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Telemedicine Medical Ultrasonic System Based on Robotic Arm

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In traditional medical ultrasound treatment, the doctor's hand needs to take the ultrasonic scanner and move it around the wound location. In this study, the ultrasonic scanner is grasped by a robotic arm, and the doctor uses the remote control robotic arm system to move the ultrasonic scanner around the wound location. In addition, a force sensor is installed on the robotic arm to sense the force feedback of the robotic arm touching the patient's body. The doctor uses the robotic arm to operate the ultrasonic scanner as if they were operating it themselves. The results show that through our developed long-distance robotic arm ultrasound system, the doctor can treat patients without the need for contact with them.

1. Introduction

As of November 2021, the number of people diagnosed with COVID-19 worldwide had reached 200 million.(1) The COVID-19 pandemic has spread rapidly, with clusters of infections in hospitals in various countries.(2) Since many patients in a hospital are vulnerable owing to their low immunity, the medical staff in the hospital need to have direct close contact with the patients. The risk is therefore high that the COVID-19 virus will spread. In many hospitals, medical staff are overloaded with work. Maintaining medical capacity and protecting the medical system will be the focus of pandemic prevention in the future.(3)

Before the outbreak of the COVID-19 pandemic, countries around the world were actively promoting medical reform policies.(4) One of the strategies is to develop the intelligent medical service industry(5) to improve medical efficiency and medical services by introducing information and communication technologies and improving system quality. The emergence of COVID-19 has accelerated the development of the intelligent medical service industry.

The World Health Organization defines intelligent medicine as the introduction of information and communication technology into the medical and health fields, including medical care, disease management, public health monitoring, education, and research.(6) Information and communication technologies have many applications in the medical field, including fast health interoperability resources,(7) medical image capture and transmission

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systems, health databases, telemedicine, radio frequency identification systems, and drug barcode tracking. These applications combine medical care, communication technology, electronic medical equipment, and other fields.

In addition, according to the definition of the US Food and Drug Administration,[8] the intelligent medical field includes telemedicine,[9] medical health information, wearable devices,[10] telemedicine and remote care, and personalized medicine applications. The software services provided by intelligent medicine can be deployed in medical equipment, wearable devices, and trackers to improve the performance of medical staff in diagnosing and treating patients, achieve the best medical quality and medical resources, and establish a complete medical system.

For current medical ultrasound treatment systems, we propose an innovative method of picking up an ultrasonic scanner using a robotic arm. This allows a doctor to treat a patient without needing face-to-face contact. Through the remote control of the robotic arm medical mode, doctors can significantly reduce the risk of contact infection with patients. In addition, there are currently no cases of such a practical application of a robotic arm on the market; thus, our proposed research method is expected to make a major contribution to future medical systems.

2. Related Work

2.1 Telemedicine

Telemedicine refers to providing clinical care services when participants are in different locations, using various communication electronic equipment and communication technologies[11] without being restricted by geography, thus serving patients who cannot reach a hospital. Applications include video conferencing, still image transmission, electronic medical care, remote monitoring of physiological systems, and medical robotic arms. Telemedicine is not limited to a single medical field and its goal is to reduce the patient's demand for medical facilities and equipment. Patients with chronic diseases can seek medical treatment through telemedicine, increasing their chances of receiving care and reducing the amount of contact between medical staff and patients.

The current form of telemedicine allows doctors to instantly interact with patients through the patient's voice, image, and physiological data. This allows the doctor to make a preliminary diagnosis and perform an integrated diagnosis, make a treatment plan, and prescribe medicine. In addition, patients can use wearable devices to monitor body information in real time through physiological sensing, such as blood pressure, blood sugar, electrocardiograms, or weight. Sensors collect various data of the human body and achieve the function of real-time recording. The data is sent remotely in real time.

Therefore, through telemedicine, patients can reduce transportation costs and also alleviate excess demand for medical resources at hospitals. Telemedicine can overcome distance- and resource-based constraints by allowing patients to see a doctor without going to the hospital. This also reduces the amount of physical contact between people.

2.2 Medical robotic arm

At present, one of the medical services used in telemedicine is the medical robotic arm. Robotic arms are not at risk of infection, reduce the risk of transmitting an infection, have high accuracy, and are efficient in assisting doctors in treating patients.

