

AnatLab: A Web-based Virtual Anatomy Laboratory

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We will be demonstrating the Iomas AnatLab system during the conference. This short paper is intended to provide a brief background on the genesis and evolution of the project over the years.

This work represents the convergent evolution of a number of technologies and research “threads.” A project called MetaMAP, which developed early hypermedia imagemap technology, dates back to 1986. Work on creating a new paradigm for doing client-server visualization over the Internet began in 1992. Another major project began in 1993 to turn the Web into a platform for interactive applications. A project to develop multidimensional imagemap technology began in 1995. Finally, work on a scalable computational server architecture called “Dark Iron” began in 1997. The AnatLab project represents the intersection of these various research efforts to create a new kind of navigable knowledgespace that leverages the advantages of each of its constituent technologies.

The seed of the idea began as early as 1984, during discussions between Mike Doyle and Maurice Pescitelli. Dr. Doyle was then a graduate student at the University of Illinois, enrolled in Dr. Pescitelli's course on embryological development. The two were computer hobbyists and wondered if it would be possible to aid in the teaching of the difficult 3-D concepts of embryology by making a computer system to build virtual models of embryos that students could interact with on the computer. Little did they know that this question was the beginning of a long and winding road.

The two collaborated on a grant application to fund a project, hoping to use the powerful new IBM AT computers that had just come out on the market to build such a system. The proposal was funded, but luckily, the project fell apart for political reasons, before the team could discover that they had gotten in way over their heads, and that the complexity of the task would have swamped such a small computer system. The seed had been implanted, however.

MetaMAP

Shortly afterward, Doyle was working as a teaching assistant in a Medical Histology class. He noticed that most of the students' questions in lab were a matter of putting the microscope's pointer on a particular location in a microscopic view and asking a TA “what is this?” He thought it might be possible to create a system that could act as a “virtual TA” to automate answering such questions via a computer screen. He set out to build such a system as a “hobby” project using his early IBM PC.

He had a third-party graphics board that could display images that were 512x480 resolution, and was able to handle 256 colors from a 16 million color palette. Doyle had gained experience in working with limited palettes due to his training as a medical illustrator. It seemed to him that 256 colors was much more than he would need to render a realistic image of a microscope slide. He began to think about using excess capacity in the 8-bit pixel to store object information, and then to use this as a basis for a

program to automatically identify image features in response to users' mouse clicks. He made a small “browser program” that allowed a user to navigate from image to image and to retrieve text information about image features merely by clicking on “hotspots” in the images. The resulting new technology, called MetaMAP, was awarded a U.S. patent (4,847,604) in 1989.

A unique aspect of this program was that this was an “open” hypermedia system, in that it allowed “webs” of information to be created and navigated that could be arbitrarily large, since it used image files and “secondary maps” that were external to the navigation program. Unlike the previously-used “closed” hypermedia systems that required the hypermedia application to store a complete representation of the network of hypertext links within the program's address space, and that resulted in large unwieldy programs needed to handle large databases, Doyle's system could use a small browser program to allow a user to navigate from image to image throughout a potentially infinitely-large web of interconnected data. As far as the authors are aware, MetaMAP was the first open distributed hypermedia system, predating the World Wide Web by three years. It was certainly the first Web-like hypermedia imagemap system, employing a true client-side imagemap architecture in the mid-1980s.

Since then, the Web has provided a simple mechanism, called an imagemap or ISMAP, for linking 2-dimensional spatial data (images) to related symbolic information (URLs). This is a simple technology that links simple polygonal regions within images to the locations of data objects on the Internet. Web imagemaps are currently an established standard mechanism that is used for creating graphically attractive user interfaces to Web pages. Unfortunately, the standard polygon-based ISMAP technology that is used in most Web imagemap systems can only work with simple polygon maps, and becomes either intolerably slow or totally unusable for mapping high-resolution images with large numbers of irregularly shaped objects, such as is the case with complex biomedical images.

