THE UNIVERSITY OF MICHIGAN VISIBLE HUMAN PROJECT (UMVHP)
QUARTERLY PROGRESS REPORT: Y2, Q1

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The University of Michigan Visible Human Project (UMVHP)
Year 2, Quarter 1 Progress Report Highlights
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Once again, there have been many areas in the UMVHP that are moving the project ahead of schedule. I am pleased to report the following:

1. The Edgewarp navigation capability has been extended to allow for user controlled arbitrary slicing across platforms. This quarter, it has been extended to run on Windows, UNIX, Linux, and Mac OS (provisionally, OS-9 and above). This capability is www enabled, and communicates requests back to the voxel server. This system has worked well into homes with a cable modem at bandwidths of 300-800kbit/sec. This means that our target seat # for the final demonstration has increase to up to 200 simultaneous users. This code was produced by PSC under subcontract.

2. Content Development efforts focused on segmentation and labeling of the VHF Pelvis and Abdomen are complete at 3mm resolution. Dr. Gest and team will fill in missing data in the intervening slices during the next 6 weeks. The data will be reviewed and edited by Prof. LeRoy Heinrichs at Stanford University.

3. The location and source of bandwidth bottlenecks to be removed to allow for I2 production performance have been identified and plans for Phase III capabilities at a minimum of 200mbit/sec aggregate throughput to the Abeline network have been identified and a plan is being formulated to test this assumption the 6th quarter.

4. The UIT team has added Brad Smith, Ph.D., Associate Professor of Art and Design and of Radiology to co-leader status. This leadership is shared with Professor Burger, who is on phased Retirement for the next 2-3 years, and who currently serves 7 months on the project and 5 months off. The UIT has populated the VH database (in the female pelvis region) with connected Anatomical content such as quizzes, dissection movies, etc. to enrich the VH content delivery capability. A detailed architecture of the front-end content delivery interface with the necessary concept maps is now being developed using the UM Gross Anatomy Dissection Manuals.

5. Filmstrip voxel touring authoring is complete in the Edgewarp 3.4 upgrade. Dr. Bookstein has made several demonstration filmstrips. These can be updated remotely using NGI capable voxel servers at PSC. These client server applications run from 2-8 mbits/sec and are metered on the fly using UM developed network performance measurement software checking the link between PSC and UM on Abeline.

6. Collaborative efforts with Stanford University have begun in earnest. Applications form both projects will be shared broadly between the 2 Institutions and a Memorandum of Understanding is being established between the 2 Institutions. One current area of focus is adding the UM VHF Pelvis data to the platform independent Browser capability for tests at Stanford University. The UM Team will also load the Lucy 2.0 female pelvis data into the Edgewarp browser, which is being extended to view surfaces in a voxel context.

7. A full-bodied Visible Human Browser (1.0) that delivers all 3 modalities of images is now available on line at vhp.med.umich.edu/tools_a.html The 2.0 Browser, to be completed by fall, will include a similar instantiation for the Male Dataset and will include scaled, side-by-side, MRI and CT datasets in the same window. This can be linked to the NLM page now.

8. The PSC has collected several of its VH slice servers into a page and has linked this to the UM VH page for eventual service to the entire Internet community. http://vhserv.psc.edu:8000/ login=umvh, password=nlm.

9. A four processor Compaq ES-40 Graphics enhanced ray-casting server and the Ethereal Virtual Presence Mirror system are planned acquisitions in the next Q. These products will enhance end-to end I2 demonstrations. The mirror system will be deployed to view stereo streams form the Stanford and UM (PSC) systems.

10. Prof. Scott Hollister is no longer able to maintain active participation with the UM VH Project. His work, which has involved rendering, is being subsumed by the PSC and UM team staff.

11. Current plans include working to demonstrate VH image data compressing for transmission at a nominal 10x compressing with 100x data compressing a reasonable target. This would extend the # of simultaneous users for the UM/PSC system to 4000 (from 40). Dr. David Neuhoff at the UM will join Art Wetzel in these efforts, which also include creating an “improved” CCD image database of the Visible Human M&F base on the film scan images available from the Anatline www site.

