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Visualization and Validation of 4D CT Scan Datasets

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OBJECTIVE

Develop a set of tools to effectively visualize, measure, and annotate 4D (3D + time) Computed Tomography (CT) images of radiation oncology patients for both research and clinical applications.

MOTIVATION

Why 4D Visualization?
Currently, radiotherapy treatment planning utilizes a 2D perspective of 4D data, thereby reducing the amount of information visually available. This information, such as the shape, movement and location of a tumor is critical in treatment planning.

SIGNIFICANCE

These tools are designed to both improve a user's perspective and analysis of tumor shape, motion, and location during respiration. Furthermore, measurement and annotation tools are designed to give users the ability to validate and report findings within visualizations.

APPROACH

The base source code is written in C++ using OpenGL for graphics visualization, TCL/TK for the GUI and GLUT to control keyboard input. Tools are developed as add-ons that provide additional functionality to this existing scientific platform. Individual modules are a combination of:

- C++ for data input/output control and algorithm implementation
- XML for data input/output characterization and general documentation
- TCL/TK for graphical user interface (GUI).

SCIRUN

• SCIRun is a Program Solving Environment, developed by the scientific computing and imaging Institute researchers at the University of Utah, that creates simulations, models and visualizes scientific problems. SCIRun is a visual programming development environment that uses numerous programs called "modules" that, when inter-connected, create a larger, more robust program.

• By designing programs through interconnecting modules, this makes each module independent of each other, allowing them to be interchangeable between applications.

• Figure 1 shows a typical SCIRun dataflow network. Note how, through visual pipes, the modules are able to exchange information.

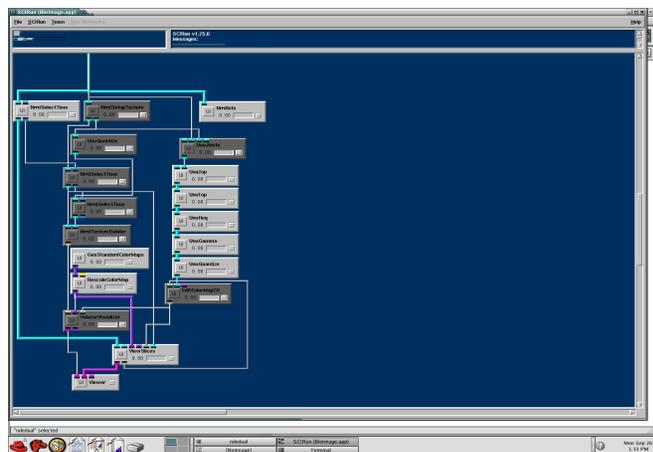


Figure 1: SCIRun dataflow network. Active modules are light grey while inactive ones are dark grey. Inputs enter at the top of each module and outputs leave from the bottom. The data types are generic and are declared using XML.

DATA VISUALIZATION

• Biolmage is a SCIRun dataflow application network, designed with a customized interface, that processes and visualizes any form of 3D or 4D data. It supports Newly Raw Raster Data files (nrrd), Joint Photographic Experts Group files (JPEG) and Digital Imaging and Communications in Medicine files (DICOM)

• Biolmage allows for the user to apply filters to display only certain aspects of the 3D model and also employs a free-movement rendering system.

• Figure 2 shows two 3D models of the same CT data cropped to the region of interest. Different tissues can be visualized together or separately.

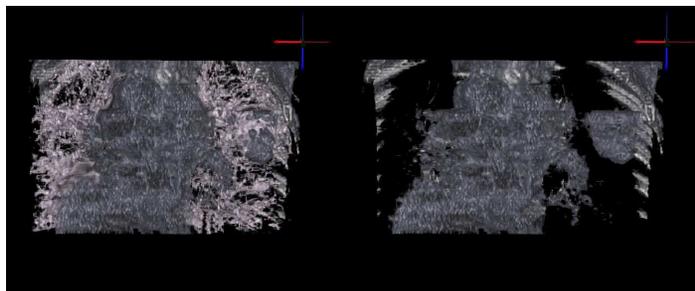


Figure 2: 2 views of 3D volumes created through the rendering system. The image on the right is of an anterior view of a tumor. The one on the left is the same view with the lungs made visible.

DATA VALIDATION

• Visualized data needs to be verified for geometric accuracy before it can be used for applications such as treatment planning.

• Basic measurement capabilities in 3-dimensions and the ability to record these measurements for future reference provide fundamental validation tools.

• CT data is visualized in three different perspectives: Axial (top to bottom), Saggital (left to right) and coronal (front to back). Measurement markers can be moved in any of these perspectives providing flexible user interaction.

• Experimentation can be done on non-human subjects to verify the accuracy of these tools. For example, Figure 3 shows a visualization of a preserved swine lung that can be measured by both real world and computer-aided means for purposes of comparison.



Figure 3: Swine lung rendering with reference object in front.

DOSE VISUALIZATION

• A visualization tool has been developed that allows physicians to import information about radiation dosages applied to the rendered subject and superimpose it onto the subject such that both can be viewed together.

• This information can help physicians see what spatial regions are getting what dosages of radiation and at what specific times.

• Figure 4 shows an example of a dosage visualization superimposed on a rendered volume of a subject's torso.

• Figure 5 is of the same data as Figure 4 but viewed from the back.

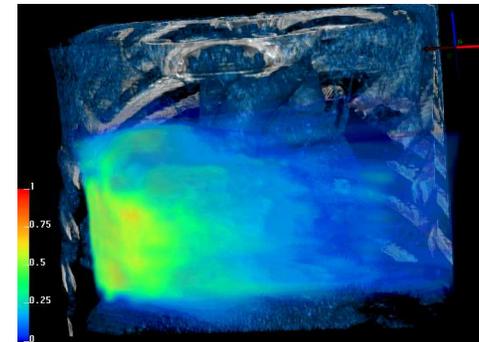


Figure 4: Dosage and torso viewed from the front. Radiation is concentrated on a tumor located where dosages are brightest.

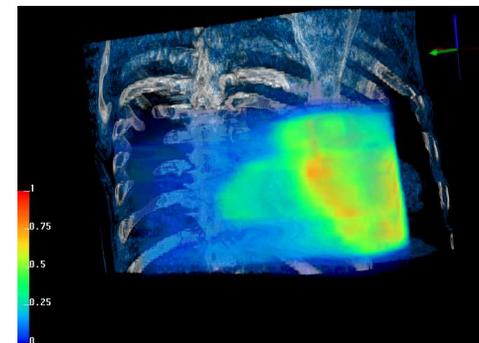


Figure 5: Dosage and torso from Figure 4 viewed from the back.

TECHNOLOGY TRANSFER: CLINICAL APPLICATIONS

• Tools can be developed that allow physicians to rapidly segment and identify regions of interest in 3 or 4-dimensions. This would be a major advancement over the current methods that approach this process one 2D subset of the 4D information at a time.

• The total time for treatment planning preparation can be reduced by allowing more efficient analysis of size, shape, and movement of tumors. This can improve the overall effectiveness of a treatment center by increasing the number of patients treatable in a given amount of time.

• Treatment planning can be done more accurately. Visualizing 3-dimensional information 2-dimensions at a time can be difficult enough without doing so over the 4th dimension of time. Visually representing the full set of information at once can free a physician's thoughts for more treatment-oriented concerns.

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