Feature

Telexistence and R-Cubed

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Keywords

Robots, Service, Telexistence, Teleoperation, VR

Abstract

Telexistence (tele-existence) is technology which enables a human being to have a real time sensation of being at a remote location, while giving the person the ability to interact with the remote and/or virtual environments. He or she can "telexist" (tele-exist) in a real environment where the robot exists or in a virtual environment that a computer has generated. It is also possible to telexist in a mixed environment of real and virtual, which is called augmented telexistence. The concept of telexistence, i.e. virtual existence in a remote or computer-generated environment, has developed into a national R&D scheme called R-Cubed (Real-time Remote Robotics). Based on the scheme the National R&D Project of "Humanoid and Human Friendly Robotics", Humanoid Robotics Project (HRP) in short, was launched in April 1998. This is an effort to integrate telerobotics, network technology and virtual reality into networked telexistence.

Industrial Robot
Volume 26 · Number 3 · 1999 · pp. 188–193
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Telexistence

It has long been a desire of human beings to project themselves into remote environments, i.e. to have a sensation of being present or existing in a different place other than the place they really exist at the same time. Another dream has been to amplify human muscle power and sensing capability by using machines while preserving human dexterity and a sensation of direct operation.

In the late 1960s a research and development program was planned on a powered exoskeleton that a man would wear like a garment. A concept of Hardiman was proposed by General Electric Co. The idea was that a man wearing the Hardiman exoskeleton would be able to command a set of mechanical muscles that multiply his strength by a factor of 25, yet in this union of man and machine he would feel objects and forces almost as if he were in direct contact.

However, the project was unsuccessful for the following reasons:

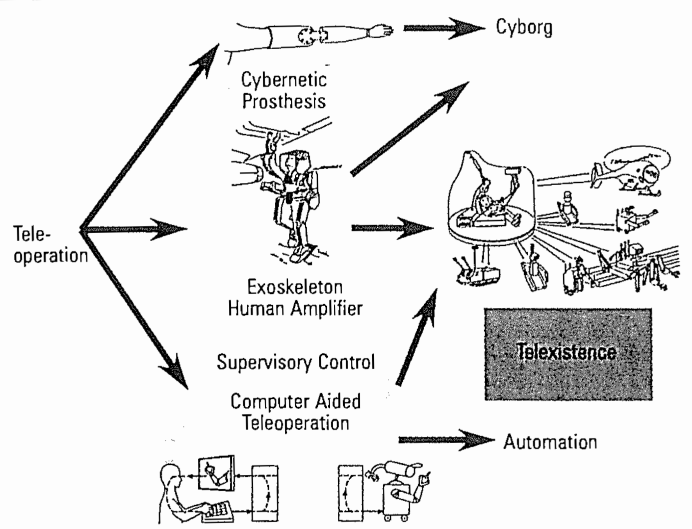
(1) It is potentially quite dangerous to wear a powered exoskeleton when we consider potential malfunction of the machine.

(2) Space inside the machine is required to store computers, controllers, actuators and the energy source of the machine, which eliminated the space for a human operator. Thus, the design proved impractical in its original form.

Developments in science and technology have now provided the means for an alternative approach to realizing these dreams. The concept of projecting ourselves by using robots, computers and a cybernetic human interface is called telexistence (tel-existence). This concept expands to include projection in a computer-generated virtual environment. Figure 1 illustrates how telexistence has evolved and emerged.

The realization of the concept of telexistence was a fundamental principle of the eight year Japanese National Large Scale Project "Advanced Robot Technology in Hazardous Environment," which started in 1983 together with the concept of Third Generation Robotics. Through this project a theoretical consideration of telexistence has been done and its systematic design procedure has been established. Experimental hardware telexistence systems have been made and the feasibility of the concept has been demonstrated[1].

Figure 1 Historical diagram on the evolution of telexistence



The first prototype telexistence master slave system for remote manipulation experiments was designed and developed, and a preliminary evaluation experiment of telexistence was conducted[2] (see Figure 2).

Augmented telexistence

Telexistence can be divided into two categories: telexistence in the real environment that actually exists at a distance, and is connected via a robot to the place where the user is located; and telexistence in a virtual environment that does not actually exist but is created by a computer. The former can be called "transmitted reality," while the latter is "synthesized reality." The synthesized reality can be classified into two, i.e. a virtual environment as a model of the real world and a virtual environment of an imaginary world. Combination of transmitted reality and synthesized reality, which is called mixed reality, is also possible and has great importance in real applications where it has been exploited since the 1940s. This we call augmented telexistence to clarify the importance of harmonic combination of real and virtual worlds[3].

