A Tele-Instruction System for Ultrasound Tele-diagnosis

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Abstract

This paper proposes a new telemedicine system using shared AR space.

The ultrasound diagnostic devices are widely used for various types of medical diagnosis. However, in order to obtain the image sequences which enables to diagnose several special diseases, the advanced special knowledge and the advanced experience about probe operation are required. Therefore, there are limited numbers of specialists who can realize advanced diagnosis with the ultrasound image sequences. To solve this problem, we need the system by which medical specialist enables it to diagnose the patient of a remote place. Therefore, authors are developing a real-time telemedicine system that transmits ultrasound image sequences. The smooth communication is essential for the smooth real time telemedicine. However, the spatial information, which is important for medical treatments, is unable to transmit via conventional multi-media communication tools. This paper presents the innovative method to transmit such spatial information using shared AR space.

Key words: Tele-medicine, Ultrasound Diagnosis, Shared AR Space and Web-Mark

1. Introduction

The medical support is indispensable as our social welfare. Therefore, the enormous sum of money is spent for the improvement of medical support. The best way to obtain much improvement of medical support with less increase of service cost is to accumulate advanced medical resources at several central hospitals. However, this continuous accumulate derives another serious problem: the service gap between rural regions and cities. To overcome this problem, the researches on telemedicine are coming [1].

Telemedicine is the medical service model, which available a patient to have medical services from certain medical bases without visiting the medical bases. In this context, telemedicine includes the traditional medical check, which gives the medical examination through the medical information such as blood sample sent from patients.

"Networked telemedicine" is the new medical service model introducing digital network to the telemedicine. Networked telemedicine offers many medical advantages not only equalization of medical services between rural regions and cities, but also improvement of first aid in ambulance or supplying higher medical services to disastrous area.

2. Ultrasound Diagnosis

When target device is widely diffused and it requires advanced techniques, a telemedicine system brings an extremely large effect.

The ultrasound diagnostic devices are widely used for various types of medical diagnosis. Moreover, the ultrasound devices can be treated much more easily than X-ray devices or MRI. Therefore, even a small clinic holds the ultrasound devices. However, the low S/N ratio and resolution of ultrasound image sequence, the positional movement of cardiac during diagnosis and the physical variations of patients make the diagnosis using ultrasound images difficult. Therefore, the number of the medical specialists who can give advanced diagnosis on some special diseases such as heart diseases using ultrasound images is rather small. Additionally, the medical image processing techniques including 3 dimensional ultrasound image reconstruction and the automatic extraction of the region of interests are indispensable for advanced diagnosis. The engineers support the rapid improvement of these techniques. Because of the reason mentioned above, the networked telemedicine treating ultrasound medical image sequences gives strong impact for medical fields; The number of medical doctors and the patients benefited from the newest improvement of medical image processing technique is enormous. Of course the telemedicine solves the service gap problem.

3. Foregoing Telemedicine Researches

The first telemedicine experiment in Japan was enforced at Wakayama prefecture in 1971. This experiment performed transfer of an electrocardiogram (ECG) via CATV and telephone and transfer of diagnosis data via facsimile. The result to prove technical possibility of telemedicine under the restricted technical environment.

Tokai University and the Radio Research Center at the Ministry of Postal Service and Telecommunications took place the first experiment with diagnostic image transfer was enforced at Mitaka City using digital communication network (INS64). This experiment inspected a possibility of a home medical treatment. Tried to through a transfer of a still diagnostic picture, however, this experiment was not sufficiently evaluated [1].

Since these experiments, a lot of telemedicine systems were introduced. However, almost these researches were tuned up for a still diagnosis image. Except for a part of researches, there are hardly researches about the telemedicine system using real time image transfer.

The telemedicine can classify into three types:

- Telecare
  - A patient can consult remote doctor.
  - A home medical treatment.
- Telemedicine
  - A reciprocal medical support among remote doctors.
  - Telepathology

    A transfer of pathological image.
  - Teleradiology.

    A transfer of X-ray CT or MRI image.
- Teleconference
  - A common ownership of medical information.
  - A medical discussion between remote site.

In this paper adopted about "Telemedicine".

