




A 360-degree Holographic Display System for Radiotherapy Treatment Planning

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ABSTRACT

Beam's Eye View is a commercial software system that is used by radiologists to plan radiotherapy treatment for cancer patients. It utilizes an algorithm that reconstructs a three-dimensional (3D) image from a serial of composite images of both Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). While it is effective, the display of 3D images on a 2D flat screen often creates confusion and limits its efficiency. In this paper, the use of holographic display is proposed. Two different holographic display systems are discussed, including the 4-side pseudo 3D holographic display system and 360-degree spinning holographic display system. The unambiguous holographic display helps the doctor to plan the radiotherapy treatment in a straightforward manner. With further development, it is expected that the proposed technology will soon find practical applications in the hospital.

KEYWORDS

3D holographic display;
Medical Image Processing;
radiotherapy treatment

1. Introduction

Radiotherapy is one of the most commonly used cancer treatment methods that saves thousands of lives every year. Presently, radiotherapy treatment planning is done using a commercial software system, called Beam's Eye View (BEV). It utilizes an algorithm that reconstructs a 3D image by synergistically fusing a series of composite images of both Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). BEV helps radiologists to attack the cancer while minimizing collateral damage to normal tissues. Though, the display of 3D images on a 2D flat screen often creates confusion and limits its efficiency. This motivates us to use the holographic display technology.

It is known that a holography displays a 3D image in the form of hologram. Instead of the stereo view on a 2D screen, it gives the volumetric view in 3D. In the past decade, a number of different methods have been developed to generate holography. The simplest method is the 4-side pseudo 3D holography system [7]. It consists of a set of 4 holographic plates, a large monitor (or 4 small monitors), and a computer software system. The 4 holographic plates are assembled as a pyramid which can reflect the light field from the monitor and generate a composite holographic image. Though, the holographic plates reflect approximately 50% of the lights and hence,

the holographic display is not very bright. Moreover, it has no images in 45° , 135° , 225° , and 315° directions which are the connecting areas of the two adjacent holographic plates. An improved method is the so-called "Transpost" presented in reference [12]. The idea is to project the images on a moving anisotropic screen to generate the 3D holography, though the projected image could be blurry. "Transpost" is based on the idea of spinning LCD method by Maeda [11, 14]. The other method is the 360-degree curved mirror display system [1, 13]. It uses a series of mirrors to generate the holographic image and has no moving parts. Its imaging quality is about the same as that of the Transpost. In recent years, the interactive feature has also been added [4, 8, 16]. Although the existing methods still need much improvement, the futuristic holographic display is very promising for radiotherapy treatment planning as it can give a 3D volumetric view.

In this paper, the use of holographic display for radiotherapy treatment planning is proposed. The rest of the paper is organized as follows: Section 2 briefly describes the BEV system. Sections 3 and 4 show the implementations of the 4-side pseudo 3D holography system and the 360-degree spinning holography system respectively. Finally, Section 5 contains the conclusions.

2. A Brief Introduction of the BEV System

The Beam's Eye View (BEV) system was first developed in 1990s [15]. It is an interactive system which is now widely used for radiotherapy treatment planning in the hospitals [9]. Based on the BEV system, the oncologists and radiation therapists will identify the location and size of the tumor and critical structures in order to plan for the radiotherapy treatment [3]. A standard treatment plan determines the position and orientation of the radiation beams, dose regimen and fractionation and the treatment setup. In general, the planning procedure includes the following steps [5]:

1. Determine the treatment position of the patient;
2. Establish reference points (e.g. using radiopaque markers) on the patient and/or in the immobilization device in preparation for the treatment;
3. Obtain diagnostic images, primarily CT [6] and/or MRI images;
4. Perform image fusion using BEV and display the 3D images on the monitor;
5. Delineate all relevant targets (i.e., gross tumor volume, clinical tumor volume, and planning target volume), organs-at-risk, skin surface, and other regions of interest;
6. Develop the treatment plan, which includes choice of treatment technique, total dose to target volume, dose per fraction, and number of fractions, and the normal structure dose constraints;
7. Conduct the treatment plan to meet the treatment goals;

8. Evaluate plan using statistical tools such as Dose Volume Histogram (DVH), and visual examination of dose distribution;
9. Radiotherapy treatment delivery.

