A Path From the National Library of Medicine's AnatLine Database to 3D Virtual Reality Modeling Language Models

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Abstract

NLM launched its AnatLine database of Visible Human Project images and segmentations in April of 2000. This database incorporates a search feature to locate a structure of interest, its component parts, and regions or systems of which it is a part. The file format incorporates several kinds of data and metadata, including cross sections digitized from the 70 mm film and segmentation masks for both black and white and color data. The programs needed for viewing as well as for parsing this complex file format into its component parts are downloaded from the AnatLine website to allow viewing and unpacking of data for individual structures within a larger unit (e.g., heart) or region (e.g., mediastinum). Software created by the coauthor (JES) was used to interpret the information files and segmentation maps and to expand these into a series of cross sectional images of each structure in correct orientation in space with unrelated pixels in the image set to black. This greatly facilitated the surface reconstruction using our IsoView software system since the segmentation mask included only data including the object of interest. IsoView was then used to smooth the models and to construct scenes by assembling selected subcomponent surface models, whose appearance was also selected as the texture map derived from the cross sectional color images, or with colors, shading and transparency determined by IsoView. Simplification (decimation) of the surface models and conversion to Virtual Reality Modeling Language (VRML) was accomplished using another utility program.

Keywords: AnatLine, Heart, Lungs, Segmentation, VhParser, VRML

Introduction

In April 2000 the National Library of Medicine (NLM) posted a beta test site titled "AnatLine," providing a variety of new resources derived from The National Library of Medicine's Visible Human Project (VHP). Included among these resources disseminated via the WWW were digitizations of the 70mm photographic images from the VHP Male; the segmentation byte masks of thoracic structures prepared by EAI, Inc. under contract with NLM; and some rendered scenes. These data are stored in an elaborate database structure designed and implemented by NLM, utilizing the vocabulary of NLM's Unified Medical Language System (UMLS).

Developers have made fantastic strides in using the VHP data in ways not initially anticipated. However, the task of segmenting individually identified structures in the data has been a major concern, and the topic of numerous reports in the literature [1, 2, 3, 4, 5], as it represents the rate limiting factor in the development process. Presentations at this conference addressed hybrid methods of segmentation [6] and demonstrated elegant graphic supplements to segmentation for smaller nerves and vessels [7]. The AnatLine Database (AnatLine Version Beta 1.0) provides segmentation masks for a considerable number of structures in the thorax of the VHP Male. Ackerman [8] recently described the Visible Human Project's history and his vision of its educational potential, and Spitzer [9] reported at this meeting progress in NIH's multi-institute project to create a functional atlas of head and neck anatomy. The potential is already being realized, as many developers have described applications of Visible Human Project data in education. At the undergraduate level, Senger [10] reported using the Visible Human Project in an anatomy and physiology course, and inclusion of spline models in future Medical College Aptitude Tests (MCAT) has also been proposed [11]. Applications in medical education abound, whether in conjunction with gross anatomy [12], or to correlate with cross sectional [13] or imaging [14] anatomy. Further advances in educational uses of the VHP data were discussed at this meeting, including suggestions that computer modeling might contribute to increased understanding by anatomists as well as students [15]. Many applications such as the University of Washington's Digital Anatomist [16] and cross sectional atlases (e.g., [17]) are accessible via the WWW. The ability of the computer to generate scenes on demand [18] requires implementation of an internally consistent knowledge system, the topic of several papers at this meeting ([19, 20, 21]). An additional indication that the complexity of developments appears to be rising to another level is the addition of functional correlations such as ECG [22], simulations [23, 24] and animations [25, 26],

The implications of three dimensionality for enhancing anatomical understanding from viewing computer models has been pointed out [27, 28], and interactive 3D lessons are being incorporated into the curriculum at UCSD and Uniformed Services University of the Health Sciences [29] This paper describes one way of processing the VHP data to create Virtual Reality Modeling Language (VRML) models, which developers in such diverse locations as Australia, Germany, France, and the United States are currently utilizing in connection with the anatomical sciences.

