Natural 3D (N3D) Display Technology and its Medical Application for DICOM Image Viewer

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Keywords: 3D, light field display, volume rendering, DICOM

ABSTRACT

We have developed N3D display that is one of the light field displays with high spatial and angular resolution, less image blur and correct depth reproduction. In this paper, we propose a N3D Digital Imaging and Communications in Medicine (DICOM) image viewer as a prototype. The N3D DICOM image viewer can provide correct depth 3D image in real time operation, so it's expected to be used for wider applications in future.

1 Introduction

3D displays are an attractive technology and these applications used in many fields especially for movies so far. In recent years, it is also expected to use for Virtual Reality, Augment Reality and related applications in the market. However, a conventional 3D display has several issues, e.g. vergence-accommodation conflict (VAC). VAC causes discomfort and fatigue for the viewer [1], so it has a limitation for practical usages.

We have developed a N3D display that can cope with issues of conventional 3Ds and achieve high spatial and angular resolution, VAC free stereo viewing and so on.

In this paper, we propose a prototype of N3D DICOM image viewer for future application. In the DICOM image viewer, it's important to perceive correct depth for 3D images, therefore we prototyped system and confirmed the performance.

2 N3D technology

Our N3D display has good 3D performance as mentioned above without moiré by optimizing optical design of the display.

Following section introduces principle of our original algorithm used for the N3D display.

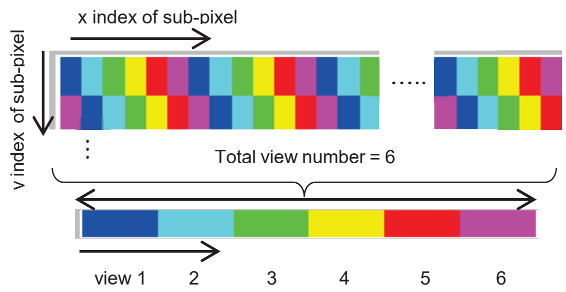
2.1 High spatial and angular resolution

Conventional 3D displays have a tradeoff between a number of views and a spatial resolution. Table 1 shows a summary of spatial and angular resolution between conventional 3Ds and N3D displays. For conventional 3D displays, perceived resolution of a 6-views 3D display decreases to 1/6 of original display resolution.

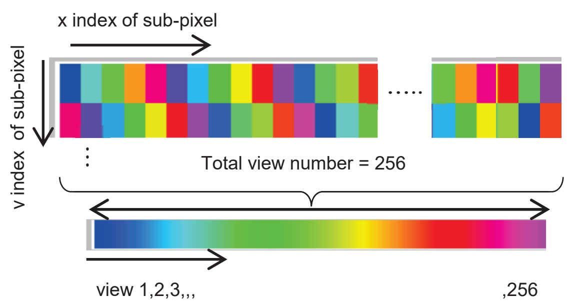
On the other hand, our N3D display can achieve 256 views with full HD perceived resolution from a 4K2K display by using a digital sub-pixel rendering. It is similar to a dithering technology that enhances the number of gray scale even though the number is small. Figure1 (a) shows a concept of normal pixel rendering and Fig. 1 (b) shows a case of digital sub-pixel rendering. The normal pixel rendering keeps an order of several view numbers, so total view number is also limited. On the other hand, in our digital sub-pixel rendering, the order of view numbers arranged with dithering consideration in sub-pixel level. Using this method, we can get many view numbers over whole area even if it has just a several views in local area.

Table 1 Comparison of conventional and N3D display

	Conventional	N3D
Number of views	6	256
Input resolution	4K	4K
Output resolution	Around SXGA	Around FHD



(a) Normal pixel rendering



(b) Digital sub-pixel rendering

Fig. 1 Digital sub-pixel rendering algorithm

2.2 Less image blur

Image blur is one of the typical issues for 3D displays. So we have developed a special algorithm to reduce image blur in 3D space.

