

**THE UNIVERSITY OF MICHIGAN VISIBLE HUMAN PROJECT (UMVHP)
QUARTERLY PROGRESS REPORT
Y3Q3**



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**UMVHP:
THIRD YEAR QUARTER THREE
REPORT
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Y3Q3 PROGRESS REPORT SUMMARY

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The University of Michigan Visible Human Project is pleased to present this report to the National Library of Medicine (NLM). The work presented represents a culmination of nearly four years of funding contract work encompassing the Planning Phase I and the Research, Development, and Prototyping Phase II which is in Year 3 quarter 3. At this point, nearly all the major project milestones have been completed, and several products are anticipated to be released within the no-cost extension phase. A short summary list of current Year 3 project deliverables is presented below, followed by more detailed reports. As always, information and answers to questions concerning this report or overall project progress can be obtained by contacting the UMVHP staff.

Year 3 Deliverables

- 4 Gross anatomy laboratories (175 students) wired for 38 workstations. UM WWW anatomy curriculum integrated with Visible Human content, labels and delivery platform, PSC Volume Browser (VB) 100 mbits/sec to I2; ~10 Visible Human content papers accepted.
- Nursing Testbed Visible Human laboratory setup 100 mbits/sec to I2. Edgewarp, iVoxel, and PSC VB being tested. JAMIA paper (Walker, et. al. JAMIA 9(4), 311-319) published to give evaluation criteria for testbeds.
- UM Visible Human Female content database and servers in place.
- 30 simultaneous Visible Human lookups in Gross Anatomy classroom setting linking PSC servers to UM clients (students).
- Other testbed collaborators and developers identified (Navajo Nation - K-12, State of Michigan, Van Andel Institute).
- PSC to go into production Sept. 30th 2002 with VH servers and VB distribution.
- UM orthogonal browsers enabled to link and display labels.
- Kendall School of Art and Design actively engaged in segmentation, rendering and content generation, delivered ~150 structures of VHF.

University of Michigan Software Product #1: Edgewarp Navigator

- A reordering of the voxel retrieval list to operate in center-out order rather than right to left (so that crosshairs of a section serve as the fovea of the browser's detailed attention).
- The appearance of curves as a data type for objects analogous to surfaces.
- An Edgewarp display mode by which any list of section planes can be displayed simultaneously.
- Extension of Edgewarp to Mac OS X (with the assistance of commercial bridging software), and Windows platforms (running under a resident, reduced set Linux kernel).

University of Michigan Software Product #2; UMich iVoxel Software

- The iVoxel software package has been divided into three modules: Volume View, Model View, and Slice View. The Volume Viewer displays volume rendered scenes, the Slice View shows a multi-resolution, two-dimensional image through the volume data, and the Model View displays, three-dimensional, shaded wireframe models.
- Enhancements to the Volume Viewer: supports the addition of up to six arbitrary cut planes, and supports the loading and display of user defined color maps; Supports stereoscopic display.
- Enhancements to the Model Viewer: supports fly-through animations in the scene, a modified interface to support asynchronous loading of models, and model display based on level of detail; Supports stereoscopic display.
- Enhancements to the Slice Viewer: supports real-time asynchronous downloading and display of multi-resolution voxel data, and reads PSC bookmark files for point-to-point navigation through the volume.

Pittsburgh Supercomputing Center (PSC) Subcontract

- Algorithm development for simple non-branching structures employing minimal contours sets produced from critical planes describing structure geometry linked to VB.
- Multiple datasets made available: VH Female CT and corrected color data; 330 wireframe models created. VH Male and CCD and Film data available on PSC server.
- Collaboration tools integrated with VB.
- Custom Widget set for cross-platform consistency.
- Compression based on a combination of wavelet encoding and discrete cosine transforms embedded into the PSC Volume Browser (VB).

4th Visible Human Conference Abstracts to be presented at this conference follow:

Evaluation of a Volume Browser: PSC-VB Geri Durka-Pelok*, Stuart Pomerantz+, Cynthia Gadd+, Terry Weymouth*, Thomas Gest*, Jie Huang*, Demian Nave+, Art Wetzel+, Wen-Yu Lee*, Brian Athey* - *University of Michigan, Ann Arbor, Michigan; +Pittsburgh Supercomputing Center, Pittsburgh.

