Wearable Telepresence System with Multimodal Communication Channels for Effective Human-Robot Interaction

한국과학기술원 양현승 · 서용호 · 박현영

1. Introduction

The trend in robot research is changing. It is no longer focused on conventional industrial manipulators or mobile robots but on more advanced anthropomorphic robots such as humanoids and personal robots with multimodal sensing and communication capability as well as intelligence for high-level planning, decision making, and social interaction. Thus, we need an advanced teleoperation system that is wearable, self-contained, and easy to operate with intelligent master-slave communication.

Several recently reported telerobotic systems highlight the possibility of a new type of teleoperation system. KIST has developed an exoskeleton type of robotic arm that can be applied to various research areas because of its high wearability and force reflection mechanism [1]. The wearable robot called 'Parasitic Humanoid', which was developed by the University of Tokyo, inspired us to develop a new type of teleoperation system[2]. These newly developed wearable robotic systems can be applied to various areas, including teleoperation in hazardous environments, human-robot interaction, medical rehabilitation, and VR experiences. Furthermore, to display more appropriate and intuitive information to operators of advanced systems, multimodal sensory feedback based on a model of human perception was recently introduced[3].

We **propose a new type of wearable teleoperation system that has the advantage of these new criteria, and we present a prototype.**

First, we describe the configuration of the proposed system, the prototype of the wearable master system, a kinematic analysis of the developed system, and multimodal communication with an intelligent slave robot. Finally we demonstrate the performance of the prototype in the experimental result.

2. Configuration of the Proposed System

In a remotely operated system, the main goal is to enable operators to accomplish necessary tasks as efficiently and effectively as possible. With operator-selective telerobotic modes of operation between a human master and a slave robot, subtasks can be done automatically, especially tasks that are repetitive, require high precision, or involve extreme patience. These modes of operation have potential for increasing the efficiency of remote work systems[4].

The master system must have a mechanism for acquiring human motion and another mechanism for appropriate force feedback. Moreover, it must be comfortable for the use to wear.

An intelligent slave robot with the capability of executing high-level tasks, such as the ability to detect 3-D objects, to automatically approach and grasp objects, and to avoid obstacles, is an ideal tool for interacting with the new master system. It is also useful for examining the performance of developed teleoperative robotic systems. The humanoid robot has all these features. It is autonomous, with a self-contained anthropomorphic body; it has sufficient intelligence to give it some degree of autonomy; and it has the capability to sense its environment and express itself. Figure 1 shows the Configuration of the proposed system.

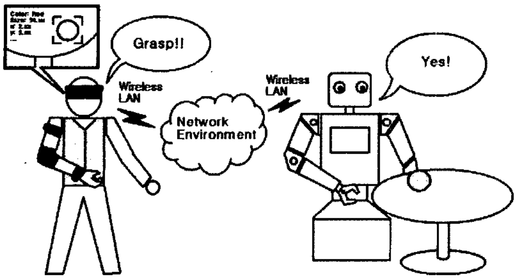

Figure 1 Configuration of the proposed system

Other important issues in advanced teleoperation include the following: intuitively sending telecommands to the slave robot, displaying more appropriate and intuitive information to the human operator, expressing multimodal telecommands, and giving multimodal sensory feedback-that is, multimodal communication.

We combined these ideas to solve real-world teleoperation applications. In the proposed system, a human operator wearing the teleoperation system sends telecommands through a multimodal channel; for example, through voice, arm and head motion. The telecommands are delivered to the target slave robot via wireless and wired networks. The intelligent slave robot can properly follow the human motion. The operator can make the slave robot do various subtasks just by voicing commands through a microphone attached to the wearable teleoperation system.

3. Wearable Master Platform

The proposed wearable master system has a self-contained computer with a stereo head-mounted display(HMD), a microphone, a speaker, a wireless LAN, and hardware for tracking arm and head motion. The motion tracking hardware comprises magnetic-based position and orientation trackers and several types of small, light sensors, such as three-axis postural sensors and flex sensors; it also has a simple force reflection mechanism that uses vibration motors at wrist joints.

The wearable master platform includes a mobile JVC Mini Note MP-XP7220 as the main computer, which is used for interacting with humans and communicating with the slave robot. The Mini Note PC has a Mobile P III 866 MHz CPU, a 256 MB memory and various peripheral interfaces, such as USB, IEEE1394 and PCMCIA. The control board and sensors for the master system are connected to the PC through the USB interface. Figure 2 shows a wearable master platform structure.

