Endoscopic Surgery Training Using Full HD Glass-less Stereoscopic Displays

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ABSTRACT

We realize an endoscopic surgery training system using a full HD glass-less stereoscopic display based on time-division multiplexing parallax barrier. Stereoscopic live action movie is displayed by using a stereoscopic camera. The result of the experiment shows that the operators can work faster under 3D condition compared with 2D condition.

1 Introduction

Traditional endoscopic surgeries usually use 2D displays to show internal organs and vessels of patients. Medical doctors are required to have the ability to construct and manipulate 3D images in their minds while observing 2D images. Therefore, endoscopic surgery requires more advanced technique and abundant experience than conventional open surgery.

To solve this problem, expansion of endoscopic surgery training system is necessary. The procedure itself can be improved by training repeatedly. However, it is difficult to cultivate the skill to grasp anatomical three-dimensional structure only with a 2D image.

To solve this problem, a surgical system combined with a 3D display has been proposed. However, most of the medical 3D displays on the market require the doctors to wear 3D glasses to view the 3D image, where the doctors cannot make eye contact with one another. The distance between the tip cameras of the 3D videoscope used in the existing 3D surgical system is fixed at 3 mm. On the other hand, when the average binocular distance of a human is 65 mm and the camera is usually expected to be located 45 mm away from the organ in focus, the stereoscopic image includes small parallax as the viewpoint is substantially too far as shown in Fig.1. Therefore, it is difficult to give the observer a sufficient stereoscopic effect, which is equivalent to viewing from a distance of 975 mm.

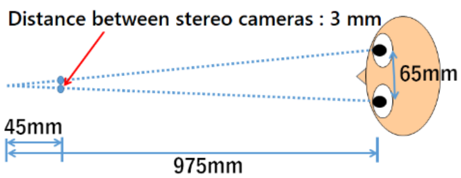

Fig. 1 Parallax of the existing 3D surgical system

In this paper, we will construct an endoscopic surgery training system using a high-resolution autostereoscopic display. With the constructed system, we evaluate the usage of 3D images and the improvement of operability due to parallax intensity.

2 Glass-less Stereoscopic Display

This section describes the glass-less stereoscopic display used in our system.

Parallax barrier method is a simple and well-known method to attain glass-less 3D. However, it has poor spatial resolution issue due to its slit structure.

Time-division multiplexing parallax barrier is proposed to solve the resolution problem by alternating the barrier pattern and the interleaved stereo image in 120HZ synchronously,[1),2)] which is shown in Fig. 2.

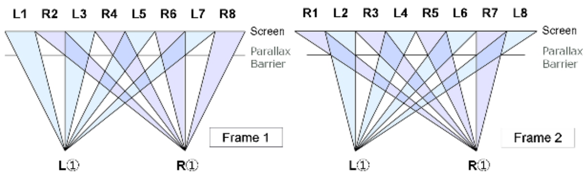

Fig. 2 Time-division parallax barrier

To expand the viewing zone, Zhang et al. proposed time-division quadruplexing parallax barrier, which can keep wide viewing zone with less crosstalk[3)-8)]. This method shows 2-viewimages by a 4-view system as Fig. 3. The left-eye image “L” is shown at pixels A and B, and the right eye-image “R” is shown at pixels C and D, so that we obtain 4 viewpoints aligned as “LLRR”. Observer can percept 3D image without crosstalk while the left eye is between points A and B, and the right eye is between the points C and D.

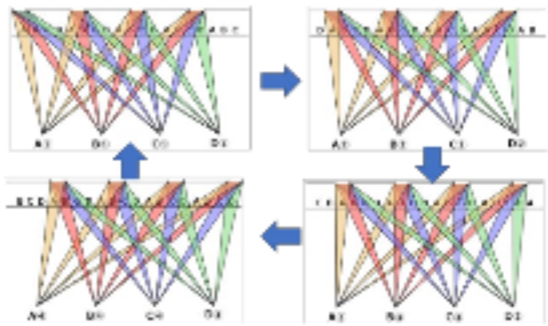

Fig. 3 Time-division quadruplexing parallax barrier

3 Endoscopic Surgery Training System

This section describes the endoscopic surgery training system used in this paper, which is constructed as shown in Fig. 4.