Methods

Data are located via NLM's Database Query search engine (Figure 1), which utilizes relationships and unique identifiers of the UMLS. Guidance is provided regarding valid terms available for search in the database

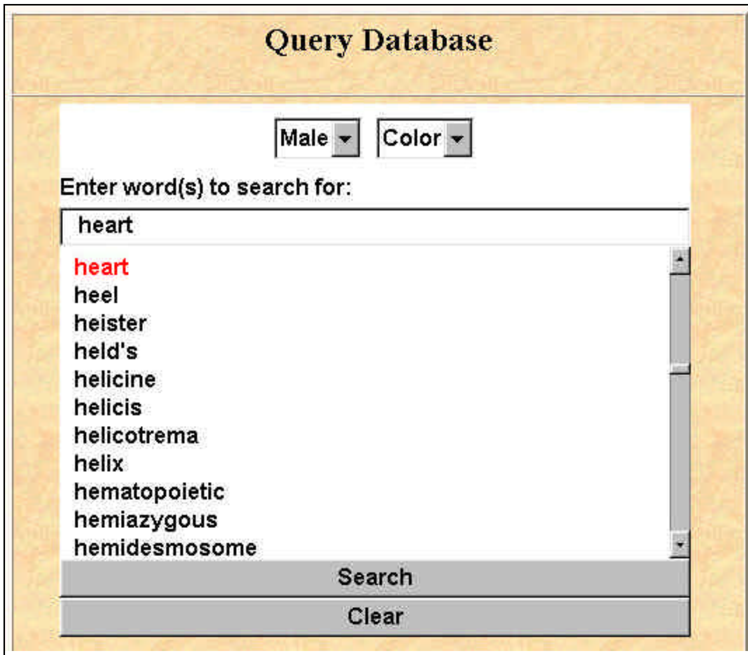


Figure 1. AnatLine Database Search Screen

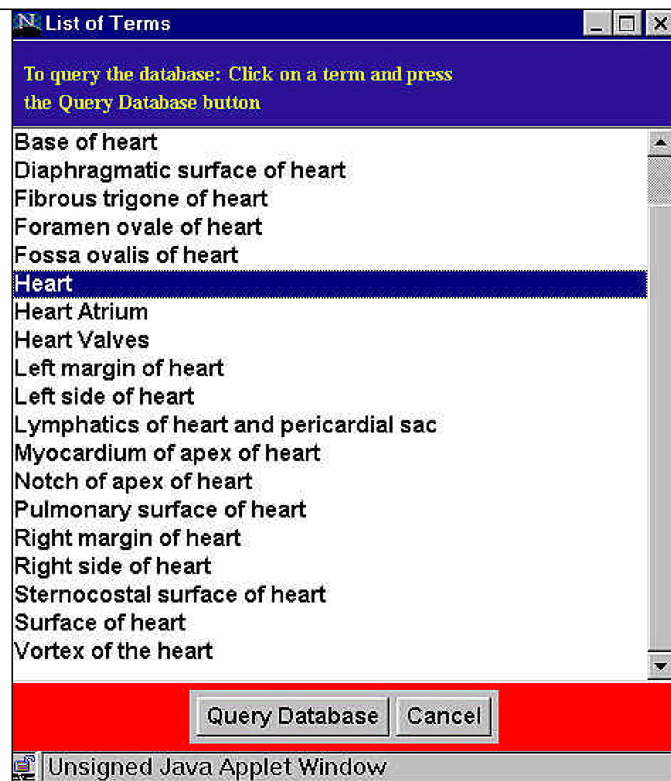
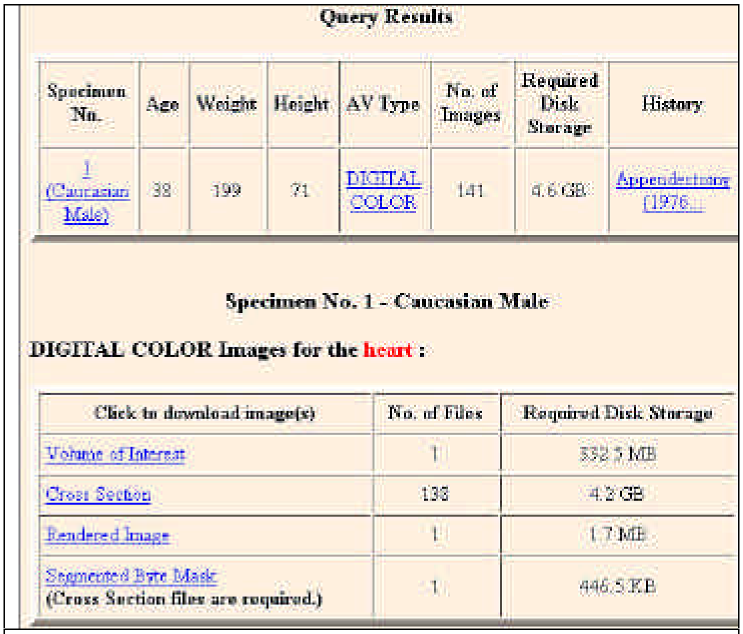