Throughout these steps, both radiation therapists and oncologists need to use the BEV system to guide clinical decision-making. Although the BEV system generates 3D images, but it is being displayed on a 2D flat screen, as shown in Figure 1. This limitation in display may give rise to difficulty in interpretation of the spatial relationship of anatomical structures and affects its efficiency.

To address this limitation with the display, we propose the application of holographic display technology.

3. The 4-SIDE PSEUDO 3D Holographic Display System [10]

The 4-sided pseudo 3D holographic display system consists of a set of 4 holographic plates, a large monitor (or four small monitors), as well as a software system. The four holographic plates are assembled as a pyramid. Its basic operation principle is the light refraction. The holographic plates are made of acrylic sheets. When the image is displayed in the monitor, the light fields enter the holographic plate. As a result, the light refraction occurs. Because of the refractive index of acrylic sheet, the light field partially refracts to the center of the pyramid, at which the 4 images are fused forming the pseudo 3D image. Figure 2 shows the light field directions of the 4-side pseudo 3D holographic display.

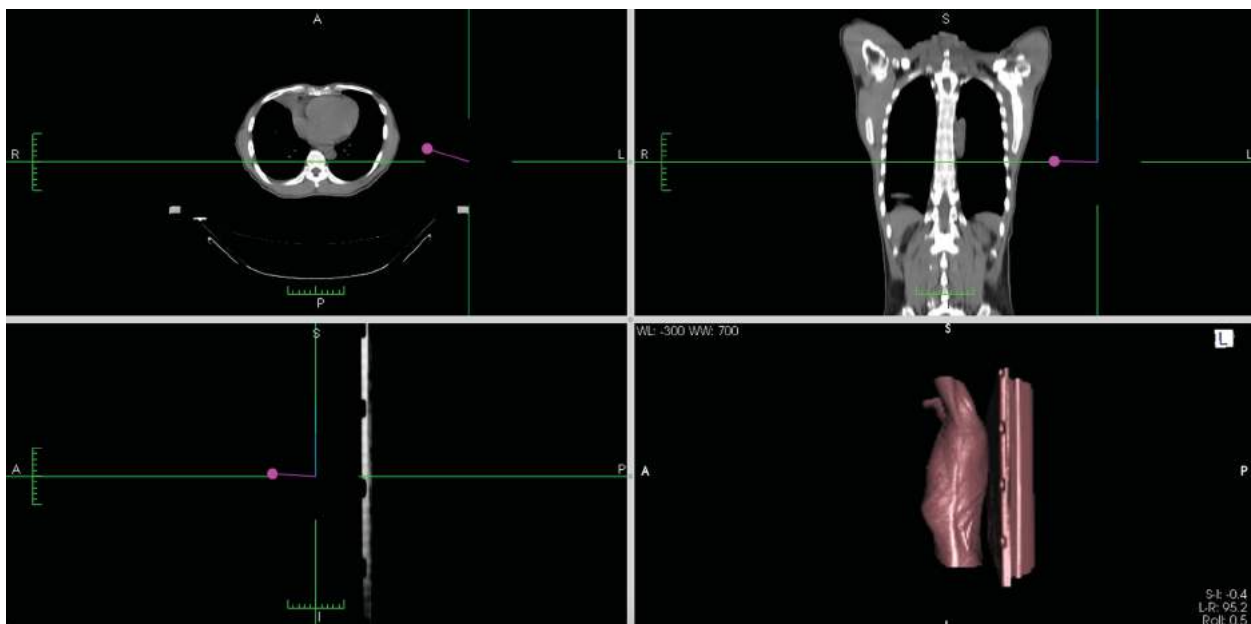


Figure 1. BEV system used on a 2D display [2].

