAN's remote system, eyeballs, and arms.

The control interface is in Figure 10. There are four parts such as eyeballs' information, connection statements, neck information, and arms' information. The eyeballs' information part consists of the realtime control eyeball control interface using the cross cursor and the numerical interface for eyeballs. The connection statements display the packet information between the local and remote site. The neck part controls the WABIAN's neck motion. The VOR can be realized by using the both motion of the eyeballs and the neck. The arm control interface have the six button presented.

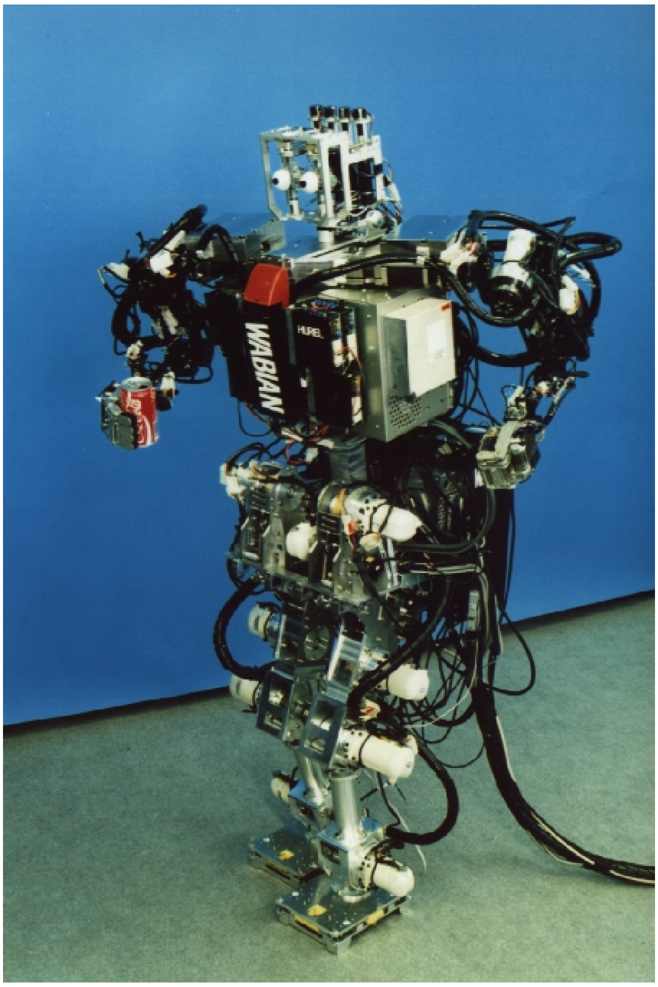
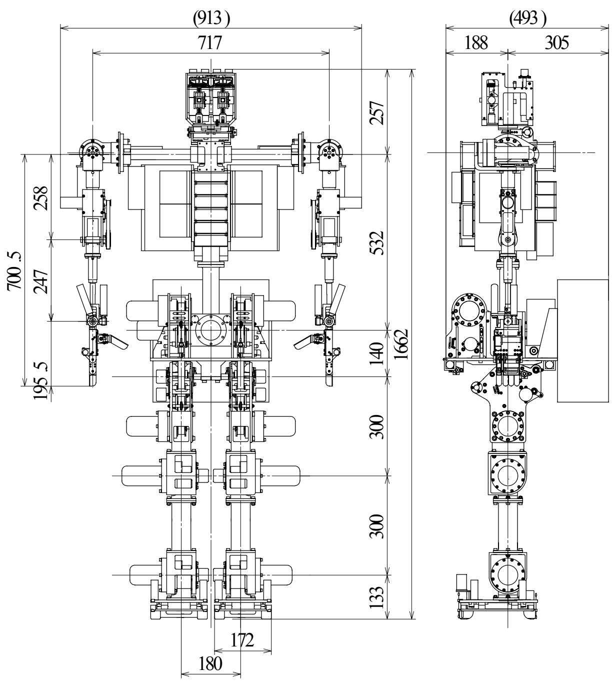
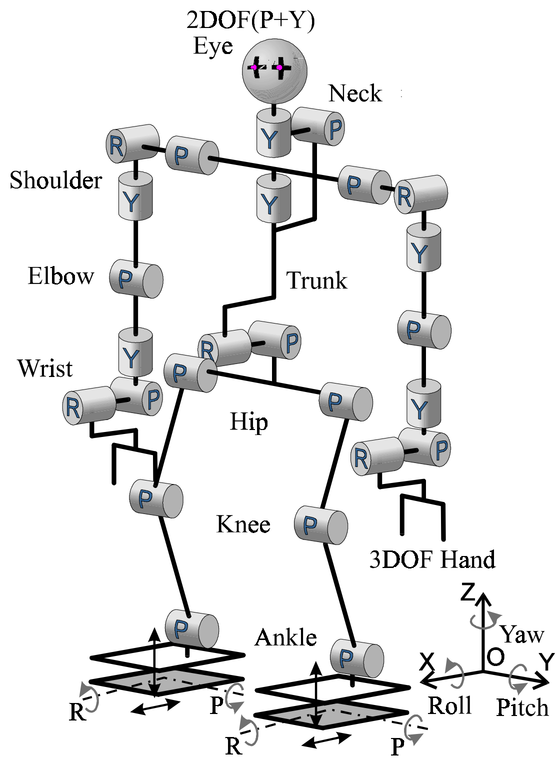