Augmented telexistence can be used in several situations. Take for instance, controlling a slave robot in a poor visibility environment. An experimental augmented telexistence system using mixed reality is constructed as in Figure 3. The environment model is also constructed from the design data of the real environment. When augmented reality is used for controlling a slave robot, the modeling errors of the environment model must be calibrated. A model-based calibration system using image measurements is proposed for matching the real environment and the virtual environment. The slave robot has a force feedback control mechanism for contact tasks and for compensating for the errors that remain even after the calibration. An experimental operation in a poor visibility environment was successfully conducted by using Telesar (Figure 2) and the virtual Telesar (Figure 4).

Figure 3 shows the schematic diagram of the augmented telexistence system and Figure 4 shows the virtual telexistence anthropomorphic robot used in the experiment[4].

Quantitative evaluation of the telexistence manipulation system was conducted through tracking tasks by using a telexistence master slave system. Through these experimental studies, it has been demonstrated that a

Figure 2 Telesar (telexistence surrogate anthropomorphic robot) developed

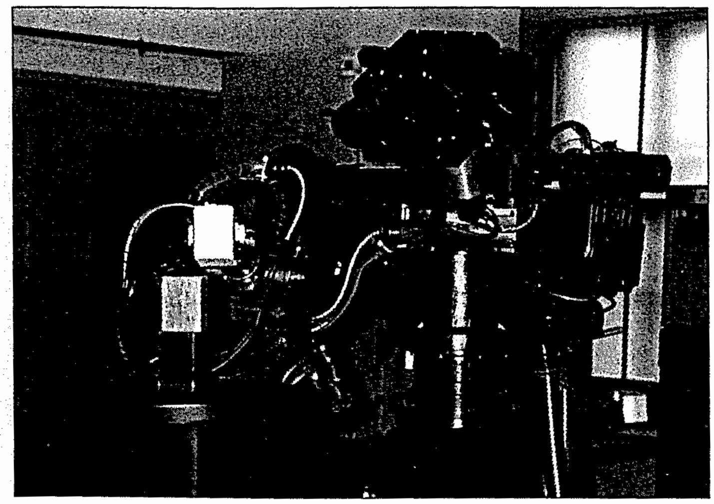
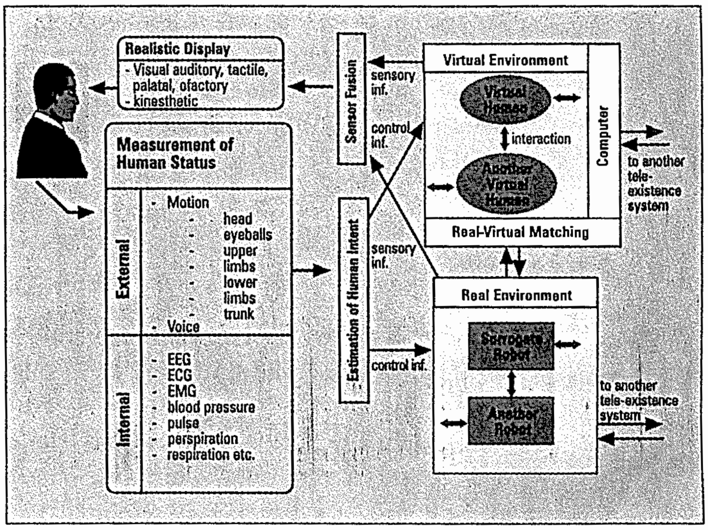