Figure 2. List of valid search terms containing "heart."

(Figure 2). A search for "heart located indexing of the term in the male dataset, represented in one Volume of Interest file, 138 cross sections, one rendered image, and one segmented byte mask file (Figure 3). Related terms for Physiological System (cardiovascular), Body Regions (mediastinum, thorax, thoracic cavity) and Substructures (pericardium, right side of heart, left side of heart, right atrium, left atrium, right ventricle, left ventricle) are also returned (Figure 4), based on relationships in the UMLS and contents of the AnatLine Database. Selecting one of the hot-linked terms under the headings of Physiological System, Body Region or Sub-structures returns the contents of the database for that term (e.g., "right side of heart" Figure 5). Selection for downloading of the various file types (cross sections, volume of interest, segmented byte mask or rendered image) whether singly or in batches is accomplished through the AnatLine GUI, which indicates the required disk storage for each file or group of files (Figure 6). The General Information page of the [AnatLine website](#) provides links to details of the new "[vhi" file format](#) which NLM has designed for these data. This file format is handled for viewing by the AnatLine program [VhDisplay](#), and is parsed into component files by [VhParser](#) which can be downloaded from the AnatLine site.



Query Results

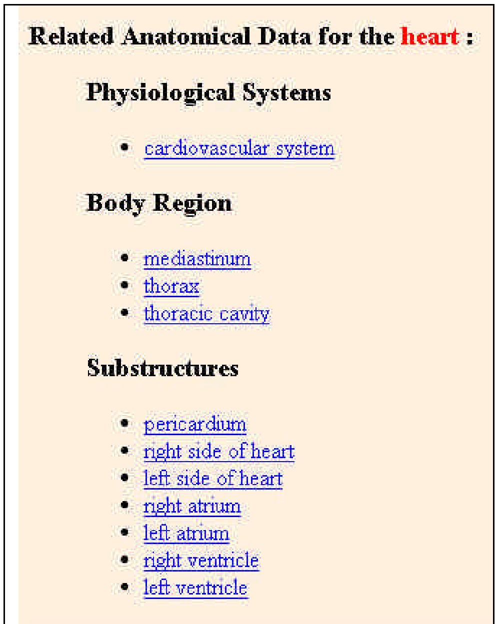
Specimen No.	Age	Weight	Height	AV Type	No. of Images	Required Disk Storage	History
1 (Caucasian Male)	38	199	71	DIGITAL COLOR	141	4.6 GB	Appendectomy (1976...

Specimen No. 1 - Caucasian Male

DIGITAL COLOR Images for the heart :

Click to download image(s)	No. of Files	Required Disk Storage
Volume of Interest	1	332.5 MB
Cross Section	138	4.2 GB
Rendered Image	1	1.7 MB
Segmented Byte Mask (Cross Section files are required.)	1	446.5 KB

Figure 3. AnatLine Search Results: Heart (of the male) located in Volume of Interest, Cross Sections, Rendered Image and Segmented Byte Mask.



