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## Tele-Existence and/or Virtual Reality

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### Abstract:

*Tele-existence is a concept named for the technology which enables a human being to have a real time sensation of being at the place other than the place where he or she actually exists, and is able to interact with the remote and/or virtual environment. He or she can "tele-exist" not only in a real world where the robot exists but also in a virtual world which a computer has generated. It is possible to tele-exist in a combined environment of real and virtual, like in the case of controlling real environment through virtual environment or controlling real environment augmented by virtual environment. Virtual reality is a technology which presents a human being a sensation of being involved in a realistic virtual environment other than the environment where he or she really exists, and can interact with the virtual environment. Thus tele-existence and virtual reality are essentially or virtually the same technology expressed in different manners. The concept of tele-existence was proposed in 1980, and it played the role of the fundamental principle of the eight year Japanese National Large Scale Project of "Advanced Robot Technology in Hazardous Environment," which started in 1983. Experimental tele-existence systems have been constructed, which enables a human operator to have the sensation of being in a remote real environment where a surrogate robot exists and/or virtual environment synthesized by a computer. In this special lecture, present status of tele-existence and/or virtual reality as a human tool for communication, control, creation, entertainment, experience, or elucidation (3C's and 3E's) is reviewed and future trend is prospected.*

**Keywords:** virtual reality, tele-existence, telepresence

### 1. Introduction

"Virtual" is defined as existing in essence or effect though not in actual fact or form [The American Heritage Dictionary], and virtual image is an example of its usage. Thus "virtual reality" can be defined as reality in essence or effect though not in actual fact or form, so that it provides a basis for the technology which enables humans to experience events and act in a virtual environment just as if they were in the real environment. Tele-existence is virtually the same concept as virtual reality, but takes a different point of view. It represents a concept that allows humans, who are assumed to be emancipated from the restrictions of time and space, to exist in a location defined by inconsistent time and space, or a virtual space.

The concept of the tele-existence was proposed by the author in 1980 and it played the role of the fundamental principle of the eight year Japanese National Large Scale Project of "Advanced Robot Technology in Hazardous Environment" which started in 1983 together with the concept of the Third Generation Robotics. Tele-existence is a concept named for the technology which enables a human being to have a real time sensation of being at the place other than the place where he or she actually exists. He or she can tele-exist in the transmitted real world where the robot exists or in a synthesized world which a computer has generated. It is possible to tele-exist in a combined environment of transmitted and synthesized, like in the case of controlling real environment through virtual environment or controlling real environment augmented by virtual environment.

One of the reasons for virtual reality and/or tele-existence attracting worldwide attention is that scientific

subjects, which have been believed to belong to completely different fields of research, are likely to be unified by the concept of virtual reality as shown in Fig.1. It is expected to play an important role as generic technology in 21st century. It was Howard Rheingold who defined computers as "tools for thoughts." In this sense, the author would like to define virtual realities as "tools for creation." Furthermore, virtual realities are tools not only for creation but also contain within itself the possibility of becoming tools which are useful for various human activities which can be termed as "human tools for 3C's and 3E's." Three C's mean control, communication, and creation, while three E's represent experience, elucidation, and entertainment.

In this special lecture, virtual reality and/or tele-existence is discussed from the standpoint of human tools for 3C's and 3E's. In order to realize the virtual reality human tools, fundamental researches must be conducted. Several projects for the fundamental studies of virtual reality are being planned world wide including the United States and Japan. Recent research results in Japan for the realization of the technology are also reported.

## 2. Tele-Existence in the Real and Virtual Worlds

It has long been a desire of human beings to project themselves in the remote environment, i.e., to have a sensation of being present or exist in a different place other than the place they are really exist at the same time. Another dream has been to amplify human muscle power and sensing capability by using machines while reserving human dexterity with a sensation of direct operation. In the late 1960s 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., for example, that a man wearing the Hardiman exoskeleton would be able to command a set of mechanical muscles that multiply his/her strength by a factor of 25, yet in this union of man and machine he would feel object and forces almost as if he or she were in direct contact. However, the project was unsuccessful because of the following reasons: (1) It is potentially quite dangerous to wear the exoskeleton when we consider the malfunction of the machine. (2) Space inside the machine is quite valuable to store computers, controllers, actuators and energy source of the machine. Thus it is not at all a practical design to use it for a human operator.