Figure 3 Diagram of an augmented telexistence system



Industrial Robot
Volume 26 · Number 3 · 1999 · 188–193

Figure 4 Virtual Telesar at work

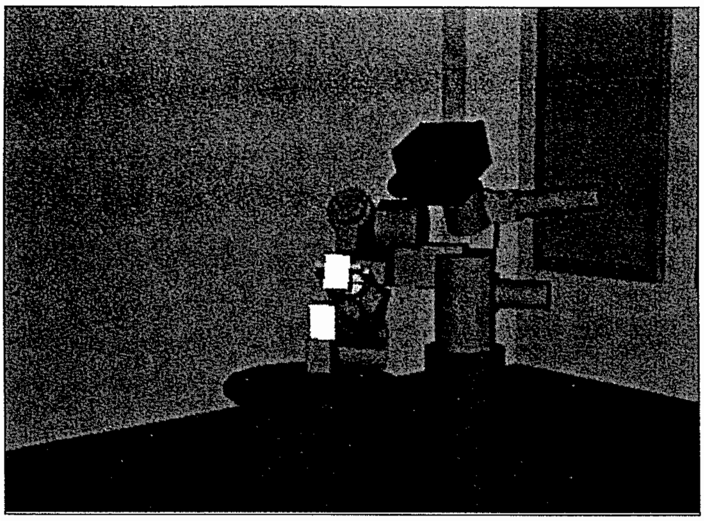


Figure 5 Conception of mountain climbing using R-Cubed robot

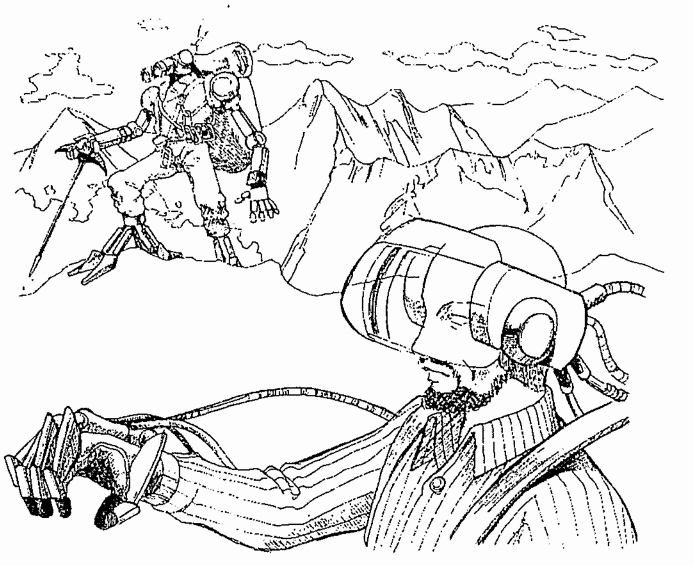
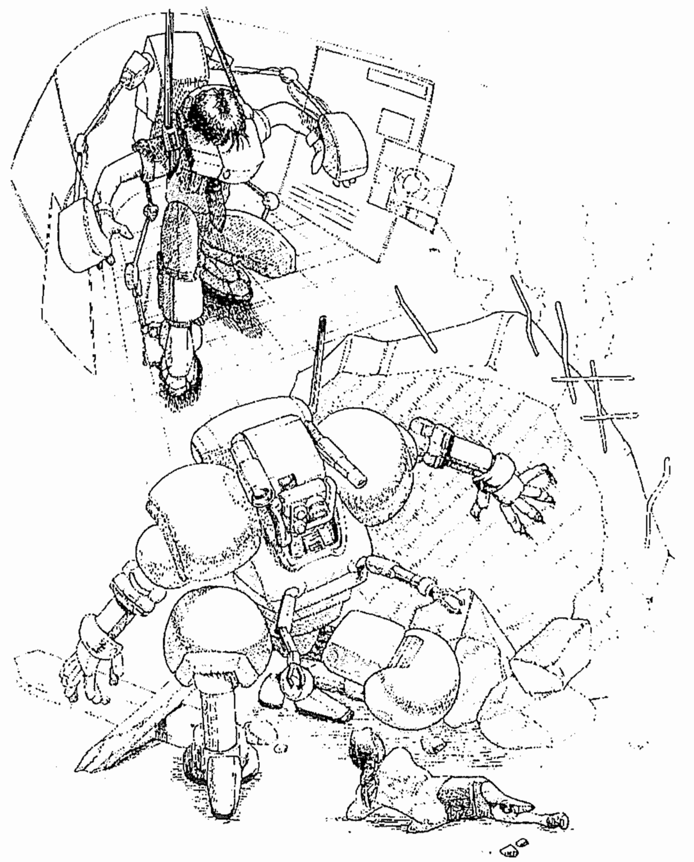


Figure 6 Conception of rescue operation using R-Cubed robot



human being can telexist in a remote environment and/or a computer-generated environment by using the dedicated telexistence system[5].

Through this research and development it has become possible to telexist between places with dedicated transmission links like optical fiber communication links as is shown by the above experiments. However, it is still difficult for everyone to telexist freely through commercial networks like the Internet or the next generation worldwide networks, and more efforts are anticipated.