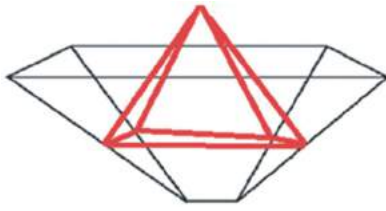


Figure 2. Light field direction of the 4-side pseudo 3D holographic display system.



Figure 3. The assembled acrylic holographic display.

The 4 acrylic holographic plates are easy to make and assemble as shown in Figure 3. This makes the 4-side pseudo holographic display rather inexpensive.

The computer software system reads the images from the BEV system and generates a fused image to display in the monitor. This can be done using a number of different ways such as MATLAB[®] and Adobe Photoshop[®]. For convenience, we use MATLAB[®]. A MATLAB program has been developed. Once all the images/ data are collected in the same folder, a merged holographic display image-needed would be generated automatically as Figure 4(e). The procedure is as follows:

1. Read the images from the BEV system;
2. Sort the images according to their respective angles;
3. Generate the four view images, each view is 90° apart;
4. Display the images on the screen.

Figure 4 shows an example. Figure 4(a), (b), (c), and (d) are four images from the front (0°), left (90°), back (180°) and right (270°), which are acquired from the BEV system. Figure 4(e) shows the four view image, and Figure 4(f) is the holographic display. Note that one can see the image in four directions: front, left, back and right. Though, there is no image in the 45°, 135°, 225° and 315° directions. Therefore, it is called the pseudo holographic display. Moreover, because of the light field reflection, the

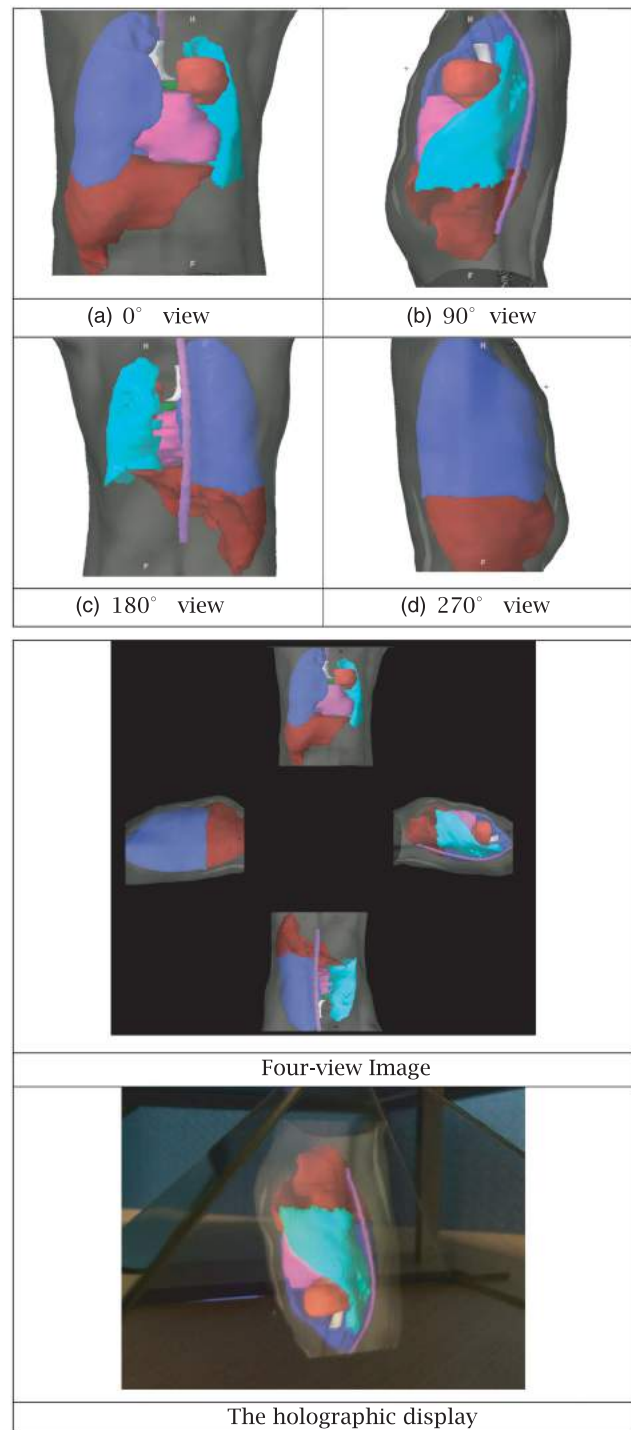


Figure 4. An example for the 4-side pseudo holographic display system.

holographic display will be dim (usually the brightness is about 50% of the monitor).