With the advent of science and technology, it has become possible to challenge for the realization of the dreams. The concept of projecting ourselves by using robots, computers and cybernetic human interface is called tele-existence. Adding to project ourselves or "tele-exist" in a remote real world, projecting ourselves or "tele-existing" in a computer generated virtual world is becoming possible. The latter concept is usually called as virtual reality. This concept was born independently both in Japan and in the United States, and was dubbed tele-existence in Japan and telepresence or virtual reality in the United States [1-18].

Tele-existence is an advanced type of teleoperation system which enables a human operator at the controls to perform remote manipulation tasks dexterously with the feeling that he or she exists in one of the remote anthropomorphic robots in the remote environment. It enables the human operator to be "virtually" inside an exoskeleton human amplifier, while actually exists at the remote place. Thus the two main problems for the use of exoskeleton human amplifier have been solved, while keeping advantage of direct operation. Tele-existence can be said to "aufheben" teleoperation and an exoskeleton human amplifier.

Tele-existence or virtual reality can be divided into two categories: tele-existence in the real world that actually exists at a distance, and is connected via robot to the place where the user is located; and tele-existence in the virtual world that does not actually exist but is created by computer. The former can be called "Transmitted Reality," while the latter is "Synthesized Reality." The synthesized reality can be classified into two, i.e., virtual environment as a model of the real world and virtual environment of an imaginary world. Combination of transmitted reality and synthesized reality is also possible and has great importance in application. Thus it might be called virtual existence to clarify the importance of harmonic combination of real and virtual worlds.

## 3. Human Tools for 3C's and 3E's

Three factors of virtual reality are as follows: (1) Virtual reality provides a 3D space which is natural to the

user (**Sensation of Presence**); (2) Virtual reality allows the user to act freely and allows the interaction to take place in natural form and real time (**Real Time Interaction**); and (3) Virtual reality provides a projection of himself/herself as a virtual human or surrogate robot (**Self Projection**). Based on this perspective, virtual reality provides human beings tools for three C's and three E's, that is control, communication, creation, experience, elucidation and entertainment as mentioned before. Figure 2 shows roles of virtual reality as tools and characteristics of VR space in the form of matrix. At each intersection, typical usages are shown.

#### **Control:**

In the field of remote manipulation of robots, teleoperation technology, which appeared in relation with development of atomic power plant technology after the World War II, and prostheses technology for the disabled such as artificial arms, developed in the 70's into the supervisory control technology [12]. On the other hand, because of the advantage of direct operation, development of exoskeleton human amplifier, which covers human body like an armor and protect the body from dangerous environment, while strengthen human power, was also seriously studied. Tele-existence is the concept which "aufheben"s the two technologies, i.e., teleoperation and the exoskeleton human amplifier. It developed rapidly since 1980. Figure 3 shows a schematic diagram of the development of tele-existence and related technologies.

#### **Communication:**

It is predicted that networked reality will be used not only in the offices and factories but also at home since the era of information highway is just around the corner. The usage of the networked reality system for communication includes the application to communications such as telemeeting, teletravel, teleshopping and virtual community experience with a sensation of presence. This field has a close relation to multimedia and internet, which means that provision of network infrastructure is one of the keen issues. However, what we must keep in mind is the fact that mere quantitative improvement of the service is not at all enough for the dramatic change of the conventional media. In order to make the networked media a success, it is required to bring about the change of quality and to introduce technology which makes what was impossible possible such as virtual reality. Thus virtual reality is expected to be a great incentive to deliver high-speed large-capacity fiber network to each home.

#### **Creation:**

We can also see the development for virtual reality in the field of design and production. One of the important directions of future production system is to supply products which are appropriate to the need and individuality of each user without losing exchangeability, expandability and openness. However, it is not admirable to pursue the product which is the most appropriate to each person by designing and producing again and again because it will cost too much, waste time and waste natural resources and energy in vain. Virtual reality, which enables virtual products, which is produced by computers and evoke us the sense of sight, hearing and touch which are equivalent to that of real products, is expected to solve the problem. This technology also offers us useful tools for the amplification of human creativity. We can embody very abstract ideas and concept in our brain as an concrete object in virtual space, and show it in a very concrete form to other persons by using virtual reality.

