TORSO
- Completion of Egocentric Telegnosis System -

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Abstract

We have proposed a system that can acquire natural and comfortable visual information and can accurately track the head motion of the person. The conventional imaging device for head-mounted display was only able to express the 3-axis rotation of the neck but our device has expressed the head motion as well as the translation motion of the neck.

Keywords: Telexistence, Master-Slave, Torso, Head motion

1 Overview

From a long time it has been the desire of human beings to project themselves into a remote environment, i.e., to create the sensation of existence in a different place while actually maintaining their position. The phenomenon of projecting ourselves by using robots, computers, and a cybernetic human interface is called telexistence. The operator of the robot can experience the sensation of existence at a different location and behave as though he exists in the same environment. Moreover, the operator can ideally meet and interact with the person of the remote environment without any uncomfortable sensation. To achieve these goals, it is necessary to accurately reconstruct the information of the operator's position and posture in a remote environment. Meanwhile, it is necessary to accurately display the information of the remote environment to the operator. In particular, the visual information constitutes a major part of it. Therefore, it is indispensable to accurately acquire and display this information in order to achieve the telexistence system.

At present, most of the imaging devices that are mounted on the remote robot for the purpose of the binocular head-mounted display have two stereocameras with three rotational degrees of freedom; they are positioned at the same level of a man's neck. However, this cannot completely express the head motion that includes the translational motion of the neck.

We propose a system that achieves the acquisition of the natural and comfortable visual information and the accurate tracking of the head motion of a person. We have developed the neck and torso of the all-in-one robot that not only has three rotational degrees of freedom of the neck but also two rotational degrees of freedom and one translational degree of freedom of the waist. This device is shown in Figure 1. The head motion that could not be attained by a conventional robot head became achievable because it was possible to express the translational motion of the neck by adding the three degrees of freedom of the waist. For example, the motion of looking around for an object and the motion of stretching became possible. Moreover, the head portion of this robot can follow the operator's head motion in real time because it is light.

Figure 1: Torso Robot.

In future, this robot will form an important part of robot-human coexistence in the society.

2 Vision

The future goal of this project is the completion of an entire telexistence system.

In future, we should be able to treat the robot just like ourselves so that it will lead to robot-human coexistence in the society. We have focused on achieving accurate head motion, and our proposed device concentrated on the acquisition and display of natural visual information. In the near future, we would be able to create a surro-

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gate anthropomorphic robot that has a very high degree of realistic sensation and presence by attaching an arm that is light and can be easily maneuvered. This system not only forms a part of the future robots but is also one of the complete robot forms.

Even though many telexistence systems have been developed, the problems of realization of ”realistic sensation” and ”presence” have not yet been achieved. Our proposed system can achieve the realistic sensation and the presence of movement. By capturing the visual information of a remote robot that accurately reflects the head motion of the operator, the visual information obtained by the operator will have a higher realistic sensation. Moreover, in a remote environment, since the head motion of the operator is accurately presented to a remote robot, the remote robot would be able to achieve the presence of movement.

This device provides a large amount of information to the telecommunication system. For example, although a remote meeting system now primarily contains the video telephone, we will be able to obtain a sensation as if we are actually participating in a meeting in a remote meeting room by using this system. Thereby the meeting will become invigorated debates. Moreover, in the present shopping networks, we can obtain the information of commercial products only from a picture or statement. If our device is used, we will be able to obtain this information of commercial products by actually viewing it. In addition, we can propose a new type of system and not only the extension of the telecommunication system. For example, we can see ourselves from a second or third person view. As a result, we will be able to propose a new sensation.

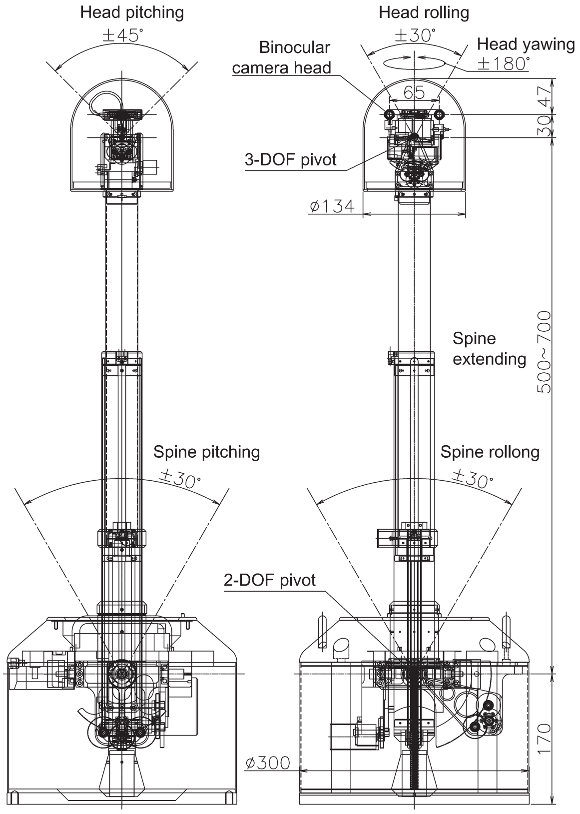

Figure 3: Schematic representation of the Torso.

