Remote-controlled Humanoid Robot System

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Abstract

Labor shortage is a serious problem in Japan where the population is aging with an ever declining birthrate. The authors propose remote-controlled humanoid robots to assist working humans. The humanoid robot is provided with a real-time stereoscopic vision system and a hearing system capable of three-dimensional sound source searching. The manipulator in a remote place builds a virtual space within ones sense to simulate the environment in which the robot is working. The necessary information on the robot environment is acquired through vision and hearing of the robot. This enables the manipulator to remote control the robot with a more direct virtual presence in real time. The authors also propose to use the robot as a remote monitor system.

1 Introduction

Robots supported the high economic growth in Japan with their extremely high productivity. The secondary industries, automobile sector in particular, fully exploited the merits of robots. Today, the high growth period came to an end and short labor with a declining birthrate and aging of the population is a serious social problem. It is expected that robots will be used in the primary and tertiary industries as well, and in medical, care and assist, and other personal applications. In the new future society, humans and robots will cooperate and live in symbiosis. To meet these needs, the authors are studying remote-controlled humanoid robots that assist humans under various conditions.

The Japanese people are concerned about recent frequent occurrences of volcano eruptions, earthquakes and other natural disasters and also nuclear reactor accidents. Work assist robots will perform necessary work, in place of humans, in an environment that is most dangerous and worst to humans. These robots are also the important theme of the present study.

2 Outline of the Study

The present system comprises three sub-systems: robot main body, remote-stereoscope vision system, and hearing system. The robot is provided with a high-level remote vision system with Stereovision for presenting real-time stereoscopic vision. The robot furthermore incorporates a high-level hearing system with a function to search sound sources in a three-dimensional space by learning in a neural network. Wireless local area network (WLAN, IEEE802.11b) is used for remote vision system and cellular communication system is used for remote controlling the robot so that remote controlling is possible wherever the manipulator or the robot may be and at any time. The sub-systems will be described in detail later in the present paper.

The manipulator acquires detailed information on the robot's working environment from the vision and hearing system of the robot. Based on the acquired visual and audio information, the manipulator builds a virtual space within ones own sense simulating the environment in which the robot works. In this virtual space, the manipulator remotely controls the robot in real time with a more direct virtual presence. The key factor is how intimately the manipulator can feel the virtual space, allowing him/her to consider it very close to the actual world that one senses with ones vision and hearing.

The manipulator uses the remote-stereoscope vision system to recognize distance to the object (absolute distance), distance between objects (relative distance), relation of objects in the longitudinal direction (perspective), and solidity of objects. The three-dimensional perception of the space is called stereoscopic perception. The manipulator can more intuitively control the robot as it moves and performs delicate work when one senses the stereoscopic perception from the vision of the robot. Information on the sound source in the three-dimensional space is captured by the hearing system, and added to the information captured by vision, providing an enhanced presence to the manipulator. Humans are not judging visual and audio information individually, but, actually, they judge them comprehensively to derive environmental information.

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3 System Structure

3.1 Robot Main Body and Robot Control

From the engineering perspective, the robot may not necessarily be of a shape after a human but can be of any desired shape. One may wish to recognize robots to be a partner to humans in working and attempt smooth communications with them. If so, the robot should preferably be in the shape of a human or a humanoid. This is because the shape of humanoid presents no feeling of wrongness to humans. Furthermore, a humanoid may comfortably act in the living and dwelling spaces of humans. Without humanoids, we cannot even imagine a near-future scene of robots getting into an ordinary car driven by a human. Humanoids are indispensable for the robots to cooperate and work with humans in the current society that is built for the humans without a feeling of wrongness.

The general view of the humanoid robot used in the present system is shown in Figure 3.1.1. The specifications are shown in Table 3.1.1.