#### **Experience:**

Experience plays an important role in learning, training and education. Application to education includes, for example, an ultimate simulation including an electronic experience simulator.

#### **Elucidation:**

Virtual reality provides quite useful and powerful tools for the elucidation of natural phenomenon. For instance, scientific visualization as a tool for scientific-engineering research. Also the use of VR as a tool for research of the functions of humans and other living creatures is possible.

#### **Entertainment:**

It is not necessary to argue this usage too much because lots of products are now in the market. The only thing to add is that virtual reality provides a new medium that, embracing linguistic and picturized expressions and going beyond them, would express human ideas and concepts.

#### 4. Recent Research on Tele-Existence

##### **Evaluation Experiments of a Tele-existence Manipulation System [18]**

A tele-existence manipulation system was evaluated quantitatively by comparing tasks of tracking a randomly moving target under several operational conditions. The effects of various characteristics, e.g., binocular vision and the effect of natural arrangement of the head and the arm, are analyzed by comparing quantitatively the results under these operational conditions. Human tracking transfer function was measured and was used for comparison. The results revealed the significant dominance of the binocular vision with natural arrangement of the head and the arm, which is the most important characteristic of tele-existence.

##### **Experimental Study on Remote Manipulation using Virtual Reality [19]**

In order to control a slave robot in poor visibility environments, an experimental extended tele-existence system using virtual reality was constructed. The environment model was constructed from design data of the real environment. When virtual 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 virtual environment. The slave robot has an impedance control system 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. Figure 4 shows the schematic diagram of the extended tele-existence system. and Figure 5 shows the tele-existence anthropomorphic robot used in the experiment.

##### **Coherency of Kinesthetic and Visual Sensation in Virtual Reality System [20]**

To realize highly realistic sensation of presence in a virtual environment, it is necessary to provide coherency between kinesthetic and visual sensation by introducing virtual human in which a user is projected just as in the case of tele-existence to the remote robot. In order to construct such an environment, an object-oriented virtual environment description method using the class of C++ language is proposed, which is flexible, easy to construct, and efficient for image generation. A virtual environment of our real laboratory with virtual tele-existence manipulation system was constructed (Fig. 6). Using the system, an experiment was conducted to demonstrate the effectiveness of the use of virtual human as a surrogate of the operator.

##### **Calibration Method of Virtual Parameters for See-Through Head-Mounted Display [21]**

Matching of location and size between objects in the real environment and in the virtual environment is crucial when See Through Head Mounted Display (STHMD) is used. A calibration method was proposed to cancel both systematic errors of visual parameters caused in manufacturing process and differences between actual and designed location of user's eye on STHMD. The former is required to be calibrated only once after the fabrication of STHMD's, where as the latter has to be calibrated every time a user starts using STHMD. By the calibration, the systematic error was reduced about 1 mm per target, which was less than one-thirtieth of that before calibration, where the error caused by individual difference of a user was reduced to about 2 mm per target, which was a half of that before the calibration.

##### **Compensation of Time Lag between Actual and Virtual Spaces by Multi-Sensor Integration [22]**

Unconstrained measurement of human head motion is essential for HMD. A method was proposed to compensate the latency, which conventional magnetic sensors had, and raised the effective sampling rate through the integration of magnetic sensor and gyro sensor by using the Kalman filter. A physically consistent system model of human rotation described by quaternion and angular velocity was derived and the optimal prediction was made using the model and measurements by both sensors.

##### **Virtual Haptic Space [23]**

A method was proposed to construct a virtual haptic space driven by the same environment model of the real world as of the visual space, and a haptic graphics system was constructed according to the proposed method. Human limb motion was measured in real time and the subspace of the total haptic space, which was or would be in contact with the human end effector, was constructed using the haptic space display device. Its end effector was an environment shape approximation device whose shape was specially designed to

approximate several shapes by changing its sides of contact. Its position and orientation was controlled by a pantographic mechanism called an active environment display. The shape of the haptic space was approximated by the environment shape approximation device, and inertia, viscosity and stiffness of the haptic space were generated by the use of the mechanical impedance controlled active environment display. Figure 7 shows a principle of virtual haptic space.

