Visualizing Anatomic Changes over Multi-Day Radiotherapy Treatments

Derek Merck, Stephen Pizer, Julian Rosenman
July 31, 2007

Keywords
Segmentation and Rendering, Visualization, Therapy Planning, Pelvic procedures

Abstract

We present a method for visualizing changes in serial 3d medical image sets, such as those gathered over a multi-day radiotherapy treatment. For clinical application of multi-day therapy, it is important to understand the changing shape and spatial relationship of the target to other anatomic structures. Our automatic scene composition method uses partial segmentations of the data to guide a feature driven clipping algorithm. The data is filtered according to the segmentations into a ranked feature volume, from which a view-dependent clip-mask is computed. Our clipping algorithm is based on a novel object-order volume shadowing algorithm rather than ray casting, so it is amenable to hardware acceleration. The clipped data is further modulated by contours from the source and target segmentations, allowing clinicians to focus and contextualize the visualization in different ways to understand a variety of different anatomic relationships over space and time.

Purpose

Radiotherapy treatment for prostate cancer is typically scheduled over several days. A planning CT is carefully segmented and a beam prescription is defined that maximizes radiation dose to the prostate, while preserving, as much as possible, the surrounding soft tissue organs. In adaptive radiotherapy, treatment plans are realigned over the subsequent days, usually according to a rigid transform based on easily found boney landmarks, but occasionally by segmentation and deformable registration of the daily images. Our method presupposes that daily scans have been both segmented and rigidly aligned. Given those inputs, our visualization method allows a physician to quickly evaluate the residual differences in shape and relative position of the soft anatomy between the daily scan and the planning scan. Important judgments include how much the prostate has deviated from its original shape, pose, and position, and how close the bladder and rectum overlap the original position of the prostate. If the prostate has significantly changed shape or position relative to the bladder and rectum, as shown in fig. 1, it may have moved out of the target area or the nearby structures may have strayed into the high dose regions and re-planning the treatment fields may be necessary.

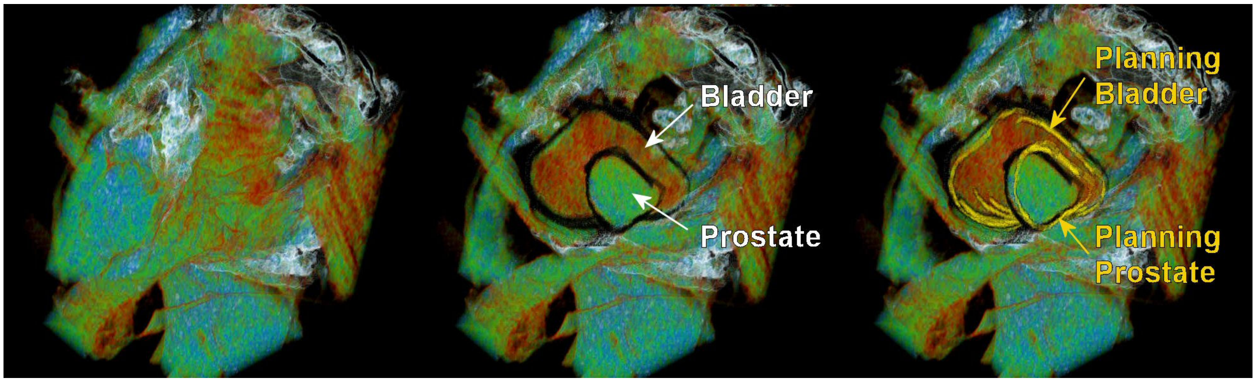

Fig. 1. Left, a daily image, normally volume rendered from the lower right, with the target region occluded. Center, the unoccluded daily image focused on the prostate with the bladder sitting above it. Right, the unoccluded daily image relative to contours of the target regions from the planning image. The prostate has significantly shifted position relative to the planning image.

Method

We begin with a planning CT image and one or more segmented CT images from subsequent days. Segmentations may be by hand, as, for example, the planning images are usually hand segmented, or they may be computed automatically by statistical methods, such as deformable shape models. Then, given a focus, each structure is ranked, and given a view direction, we generate a clip-mask for each input image by an object-order shadow volume computation. The ranked feature volume is rendered slice-wise according to an 'importance flashlight' opposite the view direction and a shadow volume is accumulated from the intermediate results. The data is then modulated according to the importance shadow to clip or otherwise subjugate voxels between the viewer and the objects of interest, as in fig. 2. A useful extension is further modulating opacity according to view-relative contours to provide context.

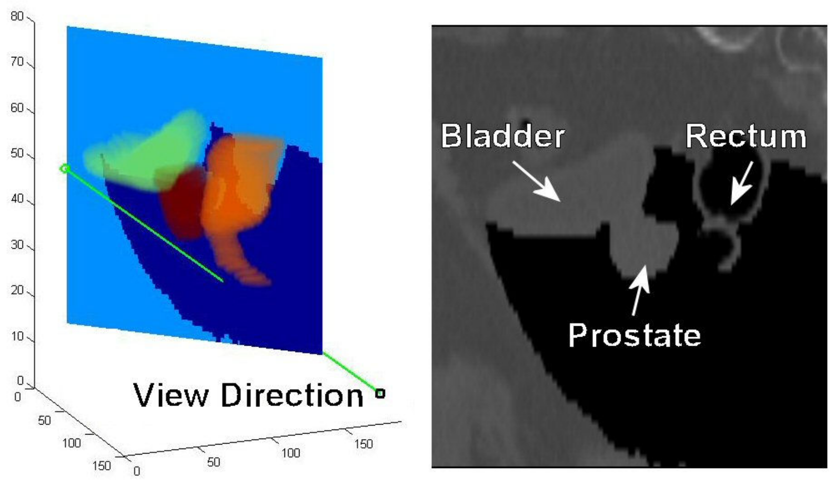

Fig. 2. Left, an oblique view of a sagittal slice through the ranked feature volume and the accumulated 'importance shadow' relative to the view direction. Right, the same slice through the shadow volume modulated data.

Unlike other importance based clipping methods, our algorithm does not rely on ray casting, so it is amenable to hardware rasterization and blending acceleration. Using the same method to both clip and project the modulated data onto the view plane yields a two-pass object-order algorithm with view-dependent importance clipping.

Results

The images in figs. 1 and 2 are based on a pilot study in which ten daily images from a single patient have been filtered off-line and then pre-rendered as movies. Clinicians concluded that this visualization would give them a useful starting point for determining when a patient's anatomy had significantly changed shape and position relative to the planning image. We are currently developing an interactive application based on this algorithm which will be applied to five different patients, each with a planning scan and between eight and twelve segmented daily scans. We hope to correlate visual evaluation of shape and position change in the prostate with retrospective computation of actual dose-to-target values.

Conclusions

This paper describes an application of our volume visualization clipping module to a particular clinical problem. The method can also be generally applied to understanding relationships in other 3d medical data with partial segmentations, such as patient-to-atlas, though the initial registration is more complex than that required for same patient views. Using statistical segmentations, i.e., parametric shape and intensity models with probability distributions, allows the method to be naturally extended to 'likelihood rendering'. This may be useful for visual evaluation of segmentation results by focusing views on where shape or intensity values differ from expectation, or for focusing on where difficult to find features are likely to be found in the data. Companion papers describing these applications and other components of our entire model-guided rendering pipeline are in preparation.

Submission Status

This work has not been submitted elsewhere for publication or presentation.