Related Anatomical Data for the heart :

Physiological Systems

- cardiovascular system

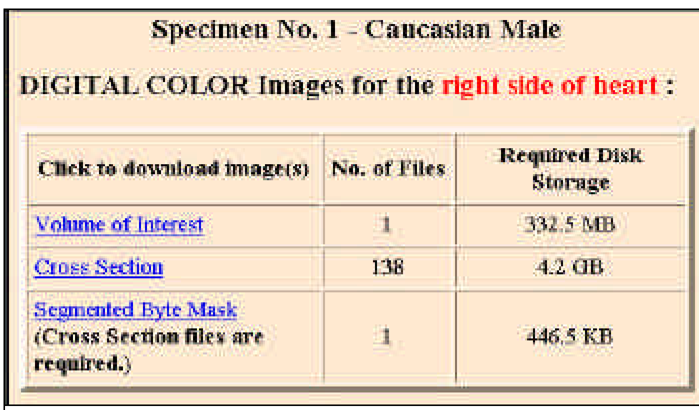
Body Region

- mediastinum
- thorax
- thoracic cavity

Substructures

- pericardium
- right side of heart
- left side of heart
- right atrium
- left atrium
- right ventricle
- left ventricle

Figure 4. Terms in AnatLine database related to "Heart".



Specimen No. 1 - Caucasian Male

DIGITAL COLOR Images for the right side of heart :

Click to download image(s)	No. of Files	Required Disk Storage
Volume of Interest	1	332.5 MB
Cross Section	138	4.2 GB
Segmented Byte Mask (Cross Section files are required.)	1	446.5 KB

Figure 5. AnatLine Database contents for "right side of heart," a substructure term selected for a follow up query from the results of the search for "heart."

Image Retrieval Results

Download multiple files

Click on a link below to download a single file:

File Name	Image Type	File Size
DSV100018787.vhi	Volume of Interest	332.5 MB

Problems? Contact the webmaster at webmaster@anatline.nlm.nih.gov

Figure 6. File name and size of type selected (e.g., Volume of Interest) from search results screen.

Several Volume of Interest files have been downloaded, including "neck," "spine," and "heart." VhParser was then used to open these files (Figure 7) extract a stack of color cross sectional images of the volume of interest, and byte masks for individual structures (Figure 8). A software utility written by one of the coauthors (JES) was used to read the byte masks and color image files and to write a series of cross sectional image files

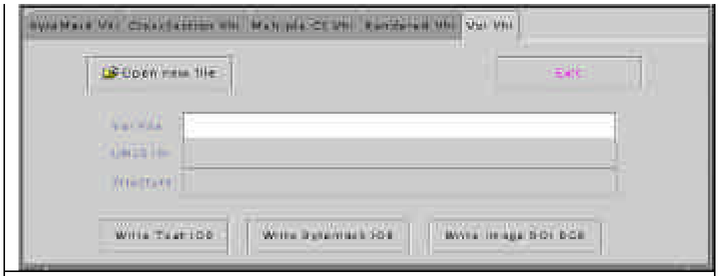


Figure 7. VhParser "Open File" menu for choosing which file to parse.

(Figure 9) which were then used as input for his IsoView software system for producing and manipulating surface models. This utility was used

Figure 9. Analyze byte masks parsed and expanded from VHI Volume of Interest.

Figure 10. Representative color cross sections for heart, expanded from VHI Volume of Interest.

