A Telediagnosis Platform based on Telexistence: Investigation of the Roles of Presence and Tactile Information in Telemedicine

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Abstract： This paper proposes a telediagnosis system that allows medical staff to examine remote patients through telexistence robot system with tactile sensor/display. The system consists of three components of an audio-visual telexistence system for telecommunication, a skin-like tactile display equipped with thermal and pressure display devices, and body temperature and heartbeat measurement equipment. In comparison with conventional telephone and videophone, this MR system is expected to allow a medical staff to examine the patient more carefully as if he or she is observing the patient face to face. To test this, 12 medical doctors and nurses evaluated this system. According to the result, the influence and effect of telexistence and tactile display on telediagnosis are discussed. Also, the feasibility of the system for improving the realism of telediagnosis is verified and discussed.

Keywords：**Teledignosis, Telexistence, Haptics, Mixed reality**

1. Introduction

In recent years many countries have come into an aging society. The cost for the elder to have a diagnosis always spends a lot no matter the time or money on the trip. Hence the health care targeted at the aged is an urgent matter. Telemedicine is suitable to do this. Traditional telemedicine concentrates on using information technology such as audio, video to provide medical diagnosis and other treatment from professional doctor to the patient. It can reduce the cost of medical treatment and the risk of cross-infection for infectious diseases. However, the conventional telemedicine system through IT systems such as videophone is not an efficient way, which limits the transmitted information for a doctor to diagnosis. By using telexistence, this research is devoted to enhancing the communication between doctor and patient and narrow the gap like in the same room. By using a surrogate that can simulate the patient's pulse and temperature, the doctor's side will feel like palpating directly.

2. Telemedicine System

Combining virtual reality (VR) with health care has been proposed for decades of years. Early surveys reported that research using virtual reality to do surgery, medical education can go back to the 1990s[1].

With the development of VR/AR/MR, more and more applications and research in telemedicine emerged. Telepresence surgery has already commercialized for many years. Also, due to the high accuracy, this kind of surgery system such as the da Vinci telerobotic surgical system, has been increasingly used[2]. Moreover, palpation based on VR simulation has also been proposed. Timothy et al. use artificial force to simulate the feeling of human skin and apply the system into the palpation and insertion training[3]. To achieve telemedicine, a robot own partial function as a human is also a viable way. Garingo et al. apply a mobile robot into neonatal intensive care to help people from a distance[4].

This research targets the daily diagnosis, which is before the confirmation of the disease and surgery. The frequency may be very high and last for a long time. To makes the palpation between people in different places possible, we propose a telediagnosis system with a tactile display. We hope this tactile display can be used in diagnosing a difficult illness, which cannot be determined without touch and some illness transferred into data in number is obscure to understand, but once being touched, these symptoms can be easily judged. In this way, the system shortens the distance between the patient's home and medical institution. There is no need for the aged to stay at the hospital every day. With this, he/she can accomplish a diagnosis just at home.

For that purpose, we choose a surrogate robot and use a surrogate arm to achieve the system. The system must follow these principles[5]. It must be real-time to ensure communication quality. A doctor can see, hear, and touch the patient to judge the condition, and able to see his body in the virtual space to ensure immersion and make interaction. We choose pulse and temperature to measure from the patient and reproduce to the doctor precisely and realistically because it is comfortable for reproduce but always essential in all the diagnosis. If this idea works, the more bio-signal can be added to the system to enlarge its usability.

The human's regular pulse is between 60~120 bpm. The disease may cause the heart rate beyond the range. For example, paroxysmal supraventricular tachycardia (PSVT) is the most common symptom of tachycardia. The pulse can reach 140~180 bpm. Besides, the temperature and pulse are in positive correlation. Usually, pulse increases by 10 bpm when the temperature rises by 0.5°C. Therefore, in response to possible occasions, we need to set the reproducing pulse range between 40~200 bpm on the surrogate arm to simulate arrhythmia.

3. System Design & Implementation

The system consists of two parts. One is the patient-side, the other is the doctor-side.

