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Force measurement of blood vessel gripping by hydraulic-driven forceps

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Abstract

Surgical manipulators are widely used for laparoscopic surgery. They have mainly been chosen for use in supporting human operations and in robot systems like the da Vinci surgical system. These manipulator systems are suitable for careful work, but they have a few problems. One is that the manipulators are not equipped with haptic sensing functions. Therefore, the operator must know advanced techniques for visually detecting the physical contact state during surgical operation. Such haptic sensing functions thus need to be incorporated into surgical manipulators. We have developed hydraulic-driven forceps with a micro bearing and a bellows tube that can convey haptic sense to the operator. For accurate surgical operation, the operator of the surgical manipulator must be able to feel the characteristics of the blood vessel and the organ. For example, it is necessary to feel the pulsation of the blood. In addition, the operator must be able to notice any potential rupture of a blood vessel to prevent a medical accident. We tested our system to determine if it could detect characteristic differences and changes of the blood vessel. This report describes the results and discusses the effectiveness of our system.
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Keywords: Hydraulic-driven, forceps, force feedback, surgical manipulator

1. Introduction

Surgical manipulators have recently been in widespread use in supporting human operations [1-5]. When the manipulator is not equipped with haptic sensing functions, the operator must possess advanced techniques for visually detecting the physical contact state during surgical operations. Recently, many researchers study about the solution to this problem. For instance, a force sensing probe to be used with the da Vinci tools [6,7] and bilateral control system for force feedback [8-10] was developed. Hydraulic-driven mechanisms have recently been used in the medical field [11] and the master-slave system using the air was proposed [12-13]. We have developed a hydraulic-driven forceps that can measure the holding force. In this study, we checked whether our system could detect characteristic differences and changes of the blood vessel. A forceps holds the blood vessel model, moves around a little while holding it, and then releases it. Models of the held blood vessel were made up of silicon rubber 0.3 mm, 1 mm, and 2 mm in diameter. The forceps was able to detect differences in size and was also able to detect the difference between a filled blood vessel model and a hollow one. The forceps was also able to measure pulsation of the blood vessel clearly. All results of experiments demonstrate the effectiveness of our system.

2. Mechanism of forceps

The drive system for the forceps is shown in Fig. 1(a). The system consist of micro forceps and water supply machine. The principle of the hydraulic driven forceps is shown in Fig. 1(b). Forceps consists of a bellows tube moving with water. Because a syringe is used to both supply and extract water, the bellows tube has to be able to both expand and contract. This is what enables the forceps to hold something [14]. The amount of liquid to supply to the bellows tube by moving the linear actuator is controlled and the operator is able to open and close the forceps precisely. The force sensor is fixed between the plunger and the actuator rod of the linear actuator. Since the

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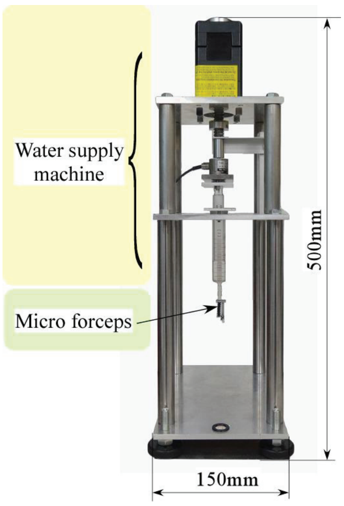
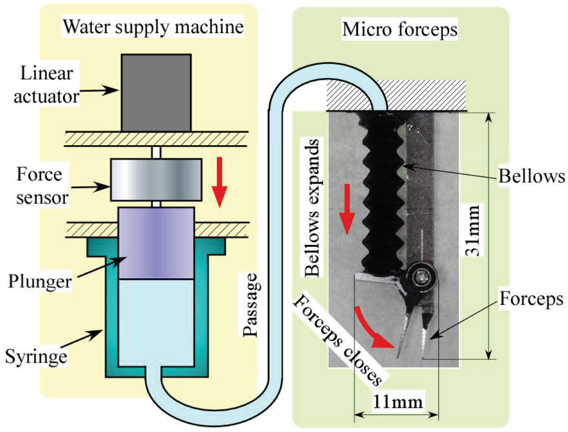
force sensor measures the amount of force acting on the plunger, the internal pressure inside the syringe can be obtained [15]. Measured internal pressure is compared with the displacement-fluid pressure model of the forceps, and the difference in quantity is measured as the holding force. This system can measure the small forces acting on the tips of the forceps by using Pascal's principle [16], [17].



(a) Hydraulic driven forceps mechanism.



(b) Principle of hydraulic driven forceps.

Fig. 1. Forceps mechanics.

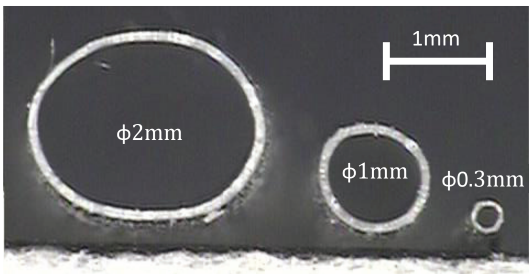


Fig. 2. Blood vessel models of different size.

3. Experiment of blood vessel gripping

3.1. Sizes of object

The experimentally produced forceps were also used in a force measurement experiment. Figure 2 shows a photograph of a blood vessel model made up of silicon rubber 0.3 mm, 1 mm, and 2 mm in diameter. Figure 3 shows the enlarged forceps to hold the blood vessel model. The linear actuator moved the syringe in accordance with a position command issued from a personal computer and supplied water to the bellows tube of the forceps to 0.05 ml by

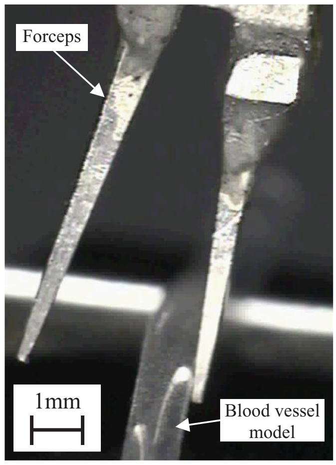


Fig. 3. Forceps holding the blood vessel model.

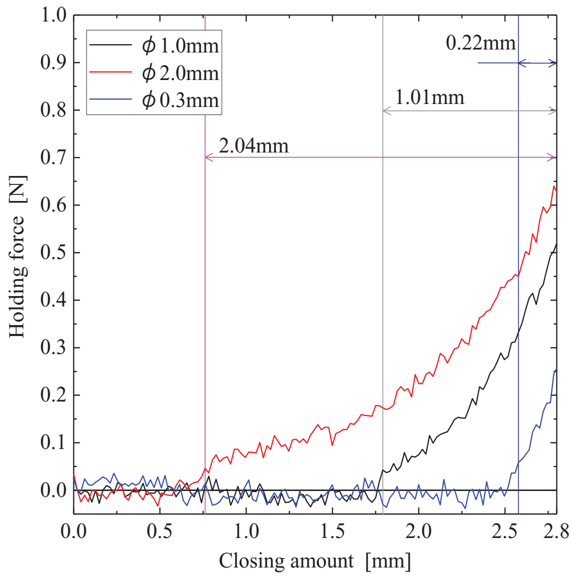


Fig. 4. Measurement force holding object of different sizes.

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