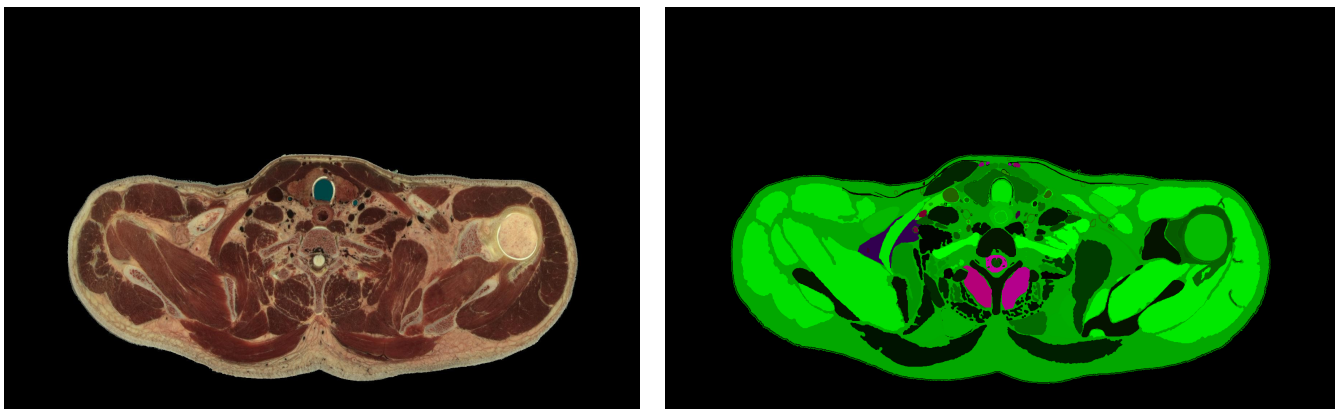


Figure 1: A very complex Web-based imagemap made possible by Doyle's MetaMAP technology

For this reason, Doyle's MetaMAP system was adapted to the Web imagemap architecture. The efficiencies that allowed hypermedia imagemaps on 4.7 MHz IBM PCs in 1986 allowed the creation of incredibly-complex imagemaps on newer hardware platforms. Current implementations of MetaMAP allow as many as 16 million different classes or hotspots within a single image, where even each pixel can be an independently-addressable hotspot (for images of fewer than 16 million pixels). Figure 1, above, is an example of what is probably the most complex type of 2-D imagemap on the web today (viewable at <http://maury.bionetlab.org/vhm10>). The left frame shows a very complex scene full of

many objects. The right frame shows the MetaMAP-based secondary map which correlates each image object to a unique 24-bit object index, where each object index appears in the map as a unique 24-bit color.

Visible Human Nameserver

The MetaMAP system was then used by the Iomas team to create an anatomical object table which corresponded to the 2000 anatomical features represented in the Visible Human Project image dataset. This table correlated the 24-bit object index with an appropriate server response. The MetaMAP server allows script-based programs to be associated with image objects. Initially, a simple html script is associated with each object. In the future, however, more sophisticated programmed responses can be associated with each anatomical object merely by setting a flag in the object's table record and inserting an appropriate Tcl script in each anatomical object record's "script" field. Using the zMap technology described below, the anatomical object MetaMAP images and the related object data table were then used to set up a Visible-Human-specific "anatomical nameserver." This server can be employed as a general-purpose information server by anyone on the Internet who has the ability to determine the x,y,z coordinate of any voxel with the VHP male dataset.

A simple HTTP GET request issued in the form of `http://maury.bionetlab.org/cgi-bin/mapper.cgi/vhm10@vh10@z.tif?x,y` will result in the nameserver returning the anatomical object name corresponding to that voxel location in the VHP male dataset. It should be remembered that the first z coordinate in the VHP male data is 1001, so the range of valid z values for the male would be 1001 to 2878. Further, the x and y origin for each section image is offset from the original NLM data by a few pixels in order to correspond to the most commonly used set of VHP image data, which has had excess image data outside of the body cropped. This system can be queried by any conventional Web browser.

For example, issuing the above request with x,y,z values of 764,554,1400 will return "Lumen of the Pulmonary Vein, Right" The complete HTTP request to receive such a response would be `http://maury.bionetlab.org/cgi-bin/mapper.cgi/vhm10@vh10@1400.tif?764,554`. A simple test of the system would be to enter the above query string into a Web browser's URL window and then hit the ENTER key. This should result in the display of the associated anatomical structure name (Lumen of the Pulmonary Vein - Right) in the browser's document window.

The zMap System

In 1995, Dr. Doyle became interested in the advantages that MetaMAP-based systems might provide with respect to increasing the "dimensionality" of Web imagemap-based media. He realized that the spatial indexing efficiencies of MetaMAP might allow it to be used as a basis for 3-dimensional image-spaces, such as used in virtual reality environments. He began work on an enhancement to the basic MetaMAP system that would allow 3-dimensional imagemaps to be created and used in support of rich interactive media viewed through Web browsers. This technology, called the zMap system, was first designed for implementing moving hotspots for animations and videos, where time is the 3rd dimension. The zMap system was awarded a U.S. Patent (6,616,701) in 2003.