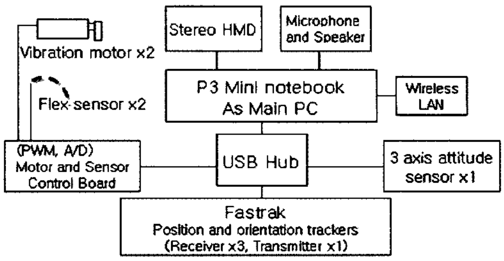

Figure 2 Wearable master platform structure

The wearable master system offers users various communication interfaces. Firstly, on the stereo HMD, an operator can see in real time a stereo scene captured from the cameras of a slave robot. Secondly, with the headphones, the operator can hear the voice and the sound information from the slave robot, and, with the microphone, the operator can send voice commands. Finally, the operator can use arm and head motion to intuitively operate the slave robot while feeling the tactile sense and force feedback of the slave robot's arm. Such operation is possible via the force reflection mechanism of vibration motors at the operator's finger and arm joints. Through these multimodal interfaces, the operator can efficiently and effectively perform the necessary remote tasks. Figure 3 shows the master system after wearing.

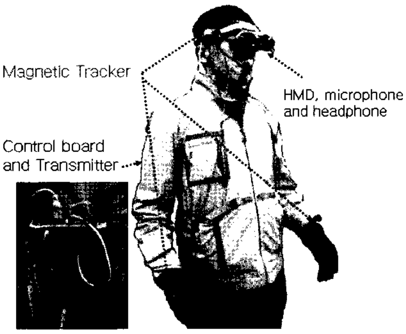

Figure 3 Master system after wearing

4. Multimodal Communication with an Intellignet Slave Robot

To enable more intuitive and efficient interaction with a remote robot in a teleoperation system, we need multimodal communication interfaces that are based on human perception and expression[3].

Considerable researches on teleoperation have concentrated on more precise tracking of the master arm and force feedback. This research has reduced the gap between the master and slave robot and given the operator a greater sense of realism. However, we chose an alternative method that uses intelligent self-sensory feedback and context-based behavior for the slave robot. The alternative method also gives feedback to the operator through a voice and visual communication channel. Rather than using precise control with high force reflection, the alternative method uses a simple force refection mechanism based on vibration motors.

In this system, we developed two subsystems, namely a master system and a slave system, for intelligent self-sensory feedback and context-based behavior in the slave robot. In the master system, the user can communicate by various channels, such as vision, voice, and motion. Users can get visual information from the vision channel. From the voice channel, they can give orders or get information. Through the motion channel, they can activate motion tracking and gesture commands. Finally, from the force feedback channel, they can get force feedback. Figure 4 shows the configuration of the master system.

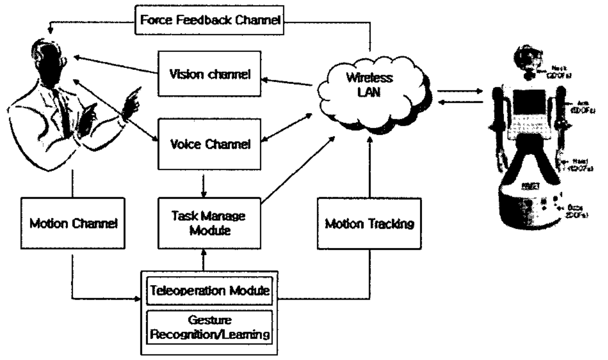

Figure 4 Configuration of the master system

In the slave system, we implemented various functions for the intelligent self-sensory feedback. The slave robot transfers the visual information to the master system through a CCD camera and communicates via the voice channel. The slave uses ultrasonic sensors to automatically avoid obstacles and, with a haptic sensor, it measures the pressure of the hand and transfers the force feedback to the master system. For context-based behavior, a behavior manager chooses appropriate behavior for the conditions.

The slave system works as follows: after picking an object in the system, the slave robot sends the operator voice expressions and information regarding the contact force information. The information is sent via the headphones and HMD. Moreover, to control the slave robot more precisely, the operator can send predefined voice commands to the slave robot via the microphone of this master system. Commands can be sent even while the operator is doing teleoperative tasks with arm and head motion. We call this system a wearable teleoperation system with multimodal communication. Figure 5 shows the configuration of the slave system.

