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Organ Dissection Training System with Elastic String and Flexible Sheets

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Abstract

In laparotomy in the field of abdominal trauma surgery, the layers of the intestinal tract and surrounding tissues are dissected to expose target organs and blood vessels. In this operation, a surgeon relies on tactile information obtained from the fingers in the absence of visual information, and the resistance is small when the fingers enter the appropriate dissection site, while the response changes when the fingers enter the inappropriate site due to interference with the ureter and other organs. In this paper, we developed and evaluated a prototype system that combines an elastic string and flexible sheets to practice redoing the operation by recognizing interference when fingers enter an inappropriate dissection site. The results suggest that the system can be applied to training to learn the tactile sensation of fingertips in case of inappropriate dissection.

CCS Concepts

• ***Hardware*** → *Sensors and actuators; Haptic devices;* • ***Computing graphics*** → *Virtual reality;*

1. Introduction

In recent years, the number of operations in the field of trauma surgery for the torso has been decreasing due to advances and the spread of non-surgical treatment for patients with severe trauma [SM05]. As a result, there are fewer opportunities for young doctors and trainees to learn surgical techniques through on-the-job training (OJT) in actual clinical settings, and off-the-job training (Off-JT), which allows them to repeatedly practice the key points of techniques, is becoming increasingly important as an alternative. There are examples of cadaver training using donated bodies and training using animal organs, but these are not widely available due to ethical issues, the large cost required for implementation, and the inability to train repeatedly. Against this background, the application of training systems based on Virtual Reality (VR) technology is expected.

In open abdominal surgery on patients with massive intra-abdominal bleeding due to trauma, to achieve effective hemostasis, it is necessary to properly dissect and rotate the organs covering the bleeding inferior vena cava to expose the hemostasis site. When the doctor is dissecting the organ, he inserts his fingers into the area that has been cut open with the electric scalpel and dissect the adhesions between the layers that the organ and surrounding tissue. In addition, if the doctor inserts the fingers in the inappropriate dissection site, they will be able to tell that they have made a mistake by feeling the ureter. Because the fingers are hidden by the organs, they cannot rely on visual information, and experience is necessary to carry it out accurately.

So far, research has been conducted on the development of surgical simulators using VR technology, and on analyzing the movements of surgeons using optical motion capture and force sensors [SSG*24]. However, there is almost no visual information during dissection, and the surgeon dissects the adhesions between organs and tissues while checking the tactile sensation with their fingertips, but there is no way to reproduce this tactile sensation at the same time. In addition, there is no established method for sensing the movement of a hand being hidden.

2. Proposed Method

We propose a system that can be used to practice organ dissection in abdominal vena cava hemostasis surgery. The system can present a tactile sensation similar to that of dissection, and can also evaluate dissection operation by quantitative measurement, while presenting the tactile sensation of the ureter as a criterion for judging errors.

In this system, the tactile presentation of organs and tissues is carried out using materials selected based on the subjective evaluation of trauma surgeons. A rubber sheet that mimics the ascending colon and retroperitoneum is placed on top of a gel sheet that mimics the surrounding tissue, such as fat, and a elastic string that mimics the ureter is used to present the sense of touch Figure 1. The gel sheet was placed on a flat base to recreate the conditions that make it easy to dissect after cutting with an electric scalpel, and the rubber sheet longer than the base was folded and placed on top of it. The adhesion of organs and tissues is reproduced by the adhesion of two types of sheets, and by inserting the fingers

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between them, it is possible to present the sensation of dissecting them. Furthermore, the elastic string was threaded through the inside of the rubber sheet to recreate the situation where, just like in the real operation, the ureter is not directly touched, but the ureter can be felt through the surrounding tissue. The elastic string can be moved left and right using an electric slider so that the presence or absence of the ureter can be presented. In addition, by measuring how the way of touching changes according to the tactile sensation of the ureter, it is also possible to provide feedback on the way of touching, so a 6-axis force sensor was attached to one end of the elastic string. In addition to presenting haptic information, we have also developed a system that combines visual presentation using a head-mounted display (HMD).

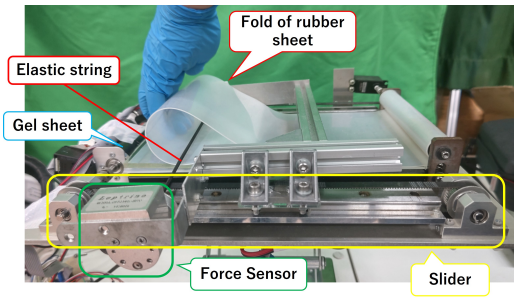

Figure 1: *System overview*

3. Prototype Evaluation Experiment

3.1. Experiment Summary

In this paper, as an evaluation of the developed proto-type system, we presented the following two patterns in an experiment, assuming the organs dissection in open surgery in the case of massive intra-abdominal bleeding.

1. Pattern of dissection with the appropriate approach
2. Pattern of dissection with the inappropriate approach

The evaluation items were whether the participants in the experiment were able to notice contact with the elastic string simulating the ureter and return to the starting point, and the force acted to the elastic string at that time was measured.

3.2. Results and discussion

The experiment was conducted with one trauma surgeon with extensive experience in this procedure and one resident, and three healthy adult males in their 20s with no visual or walking impairment and no history of VR sickness (with no experience of this operation).

Of the three participants (ID01-03) who had no experience of this operation, only ID01 was able to correctly judge the last two times, while in the first three times, he continued to dissect without noticing the interference between the elastic string and his fingertips. Figure 2 shows a box-and-whisker diagram of the mean value of the component of the force time series data in the direction of the extension of the elastic string for the first half of the trial and the second half of the trial. Mann-Whitney's U test, a nonparametric test, was used to compare the values for each participant. The significance level was set at 0.05 for each participant. The results showed a significant difference at $p<0.001$ for all participants, indicating that the participants were more careful with the dissection to minimize the force acted to the ureter.

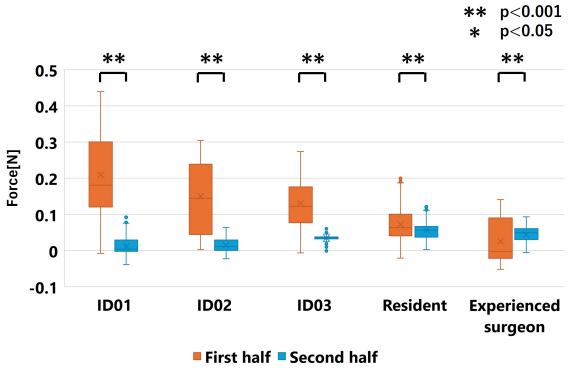

Figure 2: *Average value of force of Z-axis component*

In addition, in the open-ended questionnaire after the experiment, doctors gave positive comments such as "it feels similar to the actual ureter" and "it is useful for training to dissect while paying attention to the feeling of the fingertips". This shows that the tactile sensation of the ureter can be sufficiently reproduced, and it is also suggested that this method can be used to practice dissection operations in Off-JT as a way of learning the feel of the inappropriate dissection site.

4. Conclusion

The results of this study suggest that the proposed prototype system can adequately reproduce the tactile sensation of the ureter and may be used for learning the tactile sensation of the inappropriate dissection site. It was also found that there is a possibility of capturing movement transformation from the force sensor values for manipulations in which the fingertips are hidden. However, it is necessary to increase the sample size in order to obtain a correspondence with specific movements and to obtain key points to fill the gap with the skills of the trauma surgeons with extensive experience.

Acknowledgements

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