Creation of an educational visual module: integration of QTVR and the Visible Human Data Set Geri Durka-Pelok¹, Thomas Gest¹, Gary Nieder², Terry Weymouth¹, Jie Huang¹, Art Wetzel³, Stuart Pomerantz³, Demian Nave³, Brian Athey¹ - ¹University of Michigan, Ann Arbor, Michigan; ²Wright State University, Dayton, Ohio; ³Pittsburgh Supercomputing Center, Pittsburgh.

Bookmarking the Visible Human Dataset Geri Durka-Pelok*, Terry Weymouth*, Thomas Gest*, Stuart Pomerantz+, Demian Nave+, Art Wetzel+, Wen-Yu Lee*, Brian Athey* - *University of Michigan, Ann Arbor, Michigan; +Pittsburgh Supercomputing Center, Pittsburgh.

Using a Knowledge Base: The University of Michigan Visible Human Project Terry Weymouth*, Geri Durka-Pelok*, Thomas Gest*, Jie Huang*, Stuart Pomerantz+, Art Wetzel+, Carl Berger*, Brian Athey* - *University of Michigan, Ann Arbor, Michigan; + Pittsburgh Supercomputer Center, Pittsburgh, Pennsylvania

Investigating User Requirements: Design of Computer-based Anatomy Learning Modules for Multiple User Groups. Deborah Walker, Wen-Yu Lee, Neil Skov, Carl Berger, & Brian Athey University of Michigan, Ann Arbor

Visible Human Browsers: Formative Evaluation Based on Student Feedback. Neil Skov, EdD, Wen Yu Lee, MS, Deborah S. Walker, DNSc, CNM, FACNM, Carl Berger, EdD

Defining Individual Learning Styles for Learning Anatomy in a Technology-enhanced Learning Environment Wen-Yu Lee, Carl Berger, Neil Skov & Deborah Walker, U of Michigan, Ann Arbor

Y3Q3 REPORT: KNOWLEDGE ENGINEERING

ACCOMPLISHMENTS OF THE QUARTER JUST ENDED:

The principal accomplishments pertinent to our Knowledge Engineering theme in the quarter just ended were as follows.

1. Toward a unified Digital Human ontology

During the present quarter, work has begun that will extend our formal framework of navigations to the larger Digital Human context of additional information channels, change over time, and normal anatomical variation. A very preliminary version of this methodology was presented at a meeting at NLM in July of this year. Variation of scalar and tensor fields, variation over time, variation over scale, and variation over populations can all be expressed in coordinate systems that are not Cartesian but that instead adapt to the named anatomical structures of the anatomical atlas.

Our preliminary taxonomy sorts these into six types of coordinate system, each with its corresponding navigation (filmstrip), as follows:

- Axial -- tubes and curves, such as the optic nerve or tendons
- Radial -- cylinders and hyperboloids, such as the foramen magnum
- Cylindrical -- three coordinates, one each radial, axial, and angular, such as the major blood vessels
- Spherical -- two angular coordinates, such as the femoral head
- Surficial -- a surface normal and two tangential directions, such as the bony orbit; perhaps one of these directions is geometrically distinctive, as in the mandibular border
- Symmetrical -- a linear coordinate and also a symmetry axis, such as around the midline of the corpus callosum

In this formalism, landmark points, which were previously central to the comparative framework, take on a somewhat more subordinate status. Landmarks anchor the origins and orientations of these coordinate systems, but otherwise have no privileged role in visualizations. Landmarks are thereby classified according to the kinds of navigations they delineate: their types include terminations, branch points, intersections of curves with surfaces, centers of small inclusions, and the like.

We have examples of all these types of landmarks and the corresponding filmstrips in our preliminary Edgewarp film library. In addition to these six "generic" comparative structures, the available possibilities include a wide range of special cases, such as branching axial structures, axes penetrating surfaces, meristic series (such as the vertebral column), sphincters, layered coordinate systems, and some irreducible volumetric textures (lungs, fat, the cerebral cortex, and so on).