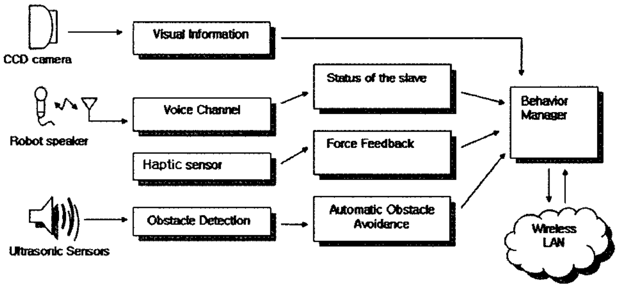

Figure 5 Configuration of the slave system

5. Visual and Voice Communication Channel

Through the visual communication channel, the view of the remote slave system is transferred to the operator wearing the master system. This view is displayed on stereo the HMD of the wearable master system after being augmented with textual and graphical information. It is useful and helpful for the operator to understand the status of the slave system and the environment around the slave system. Figure

6 shows an example of the visual communication channel.

The technology of speech synthesis and recognition has been important for human-robot interaction. It is also important for future teleoperation systems[5].

By using speech synthesis in the proposed teleoperation system, a slave robot can send remote environment information to a human operator and immediately express its internal status. Moreover, speech recognition enables operators to command the slave robot intuitively.

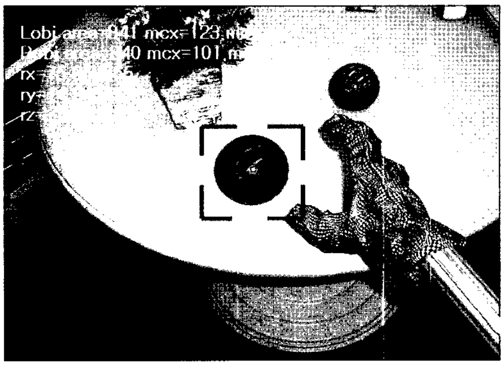

Figure 6 Visual communication channel

6. Humanoid Robot, AMI, as an Intelligent Slave Robot

To show the performance of our system, we chose the humanoid robot AMI as the target slave robot. AMI has two eyes equipped with two CCD cameras for stereo vision, a mouth for speaking, and a neck that tracks a moving target for gaze control. Its body has two arms, two hands, a waist and a mobile platform with two wheel motors. AMI also has 16 ultrasonic sensors and 12 infra-LED switches for detecting obstacles and measuring distances, as well as six force-sensing registers at the end of the fingers[6].

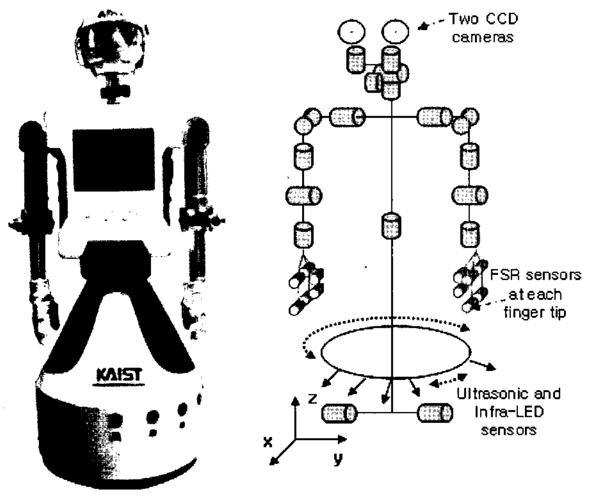

Figure 7 Humanoid robot, AMI

7. Experimental Result

To test the performance of the wearable teleoperation system, we conducted several experiments.

First, to verify the basic function, we commanded the robot to follow the movement of the user's arm and head. It showed the same exactness and precision as other systems but with improved convenience for users.

Second, the user was instructed to make the remote slave robot pick up an object on the table to confirm the overall system performance and effectiveness. Using only a voice command, the user made the robot approach the table. Once the robot moved near the table, the robot used the voice channel to tell the user the distance between its current position and the table. The user then voiced a command to the robot to approach the table up to the given distance. With self-arm movement, the user operated the robot's arm while looking at the HMD. Finally, after moving the robot's arm closely over the object, the user made the robot pick up the object through a voice command.

Third, we let the user command the system using gestures for performing a predefined task. While the robot was tracking the motion of the master arm, the user stopped and made a gesture. The robot immediately stopped tracking the motion and performed the predefined task.

Finally, while the robot was grasping the object, the haptic sensor of the slave robot hand measured the pressure of the hand, and the slave gave the information to the master system. The master system represented the pressure information through the vibration motor. Whenever the pressure rose, the intensity of the vibration increased.