4. The 360-Degree Spinning Holographic Display System

The 360-degree holographic display system is similar to the so-called “Transpost” in reference [8] and [12]. It

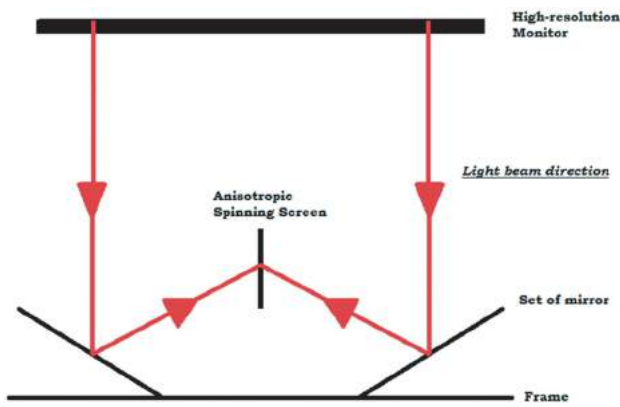


Figure 5. Illustration of the 360-degree spinning holographic display system.

consists of a set of mirrors, a large monitor or a projector, a rotating anisotropic mirror driven by a motor, and a computer software system. As shown in Figure 5, the light field is projected on the mirror, which in turn projects onto the rotating anisotropic mirror. As the rotating mirror turns at high speed (2000 RPM), the images in the monitor are displayed alternatively. Because the rotation frequency (33.3 Hz) exceeds the human perception limit, the rotating mirror gives an imagery 3D image. Note that the anisotropic mirror prevents the images in the monitor being blended together. Moreover, the 3D image

Table 1. Details of the hardware components.

Width	32 cm
Length	55 cm
Height	81 cm
Number of mirrors in a set	8
Motor model	Yaskawa-Minertia Motor R-seris
Minimum rotating speed of motor	2000 rpm

could be a kind of flickering due to the rotation of the mirror.

The computer software is similar to that of the 4-side pseudo 3D holographic display system. The computation procedure is as follows:

1. Read the images from the BEV system;
2. Sort the images from 8 different directions (0° , 45° , 90° , 135° , 180° , 225° , 270° , 315°);
3. Generate the combined 8-view image using MATLAB[®] or Adobe Photoshop[®];
4. Display the 8-view image in the monitor.

Note that one can rotate the 8-view image and hence, generate a computer animated rotating 3D display.

Figure 6 shows the prototype of the 360-degree spinning holographic display system. Comparing to the 4-side pseudo 3D holographic display system, this system is more complex, but gives a real 360 holographic display.

For the prototype, Aluminum profile is chosen to build the hardware, as the size of hardware, such as the distance between monitor and rotating anisotropic mirror, can be easily adjustable. The optimized size of the hardware component has been examined as $32 \times 55 \times 81$ cm. Acrylic board is chosen for supporting the motor and a set of mirrors. The following table is the details of the hardware components:

As an example, Figures 7(a) – (h) show 8 images from the BEV system. Figure 7(i) shows the 8-view image displayed in the monitor. Finally, Figure 7(j) shows the 3D image. From the figure, it is seen that the display is bit burry. This is because of the light reflection as well as the mirror rotation. Moreover, since the 8 images are small, the 3D image is also a bit small.



Figure 6. Setup of 360-degree spinning holographic display system.

