第 24 回日本バーチャルリアリティ学会大会論文集（2019 年 9 月）

Study on Telexistence XCV: A Telediagnosis Platform Based on Mixed Reality and Bio-signal Display Device

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Abstract： We propose a telediagnosis system that allows medical staff to interact with a remote patient through telexistence robot system. The system consists of an audio-visual telexistence system (TX-toolkit), a surrogate arm equipped with thermal and pressure displays, and body temperature and heartbeat measurement equipment. By using this system, the medical staff can examine the patient as if he or she is observing the patient face to face.

Keywords：Teledignosis, Telexistence, Haptics, Mixed reality

1. Introduction

Recent years many countries have come into an aging society. The aged have to live by themselves because their children have no time to take care of them due to their hard work. 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. However, medical treatment through a screen is not an efficient way, which limits the transmitted information. The doctor cannot teach the patient like face to face. The patient may misunderstand what the doctors mean and feel more nervous. By using mixed reality, 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 arm which can simulate the patient's pulse and temperature, the doctor side will feel like palpating truly.

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 1990s[1].

With the development of VR/AR/MR, more and more application 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 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 at 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. We propose a telemedicine system with palpation simulation, which seems like the study[3]. Also implement a function of telediagnosis, which makes the palpation between people in different places possible. This 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 can accomplish a daily 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. It must be real-time to ensure communication quality. A doctor can see, hear, and feel the patient to judge the condition, and able to see his body in the virtual space to ensure immersion and make interaction. The vital medical information in daily diagnosis such as temperature, pulse need to be gathered from the patient and reproduced to the doctor precisely and realistically.

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.

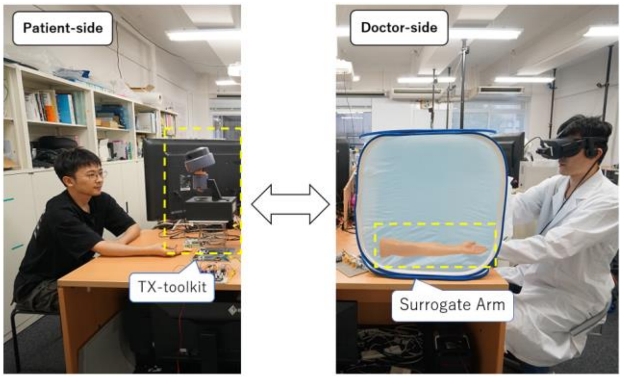

Figure 1: System overview: Patient-side and doctor-side

3. System Design & Implementation

The system consists of two parts like Figure 1. One is patient-side, the other is the doctor-side.

- Patient-side: This part is made up of two components. A surrogate robot is supposed to collect the surrounding's information and copy the posture and voice got from doctor-side. Sensors read the bio-signal measured from the patient. An MCU saves the signal and then send the data to the doctor-side.
- Doctor-side: The Head-mounted display (HMD) will reconstruct the scene of the patient's room. The HMD mounts an Ovrvision[5], which allows the doctor to recognize his arm by using chroma key. A surrogate arm equipped with many devices reproduces the bio-signal got from the patient-side, which makes the artificial arm more like the patient's real arm. The doctor would feel as if he is diagnosing the patients face to face.