Fig. 7. Humanoid Robot WABIAN



(a) Assembly drawing



(b) DOF configurations

Fig. 8. Assembly drawings and DOF of WABIAN

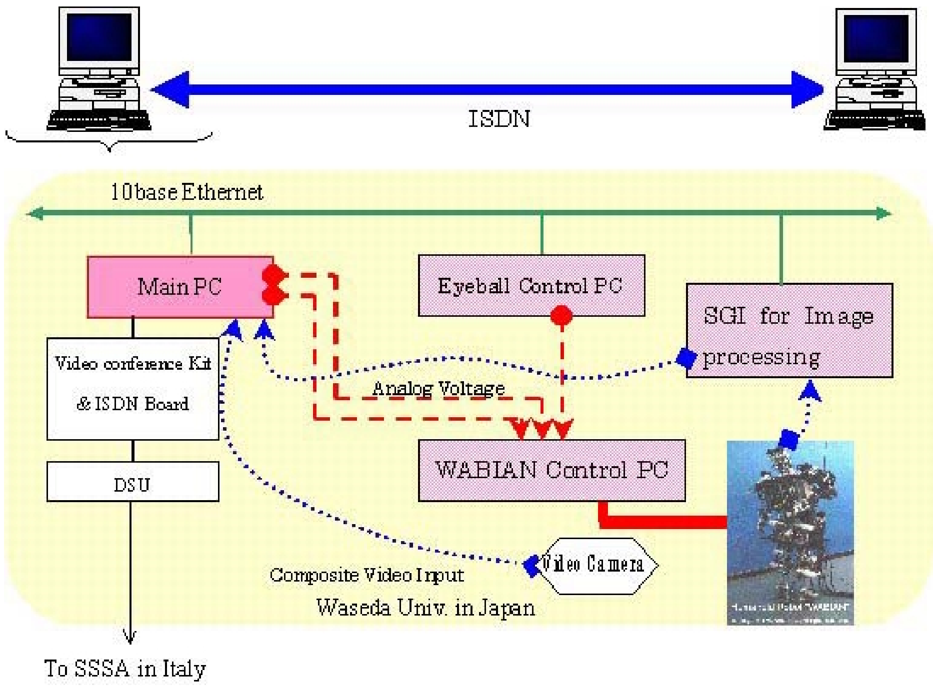


Fig. 9. Hardware configurations

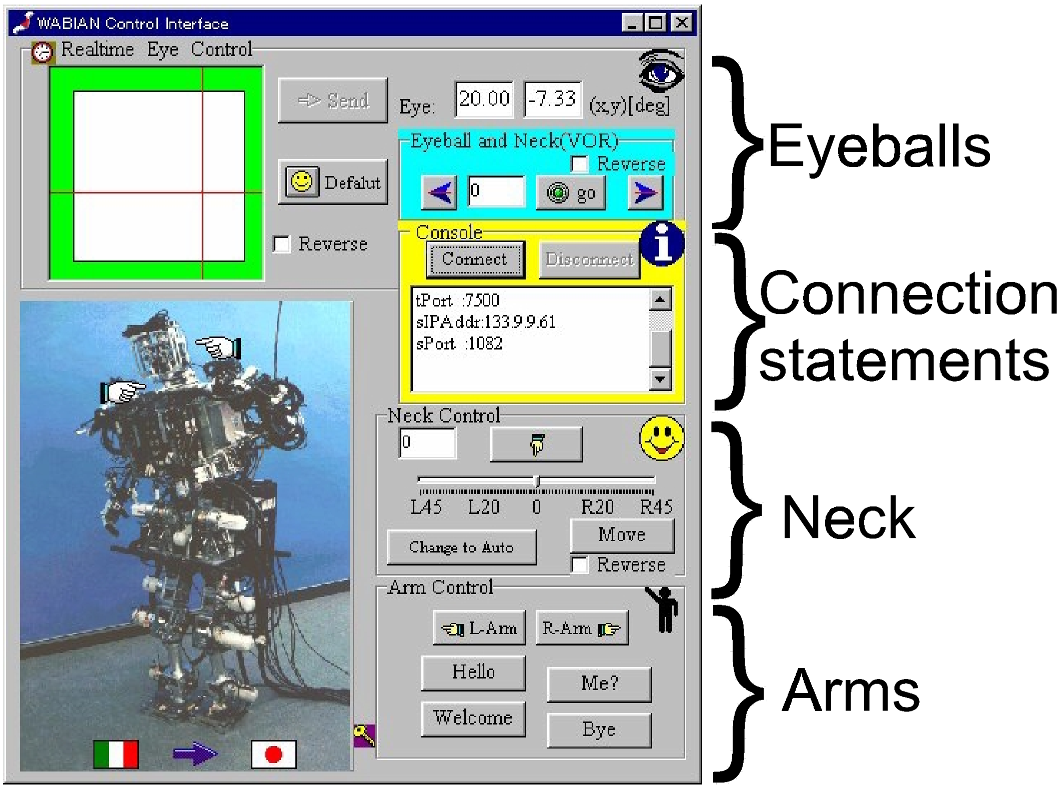


Fig. 10. WABIAN Remote control interface

4. Experiment

This chapter describes three experiments those are based on the WABIAN robot system and the ISDN telecommunication systems shown in the former chapter. The authors have done three experiments, i.e. the confirmation of basic functions of telecommunication, the tele-operation from Japan to Italy, and the tele-operation from Italy to Japan. These three experiments will be integrated in the future for more human friendly interaction between human and humanoid robots. Details of these experiments are as follows.

4.1 Experiment I

At the Narita Laboratory in Waseda University and the ARTS Lab, a preliminary experimental session on tele-operation and video-conferencing was carried out. Three functions of the system, that is video-conferencing, file-transfer and application-sharing functions, were tested under these two laboratories' staffs.

The video-conferencing functions worked well, and the file-transfer function and application-sharing did also. The application-sharing function is the most important function of this research, because this function enables us to operate the robot from remote site.

4.2 Experiment II

In this experiment II, the authors conducted a remote operation from Japan to Italy as in Figure 11. These experiments were divided into two parts: tele-operation and remote training for the operator. The experimental method and the results are as follows.

4.2.1 Tele-operation from Japan

