Visualization of 4D Computed Tomography Datasets

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Abstract

Organ motion is problematic when employing radiation therapy to treat certain types of cancers. Motion problems are commonly encountered when treating lung, thorasic, and liver cancers, since patients breathe during treatment. To begin to address this issue, clinical researchers in the Radiation Physics Division at Massachusetts General Hospital have developed 4-D computed tomography (CT) imaging (the four dimensions being height, width, depth, and time). This new imaging technology provides clinicians with far more precise information on tumor motion with which to plan and administer radiation therapy.

To aid radiologists and doctors, we have developed a visualization browser and supporting toolkit that allows for volume rendering of 4-D CT images. Included in this toolkit is the ability to simulate any amount of radiation dosage specified by the user. In our most recent enhancements to the toolkit, we have expanded its capabilities to create a fully-navigable 3-D rendering model.

We have developed this toolkit using SCIRun, a problem-solving environment specifically designed for visualization and modeling of complex scientific problems. Using SCIRun's visualization tool (BioImage), we are able to render 4-D models based on CT scans. This paper describes our present efforts developing this capability, and discusses some of the features provided by the toolset.

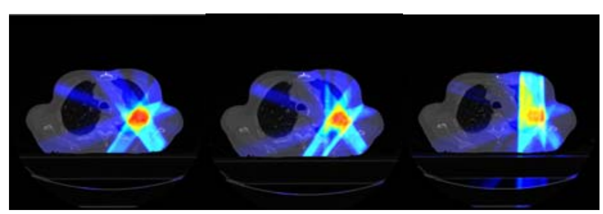
1. Introduction

Effective treatment of many types of inoperable cancer involves the use of radiotherapy. Presently the success rate of using radiation on lung cancers is low. The impact of radiotherapy can potentially be improved by increasing the precision of tumor localization and dose delivery during the treatment. Increasing the accuracy helps to insure that the entire tumor volume is treated, while limiting the impact to surrounding healthy tissue [1]. Visualization is a critical tool needed to aid the radiologist in developing the best treatment plan.

We have been working closely with the Radiation Physics Group at Massachusetts General Hospital. Our goal is to develop an effective set of 4-D visualization tools that can be used by radiologists to visualize moving tumors while planning radiation treatment. Our work complements advances in cancer screening methods that are being developed at MGH in 4-D CT [2].

2. 4D-Vis Toolkit

Our 4D-Vis Toolkit uses Radiation Therapy Oncology Group (RTOG) files to extract both CT-Scan data and dosage distribution data. We then render this data using OpenGL 2D textures. Figure 1 shows the dosage distribution generated over a period of time, as applied to a lung tumor. The dosage distribution attempts to accommodate for the shift in the tumor's location, but as Figure 1.c shows, the tumor receives a weaker dosage as it did in Figure 1.a.



a b c

Figure 1. Axial perspective of anon4877's dosage distribution over time

During the initialization process, 4D-Vis stores the corresponding gray-scale images of the entire CT-scan dataset as an array of 2-byte words. We encode the gray-scale values in 8 bits, and append corresponding structure and dosage distributions to form our 2-byte word. By representing this information as a 2-byte word, we eliminate the need to constantly access the original RTOG files. This information is rendered on the screen by clicking on the "Dosage_enable" or "Contour_enable" buttons.