Patient-side: The patient is supposed to wear a glove with sensors and sit in front of a 6 DOF robot. With the sensors embedded in the robot and glove, the audio-video information and bio-signal of the patient are recorded and transmitted to the doctor-side. This part is made up of two components: (1) A doctor-surrogate robot is supposed to perceive the surrounding's information including the patient's appearance, voice, and replicate the voice and gestures recorded from the doctor-side. (2) Sensors on the glove measure the pulse and temperature of the patient. The sensor data are stored and processed in a micro control unit (MCU), and then the bio-signal information is transmitted to the doctor-side.

Doctor-side: The doctor wears a Head-mounted display (HMD) connected to the surrogate robot in the patient-side, which reconstruct the surrounding of the patient's room. Also, the HMD is equipped with a stereo camera for achieving video-seethrough; that is, the doctor can recognize his/her own hands overlapping in the image of the patient-side. The doctor-side's image except for the hands is eliminated by using chroma key screens in a Unity project. This method realizes the mixed reality. Furthermore, a patient surrogate arm equipped with many devices is placed in front of the doctor to reproduce the bio-signal information of the patient. Owing to the system, it is expected that the doctor can feel as if he/she were diagnosing the patients face to face.

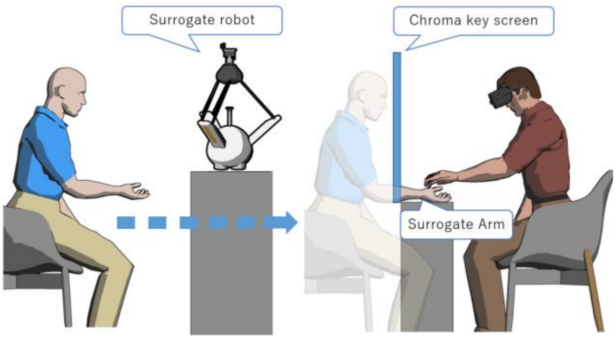

Figure 2: System schematic diagram

3.1 Audio-video Reproduction

3.1.1 Surrogate robot at patient'side

The robot (RT-Telbee) used in patient-side equipped with a stereo camera, a binaural microphone, and a speaker, making itself able to communicate like a human. It also has a 6-DOF mechanical system, which allows the doctor-side connects it with an HMD (Oculus Rift CV2, Facebook Technologies, LLC)[6] to