The ARTS Lab team made available the MOVAID manipulator in order to perform some preliminary tests on the remote direct control of actuation devices in real time. In detail, here are the following tasks that have been performed successfully:

1. Power driver's enabling/disabling (arm on/off);
2. Arm motion to two predefined positions in the Cartesian space;
3. Execution of a predefined task in the Cartesian space: the robot has been preprogrammed to write the word "HI" on a blank sheet of paper;
4. Direct tele-operation of the arm in the joint space.

4.2.2 Remote training of the operator

The remote operation of the MOVAID and URMAD man-machine interfaces has been performed. During first session, an operator who already had knowledge of the interface functionality performed this task. In this second session, an operator who had never used the interfaces before (unskilled operator) performed the same operation under the direct and active supervision of an experienced user from Pisa. The unskilled operator could simulate the operation of the MOVAID and URMAD system by using the tele-conference and application-sharing functions that were confirmed in experiment I.

4.3 Experiment III

Experiment I and II were the discrete motion or operation experiment. However, continuous and practical experiment with WABIAN should be done. The authors focused on the eyeball motion of WABIAN because eyeball motion's inertia is low, therefore it suits the remote operation experiment that may have the time-delay. The WABIAN eyeball's remote operation from SSSA to Waseda University performed successfully as shown in Figure 12.

In addition, the remote operation of the robot's neck and arms had been remotely operated from another laboratory in Waseda Univ. By integrating these remote experiments, human in remote place can operate and control WABIAN with ISDN line that is useable in the home environment.