3.1 Transmission of Behavior Information

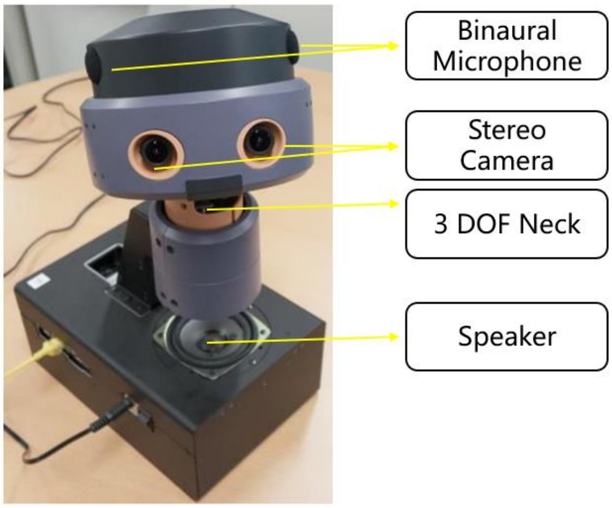

Figure 3: Mechanical construction of TX-toolkit

3.1.1 Telexistence Toolkit

Telexistence is a concept which represents the technology reappearing one's existence from a distance[6]. To achieve telexistence, a robot which has the same enginery as a human is necessary. However, popularizing a traditional robot with high cost is Economically unbearable. Telexistence-toolkit (TX-toolkit) is designed to achieve the telecommunication with low cost but high telepresence[7]. As Figure 3, TX-toolkit equipped with a stereo camera, a binaural microphone, and a speaker, making itself able to communicate like a human. It has a 3-DOF mechanical system and network function, which allow the user connects it with an HMD (Oculus Rift)[8] to control its movement.

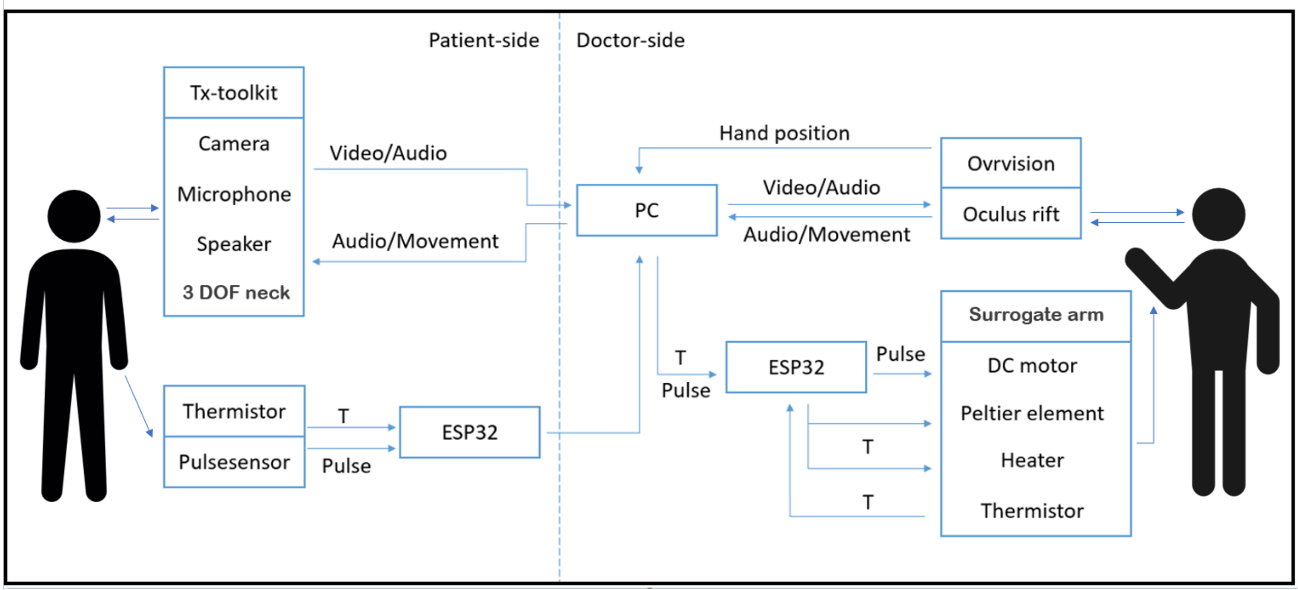

Figure 2 : System data diagram

Figure 4: Synchronization between TX-toolkit and user

3.1.2 Telecommunication

The telecommunication system works as Figure 2 upper half shows. With TX-toolkit, the image, sound at patient-side can be transferred to the doctor-side through the video, audio stream and playback on the HMD. By this way, the doctor will feel like sitting in front of the patient and move his sight as he wishes. As Figure 4 the robot has a 3-DOF neck, which allows it to copy the movement same with doctor's head. The movement information is got from the HMD. Moreover, the patient can realize the doctor's eyesight and hear his voice through the robot's rotation and its speaker. Hence Patient-side will know about what the doctor is looking at and follow his guidance. By that, it provides an efficient way for each other to communicate freely and realistically.