This formalism extends even to discontinuous comparisons (e.g., variability of branching sequences in vascular trees), insofar as they can maintain some orientation information, a proximodistal coordinate, or the like. Task 7 below proposes to continue working on these mixed continuous/discontinuous coordinate systems, in preparation for the extension of this entire Knowledge Engineering effort to the Digital Human context to come.

2. Exercise of the deformation grid module

In view of future Digital Human emphases, which will concern comparative and developmental applications of our navigation tools, we have explored the best program settings for communication of deformation grids (Edgewarp's central comparative icon) in the context of navigations.

As of now two of these comparative structures are proving most powerful:

(a) The attachment of a slider for "extrapolation" to an image consisting of a squared grid and a set of landmarks and semilandmarks as well as a complex rendered surface. Upon extrapolation, the surface is deformed according to the landmark comparison (e.g., small vs. large, or young vs. old), and the grid follows. The plane in which the grid is rendered can be varied automatically by filmstrip, while the operator alters the extrapolation and/or the global point of view by other Edgewarp controls. The result is often stunningly evocative of the anatomical foci that often come to characterize qualitatively familiar comparisons.

(b) The method of creases for the formal localization of graded shape comparisons can be implemented by systematically moving a gridded sectioning plane with the surface element display suppressed. The method consists in the search for the lowest degree of extrapolation at which a given transformation "folds", that is, collapses anatomical space in any direction. Creases can be observed by alternating the "flying carpet" navigation model with an axial rotation around the axis of any crease found in one of these restricted orientations.

The two new and powerful display modes have been displayed in exemplars for a variety of biomedical audiences. The typical audience response is along the lines of "Where can I get that program?", which seems like a fine reaction.

3. From sampled surfaces to more authoritative segmentations

Work has begun on authoritative segmentations more detailed than what is possible using human operators as tracers. In this approach, the starting point for a segmentation is a (manually produced) filmstrip of any of the types listed in #1: for instance, an axial representation of a nerve or tube, or a tangential representation of a surface. The structure conveyed by the filmstrip will be represented by a crude geometric envelope in the planes of the filmstrip (e.g., for tubes, a thick annulus) and the image characteristics of this annulus assayed in color space for mean, variance, and spatial drift. The same

operation will be carried out in both planes perpendicular to the filmstrip. (For instance, in the planes perpendicular to a centerline, the candidate boundary filter should correspond to a pair of thick segments aligned with horizontal and vertical axes and equally spaced either side of the center; in the planes perpendicular to a tangent plane, the boundary filter will be a similar "thick segment" through the centerline of the filmstrip.) We will explore algorithms that cycle through these three reference frames, searching for coherence in the correspondingly thresholded structures of image contents or gradient value in color space. Preliminary experiments are very promising, showing enormous correlations in color space within these annuli, so that parameter settings correspond to ridges in color space that can be traced quite precisely in low dimension.

PLANS FOR QUARTER Y3Q4:

4. Repackaging of the EWSH User's Manual in HTML

This task, in process, will be completed, and the User's Manual slightly updated at the same time.

5. Stereoscopic display

A test version of Edgewarp has been produced that manages stereo displays. We are experimenting with the nature of widget-driven program controls in such a display environment, and with the proper mixture of image contents (surfaces, sections, landmarks, curves) in these newly more vivid virtual worlds.

6. Automatic segmentations from filmstrips, and vice-versa

Work will continue on the segmentation task, beginning with the example of the optic nerve. As soon as we see adequate progress, we will begin as well on the inverse operation, from segmentations to filmstrips. After all, the output of an automatic segmentation is a surface in a coordinate system (axial, radial, etc.) that automatically can be converted into a filmstrip of its own. We will explore the conversion of detected surfaces into filmstrips in order to expedite their evaluation by human experts. (In other words, even when a surface rendering is not obviously wrong, its relation to the surrounding image contents can look obviously wrong as it flashes by in a filmstrip. The geometry of these filmstrips follows automatically from that of the manual filmstrips used as input to the segmentation algorithms themselves, and so the segmentation can produce, so to speak, its own confirmatory displays.)