There are several views that go into one pupil (=desirable views) and some visible views near the pupil (= undesirable views) that will cause the image blur due to an exceeded parallax as shown in Fig. 2. Therefore, we modify undesirable visible views by optimizing a parallax for each eye pupil. Then each eye will receive views that are more effective, so that the resolution will increase and the blur will be reduced [2].

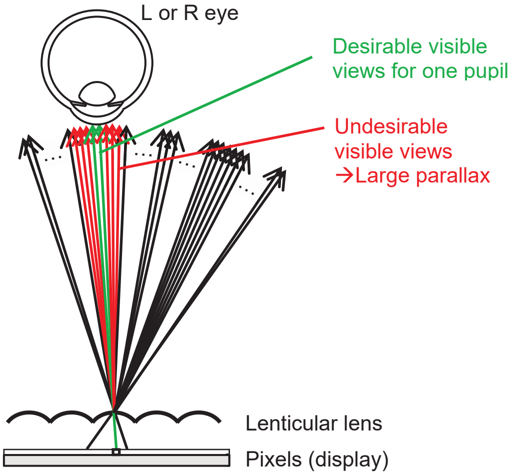
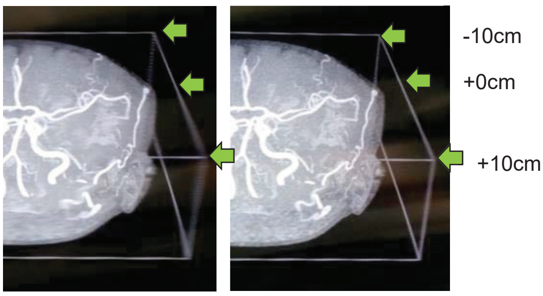


Fig. 2 Visible views for one pupil

Figure 3 shows an example of N3D image with and without image blur suppression technology. A conventional type has serious image blur at +10cm depth, but new algorithm has less image blur in all depth positions.



(a) Conventional 3D (b) N3D

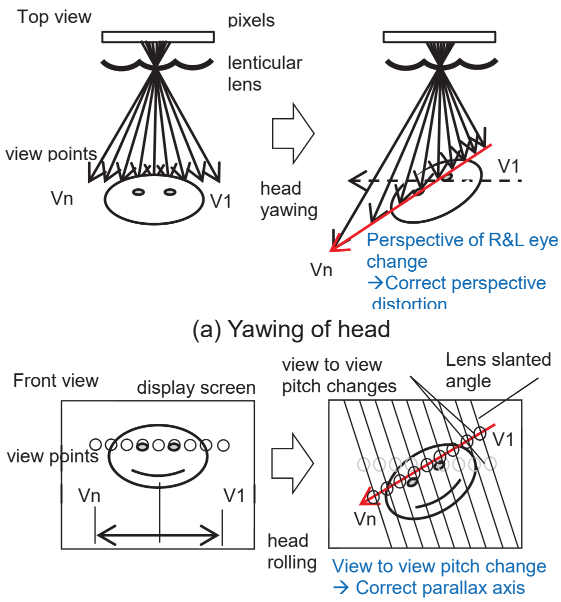
Fig. 3 Comparison of image blur in depth

2.3 Dynamic depth correction

It's limited to reproduce accurate depth in conventional 3Ds, since accurate estimation of depth information needs correct location data of viewer's eyes, e.g. xyz coordinates, even for a light field display.

A dynamic depth correction technology is based on the eyes position and orientation which are obtained by eye tracking camera, so that the system renders suitable light fields in real time. Therefore, we can get accurate depth image in 3D space, which is important for industrial 3D monitors.

We have developed the algorithm and it's used in our N3D display already. This algorithm is applicable to two cases. The first one is a case of yawing of head (Fig. 4 (a)) and another is a case of rolling of the head (Fig. 4 (b)). When we face to the 3D display screen without yawing, the perspective viewpoints in parallel to the screen are correct, so no need to modify the viewpoints based on eye position. But in case of head yawing, they become incorrect because of different distance from the 3D display screen to position of left or right eye. Therefor we need to calculate the correct perspective views based on eye position.