R-Cubed

In order to realize the society where everyone can freely telexist anywhere through network, Japanese Ministry of International Trade and Industry (MITI) and the University of Tokyo proposed a long-range national R&D scheme, which is dubbed R-Cubed (R^3), in 1995[6]. R^3 stands for the Real-time Remote Robotics. The concept is the research and development of the technologies that enable human users to telexist freely by integrating robots, virtual reality and network technology[6].

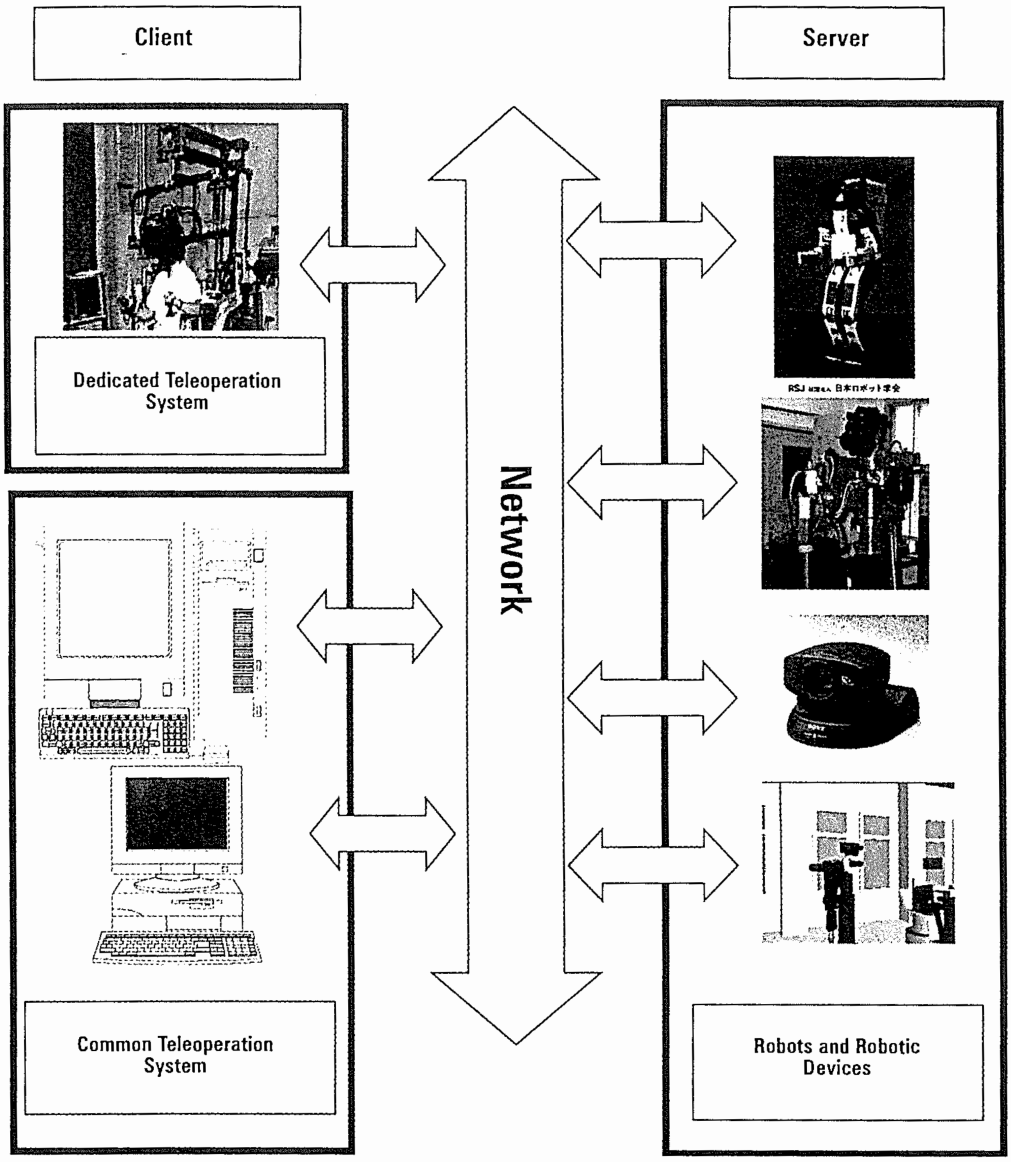
Figures 5 and 6 show examples of a conceptual networked telexistence application using R-Cubed robots.

Figure 7 shows an example of R-Cubed system. Each robot site has a server for its local robot. The robot type varies from a humanoid (high end) to a movable camera (low end). A virtual robot can also be a locally controlled system[7].