3 Technical innovation

The feature of this system is that it can express the six degrees of freedom of the upper body as well as the translation motion of the neck; it can also obtain natural visual information that is equivalent to human motion. Further details of this system are described as follows.

3.1 System configration

This system has a master/slave configuration as shown in Figure 2. In the master side, the operator’s head position and posture is measured by a sensor, e.g., potentiometer. Further, the operator employs the HMD or HMP that can project a remote environment image. The data acquired by the sensor is transmitted to the slave side. In the slave side, the motion angle of each joint is calculated using the data transmitted by the master, then the calculated values are sent to each joint. Simultaneously, a remote environment image that is captured by two cameras is transmitted to the master side.

3.2 Institution of device

The accurate head motion of the human can be achieved by the neck and torso all-in-one robot that has not only the three rotational degrees of freedom of a neck but also the two rotation degrees of freedom and one translational degree of freedom of the waist. The conventional imaging device for the head-mounted display could achieve only three axes of rotation of the neck. Our device can not only express the three rotational degrees of freedom of the neck but also its translational motion. Therefore, it is possible to achieve the head motion in a remote environment that is almost similar to human motion.

The dimensions and available range of each joint of our device are shown in Figure 3.

The three rotational degrees of freedom of the head are arranged so that each of the axes intersects at one point (Figure 4). The two rotational degrees of freedom of the waist are also arranged in the same manner. This allocation of the degrees of freedom is almost equivalent to the allocation of the degrees of freedom of a human. The translation degree of freedom of the waist not only enables stretch motion but also resolves the difference of body height among individuals. The range of motion of each joint is slightly narrower than the range of human; however, it would be sufficient if the human executes natural movement. In Figure 5, we show the comparison of the movable range of the joint of human with that of our device. The driving performance of each joint is adequate because each joint moves at a speed higher than the maximum speed of the motion of a human head. In the head part, two CCD cameras (diameter of 7 mm) are installed and the distance between both the cameras is almost the same as that of the eyes of the human (65 mm). The angle of view of the camera is about 45 along the horizontal. This angle of view is in good agreement with the field of view of the head-mounted display or head-mounted projector.

3.3 Tracking performance

We have already evaluated the tracking performance of our device. First, we measured the maximum frequency of the back-and-forth motion of the head yaw rotation and the waist pitch rotation. Then, we introduced a sinusoidal signal with known frequency into the head yaw joint and the waist pitch joint of our device. We evaluated the time of delay from the input of signal to the start of motion. We

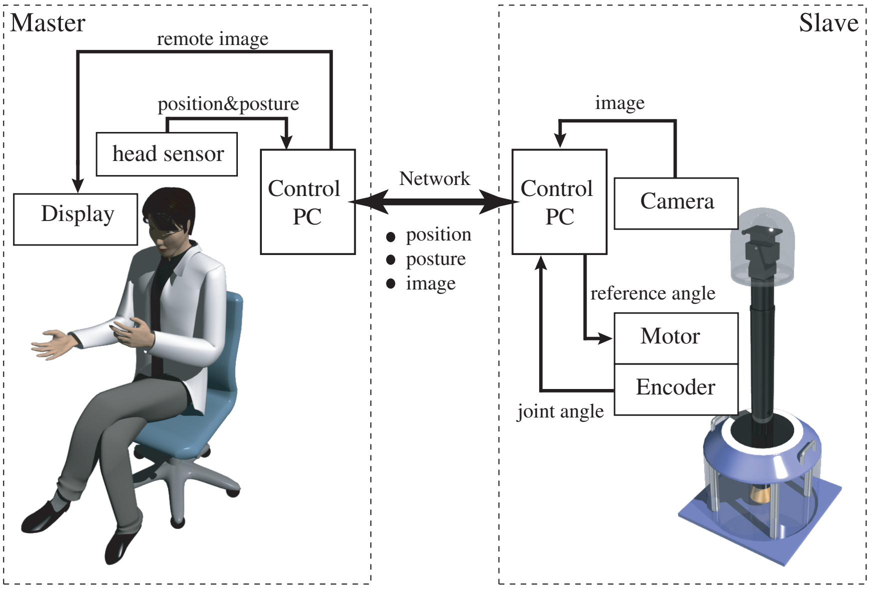

Figure 2: The Schematic Representation of the System.

