AnatomyBrowser: A Framework for Integration of Medical Information

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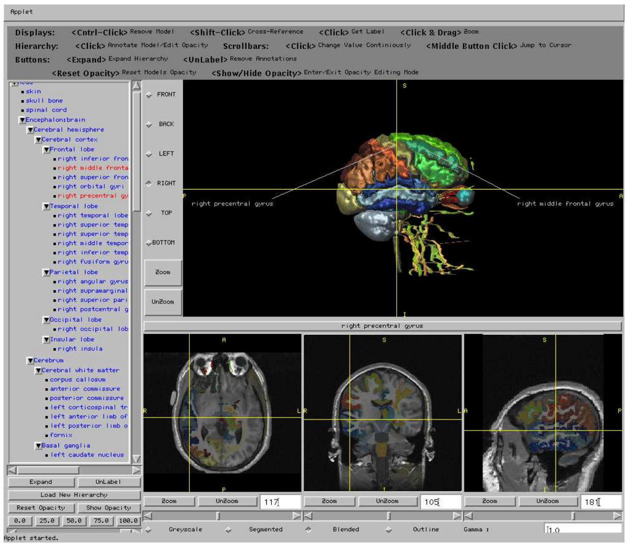
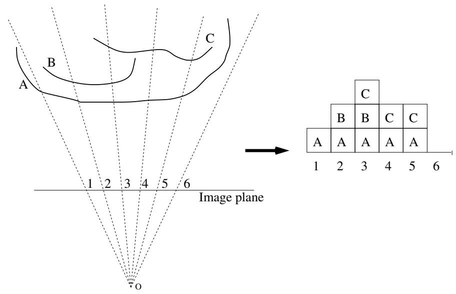
The Problem: AnatomyBrowser is a framework for integration of images and textual information in medical applications. AnatomyBrowser allows the user to generate 3D surface models of anatomical structures and combine them with the original cross-sectional slices and and the text available on the structures. In addition, it provides a rich set of cross-referencing and annotation capabilities. Based on an individual 3D scan (MR or CT), it can be viewed as a digital replacement of the conventional anatomy atlas for a particular patient. This project is done in collaboration with the Surgical Planning Laboratory at Brigham and Women's Hospital.

Motivation: With recent developments in MRI technology it has become possible to obtain high quality medical images that are extremely useful for clinical studies, surgical planning and other applications. This has spurred rapid development of algorithms for information extraction and analysis using medical imagery. These include segmentation and registration, shape and deformation modeling, etc. Importance of visualization of the results, especially 3D data, became apparent as well. AnatomyBrowser provides visualization capabilities for slice sets and 3D surface models of anatomical structures, as well as a useful set of cross-referencing and annotation features. It can also be used as an aid tool for the model driven segmentation of medical images.

Previous Work: The work on digital atlases has been pioneered by Höhne *et al.* [1]. A digital brain atlas integrating several image modalities with the information on anatomy hierarchy was proposed in [2]. In the visualization field, there are several packages available for rendering of 3D surface models (Inventor by SGI, VTK by GE, and many others), but to our best knowledge, AnatomyBrowser is the only integration environment that provides extensive referencing and annotation capabilities. This is important in clinical applications, when a user wants to establish a clear correspondence between all types of pictorial information available.



(a) AnatomyBrowser interface



(b) Multi-layer image generation

Figure 1: (a) An example of AnatomyBrowser for a brain data set. The cross-hair positions correspond to the same 3D point. Some of the structures are annotated on the 3D display. The sagittal slice is slightly zoomed in. (b) A multi-layer image. Every pixel in the multi-layer image is essentially a stack of voxels that correspond to the intersection points of the view ray with the model surfaces.

Approach: We separate the visualization process into two steps. First, the models are pre-rendered using a high-end graphics system, and the resulting images are saved in an intermediate format, called *multi-layer images*. Then multi-layer images are processed by the user-end interface to produce an image of a 3D scene. Multi-layer images are organized in such a way that the image generation by the user-end component requires only modest computational resources.

The input to the pre-rendering step is a set of surface models of the anatomical structures of interest. The surface models are represented using polygonal meshes. During the pre-rendering step, every model is rendered in isolation, with all other models removed from the image. Two images are computed and saved for every model: an intensity image generated by the renderer, and a depth image. Intensity and depth images of all models are then combined in the following way: for every pixel, a stack of $\langle k, I, d \rangle$ tuples is saved, where k is a unique index associated with a surface model (i.e., an anatomical structure that this model represents), I is the surface intensity from the intensity image, and d is the depth value from the corresponding depth image. The tuples are sorted in the order of increasing depth (Fig. 1b). In order to obtain the resulting image intensity for a particular pixel, intensity values in the corresponding stack are treated as colored (and maybe partially transparent) layers that are piled on top of each other, hence the name "multi-layer image".

Difficulty: It has traditionally been accepted that special hardware and software is required for visualization of 3D surface models. Rendering of 3D surface models is a computationally intensive operation that requires special hardware to achieve acceptable update rates. And since rendering is considered an integral part of the visualization process, the visualization itself is thought to be feasible only on high-end computers with hardware graphics acceleration. In this work, we propose a change in this paradigm. The user interface component of the system does not require special resources and can run on any platform.

Impact: Anatomy studies are the most obvious application for the system. AnatomyBrowser can effectively replace a conventional anatomical atlas book, as it provides at least as much information as the book. In fact, it is being used by several universities for their neuroanatomy courses. We also tested AnatomyBrowser on several clinical cases for surgical planning and image guided surgery. The surgeons' response to the system was extremely positive. It provided them with much greater visualization capabilities than they had before, while establishing clear correspondences between the 3D models and the more commonly used cross-sectional slice sets.

Future Work: AnatomyBrowser is currently used by researches from our and several other groups. Generating interactive anatomy atlases is an ongoing project at the Surgical Planning Laboratory at Brigham and Womens Hospital.

Remote use of the interactive atlases is another interesting direction or research that we are planing to explore. The current implementation is not suited well for remote access, as it does not optimize for the amount of the image data being transfered and the rate of update. Improving those two factors can make it possible for the remote users to access the interactive atlases online.

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References:

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