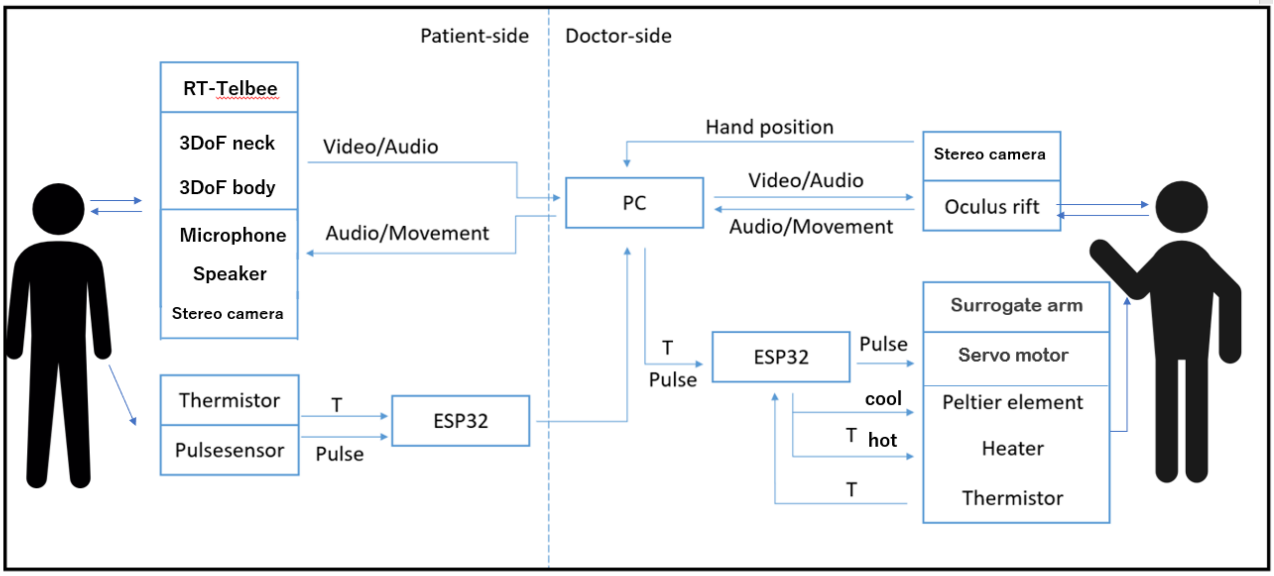

Figure 1 : System data diagram

control its movement.

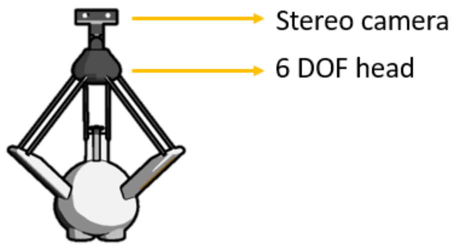

Figure 3: Construction of 6 DOF robot RT-Telbee

3.1.2 Mixed reality at doctor-side

To increase the realistic feeling and maintain the presence of the doctor-side, we attached a stereo camera on the HMD and extract the doctor's hand from the surrounds in the local by using chroma key composing. The doctor is able to see his hand while wearing the HMD, and the hand is overlapped with the background transmitted from the patient-side. Because the HMD is tracking by sensors and connected with the surrogate robot at the patient-side, while he moves, the vision in the HMD will also change like figure 4.

Figure 4: MR environment in the HMD

3.2 Bio-signal reproduction

3.2.1 Detecting glove

Patient-side uses a glove equipped with a pulse sensor (PulseSensor, World Famous Electronics llc.)[7], A negative temperature coefficient (NTC) thermistor (56A1002-C3, Alpha Sensors, Inc.) and an MCU (ESP32-WROOM-32D, Espressif Systems Pte. Ltd) to detect the pulse and temperature.

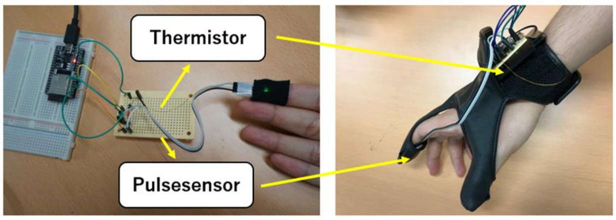

Figure 5: Bio-signal detecting glove

3.2.2 Surrogate for reproduction

Doctor-side receives the bio-signal and reproduces the pulse and temperature on a surrogate arm like figure 6. Under the artificial skin(a mixture of silicone and Al_2O_3 powder), there are a heater and flexible tube to generate heat and pulse.

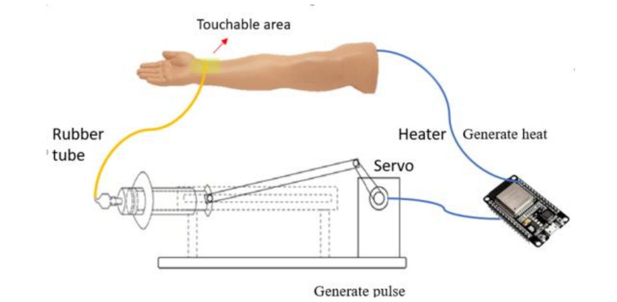

Figure 6: Mechanism of the reproduction system

But we found the surrogate in what kind of shape does not matter, so we developed a smaller one with a cooling module to replace the surrogate arm like figure 7. A heater cooperates with a Peltier element to keep the temperature the same with the patient. A mechanical crank system is responsible for applying pressure to the liquid in the tube to imitate the pulse.