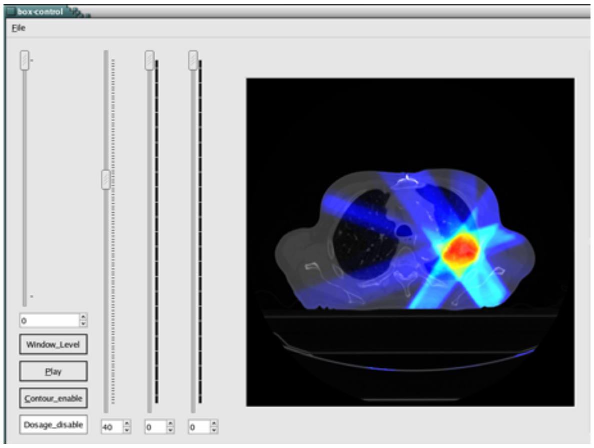


Figure 2. Control panel of 4D-Vis with axial perspective of anon 4877

8.2. 3-D Volume Rendering

We have designed our toolkit to import structure data from RTOG datasets and render the dataset in 3-D. Figure 2 shows the skin and lungs of anon4877. While this perspective conveys the general shape of a patient's internal organ structure, this view sacrifices resolution when attempting to render fine details at close range.

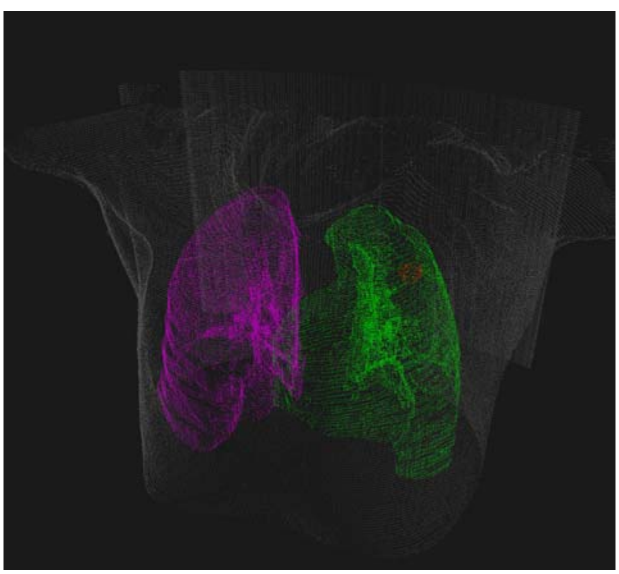


Figure 3. 3D visualization of anon4877

3. Implementation

3.1. SCIRun

SCIRun is a Problem-Solving Environment developed by the Scientific Computing and Imaging Institute at the University of Utah. SCIRun allows the user to create an environment to perform processing of any kind on sensor/image data by visually interconnecting smaller programs called “modules.” Using this bottom-up approach, several modules are connected to create a program, and these modules can be connected to represent a processing “network”. Each module is a small, independent program that communicates with other modules that share the same data format [3, 4].

The SCIRun Institute has developed an application called BioImage, which utilizes a SCIRun network to perform 2-D and 3-D render multi-dimensional medical image sets. SCIRun presently does not support rendering RTOG images, and thus cannot visualize dosage information while visualizing a lung. We have chosen to implement the dosage-rendering aspects of 4D-Vis as a series of SCIRun modules.

3.2. Module Design

We have created two modules that extend SCIRun's advanced volume rendering capabilities. The first module (InputRTOG) imports RTOG datasets using SCIRun's native **NRRD** and **field** data formats. The second module (Input3ddose), translates a standard 3-D dosage file format (.3ddose) into SCIRun's native field format. 3DDose files are dosage files generated by DOSXYZ, a program that allows for phantom dosage distribution simulation [5].

3.3. Network Design

SCIRun's visual programming environment allows us to add our modules directly into *BioImage* without any need to alter *BioImage* itself. By formatting dosage distribution using SCIRun's **field** format, we were able to render our dosage distribution as a color map that could be overlaid directly onto the generated 3D object. This capability allows the user to see how any particular treatment plan irradiated a tumor, while still maintaining the freedom of controlling the overall structure of the 3D object.

Figures 4 and 5 illustrate SCIRun's ability to render patient 7396's tumor, while superimposing the simulated dosage distribution. Figure 4 clearly shows the displacement and change in shape of the tumor over time. Figure 5 shows the simulated dosage distribution of anon7396 in three different perspectives. In Figures 5(d) and 5(f), the dosage distribution appears lighter in color compared to the rest of the dosage distribution, highlighting the area that has a more concentrated dosage. Note that in Figures 5(d) and 5(f), the radiation dose is affecting healthy tissue.