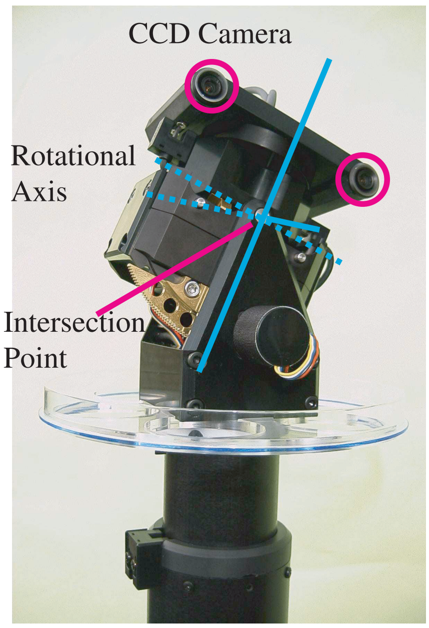

Figure 4: Head of the Torso.

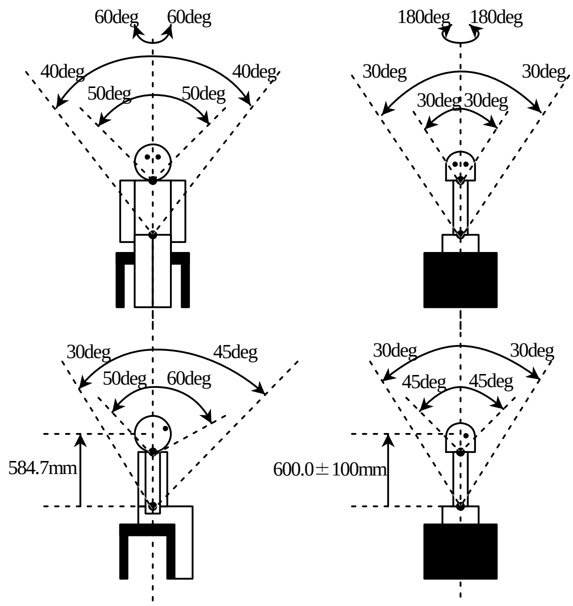

Figure 5: Movable Range of Joint.

observed in the result that the time of delay of the head yaw rotation joint was 2 3 ms and that of the waist pitch rotation joint was 1 ms. The influence of the tracking delay on the display of image is very small because the frequency of the camera was 60 Hz, i.e., it captures image at 17 ms time periods.

4 Context

The head-mounted display [Sutherland 1968] or the head-mounted projector [Inami et al. 1999] and other projection-based virtual reality systems such as CAVE [Cruz-Neira et al. 1993] have been developed.

The imaging device for the projection-based virtual reality system such as CAVE was proposed. [Yanagida et al. 1999]

Their proposed method is to maintain the orientation of the cameras, regardless of the orientation of the operator's head. Their proposed device "constant-oriented link" can solve the problems involved in constructing the exact head-tracked stereoscopic display using fixed-screen display systems. This is owing to the change in the shape of the viewing volume and the rotation of direction of the camera according to the operator's head motion (Figure 6).

In contrast, the imaging device for HMD or HMP generally has the three rotational degrees of freedom at the neck. For example, HRP

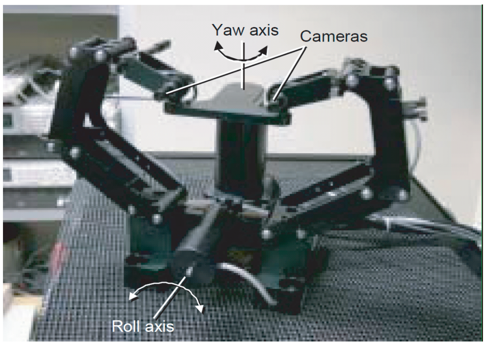

Figure 6: Constant-orientation Link.

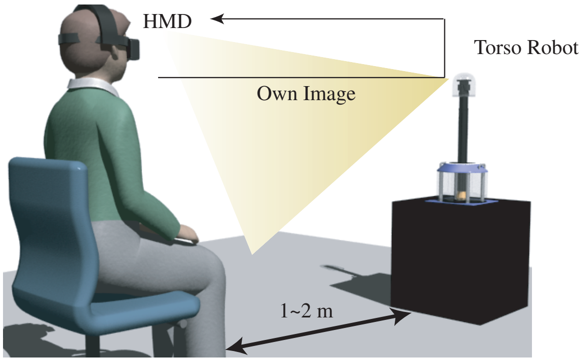

Figure 7: Plan of SIGGRAPH 2007.

and ASIMO employ such a device.

The goal of our project is to obtain the sensation of existence in a remote place. However, it is difficult to achieve this goal in a projection-based system wherein the operator can see his own hands and legs. Also, the imaging device for HMD or HMP cannot express the translation motion of the human neck; therefore, the operator experiences image mismatching. The HRP solved this problem by using an additional camera that captures the surrounding image. We tried to solve this problem by using the method that is proposed in this paper.

5 User Experience

This device is positioned at a distance from the participant and facing towards the participant (Figure 7). The participant wears HMD and experiences the image transmitted by the slave. Here, we have employed only one device. The participant can experience his own image from the view of second person. In addition, the participant can throw a soft object (for example, soft ball, soft arrow, etc.) towards the device for interaction. The participant experiences an uncanny feeling by avoiding and receiving it.

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