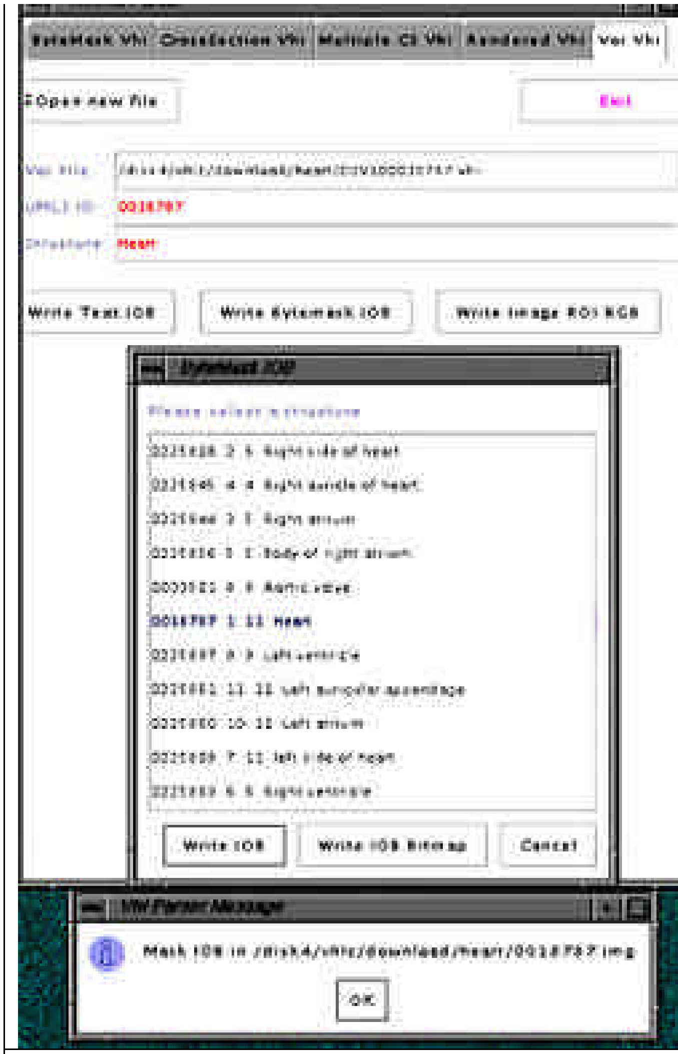


Figure 8. Parser console messages during writing of Bytemask Image file for "heart."

to read the ".inf" file parsed from the region of interest or byte mask ".vhi" file, further crop the AnatLine volume of interest cross section color images to contain only the specific sub-structure of interest, subsample the data to reduce the number of pixels, and set the value of all pixels not contained in the byte mask to black (Figure 10). This makes it easy to generate the 3D surface model of the structure of interest using threshold contours (Figure 11).

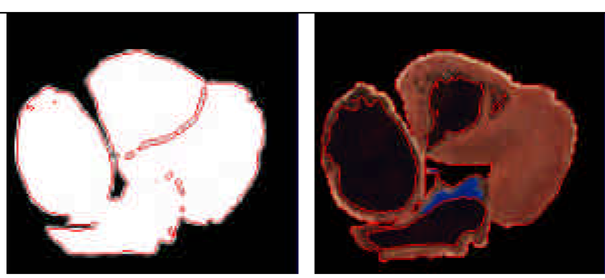


Figure 11. IsoView display of image coutours of Analyze image masks (black and white) or expansion of Volume of Interest color representation.

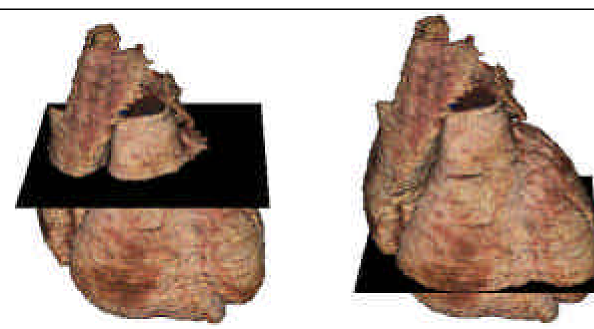


Figure 12. Surface models of heart calculated and rendered using IsoView. Representative cross sections are superimposed, illustrating that all pixels outside the structure of interest are set to black.

Results

IsoView calculated surface models based on the threshold contours of the cross sectional images parsed and expanded from the AnatLine dataset (Figure 12). Colors of the rendered texture map were derived from the color values of the corresponding pixel in the color image stack. Smoothing of the surface, normals and colors was performed within IsoView (Figure 13), followed by decimation to reduce the number of triangles in the models. Extent of decimation was determined empirically in order to achieve an acceptable balance between anatomical detail and speed of movement of the model in space, keeping in mind that the primary goal is to illustrate anatomical relationships rather than to provide “photographic realism.” Similar to the "rendered image file" for Heart (DRS110018787.vhi} in the AnatLine database (Figure 14), IsoView can be used to combine several component surfaces into a scene, and to render the scene using a data-derived surface texture map or to specify such aspects of the appearance as color, lighting, texture, transparency and shininess (Figure 15) . Another utility program was used to write VRML (wrl) format files, for subsequent inclusion with text and other images in computer aided instructional packages. A scene including the heart, lungs (partially transparent), and part of the bronchial tree was assembled in IsoView from individual AnatLine segmentations, and converted to a VRML model. Examples of screen captures of this model viewed and manipulated using Netscape with a Cosmoplayer plug-in are shown in (Figure 16). A computer aided learning web page is being prepared presents the VRML world with rollovers

