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Effect of an Encounter-Type Haptic Device on Forceps Position Reproducibility in Laparoscopic Tracking Training

Akinobu Morishima[†1], Akihiro Terashima[1], Kazutaka Obama[2], Yoshiharu Sakai[2], Taro Maeda[1] and Hideyuki Ando[1]

[1]Graduate School of Information Science and Technology, Osaka University, Osaka, Japan
[2]Department of Surgery, Graduate School of Medicine, Kyoto University, Kyoto, Japan

Abstract

This paper describes an improvement to our previously proposed laparoscopic training system that was designed to improve surgical skill transmission by allowing surgical trainees to replicate the movements of skilled surgeons displayed on a monitor. However, we found that with this system, the precision of followability in the depth direction was low in comparison with that on the monitor in the planar direction. Herein, to improve the reproducibility of the forceps position and present clues for depth perception, we provide learners with haptic feedback by reproducing the viscera wall using an encounter-type haptic presentation device.

CCS Concepts

• ***Hardware*** →Haptic devices;

1. Introduction

Laparoscopic surgery is performed by inserting a camera and forceps into the abdominal cavity. It is less invasive than laparotomy surgery; thus, patient burden is minimal. However, there is an insufficient number of expert doctors due to the high difficulty of operation. Therefore it is currently desired to develop an efficient learning method.

Here, we proposed the OI-OTRE and the OI-TORE Advance system to address the shortage of skilled surgeons [DHH*13][NKYH17]. In the original OI-TORE system, which let trainees learn efficiently by following the forceps movement of an expert surgeon, training was limited to laparoscopic ligation and suturing; however, with OI-TORE Advance, it is expected that comprehensive surgical skills can be obtained by tracking an actual surgery. In actual surgical training experiments using animals, it gave a great effect on skill acquisition, but there was a lack of learning in the depth direction, which is difficult to understand with visual feedback [NKYH17].

The OI-TORE Advance system implements an encounter-type haptic device to supplement lost depth information to the proposed system.

2. Reproducing organ position with an encounter-type haptic device

With the original OI-TORE Advance the animation of the surgery was two-dimensional; thus, the trainee could not obtain depth information from the monitor. In addition, the original system did not employ tactile feedback. As a result, these factors hampered the effectiveness of the system.Therefore, the system proposed in this research tried to reproduce the position of the internal organs using Falcon as a limited encounter-type haptic device [WM93] in order to obtain depth information from haptic feedback. This system shown in Figure 1. There is currently no evidence that haptic feedback is effective in training using a laparoscopic VR simulator [LER*09]. In this research, we aim to accuire the depth information ,which is difficult to obtain from the 2D monitor, by letting the forceps hit the virtual internal organ wall rather than reproduce the haptic sense. In particular, when the expert's forceps are in contact with the real organ wall in the actual surgical movie, the trainee foreceps tracing the experts forceps simultaneously hits the virtual internal organ wall, so that trainee could obtain the depth information lost in the 2D monitor.

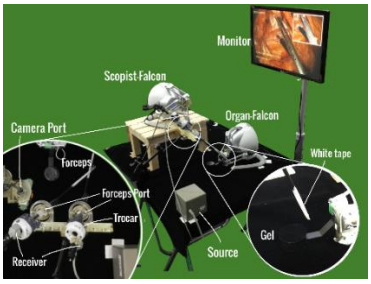

Figure 1 Names of the each device in the system

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3. Experiment

Since it was found that it is difficult to acquire depth information only with visual feedback in OI-TORE Advance, we attached an encounter-type haptic device. Therefore, the purpose of this experiment is to investigate the influence on the depth reproducibility of the forceps position with the encounter-type haptic device in order for effective training.

In an experiment, we used a video showing an inside approach of sigmoid mesenterium and confirmation of the gonadal arteriovenous vein as the training material. This scene includes many probing tasks (11 tasks/min), such as pressing forceps against the tissue to determine reaction force and the state of deformation of the tissue tactually and visually. Probing is a technique to monitor depth.

In our experiment, we compared OI-TORE Advance with and without an encounter-type haptic device. Both conditions were evaluated 16 times with a 1-min break between trials. Note that the participants did not have medical expertise, i.e., they had no knowledge of laparoscopic surgery. in 20s male, three participants for each condition.

In the experiment, the coordinates of the tip of the forceps operated by each subject on the right hand are measured. For the tip position of the right-hand forceps, the error from the position as the example is calculated as RMSE and compared between the each subjects. The example tip position of the right forceps was measured by preparing a still image every second for the recorded video, which we used for the experiment, and superimposing the forceps on each moment.

3.1 Experimental results

The position error amount was calculated for depth direction on the screen, at each second of one minute in the video. The RMSE for each subjects are shown in Figure 2. In this figure, the horizontal axis is the number of trials and the vertical axis is the error amount of depth direction on the screen.

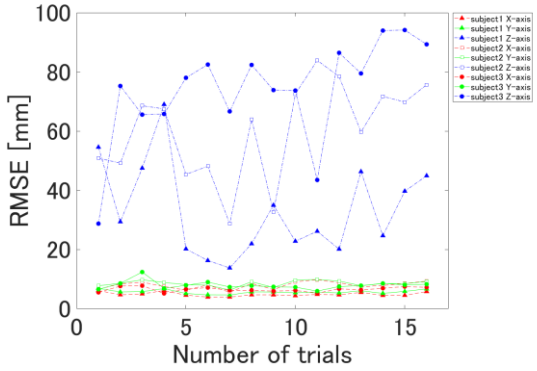

Figure 2 Error of depth direction about each subjects

The group with the encounter-type haptic device have a tendency to demonstrate smaller error compared to the group without the device. In the group that did not use the encounter-type haptic device, the subjects learned at the position in the incorrect depth direction on the screen. Moreover, the position in the incorrect depth direction varied among individuals. Therefore, the encounter-type haptic device contributes to improving the reproducibility of the forceps in the depth direction on the screen.

4. Discussion&Conclusion

The group with the encounter-type haptic device showed smaller error than the group without the encounter-type haptic device. Thus, by using tactile feedback to represent the position of virtual internal organs, the trainee was able to acquire accurate depth information.

In the existing OI-TORE Advance laparoscopic surgery training system, it is difficult to acquire screen depth information. Therefore, in this study, the internal organ position was reproduced in the OI-TORE Advance system using an encounter-type haptic device. The experimental results indicate that the error and variation of each subject were reduced relative to reproducibility in the depth direction when tracking forceps using the encounter-type haptic device. Therefore, the proposed system provides more accurate depth position information.

Acknowledgements

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