7. Continuous/discontinuous models

This work has been mentioned as a special case of coordinate navigation under achievement (1) of the quarter just completed. A particular aspect of this work is the propagation of orientation information from instance to instance even when geometric position continuity is missing. Comparisons of this sort may permit a multilevel zoom

over scaling information even when position information is unavailable between scales. The mathematics of this maneuver was already coded in one algebraic feature of our mid-1990's thin-plate spline, namely, the imposition of derivative constraints independent of position and varying only slowly over regions of the image. This machinery will be restored to Edgewarp and explored for its applications to the problem of multiscale and hyperscale image fusion.

Y3Q3 REPORT: iVOXEL BROWSER

Alexander Ade

ACCOMPLISHMENTS OF THE QUARTER JUST ENDED:

There have been many changes to the iVoxel "Slice Viewer" module this quarter. These include modifications to the Graphical User Interface (GUI) as well as internal changes to the cache system and multi-resolution display algorithm.

GUI modifications

A menu system has been added to the application for more sophisticated control of the visualization environment (fig. 1). Important or frequently used menu items are accompanied by a "keyboard shortcut", that is a keyboard combination that activates the menu item without the need to mouse over and click. Controls may appear in the menu system alone or in combination with the application's toolbar. The most frequently used controls have a button in the toolbar.

An initial "help system" has been implemented. Tooltips (floating text messages) are shown when the cursor hovers over any of the tagged GUI elements and disappear shortly after the cursor has been moved off of them (fig. 2). Also, a "help menu" contains a list of help documents, formatted in HTML, and displayed in a pop-up window. Currently available documents include an "About iVoxel" pane and a "Usage" pane.

The two windows used by the application, the "preview" window and the "zoom" window have been combined into one window with a bevel divider (fig. 3). With this layout, one view will never cover or hide the other. Resizing the window resizes the "zoom" view using a bicubic interpolation algorithm to rescale the image. This algorithm provides the highest quality image possible.

Mouse controls in the "preview" window have been modified. Mouse click and drag now moves the preview image, not the "region-of-interest" box. This was changed so that preview images of most any size can be used.

The application reads and parses the Pittsburgh Supercomputing Center's (PSC) VB bookmarks file. These files contain state information that describes a set of named views. iVoxel parses this file and adds the names to a combo box widget (fig. 4). Selecting a name from the widget moves the view to that pre-determined location. If a bookmarks file is unavailable, the widget displays "No bookmarks".

Internal Changes

The cache system (that portion of the software that holds voxel data in memory) has been updated to support an improved "Least Recently Used" (LRU) cache structure. That is, as data streams from the PSC server, the most recently used is saved in memory and the least recently used is discarded (figs. 5 and 6). The size of the cache is set at runtime and under user control.

The display algorithm has been fixed so that multi-resolution chads are now displayed properly. Incremental updates occur until the image is composed entirely of high resolution data (figs.5 and 6).

Issues

The data retrieval algorithm works slowest with pure sagittal requests. The relevant section of the application has been isolated and determined to be most likely due to byte reads from the PSC server. This has been reported this to Art Wetzel at the PSC and we are investigating.

PLANS FOR QUARTER Y3Q4:

Enhancements to the software will include, 1) a new window resize algorithm to retain the image's correct aspect ratio, and 2) the implementation of scale controls. Displaying the image in the correct aspect ration is preferred so that anatomical relationships don't seem distorted. Scale controls are necessary to show a wider field of view than is possible with the current implementation. 1:2 and 1:4 scales will be added.

A new icon set to be added to the toolbar is desirable so icons better depict their button's task. The current icon set is too generic and not well matched.

iVoxel support for the collaborative functions of VB is still being investigated. It is believed be possible to interact with the PSC collaboration server, if this feature is considered desirable by the UIT group.

Additional enhancements/bug fixes will be added as requested/discovered. Priority will be given to those deemed most important.