Figure 13. IsoView model created from AnatLine bytemask, after smoothing of surface, normals and color.

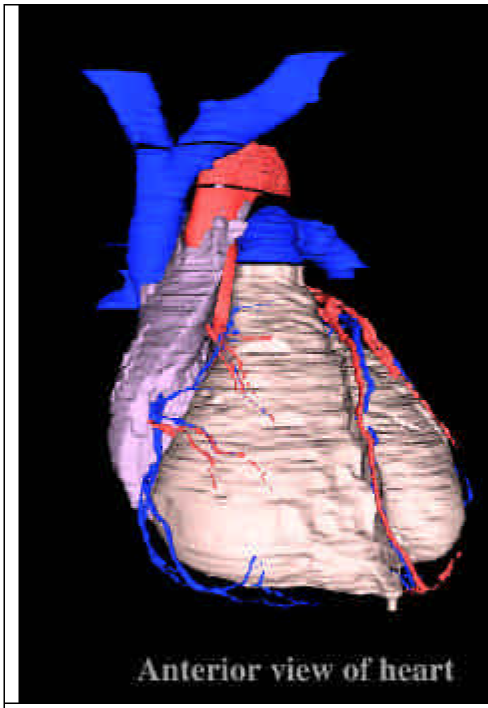


Figure 14. AnatLine Rendered Image of Heart.

Figure 15. Heart and lung scene created within IsoView combining several individual 3D models created from AnatLine segmentations. Appearance of some elements (transparency, colors etc.) was manipulated in IsoView.

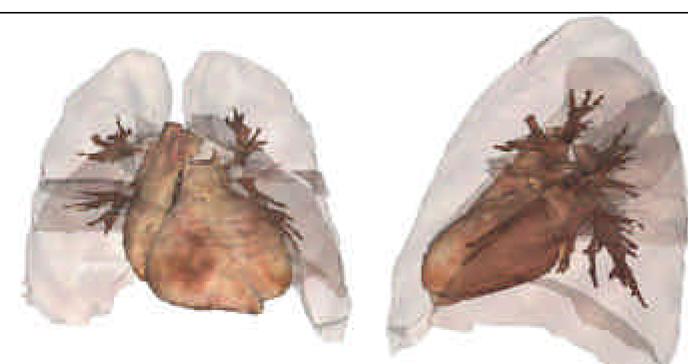


Figure 16. Screen captures of VRML model viewed from two perspectives using Cosmoplayer plugin with Netscape web browser.

and hyperlinks to identifications and descriptive text boxes associated with individual parts of the model.

Conclusions

The AnatLine database provides users and developers with significant "value added" compared to the raw CCD images previously available. The color images derived from the 70mm film are spectacular in the detail which can be observed, and their availability is beneficial. However, availability of the segmentations of structures of interest from the cross sectional data is most exciting, since this time consuming process is the primary rate limiting step in the creation of a collection of 3D Visible Human models. Downloading, parsing and expanding the AnatLine VHI files results in cross sectional masks which are easily contoured and reconstructed into surface models with minimal effort using appropriate software. Segmentations have been specified at several granularities, so that one can quickly construct models of the entire heart, or of individual chambers, or of the vertebral column or of an individual vertebra. The database provides a search engine which enables the user to learn what structures are available, and in what collections of subparts or larger systems. The database is designed to accommodate expansion, and alternative segmentations will likely be added. The availability of rendered images (TIFF files) is useful, though 3D surfaces and/or their VRML representations provide a much greater potential for a wider variety of uses.

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