The application of robotic arms in the medical field has become common, in which a doctor's operating procedures are converted into mechanical motion. Robotic arms have different functions in different medical fields.

The MAKO robotic arm joint replacement(12) is a diagnostic system robot that uses a micro-diagnostic device to enter the human body during a surgical operation. It uses the robotic arm to locate the knee joint position accurately and complete an in-depth inspection of its condition using external diagnostic equipment.

The ROSA surgical robot(13) assists surgeons in performing operations, i.e., surgical actions and postoperative wound treatment. In addition, ROSA surgical robots can automatically move and position themselves. Compared with traditional manual methods, they can reduce the number of human operation errors.

The Da Vinci robotic arm surgical system(14) uses 3D stereoscopic ultrahigh-resolution visual images and a robotic arm that imitates the wrist and has a precise and intuitive control system. The control system allows a doctor to achieve more subtle motion control and can eliminate hand shaking. The system assists the doctor in accurately determining the location of a wound and performing precise excision, repair, and suture.

3. Methods

3.1 Medical ultrasound treatment system architecture

A line of medical jelly for injection and a remote injection button are added to the robotic arm. The mechanism used for our 3D simulation is shown in Fig. 1. When the robotic arm reaches the desired position, it can automatically inject medical jelly. When the amount of

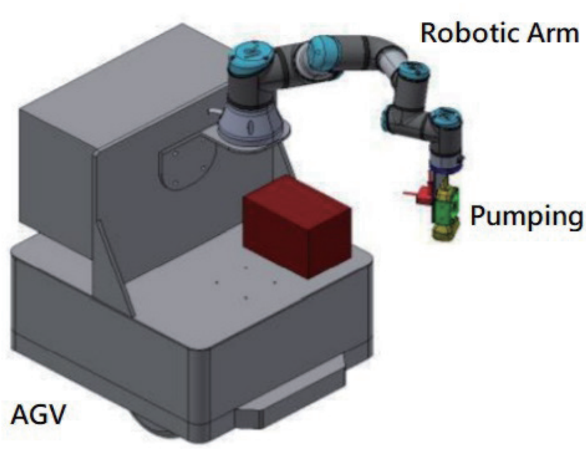

Fig. 1. (Color online) Mechanism used for 3D simulation.

medical jelly is insufficient, the remote injection button can replenish the medical jelly. It is assumed that a screw motor will drive the pump, which will be triggered by a doctor through a remote connection. The main control program in the automated guided vehicle controls the motor to rotate and squeeze the pump to achieve the desired effect.

In the mechanism design, the pump is placed on the base of the automated guided vehicle to reduce the load of the robotic arm and increase the amount of medical jelly that can be stored in the pump. In addition, a buckle structure is adopted for the replacement of medical jelly. The pump and catheter are fixed by the buckle, which is convenient and quick to replace. The diameter of the catheter in the final design is about 5 mm.

3.2 System structure

When the doctor uses the remote medical ultrasound system, it is necessary to operate the robotic arm so that the ultrasonic scanner touches the patient. We use two approaches to tell the doctor whether the touching force is excessive, as shown in Fig. 2.

First, we install a photographic lens on the robotic arm to accurately locate the patient's examination site. We use 5G[15] or Wi-Fi 6 technology to instantly return images to improve the accuracy of the frameless stereotactic movement of the robotic arm.

The second method is to install a force sensor for multi-axis force detection on the robotic arm. The force sensor captures the force status of the environment and then sends information back to the back-end system, allowing doctors to respond to various operational needs.

By adjusting the wheelbase posture of the robotic arm, we collect the force sensor data for different locations of the robotic arm. The system display of the remote control robotic arm can be operated to compensate for the gravity of the force sensor and prevent doctors from using the robotic arm to treat patients when they are experiencing discomfort caused by the robotic arm.

The robotic arm is fixed on an automated guided vehicle as shown in Fig. 3. The battery of the automated guided vehicle, which has a long life, is used as the power source of the robotic arm. The automatic guided vehicle is equipped with an optical radar. We use simultaneous localization and mapping to construct a map of the medical ward. When the automated guided vehicle is moving, it continuously calculates the current position. It updates the relative position between itself and obstacles to avoid colliding with them. The automated guided vehicle has a mass of 100 kg, so it can be loaded with other equipment to meet the needs of doctors.