The foregoing researches of telemedicine can be divided into two types; the store style telemedicine [3] and the meeting style telemedicine [4]. In the store style system, the obtained data set like MRI images are once stored into disk and sent off-line through a batch job. Therefore, this system is available on conventional image compression and transferring technique because the system is far from serious bandwidth or delay problems. However, this store type telemedicine is just the replacement of conventional medical diagnostic procedure using films and videos. Thus, it derives no changes on medical services.

On the other hand, in the meeting style telemedicine, the obtained data is sent in real time to the diagnosis site where the specialist is. Therefore, the higher medical support is available on time at the measurement site where the patient is. Additionally, the specialist can advise medical doctors or technicians at the measurement site during the diagnosis. Therefore, the diagnosis procedure goes smooth in the system and the users can increase their medical skills through the diagnosis.

Therefore, we have been developing a meeting style telemedicine system named "Tele-echo system", which sends medical ultrasound image sequences, since September 1996 [5]. In the first stage of development, we focused on an image compression method that enables to send the sector-scan ultrasound image sequences without loss in real time [6]. However, the experimental results with this compression method clear the difficulty to tell the specialist's instruction for the technician through only voice communication. Therefore, this paper introduce an innovative instruction system using augmented reality (AR) technique [7]

4. The Conceptual Design

The concept of the system is to establish "Put That There" communication [10] between a medical specialist and an ultrasound diagnostic device technician. To put it concretely, the object of this research is to produce the environment where a specialist can tell the appropriate position and orientation to put the ultrasound probe by pointing on the patient's body and saying "Put the ultrasound probe there in this direction".

AR technology is suitable for this purpose. The idealistic implementation is to exchange all the environmental information to make all the participants feel as if they are at the same place as shown in Figure 1. However, just one virtual pointer on the real patient body can realizes the "Put That There" environment. Of course, the difference of real resources between two sites results in the difference of the relationship of the environment and the users; The technician is in the AR space itself and the specialist looks down on the AR space from the outside as shown in Figure 2.

The main object of this research is to supply better communication in networked telemedicine. The idealistic implementation requires too many network and computational resources to proceed smooth telemedicine. Therefore, this paper introduces the method to produce shared AR environment for smooth "Put That There" communication with the smallest resources.