(b) Rolling of head

Fig. 4 Dynamic depth correction

In case of head rolling, view to view pitch is changed comparing to no rolling case because the parallax axis changes. Also, the perspective axis is not horizontal to 3D screen. So we have to calculate the viewpoints from the correct parallax axis.

By combining both cases, the accurate depth image can be reproduced dynamically.

3 Prototype of N3D DICOM image viewer

N3D displays with the eye tracking system can provide correct depth 3D images at any eye position, so N3D DICOM image viewer is one of the promising applications in future.

DICOM is a standard for communication and management of medical imaging information and related data [3] and medical imaging data of Computer Tomography (CT) and Magnetic Resonance Imaging (MRI) consist of typically a few hundreds slice images (= 3D volume data). But current DICOM image viewer mostly displays each slice image one by one as a 2D image, so it's difficult to understand 3D sense of organs. So, we expect that our N3D technology helps the operator to get a 3D sense easier.

We have fabricated prototype system of N3D DICOM image viewer (for research use) and Fig.5 shows the basic data flow. At first, we input the standard DICOM data (CT / MRI), then do the volume rendering [4] with eye tracking information in real time. Finally, we output N3D data frame to Innolux N3D display via normal HDMI or DP interface. We used CPU: Intel core i7 and GPU: Nvidia GTX1080 or RTX3060 in the Windows10 system.

The medical images were provided by the Medical Image Center, College of Medicine, National Cheng Kung University, Tainan, Taiwan. The project was reviewed and approved by the Institutional Review Board of National Cheng Kung University Hospital (number: A-ER-110-165).

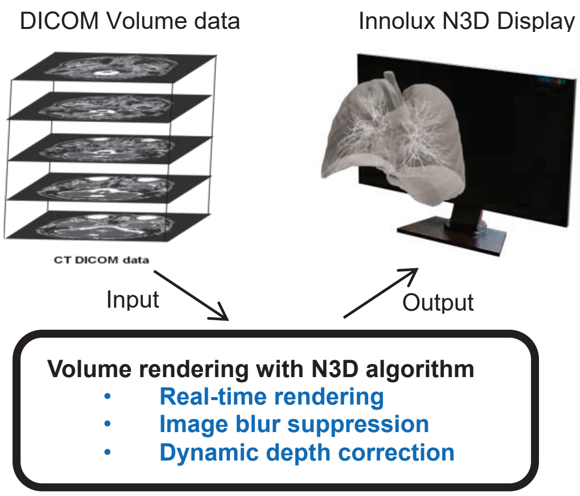


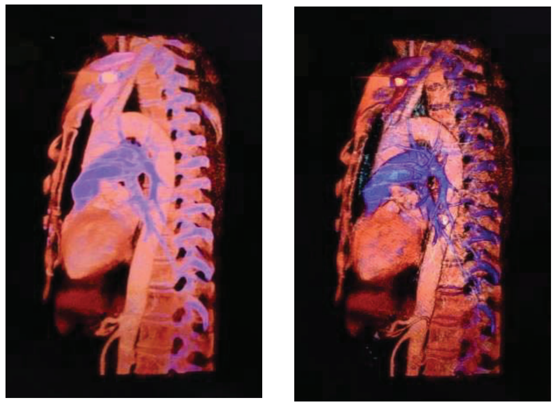
Fig. 5 Basic N3D DICOM image viewer

3.1 Volume rendering technology

This viewer has several view modes: Volume Rendering (VR), Maximum Intensity Projection (MIP) and Multi-Planar Reconstruction (MPR) with 2D / 3D switching. The VR mode is popular for DICOM image viewer and our N3D VR reconstructs the light field in front of you with sufficient resolution and accurate 3D dimension in real time (<16msec). Additionally, we developed advanced VR mode (=VR2) for this viewer. Figure 6 shows sample image: (a) VR mode (basic) and (b) VR2 mode (advanced). VR2 mode simulates specular / diffuse / ambient light reflection of each organ, so VR2 mode can support the 3D perception more. But it is not always necessary because a shadow based on a symptom may be covered by a shadow from a lighting effect, so that operator can select VR or VR2 mode depends on their purpose.