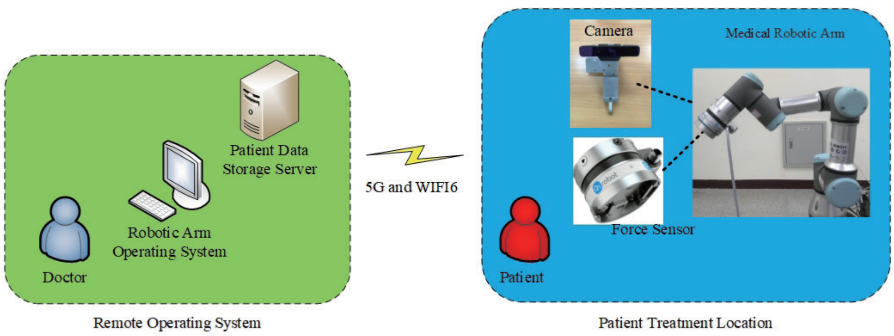

Fig. 2. (Color online) Architecture for remotely operating robotic arm.

Fig. 3. (Color online) Robotic arm and automated guided vehicle.

4. Experimental Result

4.1 Actual operation

In this experiment, we use an MS3_PLUS[16] automated guided vehicle, a UR3[17] robotic arm, and a Resusci Anne CPR doll for the experiment, as shown in the lower right, upper right, and left of Fig. 4, respectively.

We move the robotic arm directly over the human liver, as shown in Fig. 5. We next move the robotic arm to the position of the human pancreas, as shown in Fig. 6. Finally, we move the robotic arm to the position of the human heart, as shown in Fig. 7. In the actual operation of the robotic arm, we can control the robotic arm through the system when the patient is lying down. The robotic arm can reach various organs of the human body.

4.2 Force feedback

We measure the pressure on the X axis of the force sensor, as shown in Fig. 8. Then we bring the force sensor into contact with an object, and we find that the force sensor can accurately detect the moment when the object is touched. The received force feedback value (black frame) is shown in Fig. 9.

4.3 Discussion

As shown in Sect. 4.1, the robotic arm can move to the positions of human organs accurately. It is also shown to be feasible to use an ultrasonic scanner with the robotic arm. In addition, to avoid the problem of an excessive force being applied when the ultrasonic scanner touches the human body, causing discomfort to the patient, it is shown in Sect. 4.2 that a force sensor can be installed on the robotic arm to control the contact force.

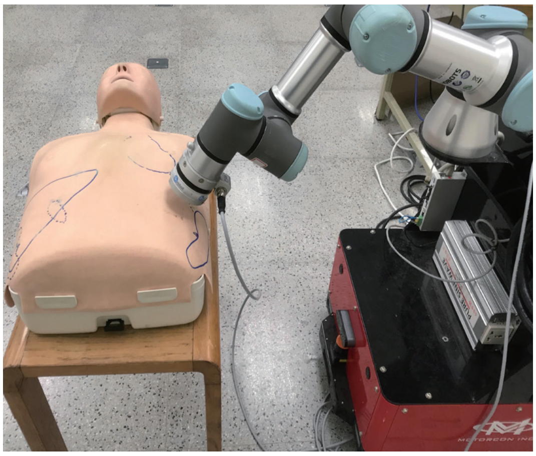

Fig. 4. (Color online) Robotic arm operation.

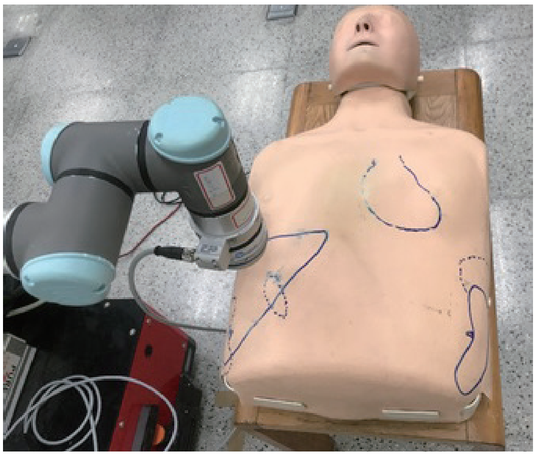

Fig. 5. (Color online) Robotic arm directly over human liver.