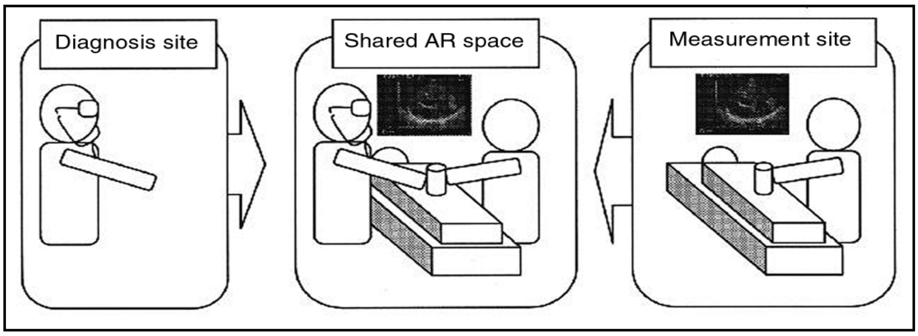

Figure. 1 Shared AR Space

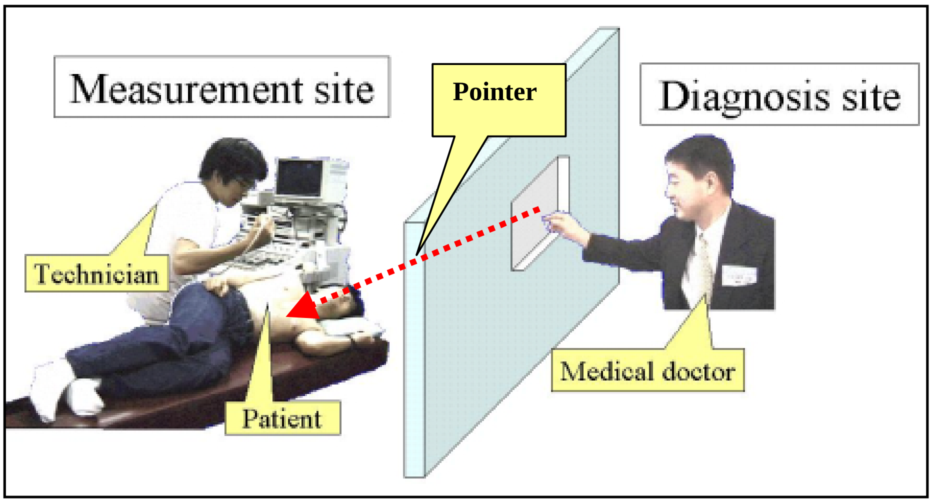

Figure. 2 Conceptual Design

5. The Concept on Interface Design

The most popular implementation of AR system interface is to use an optical or video-based see-through head mounted display (HMD) as a display device. However, this implementation requires additional devices and techniques to register the virtual space to the real one, because the display itself is strongly connected with the viewer's head. The registration based on certain motion or vision sensing techniques may derives the fatal computational delay and sensory error. Therefore, the display to visualize virtual space should be related to the real object. In this application, the real environment to register the virtual space is the body of the patient. Therefore, this paper uses the patient's body as a display.

6. System overview

In this system, the diagnosis site and the measurement site are connected over the network. Our system exchanges several kinds of data shown in Figure.3.

1. System has connection for voice exchanges between a specialist of the diagnosis site and a technician of the measurement site.
2. A patient's image that acquired at measurement site, is transmitted to the diagnosis site.
3. A specialist's instruction is transmitted to the measurement site.
4. An ultrasound image sequence acquired by technician transmits to the diagnosis site.

Until a specialist can get a desired image sequence, participants repeat procedure from the second step to the fourth step.