Both server-side and client-side systems use secondary maps of 24-bit color "indices," where a given x,y,z coordinate in the original image data corresponds to an homologous x,y,z location in the

secondary “map” of 24-bit voxels. The RGB triplet found at that location in the secondary map then acts as a unique 24-bit object index for the image feature in the original data. The system then performs a database table lookup for that 24-bit index in order to find the related descriptive text information, which may be in the form of HTML code, a URL pointer to a remote Web resource, a Tcl-based server-side script or Tcl-based applet code.

A good illustration of the zMap System in action is the AnatLab system, described below.

The AnatLab Virtual Anatomy Laboratory

The Web platform, MetaMAP, Anatomy Nameserver, zMap and distributed visualization technologies referred to above have converged in the Iomas Anatlab system. This is a Web-based multidimensional atlas of human anatomical information which presents the user with a direct-manipulation interface to browse through a high-resolution reconstruction of an adult male cadaver. This system is currently in beta-test at the University of Illinois College of Medicine, and has been integrated into the human anatomy courses being taught to first-year medical students, as well as other associated health professions students (physical therapy, etc.).

AnatLab utilizes a Tcl-based anatomical nameserver in conjunction with a zMap-enhanced tclhttpd Web server to allow users with Javascript/Ajax-capable and Flash-capable Web browsers to explore the Visible Human male dataset in an intuitive interactive way. Users can slice through the data from different directions, and interactively query the knowledge base by merely clicking on any structure in

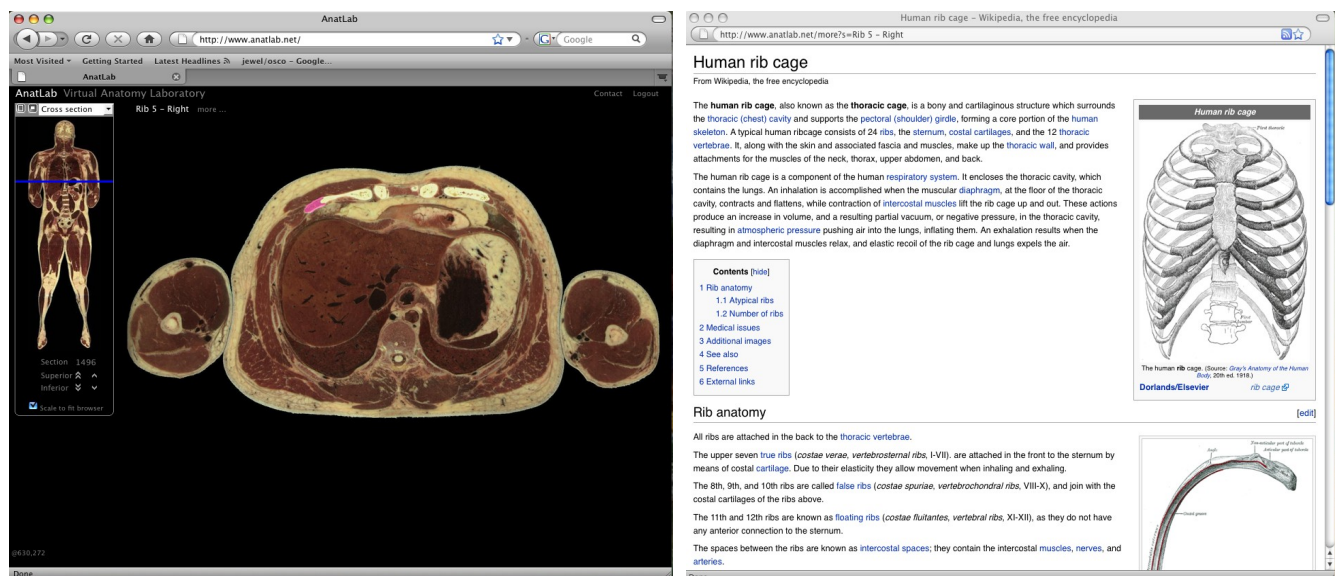


Figure 2: The Iomas AnatLab system integrates tightly with Wikipedia

the section image. The system responds by displaying the name of the anatomical structure and highlighting the extent of the structure on the section image being viewed. If the user clicks on the "more..." link, the system opens up a separate window and displays the corresponding Wikipedia page, to provide textbook-style information and illustrations concerning the anatomical object of interest. As the user clicks on other structures, the system automatically updates the Wikipedia window, tracking the user's progress through the image dataset, and keeping the Wikipedia window in sync with the

object being identified. The interface has been designed to allow the user to zoom from overview scaled images into detailed higher magnification views.

The AnatLab system has been tested on Safari, Firefox and Mozilla-based browsers on both full-sized screens and on hand-held computers, such as the Nokia 810 tablet, with good success. Support for Internet Explorer is expected in the near future.

Many other features of the system will be demonstrated during the live presentation at the conference.

For more information, please visit <http://anatlab.com>