12. The UM team has converged on a rapid prototyping model that uses Drs. Bookstein and Greene to demonstrate NGI VH navigation capabilities using a LINUX system with Open GL and a commodity graphics card. The next version of the system after prototype, is made as a web enabled version which is cross-platform in its performance. Mr. Ade (UM) and Mr. Pomerantz (PSC) are responsible for this conversion.

13. Dr. Dan Karron ended his contract with the UM. He was contracted to work on real time segmentation of visible human data. His final report is posted at the Computer Aided Surgery Inc. www.casi.com.

14. UM Visible Human Project in the News. Pittsburgh Gazzette Story, Detroit News Story, I2 www site, PSC www site (UM is a alpha user and tester of the NSF funded Web 100 project).

15. Problems. Segmentation continues to be a problem. PSC is hiring an expert in this currently who can help us. UM and PSC are evaluating Isoview amd Simplify software modules of Dr. John Stewart for possible use.

Y2Q1 REPORT, KNOWLEDGE ENGINEERING TEAM

ACCOMPLISHMENTS OF THE QUARTER JUST ENDED

The principal accomplishment of the quarter just completed was the release of a new version, EWSH3.2.6, of our familiar Edgewarp software product. The release is in the form of executables for SGI Irix platforms and for Linux machines with OpenGL support.

Features distinguishing EWSH3.2.6 from its predecessors include:

> (a) Automatic loading of the network connection with the PSC chad server, automatic memory filling under ordinary user interactions, automatic image fill at the highest available level of detail
> (b) For filmstrips representing continuously moving Edgewarp scenes, a new browser window, incorporating interactive controls of playback mode (speed, discrete search, user adjustment of projection orientation) and a complete editing station (insert, delete, replace, intercalate)
> (c) In preparation for the extension of the product to additional data sets (see below, Y2Q2-Q3 plans): a facility for displaying and extrapolating deformations between multiple volumes sharing a lexicon of landmark locations -- deformations are rendered as images of plane grids
> (d) Command-line invocation, as by link from outside EWSH, perhaps via browser window out of a lexicon

The current release of EWSH3.2.6 is accompanied by an example of curve tracing: a filmstrip following Eve's left ureter from end to end. This demonstration confirms the completion of the Curve Traverse functionality originally proposed for this contract.

PLANS FOR QUARTERS Y2Q2 and Y2Q3

1. EVALUATION

Completion of the Curve Traverse product makes EWSH relevant, at last, to the actual context of anatomical education and thus to enter into the long-awaited interaction between our group and the Anatomy Testbed Evaluation Team. Initially we expect to emphasize complementarity of the Curve Traverse to the standard classroom approach to the viscera. That standard approach emphasizes surfaces, such as are typically delimited by membranes, and involves only one dynamical coordinate, the centripetal "peeling of layers" from the skin inward. Once organs have been sectioned or reflected, they must remain so. For tubes such as the ureters, the Edgewarp pedagogic context instead will emphasize scrutiny of these extended tracts all along their length, in situ, and within that dynamics the possibility of focusing on identifiable single points and their vicinities. The evaluation task will require assembly of "filmstrips" with corresponding dissection stages, existing pedagogic browser pages (such as movies), and student assessments.

2. TOWARD EWSH3.3

Progress to date highlights four distinct directions of EWSH development that are most pressing at this point in the contract: compression of image data, a generalized facility for multiple spectra with multiple content styles, incorporation of surfaces for rendering, and the next mode of image dynamics.

i. Over the coming quarter, PSC will begin serving chads in compressed form. The EWSH kernel will be modified to accept these in either lossy or lossless versions, with appropriate user control.

ii. One general goal of this project is the incorporation of additional generalized spectra in Eve's "volume" beyond the familiar three eight-bit channels of color. Production of a 48-bit data resource that adds MR and CT contents to RGB is dealt with elsewhere in this progress report. For the connection with pedagogy, we intend to experiment also with a 16-bit volume encoding up to 64K links to associated text strings. Regions with the same color will sometimes be extended volumes of contiguous voxels and in other cases two-dimensional surfaces, one-dimensional curves, or discrete points. Each such color will eventually be linked to a lexicon entry in a browser context distinct from Edgewarp itself. Additionally, certain of these surfaces will be linked to meshes suitable for rendering in the EWSH left window (see below); and most curves and discrete points will be linked to one or more filmstrips that traverse them. In other applications, additional colors might represent other specimens deformed into Eve's coordinate frame (see under "Lucy" below). EWSH3.3 will incorporate user control of the byte(s) intended for display from these or similar multi-spectral resources.