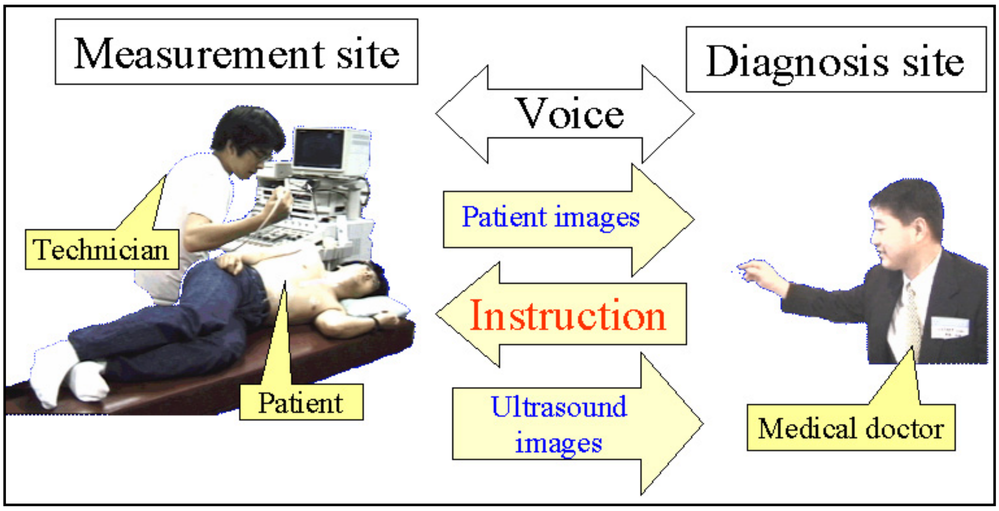

Figure. 3 System Overview

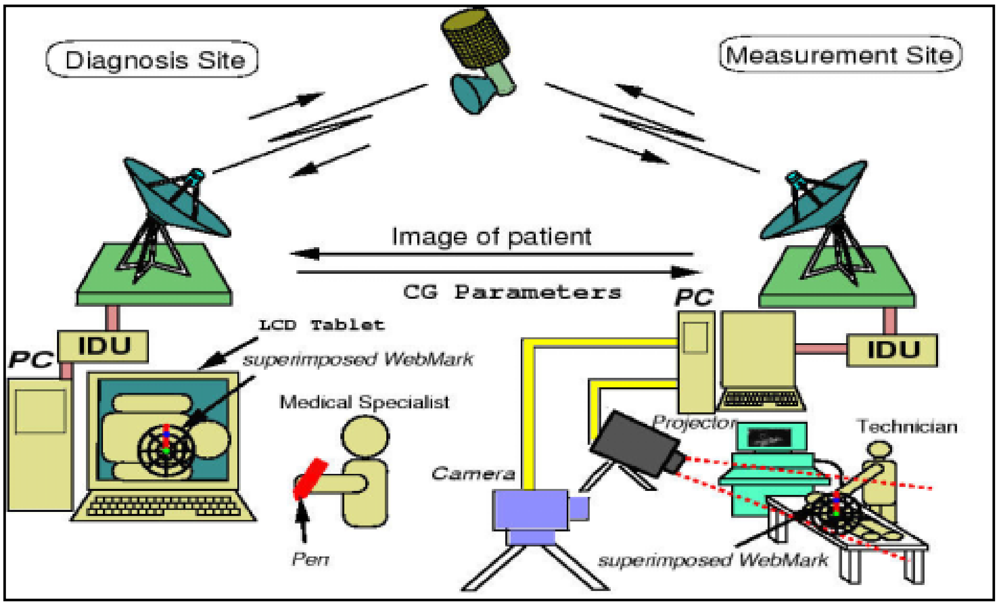

Figure. 4 Prototype System Overview

7. A Prototype System

Figure 4 shows the overview of the developed prototype system.

Figure 5 shows the interface system of diagnosis site. The liquid crystal display tablet (LCD tablet) is adopted as the interface. The specialist looks down on t the body of the patient appears on the LCD as if he is looking down on the share AR space. The instruction is performed by touching on the patient's body on the LCD with the pen-type device. This method enables the specialist to give direct instruction touching on the patient. The pointer named "Web-Mark" is used for the instruction. Figure 6 shows the Web-Mark.

Through the preliminary research, the authors found that a probe manipulation can be classified into three types; "Slide", "Rotate" and "Slant" [8][9].

A Web-Mark indicates individual parameters of these three types as shown in Figure.6. Web-Mark has three control points, a specialist can change parameter by dragging each control point with pen.

Instructions from medical specialist are transmitted to the measurement site. At the measurement site, the Web-Mark produced by transmitted parameters is projected on the surface of patient's body as shown in Figure 7. A technician is able to acquire a desired ultrasound image sequence by putting probe just on the center of the Web-Mark. Although the technician's hand hides the center of the Web-Mark, the surrounding arks indicate the center. Therefore, the technician can follow the instructions of the specialist without any troubles. Until a technician can acquire a desired ultrasound image sequence, instruction and image acquisition are repeated.