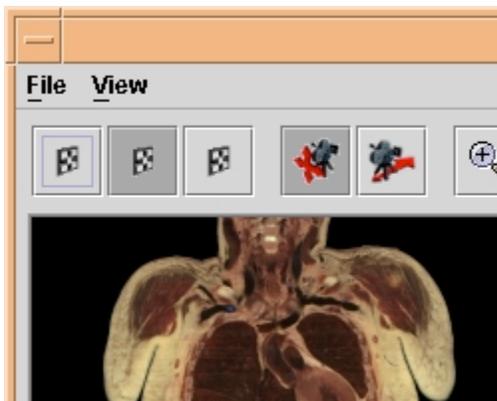


Figure 1: The application's "File" and "View" menus. Each menu has an associated keyboard mnemonic. Each frequently used menu item has a keyboard shortcut. The menu system will be expanded in future revisions of the application.

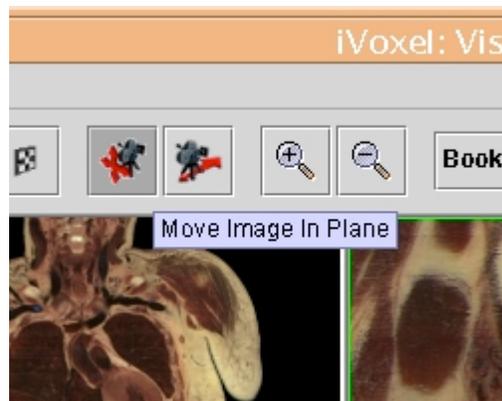


Figure 2: A tooltip displayed for the "pan" tool. As the cursor hovers over the button, a text message appears describing the function of that button. The tooltip disappears once the cursor is moved away.

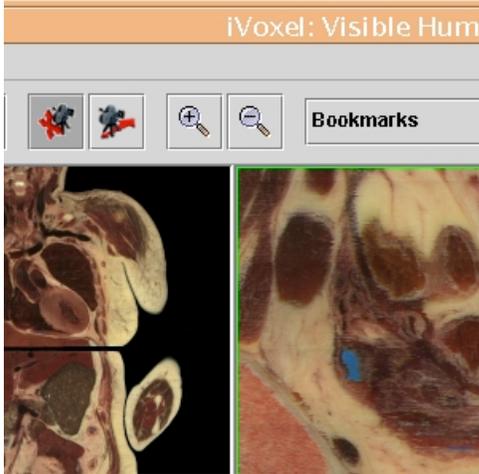


Figure 3: Both the "preview" and "zoom" windows are contained in one window divided by a bevel separator. This layout ensures that the windows don't hide or cover each other.



Figure 4: The "bookmarks" combo box widget. The widget is populated with terms from the VB bookmarks file. Clicking on a term sets the view accordingly.

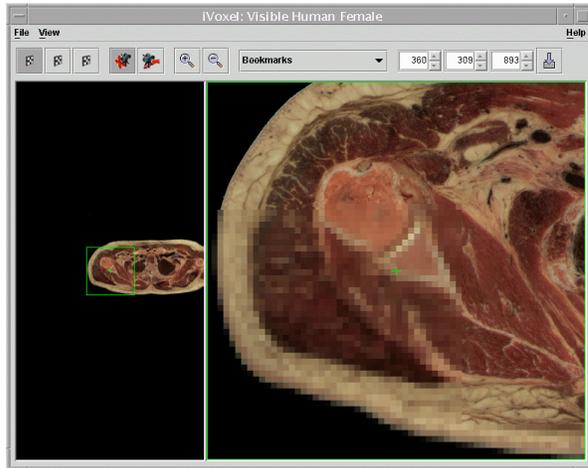


Figure 5: The LRU cache and multi-resolution display. The "zoom" view (on the right) shows an image comprised of multi-resolution data. The more pixelated lower area is made up of low resolution data while the upper area is high-resolution. The high-resolution areas are in the application's cache. The low resolution areas will be filled in with high-resolution data as it streams from the remote server.