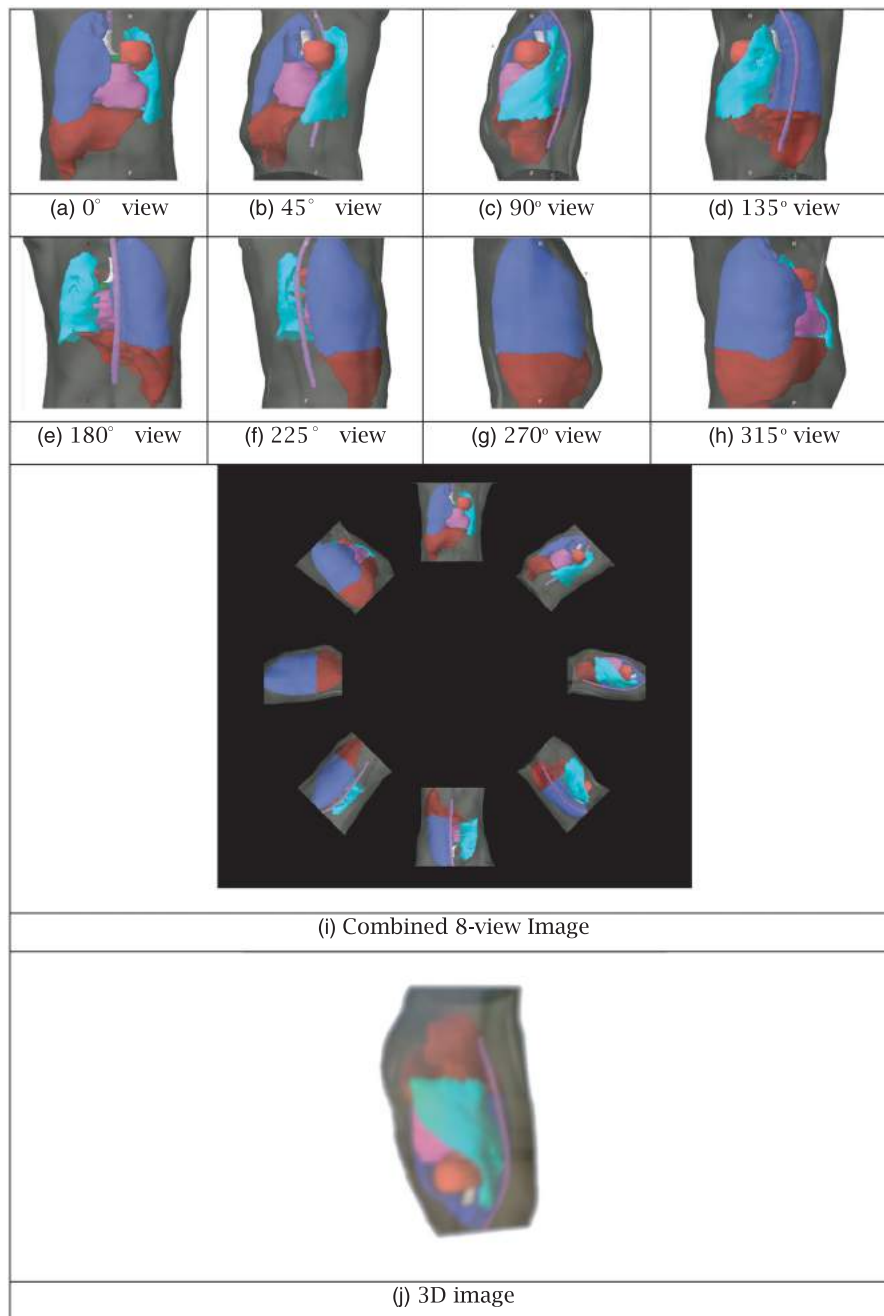


Figure 7. Image Processing.

5. Conclusion and Future Work

In this paper, two holographic display systems, the 4-side pseudo 3D holographic display and the 360-degree spinning holographic display system, are presented as possible means of improving radiation therapy through better display technology. These systems provide volumetric view and hence, can eliminate the ambiguity from looking at 2D display during radiotherapy treatment planning. Both systems are rather simple and have the potential to be integrated with the existing BEV system

to enhance its clinical applications or used as a teaching tool. The future work includes improving the quality of the 3D image (brightness and contrast) and adding the interactive feature to the system.

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