Each client has its own teleoperation system. It can be a control cockpit with master manipulators and a head mounted display (HMD) or CAVE Automatic Virtual Environment for advanced systems. It is also possible to use an ordinary personal computer system for its control system for control of simpler systems. In order to allow the low end users to control remote robots through networks, RCML/RCTP (R-Cubed Manipulation Language / R-Cubed Transfer Protocol) is now under development[7,8].

Industrial Robot
Volume 26 · Number 3 · 1999 · 188–193

Figure 7 An example of R-Cubed system

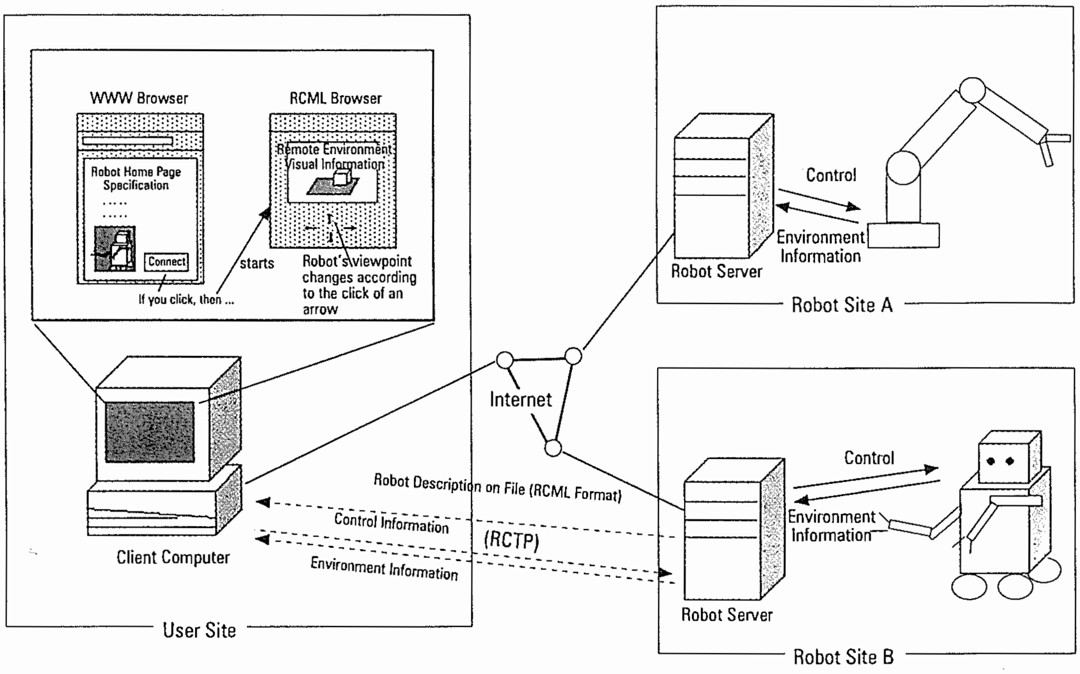


With a Web browser a user accesses a Web site providing information on a robot in the form of hypertext and icon graphics. Clicking on an icon downloads the description file, which is written in RCML format, to the user's computer and launches the RCML browser. The RCML browser parses the downloaded file to process the geometry information, including the arrangement of the degrees of freedom of the robot, controllable parameters, available motion ranges, sensor information, and other pertinent information. The browser decides what kind and how many devices are required to control the remote robot. It then generates a graphical user interface (GUI) panel to control the robot, plus a video window that displays the images "seen" by the robot and a monitor window that lets users observe the robot's status from outside the robot. If the user has a device such as six degrees-of-freedom (DOF) position/orientation sensor to indicate the robot-manipulator's endpoint, the user can employ that instead of the conventional GUI panel (see Figure 8).

Humanoid Robotics Project: HRP

Based on the R^3 scheme and after two-year feasibility study called Friendly Network Robotics (FNR), which was conducted from April 1996 till March 1998, the National Applied Science & Technology Project, "Humanoid and Human Friendly Robotics," or "Humanoid Robotics Project (HRP)" for short, has just been launched[9]. It is a five-year project toward the realization of so-called R-Cubed Society by providing humanoids,

Figure 8 Diagram for RCML and RCTP process



control cockpits and remote control protocols.

