A TELE-INSTRUCTION SYSTEM FOR ULTRASOUND PROBE OPERATION BASED ON SHARED AR TECHNOLOGY

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Abstract - **This paper proposes a tele-instruction system for ultrasound probe operation, based on shared Augmented Reality (AR) technology. Telemedicine, a strategy to diminish geographic gaps in the quality of medical service, is fashionable. However, existing medical-data transmission systems cannot convey the skills of physicians, so they cannot eliminate the problem of geographic gaps. This research developed a telemedicine system that transports physicians' skills over a shared AR space. The shared AR technology provides an environment where users can exchange spatial information, and facilitates smooth communication. This research concentrates on interfaces for physicians and technicians at the patient site. The proposed system provides intuitive and unrestricted interfaces for the physician and technician, using a data projector and an LCD tablet. At the patient site, instructions for the technician are projected directly onto the patient's body, using a data projector. The physician site allows the physician to send instructions on probe operation using an LCD tablet. This information is displayed as a "web-mark", which provides spatial information for ultrasound probe operation. Furthermore, the system sends environmental information about the patient to the physician, such as the technician's behavior and patient's posture, via an immersive display. The proposed system was tested with a physician using real tele-diagnosis. The results demonstrated the effectiveness of the proposed method in providing smooth communication in telemedicine.**

Keywords - **telemedicine, tele-instruction, shared AR space, ultrasound probe operations, web-mark**

I. INTRODUCTION

Telemedicine is a new medical service model that enables a patient to receive medical services without visiting a hospital by connecting medical sites and patients. Existing telemedicine systems use conventional multi-media communications that can handle medical data, such as vital signs, X-ray and CT images, and so on [1-2]. Such systems require physicians or medical technicians with sufficient skill to provide appropriate medical service to the patient. However, skilled persons are not always available, and an unskilled person may require the help of a specialist to obtain appropriate medical data. In such cases, the specialist must transmit instructions on how to handle medical devices with the utmost care and patience, as direct communication using manual manipulation is not available with any existing telemedicine system. This paper proposes an innovative telemedicine system that enables direct instruction, in which the participants share the same time and space via a network.

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II. METHODS

Telemedicine systems that use popular, universal medical devices are the most effective. Therefore, the authors are developing a telemedicine system that uses an ultrasound diagnostic device that is widely available, even in small clinics [3-4]. As mentioned above, good communication is necessary for smooth diagnosis. With the ultrasound diagnostic device, the most important information required to obtain appropriate medical data is the location and orientation of the probe [5]. A shared Virtual Reality (VR) space facilitates smooth communication, because it allows the exchange of spatial information. However, a shared VR environment requires many computational and network resources to virtualize the whole environment. Moreover, faults in the VR equipment may cause a fatal error in medical treatment. Augmented Reality (AR) technology can overcome these problems [6]; the participants can see the real patient directly. This paper describes a new method that focuses on the transfer of information concerning probe operation via shared AR space.

A. System Overview

In this system, the physician and patient sites are connected via a network. The system exchanges several kinds of data, as shown in Fig. 1.

At the physician site, the proposed system allows the physician to 'touch' the patient's body using an LCD tablet (Fig. 2).

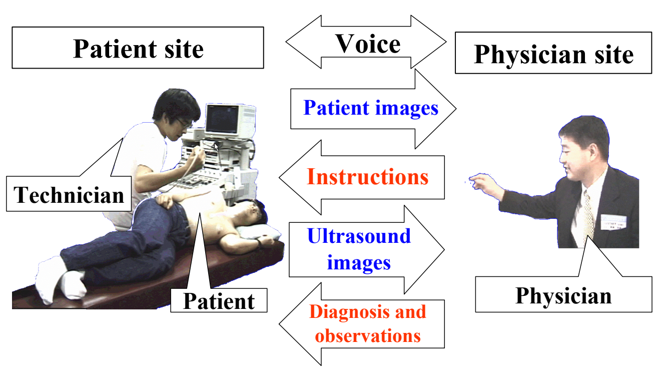

Fig. 1. Data exchange flow in the proposed system

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Abstract

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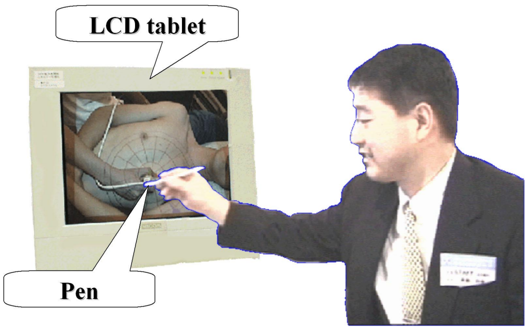

Fig. 2. Interface at the physician site

The pen substitutes for the probe; the tablet gives the position, and the magnetic positioning sensor attached to the pen determines the orientation. At the patient site, a data projector projects the information directly onto the patient's body, as shown in Fig. 3.