Besides, in order to see his own arm to create a better realistic at doctor-side, an Ovrvision is equipped in front of the HMD. The doctor can recognize his own side's surrounding through the stereo camera, yet the view of his own side will cover the view got from the TX-toolkit. Therefore, to eliminate the unwanted pixel, we use chroma key with doctor-side's background all in blue, the doctor can see nothing except for his own arm presenting in the scene of the patient's room.

3.2 Transmission of Bio-signal

Transmission of bio-information can be divided into two parts. One is gathering information from the patient-side. The other is reproducing the bio-signal on the surrogate arm through some mechanism. The surrogate arm is a silicone arm with some rubber tube under the skin, which is usually used in medical practice to train injection skill. The tube distributes like an artery. Fill the tube with water and add pressure, then the system will be like blood flowing in the arteries. We simulate the flow of blood to produce a pulse.

3.2.1 Bio-signal Gathering

We choose the pulse and temperature as the primary function to reproduce. A sensor unit is attached to the patient's finger as shown in Figure 5, which is composed of Pulsesensor[9] and a thermistor (56A1002-C3, Alpha Technics.). Pulsesensor measures the heartbeat by photoplethysmogram (PPG) while thermistor calculates the temperature at the same time. An ESP32 (ESP32-WROOM-32D, Espressif Systems Pte. Ltd.) saves both types of data. ESP32 is an MCU with integrated Wi-Fi function. It gathers the bio-signal then sends it to the doctor-side.

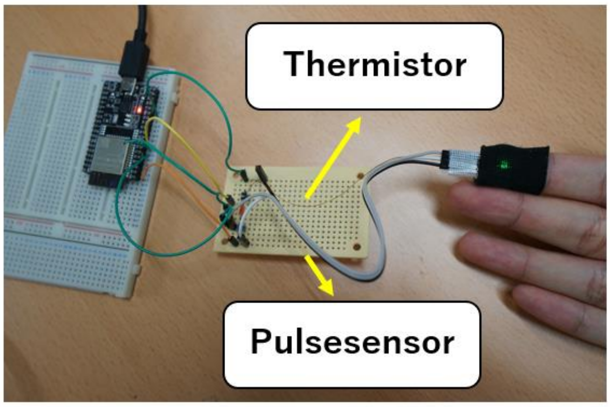

Figure 5: Bio-signal import

3.2.2 Bio-signal Reproduction

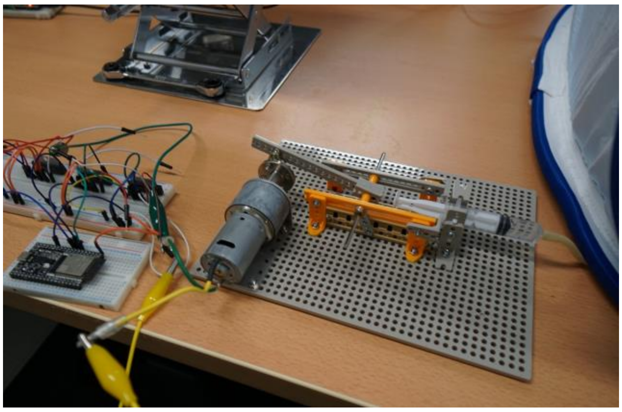

Figure 6: Pulse mechanism with Esp32

Doctor-side's PC receives the message and shows the heartbeat and temperature on the HMD's screen. Next, the message will be sent to another ESP32. This ESP32 connects to an actuator unit and a temperature control unit.

Actuator unit is responsible for rebuilding the pulse. The mechanism is shown in Figure 6. A crank mechanism is attached to a DC motor (380K75, Tamiya Inc.). The rotation rate keeps the same as the patient's heartbeat. When the motor runs, the crank will drive a syringe back and forth. The syringe connects to surrogate arm's rubber tube, within it, water will take tunes being squeezed and relaxed, which makes the process same as blood being pumped by the heart. The temperature control unit contains three components. A thermistor is used to monitor the temperature. A pair of film heater (P-13611) and Peltier element (TES1-12705) keep the temperature the same as the data received from patient-side.