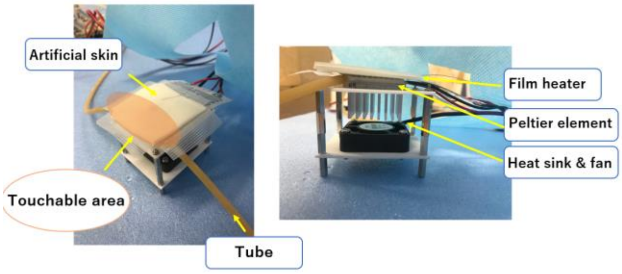

Figure 7: New surrogate with a cooling module

Figure 8: System in two sides (upper) and the view from the doctor/patient (below)

4. Experiment

To test this telediagnosis system is useful or not. More specifically, compared to the traditional telediagnosis system, this system can provide a better reality or not. Can the tactile display bring more clues and do benefits to the telediagnosis. We did an experiment with 12 medical experts. The participants were required to make a complete diagnosis like a real medical examination by using this VR system and the traditional videophone separately. The procedure is almost the same except for that in the videophone method; there is no palpation on a tactile display.

After the experience, they are asked to answer two questionnaires to evaluate the system. At last, we had an interview to listen to their comments.

5. Results

After using each system (VR and videophone), there four questions as follows:

Q1. I felt as if I were actually in the room where the patient is in.

Q2. I felt as if the patient were actually in front of me.

Q3. I felt as if the medical examination was actually performed.

Q4. I felt tense while performing a medical examination.

The score is shown as follows:

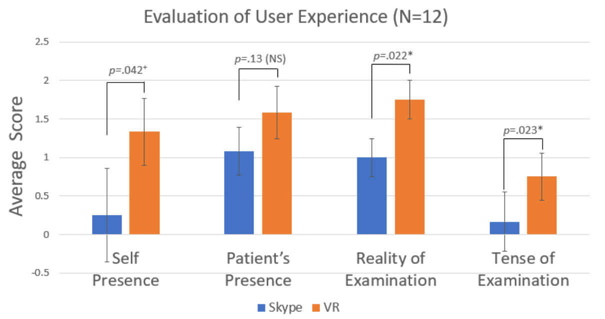

Figure 9 : Evaluation of User Experience

From figure 9, we can see that the scores for the VR system were significantly better than the videophone system except for the Q2 "patient's presence." We had an interview after the experiment and know that they are particularly dissatisfied with the image quality. Compared to the video in skype, the image quality in HMD is very poor. The patient's image isn't clear enough, so the patient's presence will also be damaged. The Q3 shows a positive overall judgment. It means that, by using VR system, the participants could have a more realistic feel for the examination. Finally. for Q4, the VR telediagnosis brings more tension. As our thought, it means the experts treat it more seriously and more like the actual diagnosis.

After all the experiments, they were required to answer about the impression of the VR diagnosis system.

Table 1: Answer of questionaire2

	YES	NO
Q1: Have you ever experienced another telemedicine system?	1	11
Q2.1: If Q1 is "YES," do you think the VR system is more real?	1	0
Q2.2: If Q1 is "NO," do you think the VR system is real?	10	1
Q3: Do you think VR experience is useful for the examination?	12	0
Q4: Do you think the tactile display is useful for the examination?	10	1
Q5: Do you want to use a VR telediagnosis system?	11	1

The results are shown in table1. Most of them agreed that this VR system is presented with a realistic experience like an actual examination. Furthermore, all of them agreed that the VR system and the tactile display is useful while performing a clinical examination. But after the interview, they also said a lot about the system defects, such as image quality, and the limitation to determine disease just by pulse and temperature.

6. Conclusion

In our research, we proposed a telediagnosis system based on Telexistence. This system contains a surrogate robot and a tactile display. By using this system, the medical staff can palpate the patient like face to face. Then, we did an experiment to compare this system with the traditional telediagnosis system. This telediagnosis system performed a better ability in diagnosis, according to the medical experts. But there are also many defects that need to be improved. In the future, the most urgent need is to improve image quality. Secondly, the tactile display should provide more information such as blood pressure or other bio-signal to enhance its usability. And versatility should also be considered, other parts like neck or foot also can be developed in the tactile display. Finally, due to the high reality, this system also can be used in medical training to improve the practical skills of medical staff.

Acknowledge

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