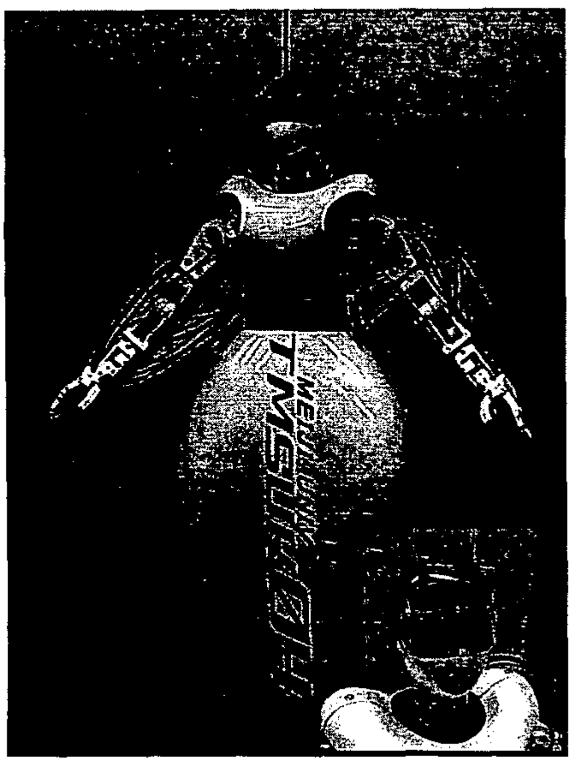

Figure 3.1.1 General View of the Robot And remote stereoscopic vision.

Dimensions and weight	Total length: Approx. 750 mm Total width: Approx. 600 mm Total height: Approx. 1200 mm Total weight: Approx. 100 kg
Degree of freedom of motion	Head: 2; chest: 1; Arms: 7 x 2; hands: 3 x 2
Traveling performance	Independent right and left 2-wheel drive, longitudinal non-track auxiliary wheels, independent suspension for front wheels. Traveling speed: Approx. 3 km/h max.
Communications	Personal handy-phone system (PHS) PIAF2.1 system, Best Effort type Transmission speed: 65 kbps
Power supply	Ni-Cd batteries

Table 3.1.1 Robot Specifications

The operation part and the robot have the same number of joints, and when a manipulator moves the operation part, that joint of the robot moves only to the angle of each joint that it worked. Fig3.1.2 is the robot, and Fig3.1.3 is the operation part. It is the state of the remote control together.

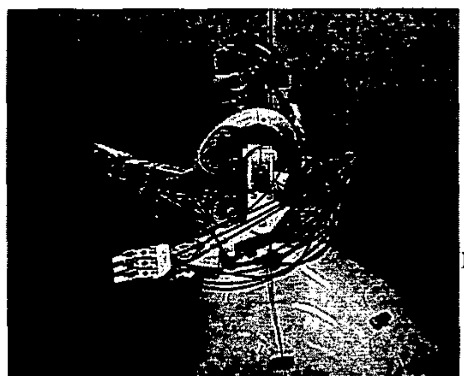

Figure3.1.2 Robot in state Of remote control

Figure3.1.3 Operation part in state Of remote control

The arms of the robot have similar degrees of freedom as humans. Accordingly, the robot can use various tools available in the world of humans. Humans are very much skillful but can not do all work by themselves. They use a tool called car, for example, to move to a distant place and use another called a drill to drive a hole. Robots are same as humans in this sense. If they can use tools of humans, their skill increases very much. If we were to build tools special for robots, there would be no end to it.

With the recent robots manufactured, a small motor is generally built in each joint of arms. With our robot, all these motors are centrally located at the lower portion of the robot, with the driving power transmitted via steel wires. The light arms without motors facilitate quick and delicate action, and stabilize the main unit.

The robot is 4-wheel driven. Researchers also actively study two-foot walk design. Recently, barrier-free design is popular in constructing various facilities to ensure comfortable life for the old and physically handicapped people. The barrier-free design will be much more popular in the future when the robots of this type would be used in quantity. Furthermore, balancing in movement and operation is important. Considering these points, the authors decided not to emphasize the 2-feet walk design.

3.2 Remote-stereoscope Vision System

The following Fig3.2.1 is the outline figure of the remote vision system.

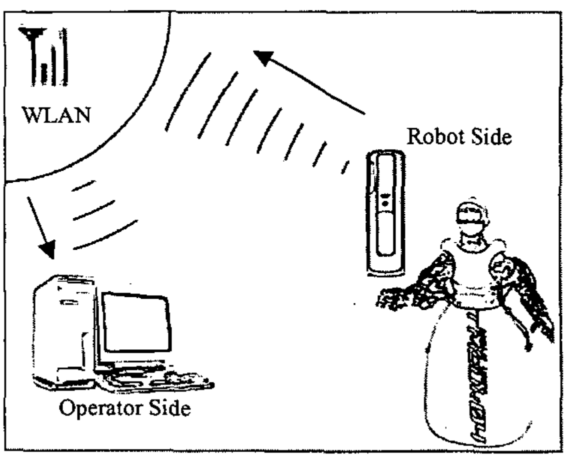

Figure 3.2.1 Outline of remote vision system

The vision data of the remote place where it was acquired from the stereophonic vision of the robot are transmitted to the display of the operator through the WLAN by the robot side PC. The operator operates the robot by the solid vision information indicated in the display.

