Volumetric 3D Display for Radiation Therapy Planning

Jason Geng

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Abstract

In current clinical practice, radiation therapy planning (RTP) has often been treated as a two-dimensional (2D) problem, mainly due to the limitations in visualization technology available to date. The slice-by-slice display format makes it difficult to visualize the path of radiation beam not perpendicular to the axis of the CT slices. This discourages consideration of treatment plans that utilize radiation beam out of the transverse plane. Human body anatomical structures are inherently three-dimensional (3D) objects, and tumors and tissues/organs involved in the RTP are all of 3D shapes. A clear understanding of 3D spatial relationships among these structures, as well as the anatomic impact of 3D dose distributions, is essential for designing and evaluating radiation therapy plans.We have recently made an important breakthrough in the high-resolution volumetric 3D display technology and have made an initial attempt to apply it to RTP applications. By “volumetric 3D display,” we mean that each “voxel” in the displayed 3D images is located physically at the (x, y, z) spatial position where it is supposed to be, and emits light from that position to form real 3D images in the eyes of viewers. We have demonstrated the feasibility of our system design by building full-scale prototypes and achieved a multi-color, large display volume, true volumetric 3D display system with a high resolution of over 10 million voxels in a portable design. This type of true 3D display system is able to present a 3D image of a patient's anatomy with transparent skin, providing both physiological and psychological depth cues to oncologists in perceiving and manipulating radiation beam configuration in true 3D fashion, thus offering a unique visualization tool to ensure the safety, effectiveness, and speed of the RTP process.The volumetric 3D display technology holds promise to significantly enhance the accuracy, safety, and speed of RTP procedures. Such an “understanding at a glance” capability is necessary to keep the clinicians from becoming bogged down in details, as he/she would be if provided only with conventional 2D display of CT slices with overlaid isodose lines.The main focus of this paper is to provide technical details on the volumetric 3D display system we developed, and present some initial results on its capability of displaying true 3D images. While the system design framework of applying such technology into RTP is introduced, its full scale clinical applications to RTP is still an ongoing effort and will be reported later in other publications.

PDF Article

Intensity Modulated Radiation Therapy (IMRT). Volumetric Modulated Arc Therapy (VMAT). Stereotactic Body Radiation Therapy (SBRT). Quality assurance for radiation therapy. Rationale for EPID based dosimetry. Thesis context and objective. Figure 1.2: The upper left panel displays a six-eld 3D beam arrangement for a prostate case viewed along the superior-inferior axis. The upper right panel shows the uniform conformal dose zones (red line) covering the tumor volume and prostate in the isocenter axial plane. Lower panel displays a beam shaping relative to the contour of the tumor volume (solid light blue) and shielding of of the rectum (brown wire cage) and bladder (yellow wire cage) [10]. 3D conformal radiation therapy (3D-CRT) is a radiation therapy technique that involves CT planning where the volume to be treated is defined on a 3D data set. Therefore, organs at risk can also be delineated to shield these and reduce treatment side effects. Radiotherapy planning software is used to design complicated beam arrangements and to assess dose-volume histograms for the tumour and organs at risk. In its simplest form, 3D-CRT uses a multi-leaf collimator (MLC)

40-80 tungsten leaves, which can move independently into the beam