4. Results

The system prototype was implemented with the following specification.

- Robot: TX-toolkit with a built-in stereo camera, binaural microphone, speaker, and 3-DOF mechanical system.
- MCU: ESP32-WROOM-32D
- VR headset: Oculus Rift CV2 with Ovrvision
- Sensor: Pulsesensor and NTC thermistor
- Display: 380K75 motor, 4cm×4cm Peltier element, and film heater on a surrogate arm.

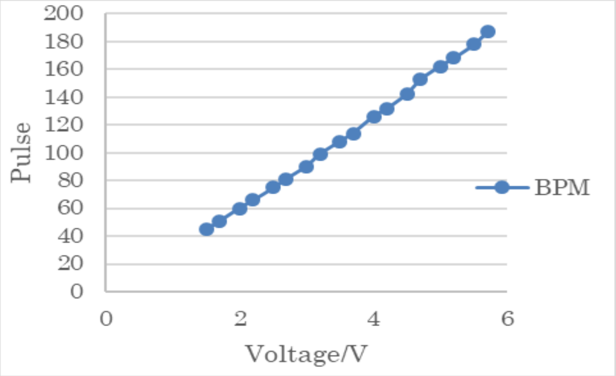

Figure 7: Linear relationship between pulse and voltage

The relationship between the voltage applied to the DC motor and the pulse is shown in Figure 7. Voltage (V) and pulse rate (R) are close to a proportional relationship as follow.

$$R = 33.93V - 8.9805 \qquad (1)$$

Required pulse range corresponds to a voltage range of 1.5~6V. By controlling the applied voltage, the pulse rate can be displayed correctly.

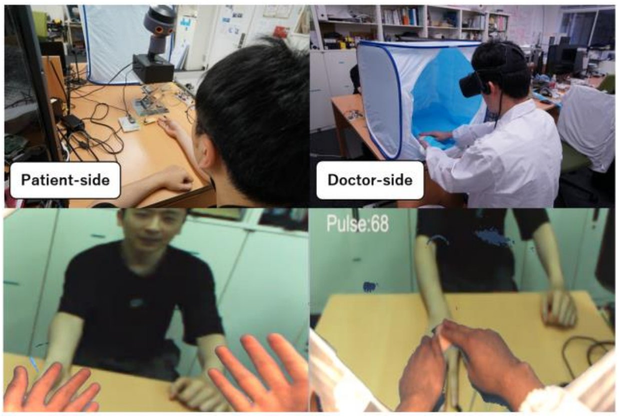

Figure 8: System in different angles and doctor-side's view: Patient-side's image mixed with the doctor's hand

This system achieves a simple application scenario for telediagnosis. The patient sits in front of the TX-toolkit and put his arm on the desk, following the doctor's guidance. At the same time, the doctor faces a blue background box. In the box, the surrogate arm is also in blue. With the Ovrvision, all the background and the surrogate arm will become transparent by using chroma key. Like Figure 8, the image shown on the HMD only contains his own arm and what the robot sees at the patient-side. Therefore, the doctor just like sitting in the same room and naturally put his own arm on the patient's wrist to diagnose. The surrogate arm reproduces the bio-signal got from the patient-side. So, the doctor can feel the warmth and the pulse as he is touching the real arm.

5. Future Work

Usability testing is in the top priority. A series of verification test among medical staff is being planned and conduct in the future to test whether the system is realistic or not.

Furthermore, more function of bio-signal test can be added to the system such as ECG. With more function, the practicality will increase considerably.

6. Conclusion

This research proposes a telediagnosis system that allows medical staff to interact with a remote patient through telexistence robot. Also, a surrogate arm equipped with a thermal device and actuator is used to present the patient's temperature and heartbeat. This system provides a more realistic way for remote diagnosis.

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