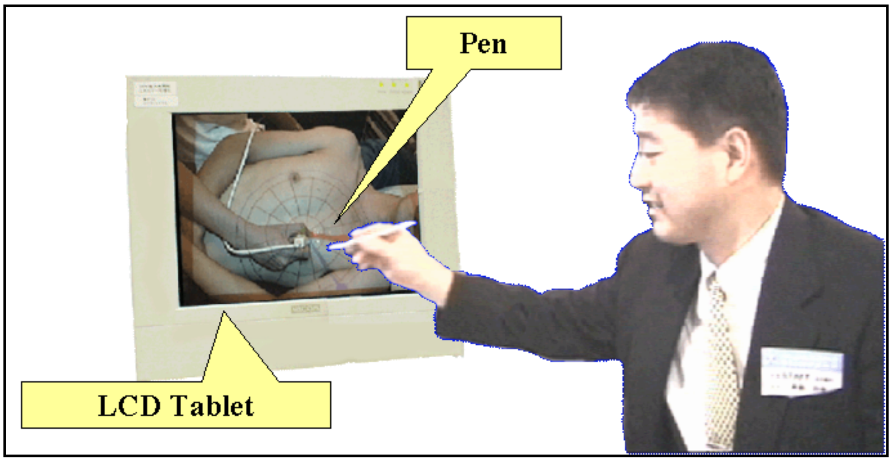

Figure. 5 Interface of the diagnosis site

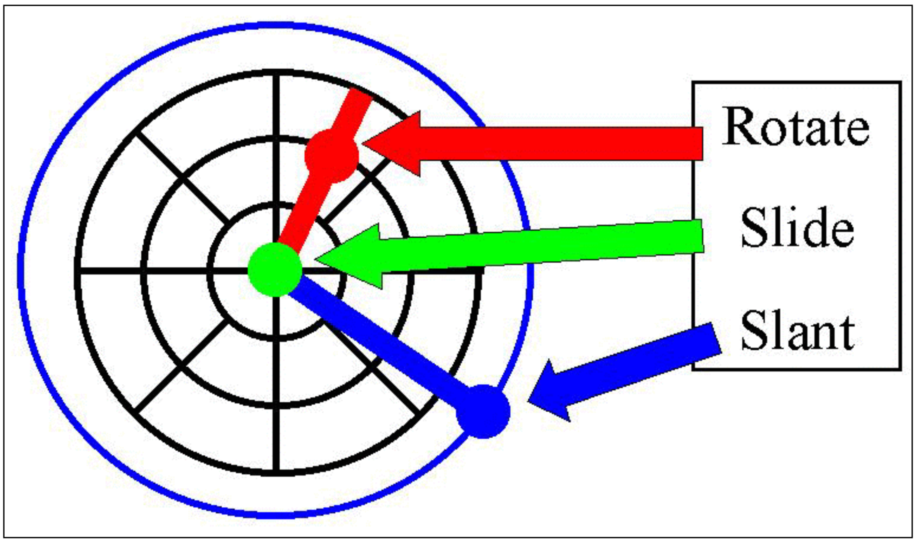

Figure. 6 The Web-Mark

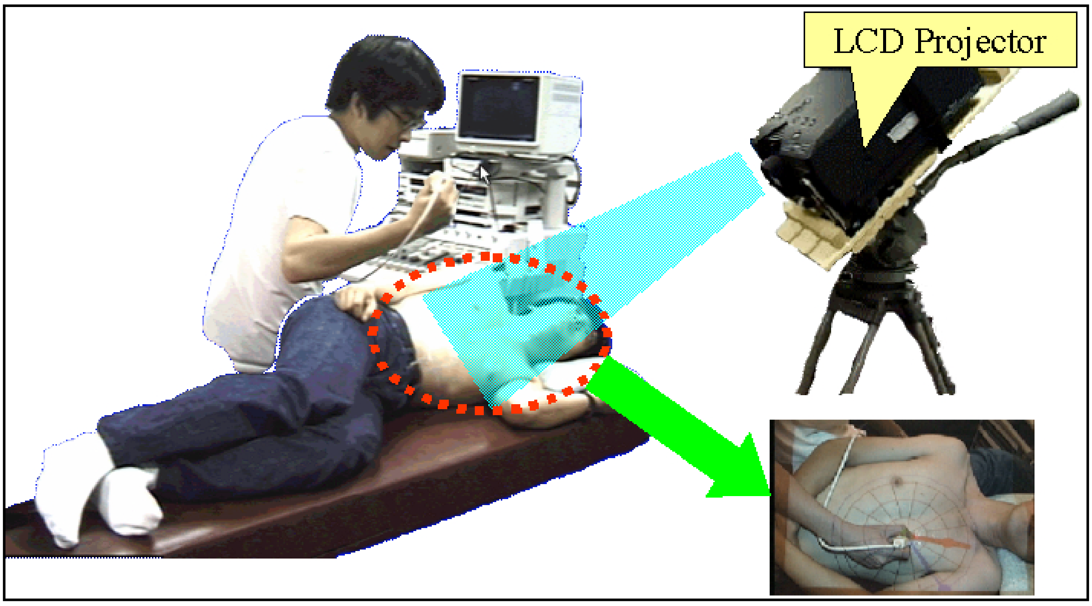

Figure. 7 Interface of the measurement site

8. Experiment

The prototype system is evaluated through telemedicine between Nara and Hokkaido. A diagnosis site was established at Hokkaido, and a measurement site was established at Nara. A medical doctor of the School of Medicine, Hokkaido University filled the role a medical specialist (see Figure.8), and master course student of Nara Institute of Science and Technology filled the role a technician (see Figure.9).

Image sequences were acquired from the patient's chest (see Figure.10) and left side (see Figure.11).