Japan's population is aging rapidly and people are having fewer children. This means that efficient and human friendly machinery that can support daily life and the activities of humans, such as attending to the elderly and the handicapped, is in great demand. Thus, the HRP project aims to develop a safe and reliable human friendly robot system capable of carrying out complicated tasks and supporting humans both at work and in leisure activities.

Through development of such a system, this project will contribute towards the improvement in efficiency and safety in industry, making society and the living environment more convenient and comfortable, and towards the creation of new industries in the manufacturing and service sectors.

Research and development will be implemented as follows:

(1) *Development of a platform for a human friendly and supportive robot:* human friendly and supportive robots capable of basic motions and movements within human work and living environments and having communication ability and main parts consisting of modular structures making the addition and modification of functions easy will be developed. A teleoperation system will also be developed.

(2) *Development of a virtual platform for a human friendly and supportive robot:* a virtual platform consisting of a simulator and software for operating platform hardware and a simulator will be developed.

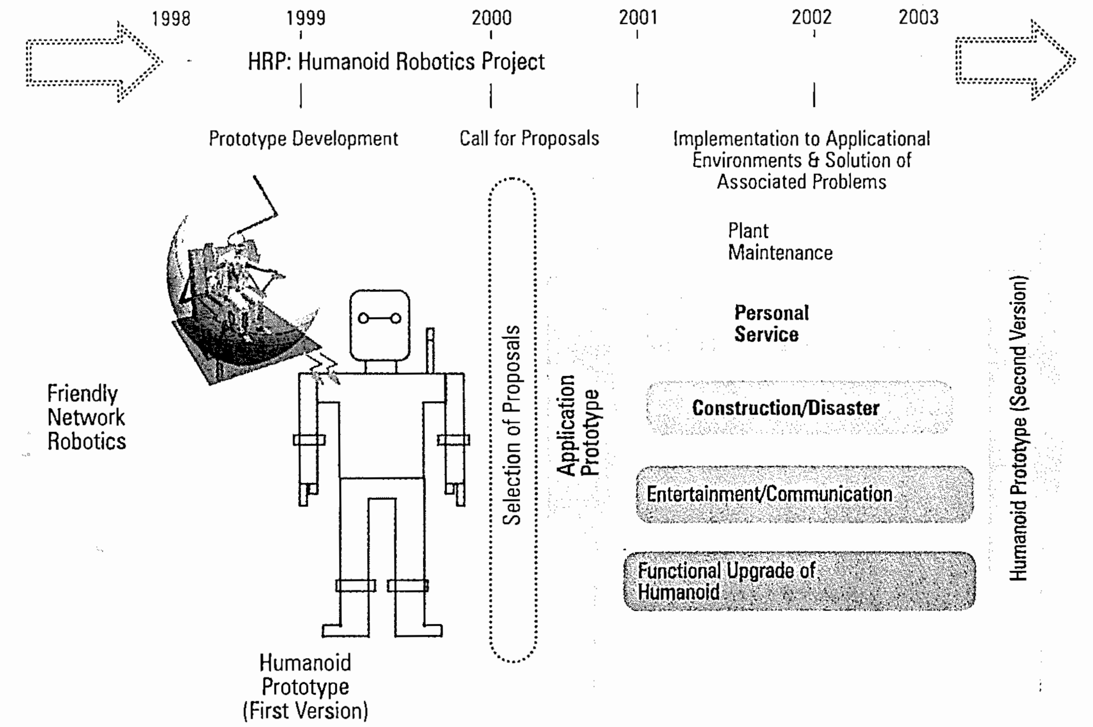
Figure 9 shows how HRP is carried out. A Prototype Robot (Humanoid Platform) is now being developed by Honda, while the telexistence cockpit is being developed by Matsushita Electric Works, Kawasaki Heavy Industry, FANUC and the University of Tokyo. Humanoid simulator (Virtual Platform) is being developed by Hitachi, Fujitsu and the University of Tokyo.

Conclusion

One of the most promising technologies today is the integration of virtual reality and robotics on the network. It is called networked robotics in general and R-Cubed (Real-time Remote Robotics) in particular. R-Cubed is a Japanese national R&D scheme toward the realization of the augmented telexistence through various kinds of networks including the Internet. Japanese Ministry of International Trade and Industry (MITI) launched the "Humanoid and Human Friendly Robotics (HRP)" five-year Project in April 1998. This is the first step toward the realization of R-Cubed and the results are much as anticipated for this stage of the project.

Industrial Robot
Volume 26 · Number 3 · 1999 · 188–193

Figure 9 HRP (Humanoid Robotics Project) general plan



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