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Application of high-resolution autostereoscopic display for medical purposes

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Abstract

In this paper we propose an application of high-resolution autostereoscopic display for medical purposes. To realize high resolution autostereoscopy for medical applications, we use time-division multiplexing parallax barrier technology. Moreover, we evaluate the merit of using the autostereoscopic display we propose based on subjective experiments. From the results of the subjective experiments, we find out that 3D image is perceived to have a higher resolution compared with the 2D image.

Introduction

Parallax barrier is one of the simplest methods to realize autostereoscopy. In the conventional parallax barrier systems, however, the viewing zone maintaining stereoscopy is narrow, and the resolution of image is lower than that of the two-dimensional displays. Though the resolution is maintained if time-division duplexing parallax barrier is applied [1,2], the viewing zone without crosstalk is limited.

To deal with the viewing zone issue, head-tracking technology has been introduced to follow the viewer's motion [3-6]. By detecting the position of the observer's eyes and changing the pattern of the barrier and the displayed image accordingly, the viewing zone is greatly expanded. Furthermore, Zhang et al. proposed time-division quadruplexing parallax barrier, which shows 2 viewpoints in full HD and holds a wider viewing zone for each viewpoint with less crosstalk [7-10].

Figure 1 shows the configuration of a time-division quadruplexing parallax barrier. In the proposed system the same image is delivered to 2 of the 4 viewpoints, which suppresses emergence of crosstalk when each of the viewer's eyes is positioned between the two viewpoints showing the same image. The theory on the viewing zone free from crosstalk has also been established [11]. According to the theory, the viewing zone in the depth direction is still limited as long as the width of slits and the number of time-division are fixed.

One method to expand the viewing zone is to widen the width of slits in the parallax barrier [11,12]. When we apply the stereo pair to the viewpoint A(L), B(L), C(R), D(R), we obtain 4 viewpoints aligned as "LLRR", so that when the left eye is between points A and B, and the right eye is between the points C and D, 3D images without crosstalk are observed.

Based on this system, shift of the slits by subpixel unit has been introduced, which realizes finer control of barrier slits to reduce the crosstalk [13]. Subpixel shift is enabled when the slits are slanted by tan^{-1} 1/3. To reduce the moiré caused by the layered panels without destroying stereoscopy, a lenticular lens that diffuses light only along the inclined slits is inserted as shown in Fig. 2.

Further fine shift of slit is realized by a slanted barrier slits whose inclination angle tan^{-1} 1/6 [14]. Here the directional diffuser is set so as to diffuse the light in the same direction as the inclined barrier slits. In this system, the slit moves by 1/2 subpixel in the horizontal direction when the slit is shifted by 1 pixel in the vertical direction. When the minimum shift unit is half the original size, the viewing zone without crosstalk is expanded due to the fine tuning of barrier pattern. The viewing zone in the depth direction has also been expanded by changing the number of time-division adaptively [15].

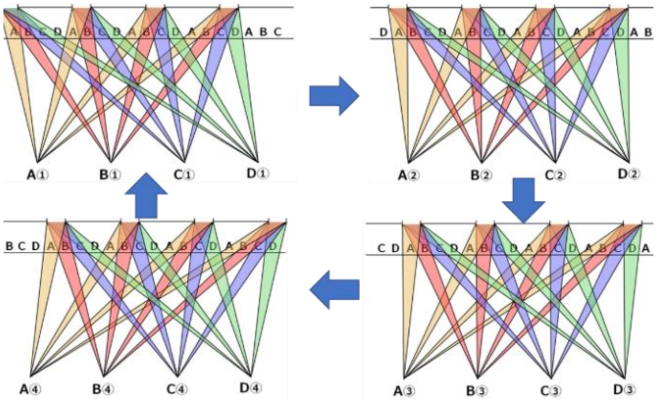


Figure 1. Quadruplexing Parallax Barrier

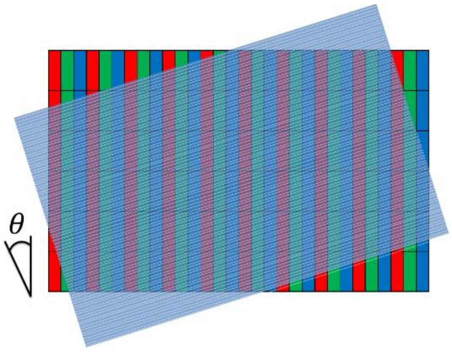


Figure 2. Inclined directional diffusion

As described above, a 3D display with time-division multiplexing parallax barrier attains high-resolution autostereoscopy with a wide viewing area. To take advantage of these features, we propose an application of high-resolution autostereoscopic display for medical purposes in this paper. Moreover, we evaluate the merit of using the autostereoscopic display we propose based on subjective experiments.