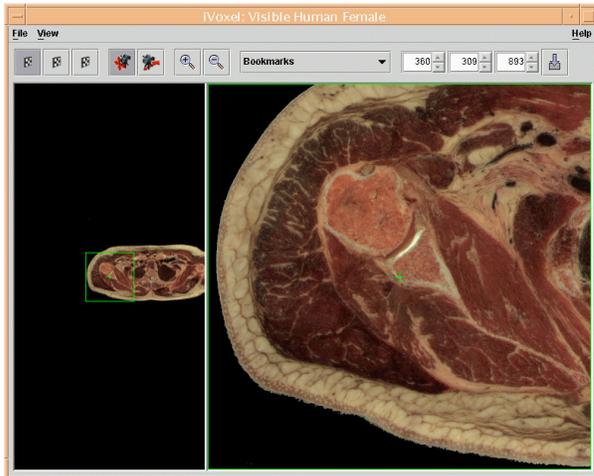


Figure 6: The "zoom" view shows a high-resolution image. These chads are now cached by the application.

Y3Q3 REPORT: PSC SUBCONTRACT STATUS

ACCOMPLISHMENTS OF THE QUARTER JUST ENDED:

- (1) Preparation for public access to the "vh.psc.edu" server and the associated release of PSC-VB
- (2) Addition of enhancements to PSC-VB requested by University of Michigan users
- (3) integration of the streaming decompression codes into PSC-VB
- (4) Improvements to the surface reconstruction process resulting in many new surface models
- (5) Improvements to Web100 to support IPv6 network protocols
- (6) Preparation for the October VHP conference.

(1) The major task for the quarter has been to make sure the PSC Volume Server and PSC Volume Browser are both ready for the public release that we will announce at the forthcoming VHP conference. This includes revamping the PSC Visible Human web pages, writing documentation, adding a tool tips help function to PSC-VB, fixing memory consumption problems in both the client and server codes and general performance tuning beyond what had been required for the deployment of the system to more than 30 stations in the anatomy classroom.

The revised web pages, which are now located permanently at <http://www.psc.edu/biomed/research/VH/PVB/>, are delivered from the same web server as all of the other PSC Biomedical web services. The new documentation was written by professional writer Liz Barrows. Update of the web documentation will be an ongoing maintenance task as the system continues to evolve. The largest additions are devoted to a PSC-VB user's guide which documents all of the public features and controls. There are separate sections for installation, navigation and segmentation instructions along with detailed explanations of the slice and context windows. We have currently inserted placeholders for the few features that we do not want to make available to the public. The most notable of these is the collaboration feature since we do not yet have a collaborative session manager to prevent arbitrary users from interfering with each other either by accident or intention. Therefore, this feature will be disabled in the public PSC-VB release but will remain active in the version used by the UMH team.

Improvements to the self documentation of PSC-VB to help new users have also been implemented. A 'tool tips' help function was added to the widget interface. This provides a one line help message for each of the menu controls for users who are unfamiliar with the tool. Tool tips are activated by holding the mouse over a widget control and hitting the keyboard F1 key. This is currently in operation with many of the controls and we are completing the full list in time for the VHP conference release announcement. We have also clarified which widgets can be used at any time by providing an active indication when the users cursor passes over them. Active widgets change color when the cursor is in position to indicate that they are 'click-able'; i.e. the widget can be used to perform a function. Previously, widgets remained in a constant color until clicked but this had

made it difficult in some circumstances to know when the mouse was properly positioned and which subset of features would be inactive in the current usage context.

Load and normal usage testing resulting from deployment in the Michigan anatomy laboratories this quarter had uncovered several latent problems in allocating system memory in both the client and server. These did not affect typical use but did result in situations where operating speed could become progressively slower during a long session as internal data structures would grow without bound. These have been repaired by imposing limits on data structure size. When the user hits these limits the memory devoted to the least used parts of the structure is recycled. This is a seamless operation to the user since the least used parts corresponds to the caching of data volumes that the user has passed through but which are not currently in use. If the user returns to these locations the data will be re-fetched from the server as needed.

Public deployment has also forced us to look at the network usage and tuning to support users who will not have NGI level network connections. This include DSL and cable modem connections and the extreme case of telephone dial up service. These low performance connections typically have both low bandwidth and high latency. Previously the PSC-VB network activity was operating in chunks whereby one set of requests was issued and further requests were held until previous requests were completely filled. This resulted in bursts of network activity with interspersed idle periods corresponding to the sum of the network latency plus the client time needed to completely process incoming data. While this was not a problem for users with a high performance network link, it provided poor bandwidth usage in the high latency situations. The revised implementation produces a steady flow of both requests and data downloads to eliminate the idle periods. Therefore, users with low speed connections will operate at the full bandwidth available from their network rather than at a needlessly reduced rate. Clearly, low speed and high latency connections will never provide the same service as a high performance link but these improvements provide good results for DSL and cable modem users and even tolerable use over phone lines if the user operates in an incremental position mode rather than doing broad continuous navigation.