## 5. Conclusion

In the United States the Committee on Virtual Reality Research and Development was established by the National Research Council in 1992 at the request of the Federal Government, and the report was submitted in 1995 recommending a national research and development agenda in the area of virtual reality to guide government research and development over the generation. In Japan the Ministry of Education, which is in charge of the academic researches in Japan, selected Virtual Reality as one of the most important areas to be researched, and started the three year project of the Fundamental Study on Virtual Reality from the academic year of 1995 (April 1995). The Japanese Ministry of International Trade and Industry (MITI) began a feasibility study of Virtual Reality as Human Centered Media in 1994, and planning to launch a National Large Scale Project on virtual reality as human media. These actions in both countries and other similar activities including in the United Kingdom, France and Germany strongly indicate the importance of virtual reality as generic technology for the 21st century. Fundamental researches and development are needed for the healthy development of the technology, which includes not only scientific and technological developments but also psychological, social and ethical considerations.

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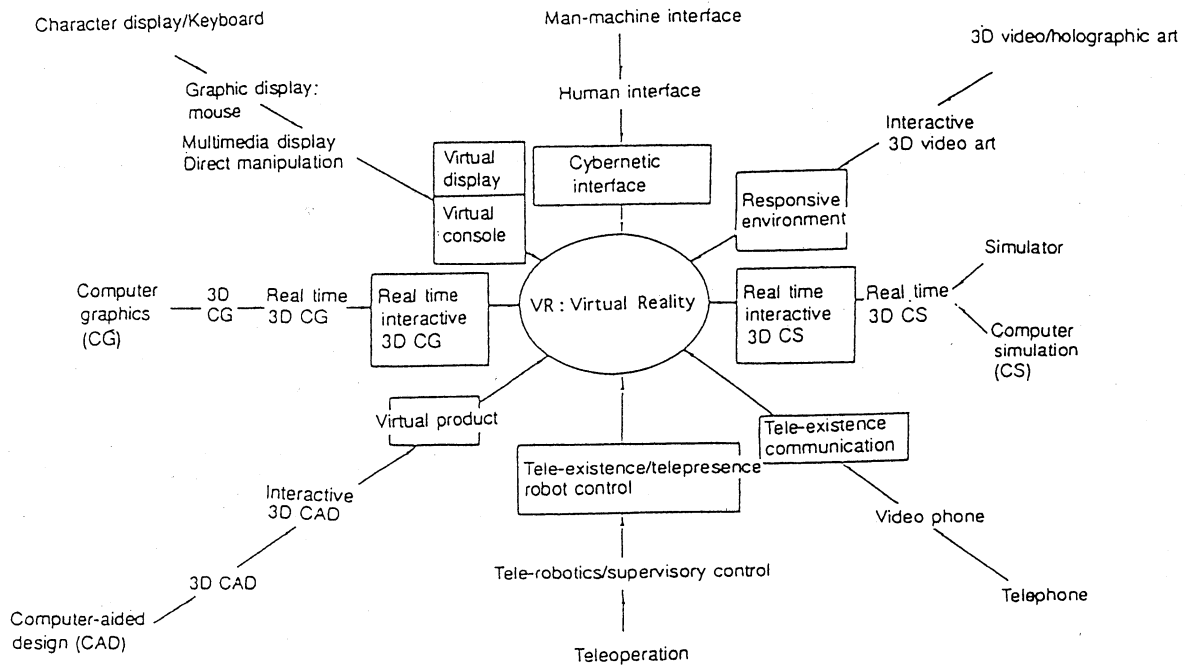


Fig.1 Present Status of Virtual Reality.

Roles as Human Tools  Space Characteristics		3C's			3E's				
		control	communication	creation	elucidation	experience	entertainment		
Transmitted Reality  [ Including Augmented Reality and Transmission through Virtual Space ]		Tele-Existence Robot Control          Tele-Conference with a Sensation of Presence			Experience using Tele-Existence          Tele-Existence Adventure				
Synthesized Reality	Reality Based Space	Design  Embodiment of Abstract Concept						VR Simulation  Visualization	VR Model  Experience Simulator
	Hyper Reality Space	Virtual Community			Art		Game Amusement		

Fig.2 VR as Human Tools for Three C's and Three E's.