The vertically divided frame sequence method (hereafter called 2FS) is used in the present remote vision system to generate binocular stereoscopic images. The right and left images from Stereovision are alternately displayed on the manipulator display at high speed. The manipulator uses the goggles which right and left shutters are alternately closed to view respective images at the same timing as the images switch. Independent images from the right and left cameras corresponding to respective eyes are displayed to generate stereoscopic images. Figure 3.2.2 shows the goggles and the infrared signal generator. The goggles are on the market.

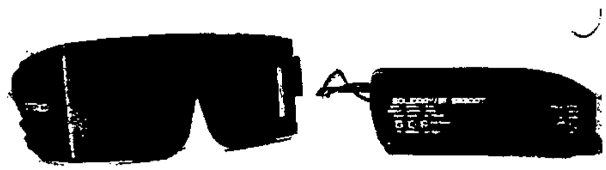

Figure 3.2.2 Goggles and Infrared Signal Generator

An infrared signal generator is used to switch the shutters. Wireless local area network is used for image data transmission between the manipulator and the robot cameras located in a remote place. The flow of the data is as the following.

The stereo camera images are:

(1) Converted into the Field Sequence format by picking the right and left images in each field.

(2) The format is reconstructed as vertically-divided frame sequence format by the Frame Sequencer.

(3) Image compression (e.g. MPEG-2) does the sequential frame information and it is transmitted onto WLAN.

(4) The frame information that it was received is restored, and it is indicated by non-interlace on the display.

(5) The vertical sync frequency of the monitor is doubled (from 60 to 120 Hz) while the right and left images are vertically-divided displayed.

This allows for alternate display of the right and left images without flicker. Figure 3.2.3 shows the flow of data.

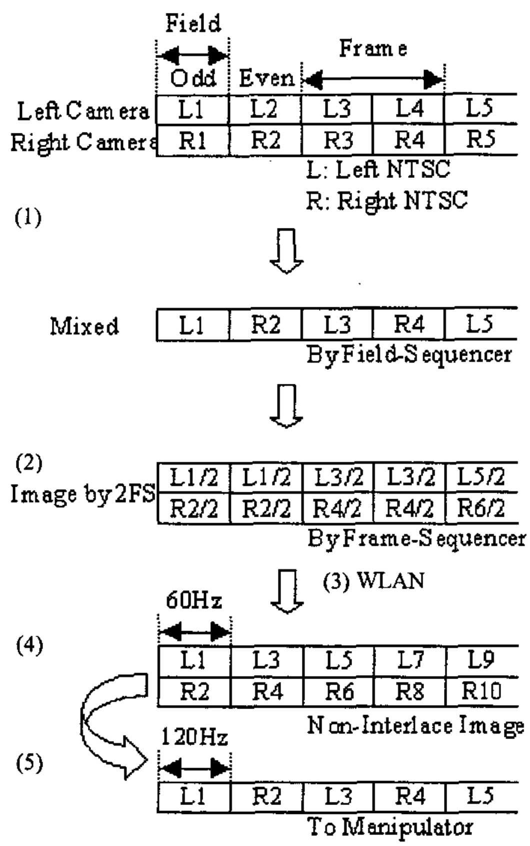

Figure 3.2.3 Flow of data

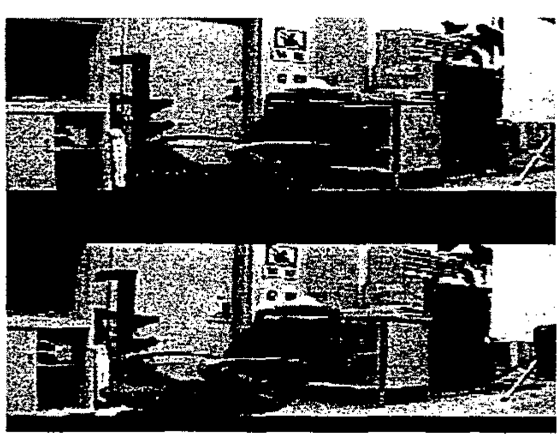

Figure 3.2.4 vertically divided frame sequence data

And, the example of vertically divided frame sequence data that is transferred to the operator from the robot shows Fig3.2.4. The image of the left camera is indicated in the top, and the image of the right camera in the bottom part.