In order to keep a distance between the installed 3D camera and training box, two plane mirrors are placed. The first mirror should be installed 6 cm apart, 6 cm high, and at an angle of 53° to the horizontal. The second mirror should be installed directly above the first one at a height of 31.3 cm so that it may be at an angle of 28° to the horizontal.

The 3D camera installed at a height of 12.5 cm in the back of the training box and at an angle of 30 °upward. By double-folding with plane mirrors in this way, the virtual image of the camera is 13° tilted, resulting in that the 3D camera is 97.5 cm away from the surgical training box optically. By ensuring this distance, the parallax amount presented by the existing 3D endoscopic surgery system is reproduced.

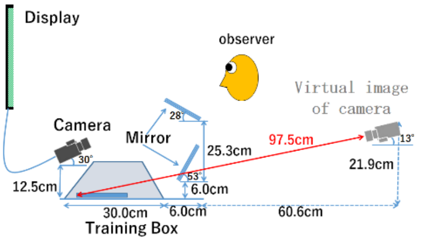

Fig. 4 System configuration

4 Experiments and Results

This section describes the comparative experiments with the constructed endoscopic surgery training system.

4.1 Comparative experiment between 2D Condition and 3D Condition

The following comparative experiments were conducted to evaluate the improvement of operability by using 3D images compared to the conventional 2D display. While observing the display, each subject used two forceps to move four rubber bands, each originally placed at four protrusions on the left side of the training box, to the same-colored protrusions on the right side, and then back to the original positions. The subject was asked to hand over the rubber band in the air from one forcep to the other on the way. For each subject, we measured the time required for the above work under 2D and 3D conditions. A scene in the experiment is shown in Fig. 5.

The experiment above was conducted on eight subjects, all male in their 20s to 40s with corrected visual acuity of 0.7 or higher. Half of the eight subjects operated under 2D conditions first, and the remaining performed operations under 3D conditions first. Fig. 6 shows the operation time of each subject under 2D and 3D conditions, and Fig. 7 shows the average. Paired T-tests with the data in Fig. 6 show statistical significant difference with p = 0.021, and we can conclude that the operability is improved by using 3D images instead of 2D images.

Fig. 5 Training task of operability comparative experiment between 2D condition and 3D condition

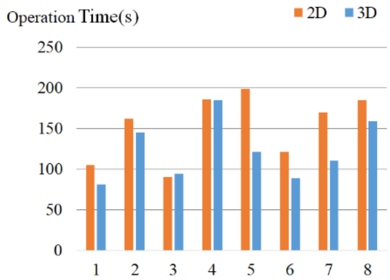

Fig. 6 Result of experiment comparing operation time between 2D and 3D conditions

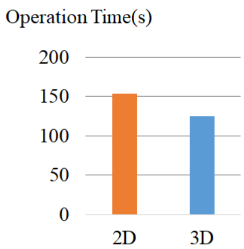

Fig. 7 Average of operation time

4.2 Comparative experiment under different amount of parallax

The following comparative experiments were conducted to investigate the difference in operability depending on the amount of parallax. The task of each subject is almost the same as mentioned in Section 4.1. The difference is that they will repeat the work in four experimental conditions under different amount of parallax.

Under parallax condition I, the virtual image of the camera is 97.5cm away from the operating space, which is the same as the amount of parallax presented by the existing 3D endoscopic surgery system. In conditions II to IV, the 3D camera was moved closer to the plane mirror by 5cm repeatedly. As a result, the optical distances were 92.5cm, 87.5cm, and 82.5cm respectively, and the amount of parallax increased accordingly.