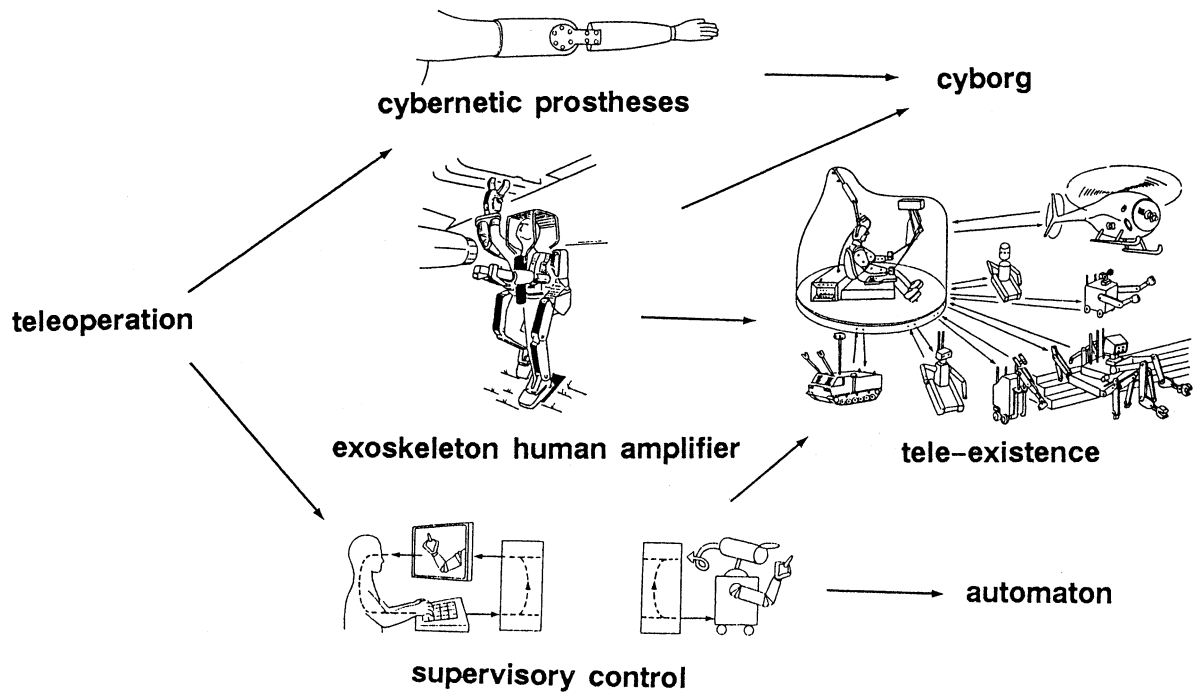


Fig.3 Historical Diagram of Tele-Existence and Related Technologies.