The final aspect of the public release is just being completed is a mechanism to track the versions of the client and server so they can stay in step as future development takes place. We want to encourage but not force users to upgrade their browser as we make further improvements. However, at some point older versions will have to be retired and newer versions used to access new features. In particular, compression modes will continue to evolve and additional data sets will be provided using those new modes. Similar to the evolution of other programs we will provide a backwards compatibility in accessing data. This progressive development track depends on a connect time negotiation between the client and server so they can detect the best compatible operating mode. This is similar to the connect time negotiation between FAX machines to select compression and speed. At connect time the browser makes a special request for service description data. That data includes a version number along with the various data delivery modes it can provide. Similarly, the client sends a description of its capabilities

back to the server. In this way, the server and client are free to use all of the modes that they both support and avoid any that are not available on both ends.

(2) PSC-VB code was modified for deployment in the Michigan anatomy labs as a result of preliminary tests during the summer. The bookmarking feature was extended to read and write zoom information, per bookmark. Therefore, when students load the bookmark file for a specific anatomy lesson they will see the exact view that was stored in the bookmark file rather than operating with the same zoom as they may have currently selected. Of course, once the student has seen this initial view they can change it in anyway that the usual navigation tools provide. Additional bookmark adaptations were implemented to support Macintosh environment messaging. This lets the user double-click on a bookmark file icon and to automatically have the PSC-VB move to the first bookmark position and be tied to a World Wide Web browser as a helper application in the Macintosh OS X environment. Finally, documentation for the bookmark file format was also written and provided from the web pages and by student handouts.

A new logging daemon was written to support the logging of user actions. This new PSC-VB client oriented log replaces much of the earlier server log function and is more readable since it directly captures user operations rather than indirectly inferring them from server activity. The logs will be analyzed by the PSC and University of Michigan teams to provide information about how users do and do not use the system in order to focus further development work where it is needed. Corresponding logging hooks were put in to the PSC-VB code to allow the client/server system components to connect.

Segmentation users have also asked for a special rotation mode which restricts rotation to one axis at a time. When using the more general rotation under mouse control users would typically rotate in a slightly off axis direction. The new constrained rotation is provided by holding the shift key while rotating which restricts rotation to the principle axis indicated by the largest component of the mouse drag direction.

In addition to the specific Michigan requests there have been additional general use improvements to the PSC-VB functionality. One of the user difficulties in looking at the VH data has been in seeing any detail in some of the darkest areas such as the lungs. Because we have no direct control over the monitor brightness and contrast settings and because many users prefer to have their monitor contrast set too high much of this dark imagery is effectively flat black on most displays. A software gamma correction function was added to the volume browser so the user can boost the brightness of PSC-VB slice displays without physically changing their CRT settings. A variation of this function is also capable of performing a close approximation to the remapping of the CCD data characteristic colors to the 70mm film color space.

Internal PSC-VB modifications have been done to improve performance, fix bugs and enhance function. For example, PVB's point markup code was rewritten to use a more efficient data structure so that point set scanning operates more quickly. A bug which caused incorrect drawing order under some circumstances was identified and corrected.

Data set selection code was also reworked for the display of multiple data sets and the ability to switch between them on-the-fly.

(3) Integration of the 3D data decompression code into PSC-VB was completed. This required a substantial rewrite of the browser's core networking code into a continuous stream model rather than the previous fixed size chunk method. This rewrite also provides greater interface speed and network efficiency even when used with uncompressed data. The decompression code was placed in a separate code library so that it can be compiled with a C rather than C++ compiler to get extra speed optimization and also facilitate its use with the hop server which will provide decompression for the Michigan Edgewarp and iVoxel viewers.