This interface allows users to show and see information about probe operation directly on the patient's body, enabling smooth communication. The spatial information about probe operation is 5D, consisting of 2D position information and 3D orientation information. In order to show this 5D information on a 2D screen, the authors designed a "web-mark" as a pointer to relay instructions. Fig. 4 shows the cobweb-shaped pointer used as the web-mark.

The web-mark shows the following information:

1) The center is where to place the probe.
2) Special arc 1 indicates a "rotation angle" that surrounds the probe.
3) Special arc 2 indicates the "slant direction" and "slant angle" of the probe.

The physician can show the 5D spatial information by changing these three features of the web-mark using a specially developed pen containing a magnetic sensor, as shown in Fig. 5.

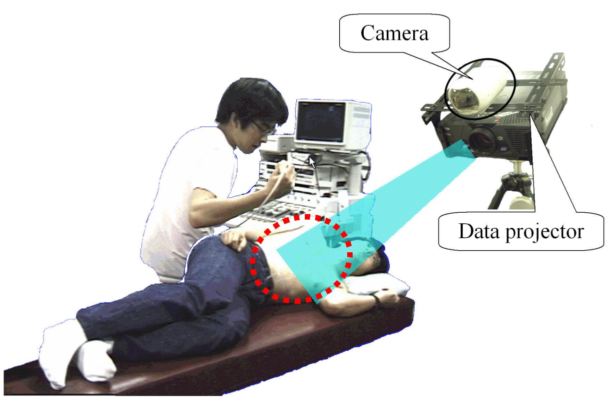

Fig. 3. Interface at the patient site

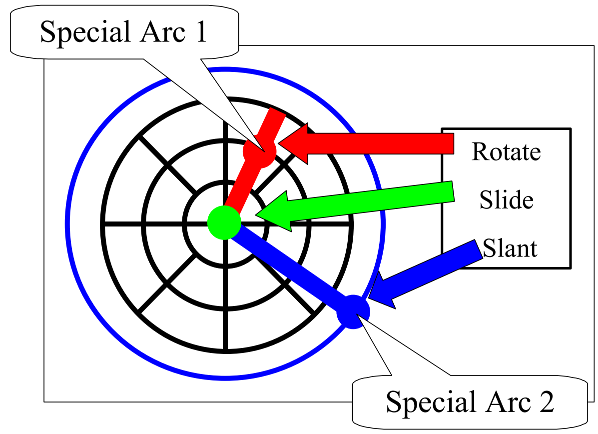

Fig. 4. The web-mark

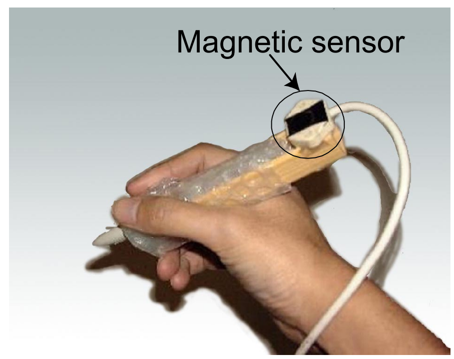

Fig. 5. The magnetic sensor pen

B. System support information

In another experiment, we identified the following problems. When the web-mark was projected on the side of the body, it was distorted and "slant" and "rotate" information were lost (Fig. 6). To solve this problem, the technician sometimes needed to ask for instructions repeatedly. We therefore added support information to the web-mark (see Fig. 7).

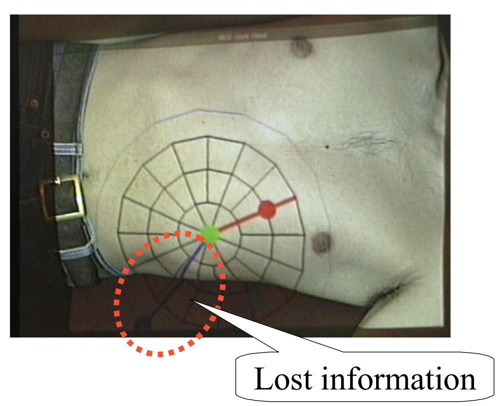

Fig. 6. Lost information

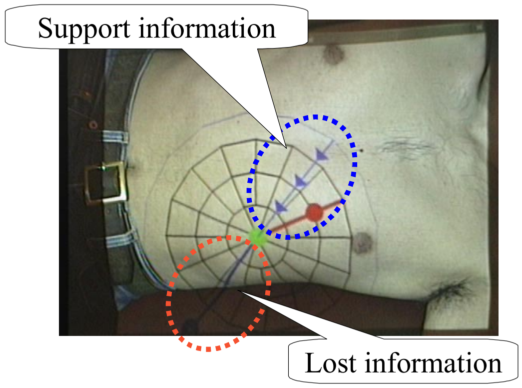

Fig. 7. Support information

The support information provides updated instructions, and was added to the web-mark, as shown in Fig. 8.