3.3 Hearing System

The hearing mechanism of humans comprises the outer, middle, and inner ear. The shape of the outer ear plays a critical role in the localization of sound source. The complicated shape of the outer ear suggests that humans have acquired a peculiar directivity. We noted the shape of the outer ear of humans, and constructed an artificial hearing system. This hearing system comprises an artificial hearing model simulating the human hearing mechanism and a processor for processing information supplied by the artificial hearing model. The area on the artificial hearing model corresponding to the outer ear is constructed artificially. The area corresponding to the middle and the inner ear incorporates an electric capacitor microphone and a mixing machine with analog I/O Sound board, respectively. The processor is a dual neural network system. The present hearing system simply uses two microphones.

The coordinate data for three-dimensional spaces are input from the artificial hearing model. The neural network will learn this data. We use the patternization technique for the teaching data to enhance learning efficiency of the neural network. The result of processing by the neural network responsible for pattern classification is further analyzed in the other neural network responsible for detection of sound source coordinates (Figure 3.3.1). The dual neural networks are used in series to improve accuracy of sound source search.

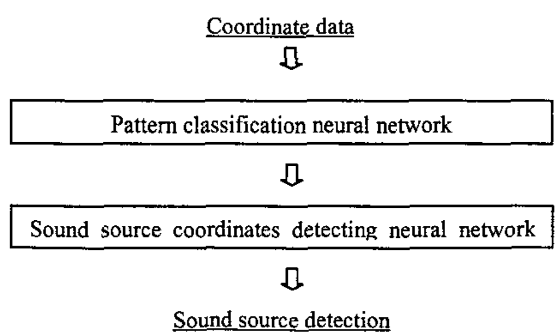

Figure 3.3.1 Dual Neural Network

4 Proposal of Remote Monitor System

The authors propose a remote monitor system that incorporates the remote-controlled humanoid robot system described above. A satisfactory level of monitoring information is obtained even in a remote place thanks to the high-level vision system and the high-level hearing system, the features of the system, that together provide virtual presence of the environment in which the robot stands. A highly reliable security system with centralized control in a remote place assures reduction in the labor requirements, personnel hazard, and administration cost. A safer and more rigid monitor system can be constructed more easily.

The image figure of the remote monitor system is shown in the following Fig.4.1.

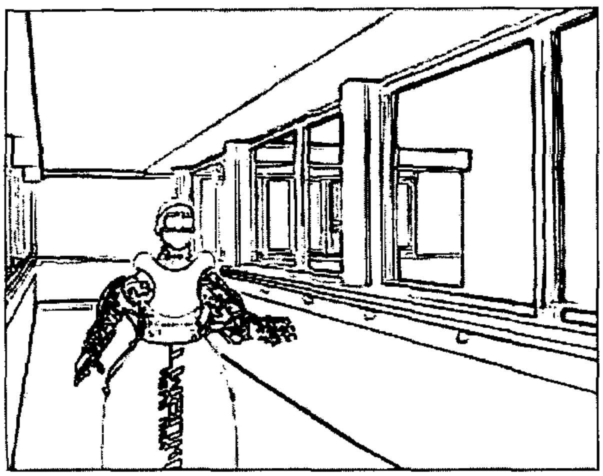

Figure 4.1 Image figure of the remote monitor system

The proposed monitoring system can be used as a nighttime security system in commercial buildings and public facilities, 24-hour maintenance control system in nuclear facilities and nuclear fuel cycling centers, and in many other applications.

5 Conclusion

We propose remote-controlled humanoid robots that cooperate and act in symbiosis with humans and help them, a remote monitor system and a work assist robot useful in a disaster or an accident in particular. We will further improve the remote control system so that a virtual presence closer to actual presence can be formed through more intensive fusion of robot operation and visual and audio information in the virtual manipulation space. In parallel with these efforts, we will achieve more delicate tasks of enhancement of operability by hardware and improvement of reliability of the communication system. It is currently obvious that this robot is required in the market. We are absolutely determined to proceed with further research and development efforts to commercialize the robot as soon as possible.

The result of research and development activities on humanoid robots is announced on a large scale one after another recently. Each of these events is highlighted dramatically. Humanoid robotics is undoubtedly a new, indispensable industry in the 21st century. Under these circumstances, the authors sincerely hope that their research efforts will contribute to the development of robots.

Remarks

This research was made with Mr. Katsunori Tanaka (Meiji University), the BIT Co. for the remote stereovision, Mr. Arai (Meiji University) for the hearing system and TMSUK Inc. for the robot body. We will give them thanks deeply for the nice cooperation.

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