iii. Surface meshes generated elsewhere in this project will be standardized for EWSH rendering in the left (global) window, where user controls already exist for changes of point of view. Up to 255 such surfaces can be visualized simultaneously as specific colors in the right-hand window, where they will appear as curves within the section plane. We currently expect each such surface also to appear in the Lexical Volume under its own color, whereby it can be linked to text in browser windows, appropriate Surface Traverses, and the like.

iv. Now that Curve Traverse mode is completed, we will turn our attention to Surface Traverse mode. Where Curve Traverse is dominated by the natural ordering of dynamics by the single parameter of position, Surface Traverse can be ordered by a greater variety of display strategies, including rotating a single normal plane around the surface normal, marching a section plane down the normal, and passing tangent planes along the surface on geodesic paths. We will experiment with these on suitable prototype organs in Eve and package them with other pedagogic materials for evaluation in anatomy teaching as for curves.

3. USER DOCUMENTATION: MAJOR REVISION

Corresponding to the completion of filmstrip editor, grid visualization, and chad server modes, there is need for a major revision of the current EWSH manual. This document will be prepared flexibly for on-line invocation, with links from the EWSH buttons themselves, and with two tracks of text: one for content consumers, such as medical students, and the other for content producers, such as anatomists preparing filmstrips. Consumers, in turn, will be considered in two different subgroups: the more sophisticated, such as our colleagues at the Stanford and Colorado sites, who wish to use EWSH to see details of the data sets we are jointly developing; and the less sophisticated, such as image analysts wishing to coordinate the volume of Eve with volumes they themselves can acquire in EWSH formats for the purposes of their own investigations.

4. ADDITIONAL IMAGE VOLUMES

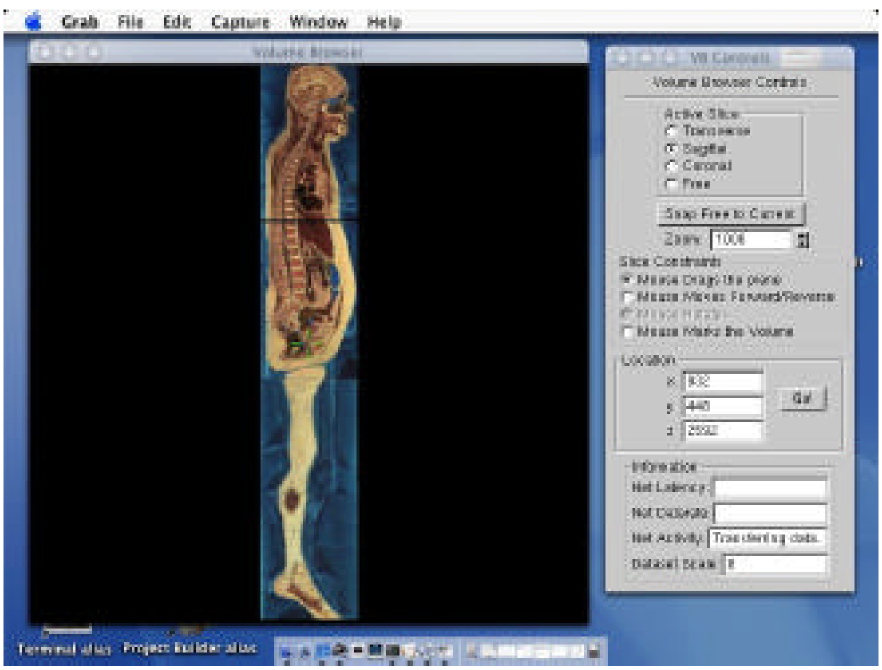
Over the next two quarters we will go forward with the loading of Lucy2.0, the Stanford female pelvis data resource, into EWSH, along with the associated visualizations and lexicons. The comparison of Eve with Lucy is a promising new testbed for software development. Initial experiments will use the current "unwarping" module of EWSH to bring Lucy into Eve's coordinate system as a set of three additional colors.