The experiment was conducted on 10 male subjects in their 20s to 40s with corrected visual acuity of 0.7 or higher. Half of the 10 subjects were tested from conditions I to IV and the remaining five subjects were test from conditions IV to I. Fig. 8 shows the operation time of each subject under the four parallax conditions, and Fig. 9 shows the average. Table 1 shows the results of paired T-tests for each value in Fig. 8.

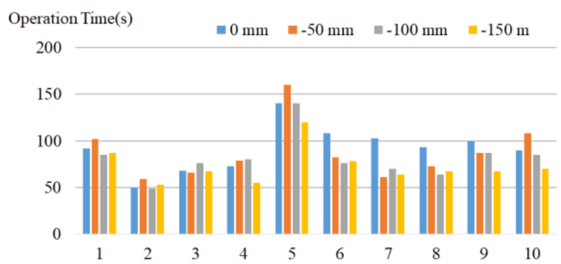

Fig. 8 Result of experiment comparing operation time under 4 kinds of parallax

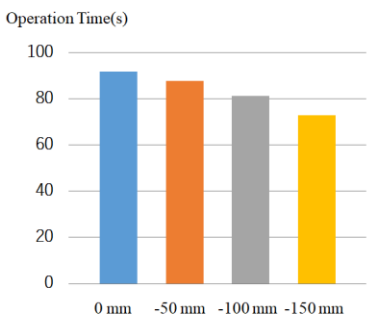

Fig. 9 Average of operation time

Table 1 Result of T test (p values)

	0 mm	−50 mm	−100 mm	−150 mm
−150 mm	0.002	0.013	0.056	
−100 mm	0.041	0.091		
−50 mm	0.533			
0 mm				

With the experimental results, it is confirmed that the increase of parallax contributes to the improvement of operability.

5 Conclusion

In this paper, we have constructed an endoscopic surgery training system using a full HD autostereoscopic display. We have succeeded in presenting the 3D image of surgery to observers in real time while showing the surgical operation space. Two comparative experiments were conducted with this system and it was confirmed that the operability was improved by using 3D images compared to the conventional 2D display. Furthermore, it was confirmed that the operability was improved by setting the parallax larger.

References

[1] Ken Perlin, Salvatore Paxia, Joel S. Kollin. An Autostereoscopic Display. Proceedings of the 27th Annual Conference on Computer Graphics and Interactive Techniques; 2000: 319-326.

[2] Hyo Jin Lee, Hui Nam, Jang Doo Lee, Hyoung Wook Jang, Myoung Seop Song, Beom Shik Kim, Ja Seung Gu, Chan Young Park, Kyung Ho Choi. A High Resolution Autostereoscopic Display Employing a Time Division Parallax Barrier. SID Symposium Digest of Technical Papers 2006; 37: 81-84.

[3] Q. Zhang, and H. Kakeya. An autostereoscopic display system with four viewpoints in full resolution using active anaglyph parallax barrier. Proc. SPIE 8648; 86481R:1-10.

[4] Q. Zhang and H. Kakeya. Time-division multiplexing parallax barrier based on primary colors. Proc. SPIE 9011; 90111F.

[5] Q. Zhang and H. Kakeya. A high quality autostereoscopy system based on time-division quadplexing parallax barrier. IEICE Trans. Electron; E97-C(11): 1074-1080.

[6] Q. Zhang and Kakeya, H. Time-division quadruplexing parallax barrier employing RGB slits. Journal of Display Technology; 12(6): 626-631.

[7] H. Kakeya, K. Okada, and H. Takahashi, “Time-division quadruplexing parallax barrier with subpixel-based slit control,” ITE Trans. on MTA, Vol. 6, No. 3, pp. 237-246 (2018)

[8] H. Kakeya, A. Hayashishita, and M. Ominami, “Autostereoscopic display based on time-multiplexed parallax barrier with adaptive time-division,” Journal of the Society for Information Display, Vol. 26, pp. 595-601 (2018)