Nara and Hokkaido were connected with a 128kbps integrated service digital network (ISDN).
We used "Microsoft NetMeeting" for voice communication. The compressed patient's image by an original motion-JPEG based compression method is transmitted through UDP/IP protocol (see Figure.12).
The acquired ultrasound image is transmitted in the same way (see Figure 13).

Figure. 8 the diagnosis site

Figure. 9 the measurement site

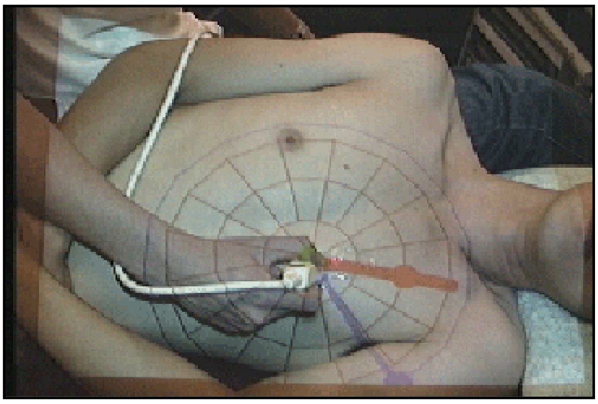

Figure. 10 An acquire image from chest

Figure. 11 An acquire image from left side

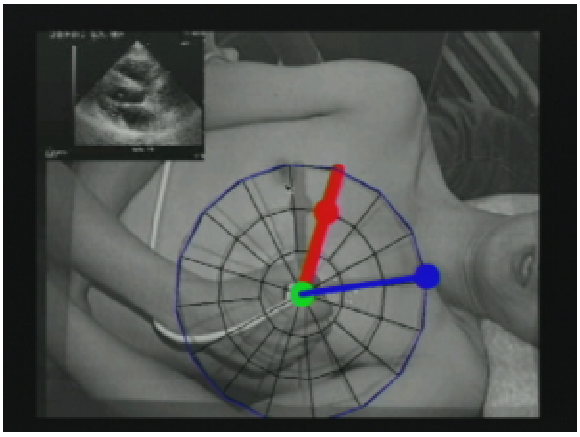

Figure. 12 An image on LCD tablet

9. Experimental Result

We recorded by video cameras the instruction sequence among a specialist and a technician, and analyzed the comprehensibility of instruction.

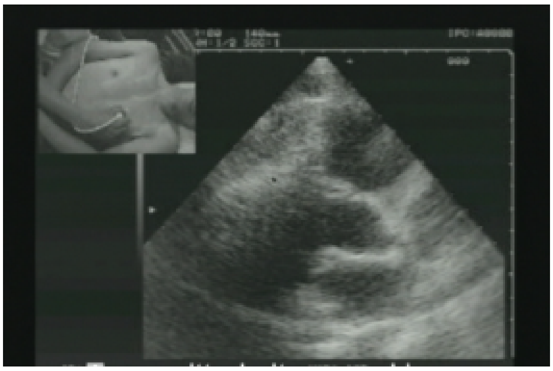

Figure. 13 An acquired ultrasound image

This analyzes cleared the following results.

- <u>acquisition from chest</u>
  All instructions ("Slide", "Rotate" and "Slant") were certainly transmitted to measurement site.

- <u>acquisition from left side</u>
  There were several scenes that a student can't understand an instruction of specialist. Therefore, instructions were performed again and again. Especially, "Rotate" and "Slant" seemed difficult to tell.

Although, there were some difficulties in case of image acquisition from the side the communication in telemedicine was realized almost smoothly through proposed system.

10. Discussion

The proposed system realized smooth communication in telemedicine. However, some problems are occurred in the trial to acquire the image from the side.

This is because the Web-Mark is distorted due to non-flat display, that is, the patient's body. Especially, in the case of the side, Web-Mark is too strongly distorted to give accurate instructions because of the high curvature of the side of patient.

The system should include the 3D acquisition of patients body surface to overcome this problem.

11. Summary

In this paper, we proposed a new telemedicine system using shared AR space between the diagnosis site and the measurement site.

Using proposed system, a student who doesn’t have experience of ultrasound probe operation could acquire appropriate ultrasound image sequences.

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

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