Y2Q1 PSC VISIBLE HUMAN SUBCONTRACT STATUS REPORT

1) DESCRIPTION OF PROGRESS TOWARDS/COMPLETION OF QUARTERLY MILESTONES & DELIVERABLES.

Principle areas of progress over the past quarter centered on the development of a platform independent library of client side support routines, incorporation of those routines into a new volume slice browser and improvements in high speed networked data delivery. Additional work continues on integrating compressed data representation into the client support, production of segmentations and meshed surface representations and use of WEB-100 tools for network measurement and tuning.

The new client side support library was developed to extend volume slice viewing beyond the limited platforms supported by the current Edgewarp to cover nearly all of the standard PC and Macintosh desktop machines. The library consists of network interface, cached data structures, slice generation, slice display and user interface components. We are currently working to insert the decompression module. The combination of all of these pieces naturally provides a new platform independent volume browser which is functionally similar to the right Edgewarp window but with a reduced user interface. The startup appearance of the new browser as running on an Apple iMac with OS X can be seen at http://www.psc.edu/~awetzel/vbscreen.jpg



Our design is intentionally very modular so the pieces can be used individually or together to provide many alternative special purpose applications. For example, the user interface work being done by Alex Ade and the Michigan team will be able to substitute another user interface component but still use all of the other pieces without having to rewrite the networking, decompression or other codes. The existing Edgewarp should also be able to use the decompression and network modules. This also means that we can individually replace modules as they are improved and immediately reap the benefit across all users. Portions of this code will also be applied to direct slice generation on the server for delivery to very low speed phone link clients.

The primary platform targets for the new browser are PC and Macintosh machines running MS Windows 95/98/ME and Mac OS X. It also operates on Linux and standard UNIX platforms such as SUN and SGI. Given this broad coverage, ports to any additional environments should be relatively simple if needed. Mac OS 9 and Windows NT/2000 are not yet in place but could be done with only a few days work when test machines are available. Our standard development is done on Linux, Windows 98 and our newly aquired iMac. Additional testing is regularly done on Windows 95, Windows ME and SGI machines.

The resulting browser is quite useful over a broad range of network speeds ranging from the high speed connections at PSC down to cable modem speeds in the 200Kbit/sec range. However, we do see that the user's method of operation is very different depending on the network performance. At high speeds use can be rather ad hoc while use on a low speed connection is much more planned and deliberate.
We have demonstrated that even midsize PC and Mac platforms can provide usable performance if the network rate is greater than about 1Mbit/sec.

At the end of the previous quarter we had demonstrated volumetric data delivery from the PSC server to Edgewarp clients for full body visible human slice browsing. During the quarter we have continued to deliver volumetric data to Edgewarp and now to the new volume browser from the same ES-40 server in the PSC machine room. We have a great deal of experience with up to 6 simultaneous users and regularly serve several gigabytes per day during normal development use. The server process has been very stable and available 100% of the time outside of equipment and software service times.

The PSC team has been evaluating network performance levels and identifying bottlenecks to remote sites. Using a test machine with a short (~20 foot) link to the ES-40 server we have seen data rates which peak at 900Mbits/sec as driven by test programs when using 9K byte jumbo frames. Ultimate performance is very sensitive to packet size and rates fall to 400Mbits/sec when using the 1500 byte MTUs. Unfortunately, this is the MTU supported by most external network paths including the Abelene connection to Michigan. Currently we also have some local path limitations but upgrades planned for the July will raise all of the critical paths to 2.5Gbits/sec.
Summary graphs of test results and network configurations can be see at
http://vhserv-archive.psc.edu:8000/vhserv/Perf_test/vh_gige.html
which uses the regular project name and password protection.

Network testing and tuning has been assisted by the first official release of the WEB-100 tools in March. This code is now operating on the full 4 processor ES-40 configuration after an initial problem limited it to single processor operation. Results from WEB-100 are being used to tune the proper look-ahead fetch queue length for client programs as a function of network bandwidth. Currently the best results are to request data that is expected to be needed within the next 250ms. However, network bursts and lags are sometimes a problem especially with low speed links.