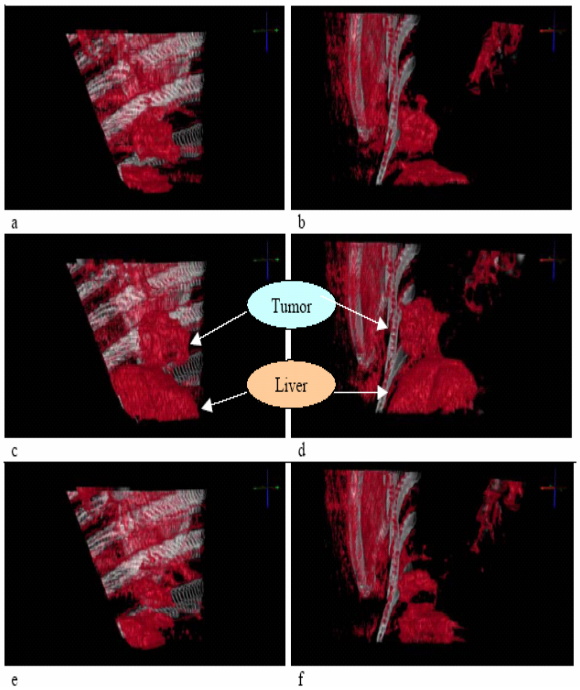
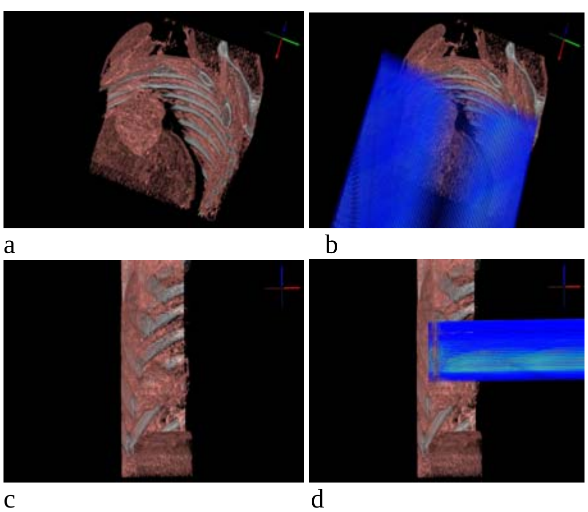


Figure 4. Anon7396's tumor. Directly below the tumor is anon7396's liver, clearly seen in figures 3(c – d).



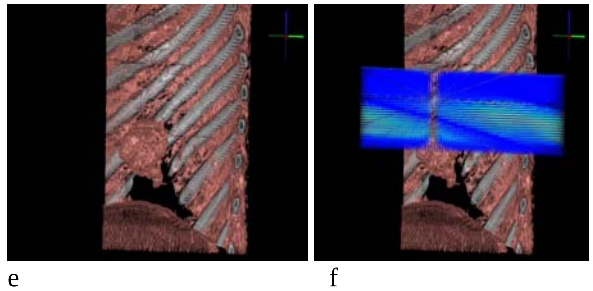


Figure 5. SCIRun visualization of anon7396's dosage distribution

4. Future Work

We have already helped to capture new perspectives of a tumor in moving body parts that can greatly enhance the effectiveness of radiation technology. As part of our future work, we plan to tune the performance of our 4D-Vis algorithms. The main objectives will be to reduce loading time. We will also continue to work in seamlessly interacting with other dosage file formats in order to be compatible with the SCIRun problem-solving environment.

5. Conclusions

In this paper, we have described the development of 4D-Vis. We have found this toolset to be robust. The toolset renders 4-D CT Scan and dosage distribution in either a 2-D and 3-D environment. We believe that this information will enhance MGH's capabilities to better assess the progress of a patient over time.

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6. References

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