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GENERATION OF VRML ANATOMICAL MODELS FROM SPIRAL CT IMAGES

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1. ABSTRACT

Three-dimensional models can be generated from slice images, such as those obtained from computed tomography (CT) and magnetic resonance imaging (MRI) using a variety of techniques (1-5). A popular method for rendering 3D anatomical models is the creation of polygonal mesh surfaces representing the boundary between tissues. Mesh surfaces can be rendered extremely quickly using conventional personal computers, without recourse to more expensive graphic workstations.

The dissemination of three-dimensional (3D) models across the Internet has been made significantly easier by the definition of the Virtual Reality Markup Language (VRML) format. The VRML definition allows the parameters and relationships of 3D objects to be described in a text format. The text file can be transfered from a host computer to a remote client computer through the World Wide Web and viewed using readily available software (See Appendix). VRML is based on the definition of primitive 3D objects such as polygons and spheres. Consequently, the transition from a mesh surface derived from a clinical image data set to a VRML object is relatively simple, allowing for convenient and cost-effective dissemination of 3D clinical models across the internet.

2. METHODS

All CT data was acquired using a HighSpeed Spiral CT scanner (General Electric Medical Systems, Milwaukee, WI) equipped with a power injector and automated contrast injection timing software. Vascular images were acquired during the arterial phase of contrast administration. Bronchial images were acquired during one or two breath-holds. Slice thickness, pitch and field of view were optimized based on radiological, hardware and dosimetric requirements. Typical slice thicknesses were in the range 1.5mm to 3mm with a slice pitch between 1.5mm and 3mm. All images were originally 512 x512 pixels in size with a field of view in the range 28cm to 36cm.

All post-processing was performed on a SPARCstation 20 MP with a ZX graphics accelerator (Sun Microsystems, Inc. Mountain View, CA.). CT images were transferred to the workstation by means of a 4mm Digital Audio Tape (DAT) and imported into the AVS processing environment (Advanced Visual Systems, Inc. Waltham, MA.) which provides many image processing operations and allows custom operations to be written and implemented quickly. Preliminary processing involved reduction of the slice resolution of the CT images from 512 x 512 to 256 x 256 by voxel averaging and cropping the data set to the volume of interest.

A point within the structure to be segmented (such as the bronchial airway) was selected manually. A region was then "flooded" from this starting point with boundaries defined by a manually selected maximum and minimum image intensity. The resulting set of voxels defined all connected elements in the data set with an image intensity in the predefined range. This algorithm was implemented as a custom operation within the AVS environment.

The region was then passed to the isosurface module provided by AVS and a mesh surface defined for viewing and checking the segmented structure. The region was also passed to a custom written module which implemented the "marching-cubes" algorithm (60 and generated triangular mesh surface information in VRML form as a text file. The text file (with a .wrl suffix) could then be linked to a web page and disseminated across the Internet for remote viewing.

In this implementation, the true spatial proportions of the data were preserved only approximately by interpolation of the data points. Consequently, quantitative measuements of distance, area or volume from the VRML datasets are not possible. Future versions of the VRML module will include this feature.

3. RESULTS

Each of the images shown below is linked to an associated VRML model. Click on the image to start downloading the model. When all the data is transferred, your browser should start a VRML viewer through which you can then interact with the VRML object. See the Appendix (on-line article) for details of configuring Netscape to view a VRML object.

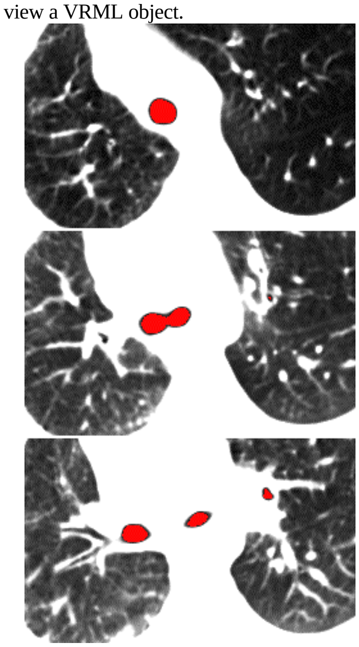

Figure 1. Simple image segementation was achieved by "flooding" a region from a seed point using an image intensity range as a constraint. The resulting set of points described a connected volume corresponding to a given material (in this case air within the tracheobronchial tree). No adjustments were made for partial volume effects.

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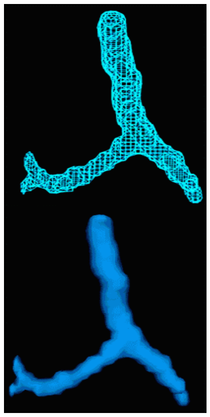

Figure 2. The results of applying the marching cubes algorithm to the segmented data of the previous figure. Marching cubes generates a triangular mesh surface representing the boundary of the segmented volume. The Gouraud shading algorithm generates a smooth, lit version of the mesh surface. The mesh information is easily converted to VRML form for Internet dissemination.

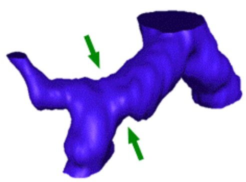

Figure 3. Surface model of the anastomosis of a lung transplanted to a recipient bronchus. The anastomosis location is shown by arrows. The original spiral CT data was acquired during a single breathold.

Figure 4. Surface model of the origin of (from L to R) the left subclavian artery, the common carotid artery and the brachiocephalic trunk from the aortic arch. The division of the brachiocephalic trunk into the right common carotid artery and right subclavian artery is also clearly seen. Smaller vessels such as the thyroid artery are not visualized. The original spiral CT data was acquired during the arterial phase of a contrast bolus.

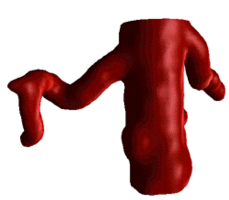

Figure 5. Surface model of the origin of the renal arteries from the descending aorta. Spiral CT data was again acquired during the arterial phase of the contrast bolus.

Figure 6. Surface model of a trachea with an abnormal constriction (arrows). Spiral CT data was acquired during multiple breath-holds.

4. DISCUSSION

We have shown that geometric surface generation from spiral CT data allows the creation of 3D models which can be easily converted to a form which is widely accepted across the World Wide Web. The VRML format allows remote interaction with 3D models generated directly from clinical data without the requirement for expensive computer visualization hardware at the remote location. The VRML definition allows many more properties, including textures, animation, multiple objects and hot-linking, that have not been implemented in this project. In the future, some of these features may become useful for attaching additional information to the model. It is also conceivable that VRML models may be generated following a CT examination and incorporated into online reports for a referring physician to view alongside conventional 2D slice images.

5. ACKNOWLEDGEMENTS

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