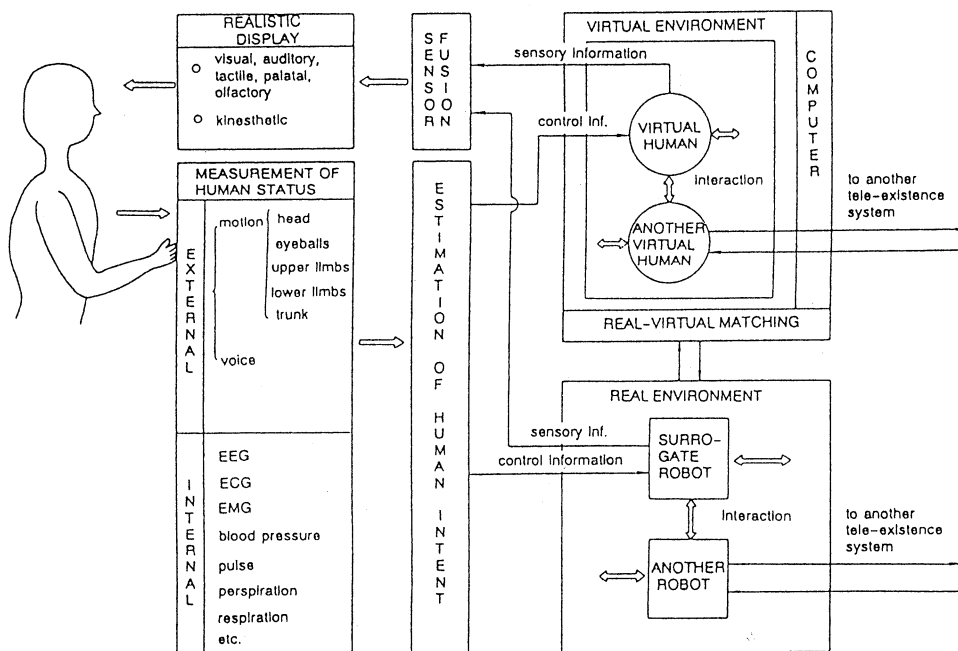
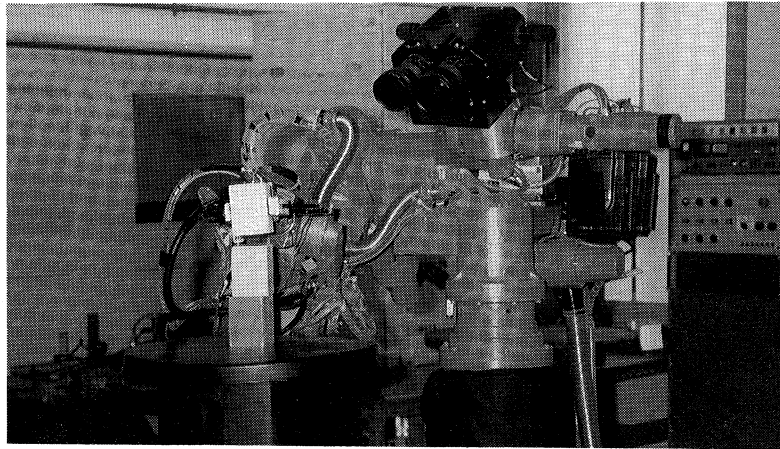
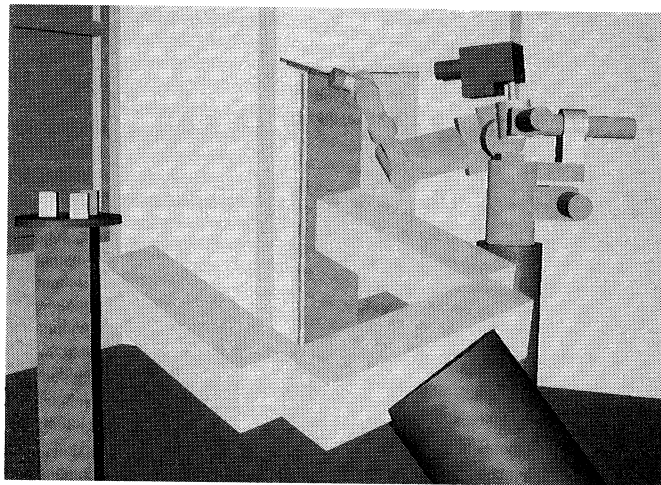


Fig.4 Organization of Tele-Existence System.

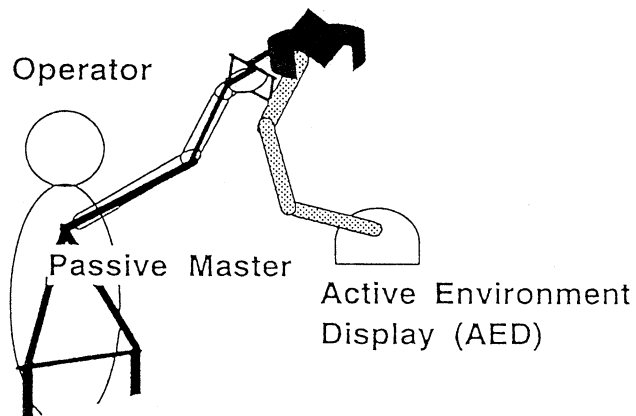


**Fig.5 Tele-Existence Master Slave System.**



**Fig.6 Tele-Existence System in Virtual Space.**

### Shape Approximation Device (SAD)



**Fig.7 Construction of Virtual Haptic Space.**