3D and 2D resolution comparison experiment

To measure the effect of resolution perception when we use a 3D display, we compare the 3D imaging with 2D imaging by projecting it on the 3D display we have developed based on time-division multiplexing parallax barrier. 3D images have more information than 2D images since two different images are shown to each eye. Therefore, a 3D image with binocular parallax may be perceived to have a higher resolution by the viewer even when the resolution is the same as that of the 2D image.

Experiment

To test the above hypothesis, we conducted the following experiment. We showed each subject both 2D and 3D images at the same time and asked whether the resolutions were the same or not. First, we displayed a low-resolution 3D image and the original high-resolution 2D image top and bottom, and asked the subject to compare the resolution. We gradually increased the resolution of 3D image. Each time the subject was asked if the resolutions of the two images were equal or not.

The image we used the stereo image “Adirondack” for this experiment, which was obtained from Middlebury Datasets. Since the purpose of this experiment was to compare resolution in detail, we used an image including high frequency components, while the binocular parallax was small and gradual.

To compare high-resolution image with low-resolution image, we created low resolution images by using Fourier transform. The procedure is shown in Figure 3. First, we applied Fourier transform to the image. Second, we masked the high frequency components. The step of mask size is shown in Table 1. Third, we performed inverse Fourier transform to generate the low-resolution image. Finally, we cut out the part with small and gradual parallax to be presented in the experiment.

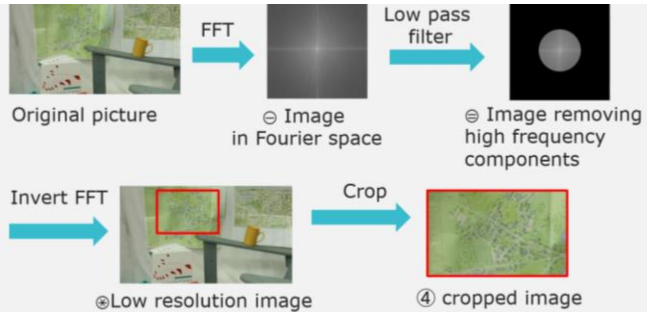
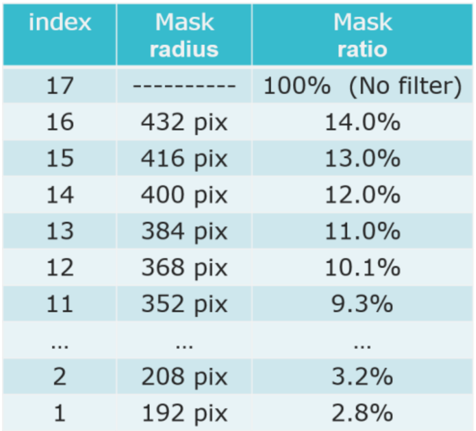


Figure 3. Process to make a low-resolution image

The concrete experimental procedure using the above prepared low-resolution images are as follows. The autostereoscopic display used for this experiment had a 24 inch screen with the resolution of 1920 x 1080 pixels. Twelve subjects in their 20s and 30s participated in the experiment. First, as a control experiment, we showed a pair of 2D images with different resolutions to each subject. We gradually increased the size of mask applied to the low resolution 2D image till the subject answered the subject answered that the top and bottom images had the same resolution. In order not to be affected by the positions of the two images, we showed the low-resolution image at the bottom to 6 subjects, while we showed the low-resolution image on top to the other 6 subjects.

Second, we showed a low-resolution 3D image and the high resolution 2D image and asked each subject to compare the resolutions. Again, we gradually increased the size of mask applied to the low-resolution 3D image, while the resolution was increased till the subject answered that the top and bottom images had the same resolution. Here again the position of the paired images was swapped to avoid the influence of positioning difference.