2) PROBLEMS ENCOUNTERED DURING THIS QUARTER.

Our largest problem continues to be the segmentation area. This work has consumed a great deal of effort but with very mixed results. We are still seeing segmentation errors when extending 2D fill methods to 3D. These are not program errors but rather result from the fact that nearly all of the segmentation targets have some small regions of connection with very different characteristics from the major surface regions. A related area of difficulty is the efficient mesh representation of segmented surfaces. These are discussed in sections 3 and 4 below.

Smaller problems we encountered include the accidental damage to one of the ES-40 power supplies during wiring changes in the machine room, bottlenecks in network transmission rates and a problem with multiprocessor support in the first version of WEB100.

3) RESOLUTION OF PROBLEMS.

We are attacking the segmentation and mesh construction problems by putting more effort into support for rapid computer assisted but manually guided segmentation and also by adding a new staff member who specializes in mesh techniques. During the past several weeks we have been working with Brad Smith and others to select a subset of features that are useful for manually guided segmentation and which can be inserted into either Edgewarp or the new volume browsers. We have initially inserted a limited point marking facility in the new browser and will also be adding flood filling, thresholding, painting and other user controls. The resulting data will be ready for use by the mesh construction process.

We are adding a third power supply to the ES-40 to provide redundant operation. The machine currently has two power supplies and needs both of them for normal operation. (It can run for a short time on just one but that is marginal.) With a third supply the machine can continue to run even if one fails and the dead supply can be hot swapped without taking the machine offline.

The initial WEB-100 tools were developed on single processor machines and a bug was identified with SMP support which would hang our ES-40 server. By taking the machine offline and running controlled tests we were able to debug that problem and develop a code patch.

All of the local PSC network bottlenecks will be relieved by planned summer upgrades relating to the PSC TCS project. However, these upgrades will not be in time for the June demonstration at NASA AMES. We are planning workaround service from another machine that will be sufficent for that remote network demonstration.

4) GOALS FOR THE NEXT QUARTER & ACTION PLAN FOR THEIR COMPLETION

We are adding a new staff member to the PSC team on May 1 who specializes in delaunay mesh construction techniques and parallel programming. He will be working on the segmentation and model building parts of the project. Together with the additional features being added to the browsers to support manually driven segmentation we will be able to move ahead with support for geometric surfaces and textures on both the server and clients.

Enhancement and optimization of the new browser library will be a major area of work. Much of the enhancement will be to add the features needed for segmentation and direct result data capture back to the server.

We will also be rebulding the server database to provide access to the de-noised compressed volume data with color and contrast mapping matched to the 70mm film data equivalents. The uncompressed CDD data will still be available for comparison and evaluation by the user interface team. We will represent the new database in an 8 byte per voxel format which allows for all 6 data channels plus a 16 bit tag supporting up to 65535 feature label regions.

One version of the new database will also represent specific translucent projected raycasted views similar to those provided by the SDSC MPIRE program but using a more cost effective precomputed strategy. This will benefit from additional user controls to manipulate tissue transparency and eventually stereo views. We are beginning to exchange data with the Stanford team to ensure compatibility of stereo viewing methods.

We are also working closely with the user interace team to flesh out the support of anatomy laboratory lessons following the model of the existing anatomy lab workbook. This work will suggest additional modifications to the volume browsers and make use of the surface display features that are being added over the next quarter. One area of this work is to ensure similar behavior between Edgewarp and the new PC/Mac browser along with filmstrip support in the new browser. Additional instructor and collaboration modes of shared operation between several users are also being considered.

5) NEXT QUARTER NEEDS

During the next quarter we are adding one more staff member whose special expertise is mesh construction techniques. We will be purchasing additional PCs to support the new staff and our need for multi user testing and development and a small amount of additional network interface hardware.

DESIGN AND IMPLEMENTATION OF THE UNIVERSITY OF MICHIGAN'S VISIBLE HUMAN DATABASE
Alex Ade

Description
The fifth quarter has been primarily dedicated to enhancing and populating the UM anatomical database, including middleware development, performance enhancements, and integration with the UIT group's educational model.