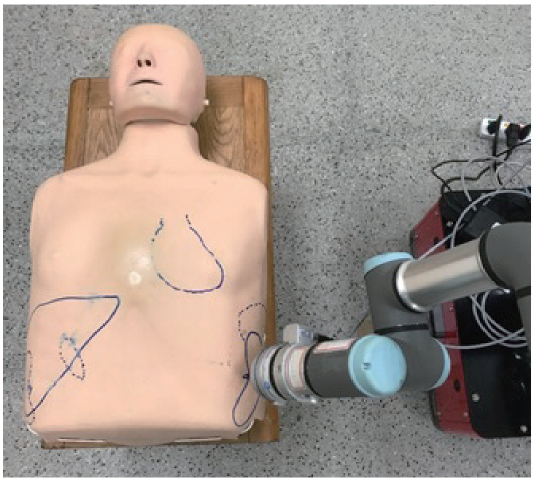

Fig. 6. (Color online) Robotic arm directly over human pancreas.

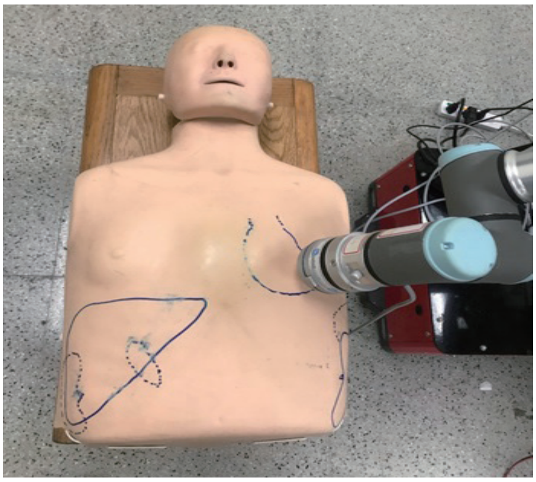

Fig. 7. (Color online) Robotic arm directly over human heart.

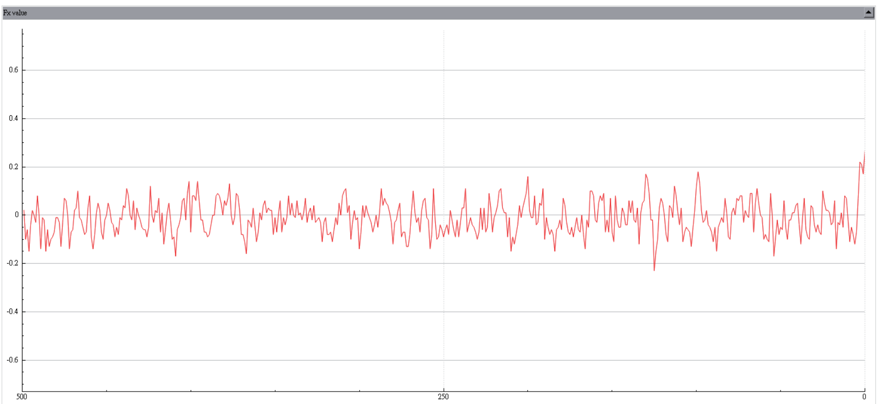

Fig. 8. (Color online) Force measured on the X axis.