3.2 Segmentation

Segmentation is a function to separate whole volume to each specific organ based on manual or semi-automatic process. Our N3D DICOM image viewer has manual segmentation tools and semi-automatic lung segmentation tool.



(a) VR mode (basic) (b) VR2 mode (advanced)

Fig. 6 Comparative image of VR and VR2 mode

3.3 Result of Prototyping

Table 2 shows features of the prototype of our N3D DICOM image viewer. From this result, we have achieved sufficient resolution for DICOM volume data and it can be reproduced accurate 3D depth image and less image blur. Figure 7 shows comparable photos between conventional 2D and N3D DICOM type. Figure 7 (a) shows 2D and (b) shows N3D image. N3D image seems easy to understand each of organs and to be getting more information in 3D space comparing with 2D image.

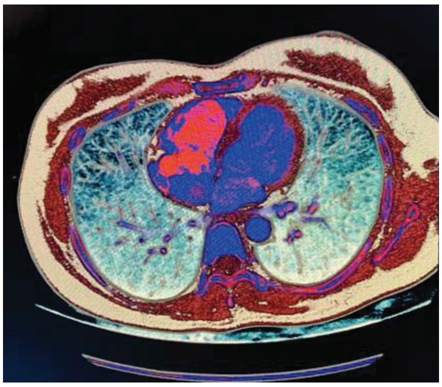
Table 2 Features of the prototype

Display type	LCD (IPS mode)
Display size	27 / 31.5 inch
Input resolution	3,840 x 2,160
Output resolution	Around Full-HD
The number of views	256
VAC	No
Moiré	No
Image blur	Less
High depth accuracy	Yes

For segmentation result, Fig. 8 shows the automatic segmentation result of lung. Green circle area is target nodule after segmentation processing. Blood vessel (pulmonary artery and pulmonary vein), bone and bronchi are separated in the different colors. Now we have eight segmentation slots and the operator can edit and analyze each segment in real 3D space easily.

Note, the above result depends on the condition of viewer setting and test images, so we need to confirm with variable conditions.

(a) Conventional 2D image



(b) N3D image

Fig. 7 DICOM image comparison

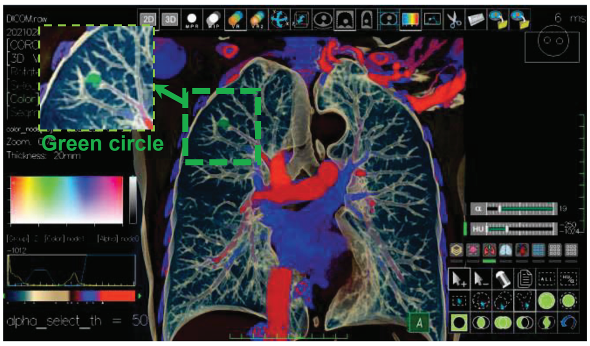


Fig. 8 Segmentation image of Lung
(Input data: CT, lung, 512x512x500 volumes)

3.4 Future applications

We would introduce five applications of N3D DICOM image viewer that are expected from doctors' voice in several fields.

(1) Pre-surgery planning
(2) Intra-surgery navigation
(3) Diagnosis
(4) Shared decision making (SDM)
(5) Education

For the application (1) and (2), we received many positive feedbacks, so that our N3D DICOM image viewer would be able to provide quick and accurate medical information to operators.

4 Conclusions

In this paper, we introduced the N3D technology and its novel algorithm. We have prototyped N3D DICOM image viewer and confirmed its performance with several experiments. For DICOM image viewer, it is required that high quality image to diagnose condition of organs, and it's important to provide accurate 3D image quickly for operators. Our N3D technology can fulfill those quite hi-level requirements with less image blur in real time. Altogether, our N3D display can be promising solution for the DICOM image viewer and several applications in future.

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