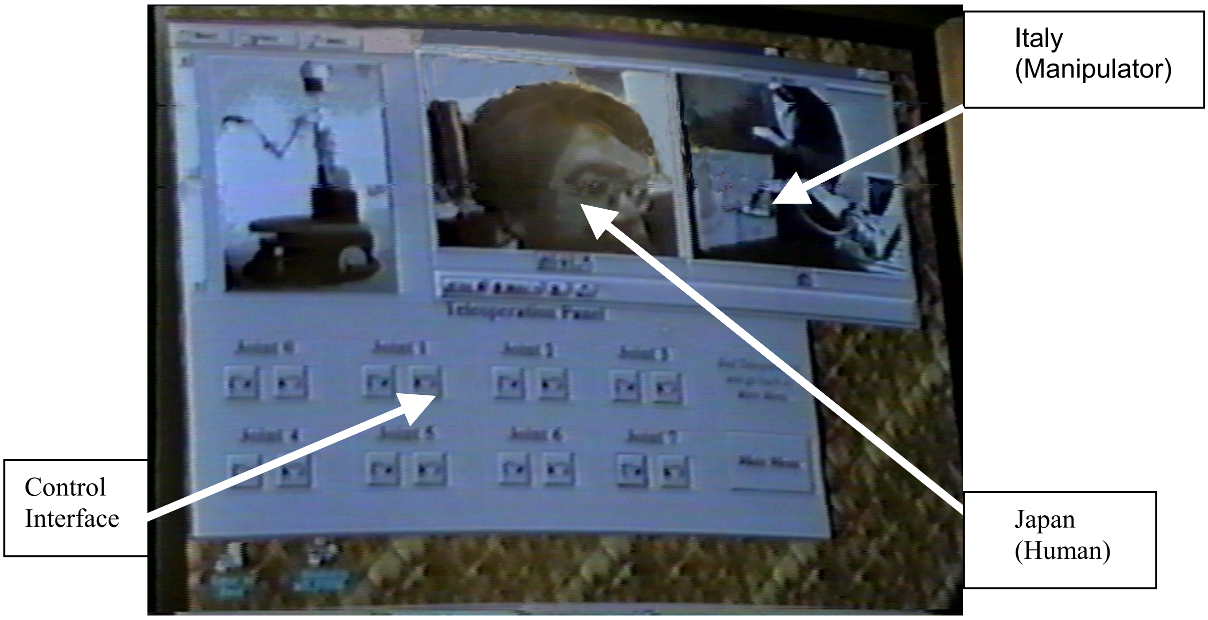


Fig. 11. Remote operation from Waseda to SSSA (Experiment II)

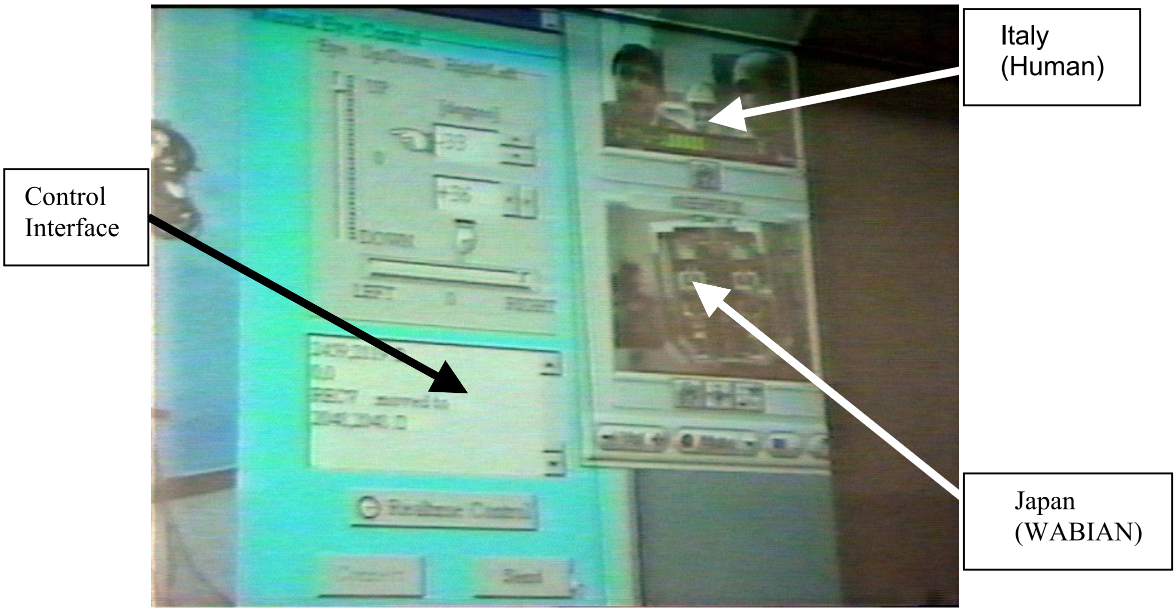


Fig. 12. Remote operation from SSSA to Waseda (Experiment III)

5. Conclusions

A part of the international joint research on interactions between human and humanoid robot had been performed. Preprogrammed arm operation from Japan, and real-time eyeball operation from Italy had succeeded.

Acknowledgments

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