Table 1 Steps of mask sizes



index	Mask radius	Mask ratio
17	----------	100% (No filter)
16	432 pix	14.0%
15	416 pix	13.0%
14	400 pix	12.0%
13	384 pix	11.0%
12	368 pix	10.1%
11	352 pix	9.3%
…	…	…
2	208 pix	3.2%
1	192 pix	2.8%

Result

Figures 4 and 5 show the results of the experiments. These graphs show the mask numbers when the subjects perceive no difference in resolution. Compared with 2D, the subjects answered that the resolution was the same even when the mask size was smaller, which means that the 3D image is perceived to have a higher resolution compared with the 2D image. This result supports our hypothesis. Subjects in group A are shown 3D image on the top and 2D image on the bottom, while those in group B are shown the images in the opposite order.

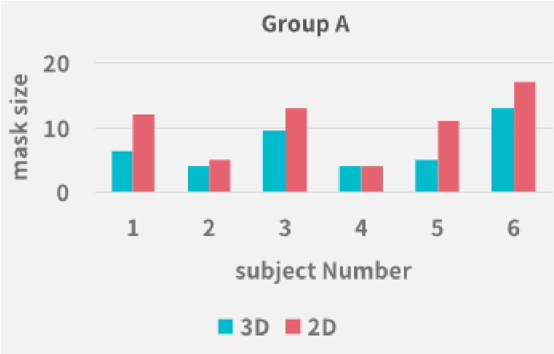


Figure 4. Experimental results of group A

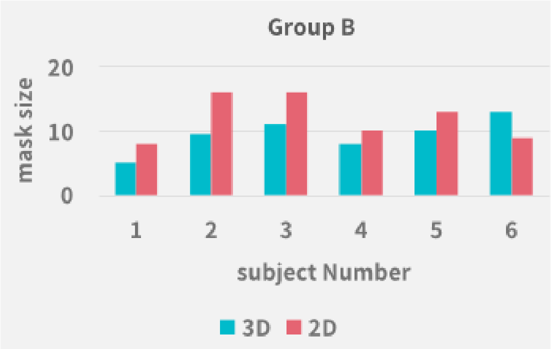


Figure 5. Experimental results of group B

Proposed application

In this section we introduce medical application of the high-resolution 3D display we have developed. As shown Figure 6, the software shows a stereo pair of the volumetric image presented side by side, which is converted to an interleaved image with parallax barrier by the display driver. Since the rendering software is connected to a head tracking device, a 3D image with proper motion parallax is provided to follow the viewer's motion. Besides, this software has various functions required when performing a surgical operation, which are described in the following subsections.

Figure 6. A screen shot of the software developed for 3D medical imaging

Annotate CT images with the help of AI

The developed software can automatically draw lines by identifying boundaries with the help of image processing technology. As shown Figure 7, the user can easily and intuitive annotate a specific part, like a lesion, of the CT image with the help of this software.

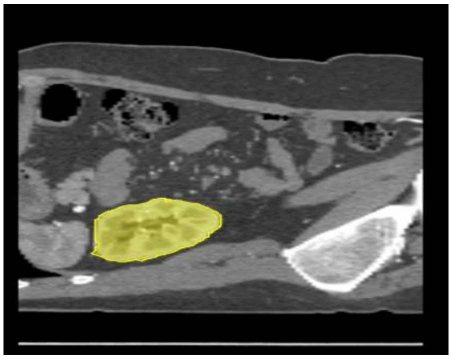


Figure 7. Annotation of kidney with the proposed software

Simultaneous drawing of multiple data

As shown Figure 8, the annotated labels and the volumetric CT data can be shown simultaneously with this software. This feature is useful when a doctor needs to check the position of the lesion and the position of the organ simultaneously.

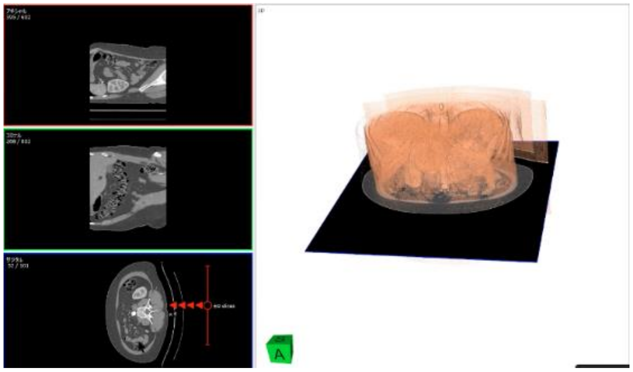


Figure 8. Volumetric imaging with the developed software

3D image drawing using head tracking

This software operates with the autostereoscopic display we have developed. A side by side image generated by this software is shown on the left-hand screen. As the viewer moves his head, the model moves accordingly to show the proper motion parallax, as shown in Figure 9. This enhances the doctor's understanding of the 3D structure of human body. On the right-hand side, the autostereoscopic display is placed, which show the stereoscopic image generated by the side-by-side image provided by the software. We have confirmed the 3D medical image is properly observed with the autostereoscopic display.