Middleware development:
Information is queried from the relational database management system (RDBMS) through an independent database module (the middleware) running on the web server and formatted on-the-fly into XML. XML was chosen to facilitate sharing of anatomical information between UM and its collaborators (e.g. Stanford). XML is converted into HTML for display in a web browser. The HTML conversion may be custom tailored to any format required, so that any or all of the XML may be displayed. These custom views (templates) are designed by the instructor to present information in a way that's compatible with their teaching method/environment. A framework is in place for XML conversion into non-HTML for display by devices other than web browsers.

Performance enhancements:
Extensions to the middleware have been developed and implemented to improve performance. For example, connection pooling is now used to cache open connections which reduces the overhead of creating and destroying database connections.

UIT integration:
The database now stores Edgewarp save files (.sav) which are used to cue Edgewarp to a particular place and orientation within the Visible Human dataset. Mime-types on the UM VH web server have been modified to realize these save files so that Edgewarp can be launched by clicking on a link from within any HTML document. The link can point to a still frame, or can begin an Edgewarp fly-through.

An authoring tool has been designed to allow drag-and-drop customizations to individual database views. Instructors will use this software to create learning modules.

Finally, the web based volume visualization software has been extended to allow stereo viewing. Stereo shutter glasses, an emitter, and an appropriate graphics card are required. Stereo improves the experience of navigating within a three-dimensional world, showing realistic spatial relationships between models and allowing for a more natural 3D selection method.

Problems
The stereo view shows intermittent ghosting which I will address and correct during the next quarter. Also, geometric information about the VH dataset must be described and databased. By this I mean, for example, the branching of nerves and vessels. This, too, will be addressed during the next quarter.

Goals for Sixth Quarter
During quarter six, I'll continue to expand the database to include geometric information about the anatomical structures. I also intend to database detailed information about the multimedia objects we'll use in the educational modules. An initial framework for authoring views into the database will be implemented. An instructor will use this to create learning modules specifically designed for his/her teaching method.

I will continue to develop a bridge to the PSC cubelet data server that is optimized for Java so that various cube sizes and resolutions may be loaded into and viewed within a web browser. This work will be done in conjunction with programmers at the PSC using their navigational engine as a kernel.

Y2Q1 REPORT: UIT INTERFACE PROTOTYPE; ANATOMY, NURSING

DESCRIPTION OF PROGRESS

Manual segmentation of the major structures (vessels, organs, bones, musculature) of the pelvis cavity has been completed at 10 slice intervals, together with partial peripheral musculature. Coordinates of their locations have been translated and will be placed in the database when the SunT3 RAID unit is installed on the interim server. This list follows. The slice range concentrated on: 1800a to 1930a, with extensions of certain structures above this region.

Pelvis :

vertebrae T6-T12, L1-5
vertebral discs included
sacrum
coccyx
femur

great saphenous vein
femoral vein
deep femoral vein
External iliac vein

External Iliac artery
Femoral artery
deep femoral artery

sartorius
Piriformis
gluteus maximus
Levator ani
coccygeus
iliopsoas
rectus abdominus
linea alba
rectus sheath

Inguinal lymph nodes

hamstring tendon
round ligament
ischial nerve
femoral nerve
Lumbosacral trunk
Sacral plexus
coccygeal plexus
(only the major divisions of
the plexus's could be followed)
obturator nerve

uterus
ovaries (every 2 sections)
uterine tubes
vagina
bladder
lumen of bladder
ureters
uretha

rectum
bowel (1500a to

Partials (every 30th slice, or small areas, e.g. the transversus, int. and ext. obliques are tailing off in the early 1800s slices, but we include them for completeness)

transversus abdominis
obturator internus
gluteus minimus
gluteus medius
rectus femoris
tensor fascia lata
pectineus
sup. gemellus
quadratus femoris

vastus lateralis
vastus intermedius
adductor brevis
adductor longus
adductor magnus
semitendinous
gracilis
int. oblique abdominis
ext. oblique abdominis

For the anatomy testbed, the M1 laboratory dissection manual, based on regional anatomy, is being used as a framework for building student evaluation sessions. For the nursing testbed, the systemic teaching model will be emphasized. These approaches will make use of all software developed to date.