Furthermore, the system provides information about the patient's environment to the physician, such as the technician's behavior and the patient's posture, using an immersive display (Fig. 9). The immersive display consists of three 94-inch screens covering 120 degrees, which is the human field-of-view.

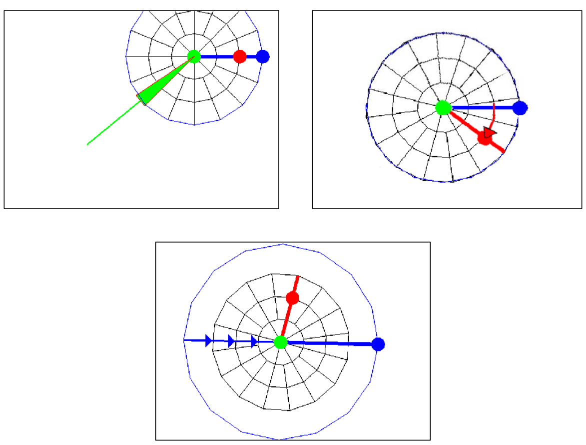

Fig. 8. Type of support information

Fig. 9. Immersive display at the physician site

III. EXPERIMENTS

The prototype system was evaluated using real-time tele-diagnosis of heart disease, via 128-Kbps ISDN connections between Nara and Sapporo, and Nara and Kurashiki, and at two virtual sites in our laboratory in Nara via a local network. These experiments involved physicians (Fig. 10) and postgraduate students of the Nara Institute of Science and Technology who filled the technician's role (Fig. 11).

In this test, the authors evaluated the utility of the proposed system, and the accuracy of the transmitted instructions.

IV. RESULTS

Using the proposed system, the physicians were able to instruct the technicians how to handle the ultrasound diagnostic device without special lessons.

Using video cameras, we recorded the instruction sequences between physicians and technicians. Then, we analyzed the "comprehensibility" and "rapidity" of instructions.

Fig. 10. The physician site

Fig. 11. The patient site

The results were as follows:

A. Comprehensibility of instructions

1) Proposed system (without support information)
   A) Acquisition "*Long axis view*" of the chest
      All instructions ("Slide", "Rotate" and "Slant") were accurately transmitted to the patient site.
   B) Acquisition "*Four chamber view*" from the left side
      The students sometimes couldn't understand the instructions, which then had to be repeated. Especially, "Rotate" and "Slant" seemed difficult to communicate.
2) Proposed System (with support information)
   A) Acquisition "*Long axis view*" of the chest
      All instructions ("Slide", "Rotate" and "Slant") were accurately transmitted to the patient site.
   B) Acquisition "*Four chamber view*" from the left side
      All instructions ("Slide", "Rotate" and "Slant") were accurately transmitted to the patient site.

Smooth communication was realized using the proposed telemedicine system. Without support information, there were some difficulties in image acquisition from the side. However, the support information solved this problem.

B. Rapidity of instruction

The results (Fig. 12) depended on which of three methods of instruction were used: Instruction by voice only, instruction by voice and the proposed system without the immersive display, and instruction by voice and the proposed system with the immersive display.

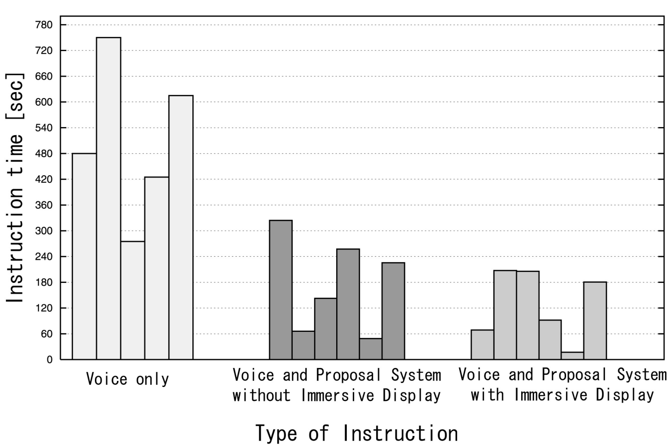

Fig. 12. Instruction time

Using the proposed system, the required time decreased drastically. Although no definite difference was found with the immersive display, the physicians commented that the instructions were most easily explained using the immersive display.

V. Discussion

In this paper, we propose a new telemedicine system using shared AR space between diagnosis and measurement sites. Using the proposed system, a student with no experience was able to use an ultrasound probe to acquire appropriate ultrasound images.

The proposed telemedicine system realized smooth communication and an intuitive interface. However, some problems occurred in the first trial when acquiring images from the side, because the web-mark was distorted due to the non-flat display surface, i.e., the patient's body. The experimental results confirmed that support information effectively resolved this problem. Although a definite difference wasn't found, the immersive display seemed to be more useful for tele-instruction.

The authors believe that the proposed system will increase the quality of medical services in the near future.

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