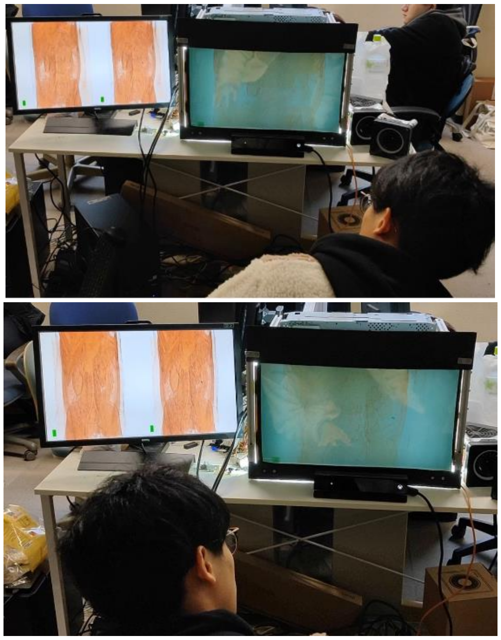


Figure 9. Observation of a volumetric CT data with the full-HD autostereoscopic display based on time-division multiplexing parallax barrier.

Conclusion

In this paper we have compared perceived resolution of 3D and 2D images provided by a full-HD autostereoscopic display. The result of the experiments indicates that the 3D image is perceived to have a higher resolution compared with the 2D image. We have developed a medical 3D software that works with the full-HD autostereoscopic display to take advantage of the high resolution.

Acknowledgement

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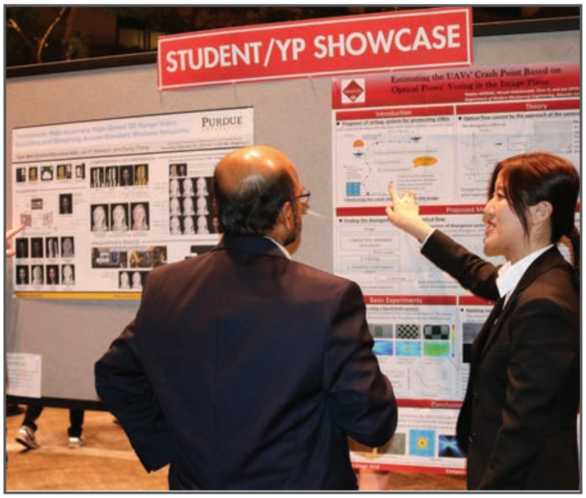
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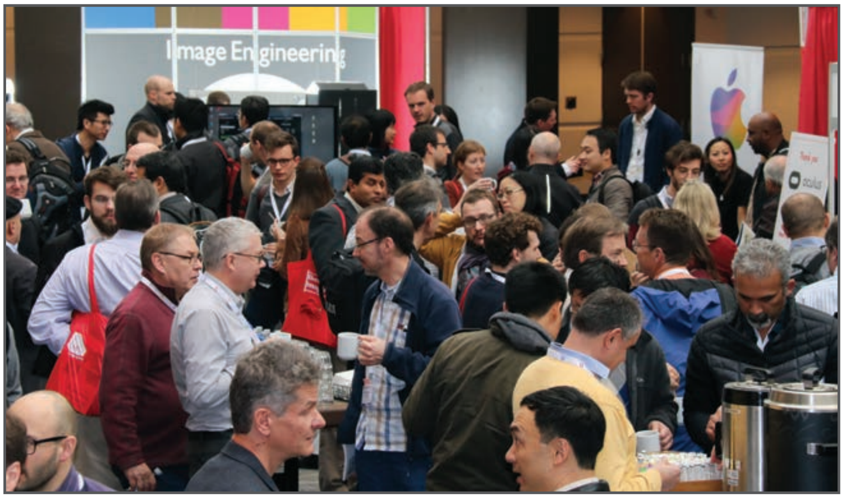
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My first working AR prototype
Today's platforms
Ubiquitous consumer AR