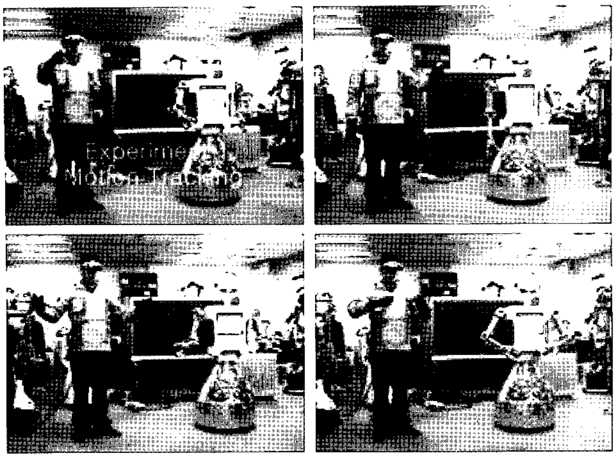

Figure 8 Experiment - motion tracking

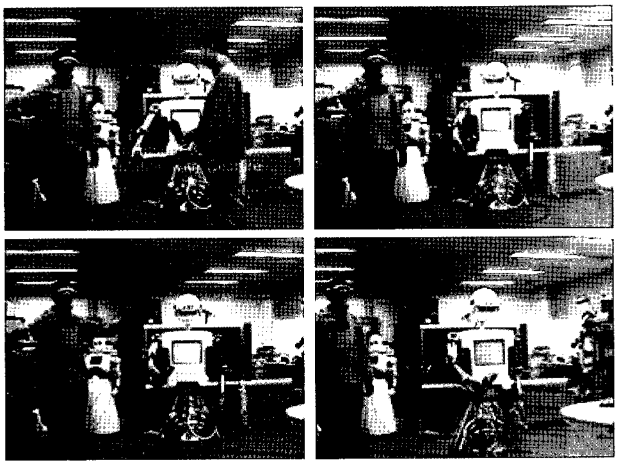

Figure 9 Experiment - overall experiments with multimodal communication

8. Conclusion

We proposed a wearable teleoperation system and explained the implementation of the prototype. In several experiments, we used the humanoid robot AMI as a slave robot to confirm the performance and effectiveness of the system.

Through these teleoperation experiments, we successfully demonstrated several teleoperative tasks, including motion tracking, mobile platform control of AMI, object manipulation, gesticular commands, and force reflection. In short, we demonstrated the efficient performance of our wearable teleoperation system.

In the future, we plan to research how the master system can utilize more advanced visualization through AR technology. To test the performance of the wearable teleoperation system, we conducted several experiments.

References

[1] Younkoo Jeong, Dongjoon Lee, Kyunghwan Kim, Jong Oh Park: "A wearable robotic arm with high force-reflection capability," proceedings of IEEE RO-MAN 2000, pp.411-416 (2000)

[2] Taro MAEDA, Hideyuki ANDO, Make SUGIMOTO, Junji WATANABE, Takeshi MIKI: "Wearable Robotics as a Behavioral Interface-The Study of the Parasitic Humanoid-," proceedings of IEEE ISWC '02, pp.145-151 (2002)

[3] Kammermeier, P., Buss, M.: "A human perception model for multi-modal feedback in teleoperation systems," proceedings of IEEE SMC '99, pp.1020-1025 (1999)

[4] William R. Hamel: "Fundamental Issues in Telerobotics," proceedings of IEEE-RAS HUMANOIDS 2003, pp.66 (2003)

[5] Sidner, C.L., Lee, C., Lesh, N.: The Role of Dialog in Human Robot Interaction. International Workshop on Language Understanding and Agents for Real World Interaction (2003)

[6] Yong-Ho Seo, Ho-Yeon Choi, Il-Woong Jeong, and Hyun S. Yang, "Design and Development of Humanoid Robot AMI for Emotional Communication and Intelligent Housework," Proceedings of IEEE-RAS HUMANOIDS 2003, pp.42 (2003)

양 현 승

1976 서울대학교 전자공학과(학사)
1983 Purdue University(석사)
1986 Purdue University(박사)
2006 현재 한국과학기술원 전산학과 정교수
관심분야 : 컴퓨터 시각, 로보틱스, 인공지능, 가상현실, 유비쿼터스 컴퓨팅
E-mail : hsyang@paradise.kaist.ac.kr

서용호

1999 한국과학기술원 전산학과(학사)
2001 한국과학기술원 전산학과(석사)
2006 현재 한국과학기술원 전산학과 박사과정
관심분야 : 로보틱스, 인간로봇 상호작용, 로봇 시각, 웨어러블 컴퓨팅
E-mail : yhseo@paradise.kaist.ac.kr

박헌영

2003 한국과학기술원 전산학과(학사)
2005 한국과학기술원 전산학과(석사)
2006 현재 T-max 소프트웨어 DB연구실 연구원
관심분야 : 인공지능, 데이터베이스, 인간 로봇 상호작용