Development of the interface design template continues. A demonstration of a Visible Human Teaching Module was presented at the Y2Q1 meeting on Friday, March 23. The template was specified by Carl Berger and Sylvia Lee. The user begins by navigating to a specific module and then to a particular structure. Once a structure has been chosen the user then views it a variety of ways (i.e. 3D Models, Visible Human Slices, 3D Navigation through Visible Human Data via Edgewarp type browsing). The module also includes resources such as movies, text, and quizzes. A concept map remains in the background to help the user navigate through the module. Buttons such as: Help, Search, Links, and Table of Contents appear in every window to make it easy to find additional information. The module will be tested and refined with feedback from testbed groups.

The sequence of images shows how the user would navigate through the module.
In the first window (figure 1) the user has selected Visible Human> Female> Regional Anatomy. In figure 2 the pelvic region has been selected and a simple map appears with the various structures of the pelvis. The third window (figure 3) shows how the options available for the structure that has been selected; in this case the bladder, may be accessed.

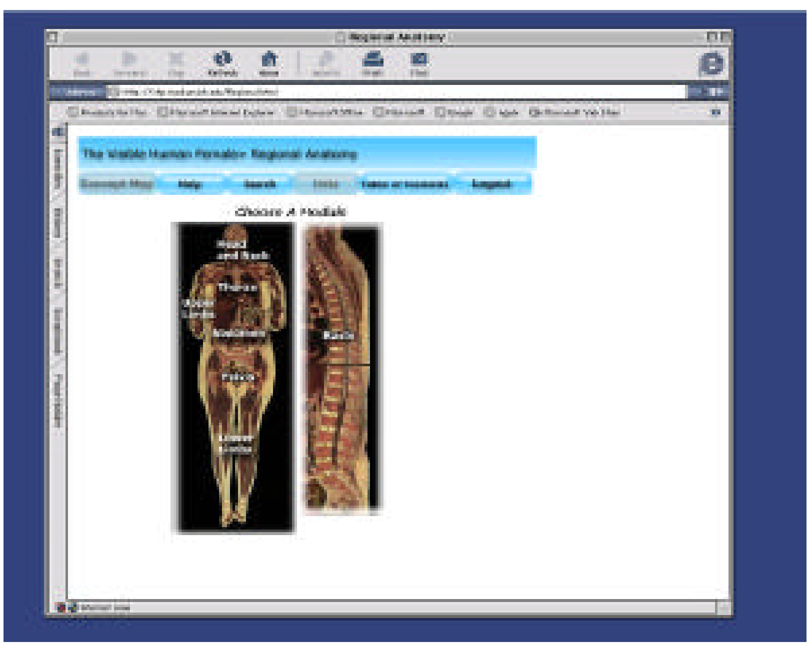


Fig. 1 Regional Anatomy

Fig. 2 Navigating through the Pelvis Module

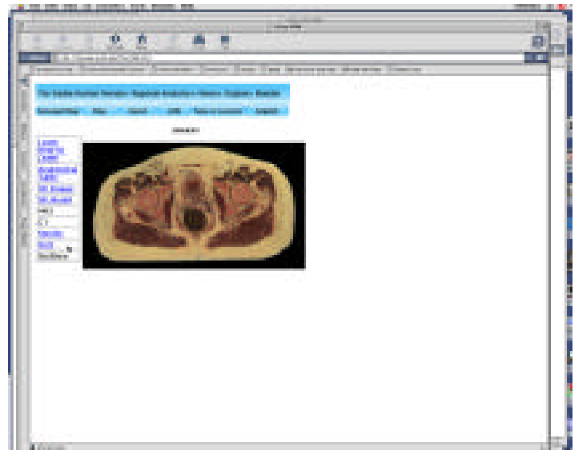


Fig. 3 Transverse section showing the bladder

GOALS FOR THE NEXT QUARTER
Fascial compartmentalization of the pelvic cavity.
Addition of the smaller vessels and nerves.
Continuing of segmentation into the abdomen and the thoracic cavity. Use of segmentation software should increase productivity.
With the introduction of the streamlined arbitrary slicing interface and the UIT interfaces, student evaluation of all software/protocols/databases developed will commence.

NEXT QUARTER REQUIREMENTS
Installation of Dell 4100 series computers in Medical Science Building II for student testing.