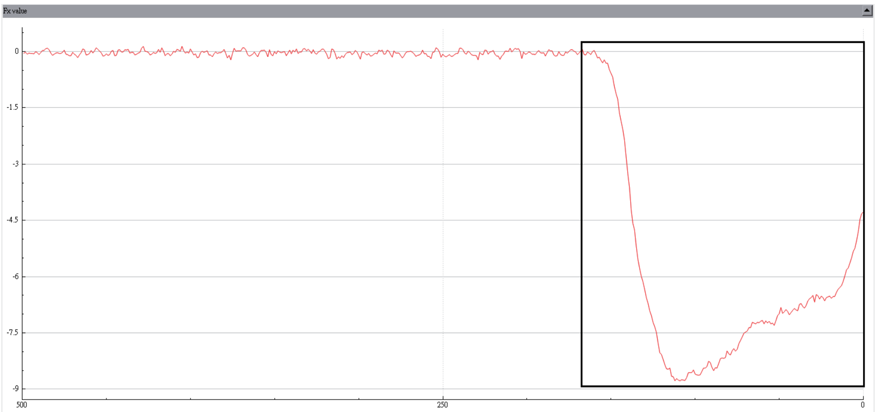

Fig. 9. (Color online) Force measured on X axis when force sensor comes in contact with object.

5. Conclusions

Intelligent medicine has recently been actively promoted as a policy in countries worldwide, particularly since the outbreak of the COVID-19 pandemic, because avoiding human-to-human contact helps prevent infection, particularly in hospitals.

In this study, we use a robotic arm controlled by a doctor to apply medical jelly to a patient's examination site as an anti-infection measure. The doctor then uses an ultrasonic scanner installed on the robotic arm to check the patient's examination site. As a result, the doctor can treat the patient through the remote robotic arm operating system, reducing the doctor's risk of infection and increasing the quality of medical care.

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References

1 W. Mohl: Wien. klin. Woch. **121** (2009) 1. https://doi.org/10.1007/s00508-009-1195-6
2 S. K. Cheng, K. Y. Chau, Y. K. Tso, W. C. Tsang, Y. F. Li, K. C. Wong, and S. C. Fung: Ther. Adv. Infectious Dis. **7** (2020) 1. https://doi.org/10.1177/2049936120978095
3 J. L. Pomeranz, L. Zellers, M. Bare, and M. Pertschuk: Am. J. Prev. Med. **56** (2019) 47. https://doi.org/10.1016/j.amepre.2018.07.027
4 K. Sheikh and D. Nambiar: Natl. Med. J. India **24** (2011) 245. https://pubmed.ncbi.nlm.nih.gov/22208151/
5 G. Eysenbach: J. Med. Internet Res. **3** (2001) 1. https://doi.org/10.2196/jmir.3.2.e20
6 W. H. Organization: Telemedicine: Opportunities and Developments in Member States. Report on the Second Global Survey on eHealth (CAB Direct, 2010) 93.
7 A. Boussadi and E. Zapletal: BMC Med. Inf. Decis. Making. **17** (2017) 1. https://doi.org/10.1186/s12911-017-0513-6
8 K. Kadakia, B. Patel, and A. Shah: NPJ Digital Med. **3** (2020) 1. https://doi.org/10.1038/s41746-020-00371-7
9 A. Chib, M. H. V. Velthoven, and J. Car: J. Health Commun. **20** (2014) 4. https://doi.org/10.1080/10810730.2013.864735

10 R. R. Kroll, J. G. Boyd, and D. M. Maslove: J. Med. Internet Res. **18** (2016) 253. https://doi.org/10.2196/jmir.6025
11 B. Haralambous, S. Subramaniam, K. Hwang, B. Dow, and D. LoGiudice: Asia Pac. Psychiat. **11** (2019) 12355. https://doi.org/10.1111/appy.12355
12 A. D. Pearle, D. Kendoff, V. Stüber, V. Musahl, and J. A. Repicci: Am. J. Orthop. **38** (2009) 16. https://www.researchgate.net/publication/24251991
13 M. Lefranc and J. Peltier: Expert Rev. Med. Devices **13** (2016) 899. https://doi.org/10.1080/17434440.2016.1236680
14 J. Bodner, H. Wykypiel, G. Wetscher, and T. Schmid: Eur. J. Cardio. Thor. Sur. **25** (2004) 844. https://doi.org/10.1016/j.ejcts.2004.02.001
15 N. Hassan, K. L. A. Yau, and C. Wu: IEEE Access **7** (2019) 127276. https://doi.org/10.1109/ACCESS.2019.2938534
16 MOTORCON INC: http://www.motorcontech.com/en/index.php (accessed November 2021).
17 UNIVERSAL ROBOTS: https://www.universal-robots.com (accessed November 2021).

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