There are a number of compression modes and we continue to evaluate the properties of various combinations. The best choice is not the same under all conditions of network bandwidth, latency, user behavior and quality requirements. The mode used for the initial public release uses a 3D DCT representation for the coarse data level (ie. 1/8th resolution). The higher resolutions build on this in a progressive wavelet fashion by encoding the difference between a prediction from one resolution level to the next. This provides a high visual quality at 30:1 lossy compression with a lossless overlay at 2:1. Higher quality lossy compressions have been evaluated but they operate more slowly and at lower compression ratios but allow higher compression in the lossless overlay up to about 3:1. The combination 30:1 lossy and 2:1 lossless is a choice we have made based on the evaluation of the range of options.

As improvements are made to compression and representation techniques the compression ratios and the precise tradeoff point will change. This is part of the reason for the client server startup negotiation. As time progresses the client can continue to support the broad range of decompression methods. However, each released data set will be provided using a selected current best compression representation from the server along with a backup representation that is compatible with older browsers. Currently that backup is direct uncompressed lossless transmission. That maintains direct compatibility with Edgewarp and iVoxel and is suitable for high speed NGI operation.

(4) Over the past quarter, we have developed new algorithms for reconstructing surfaces from contour data generated primarily by anatomists using the PSC Volume Browser segmentation tools. The variety of (mathematically) distinct anatomical structures necessitates a more systematic approach to surface reconstruction, hence we have developed an initial, albeit simplistic, taxonomy of structures based upon mathematical classification of their shapes. This taxonomy has pointed out the need for specific surface reconstruction algorithms for each of the different classes of structures.

We have developed algorithms for "tubes" and "branches" which can produce mathematically correct surfaces. These surfaces are then passed as input into an iterative process, consisting of semi-automatic segmentation and surface correction steps, to produce the final anatomically correct surfaces. The fundamental benefits of this approach are that only a few contours need to be drawn, and that the contours need not be

axis-aligned (although the algorithms support this mode of operation). Indeed, the algorithms work more effectively if the contours have been carefully drawn to provide more information about the surfaces than would be available with strictly axis aligned contours.

Our approach has been used successfully to create several hundred representative surfaces, including surfaces for which only axis-aligned data was available. More details of our approach will be presented at the Fourth Visible Human Conference.

(5) Improvements to the Web100 software have been made to support IPv6, also known as Next Generation Internet Protocol or IPng. These changes are currently being tested on a number of machines at PSC and elsewhere and will be installed on the "vh.psc.edu" server once it is completely stable. IPv6 fixes a number of problems/shortcomings in IPv4, such as the limited number of available IPv4 addresses. It also adds many improvements in areas such as routing and network autoconfiguration. Since IPv6 will gradually replace IPv4 over a number of years it is important to support both and provide for early testing of the new features such as QOS, IPSEC, header compression, and mobile registration.

(6) We are preparing 3 presentations/papers for the October VHP conference in Colorado. These relate to (a) a general system overview, (b) browsing with PSC-VB and (c) surface model construction. We also plan to provide hands on demonstrations to the extent that is possible using the DSL connection that we understand will be the only network facility available. As discussed earlier, we will announce public opening of our server at the conference and public download of PSC-VB. The PSC is preparing a press release to coincide with the conference announcement.

PLANS FOR QUARTER Y3Q4:

A number of areas of work have been continuing and will be the subject of further work in the next quarter. These include ray cast projection, which is now operating in a small standalone proof of concept implementation, along with completion of various PSC-VB segmentation tools which have been held off while completing the public release work. We are also working on the link between PSC-VB's tool tips and the associated but more extensive web page feature descriptions. A great deal of additional work has gone into the preparation of the 70mm Visible Male data. With the addition of memory and disk space during this past quarter we have been able to build the dataset but it is not yet linked into the server. It is not yet clear if we will be demonstrating the 70mm data in Colorado as it depends on priorities related to the other essential features for the public service release.

Additional work areas include documentation of new features, more extensive surface model building, increased symmetry of operation between the two PSC-VB windows, and a collaborative session manager. Results from the anatomy lab usage so far continues to indicate a large percentage of principal plane operations. Consequently we

are also planning a planar retrieval mode from the server that will reduce the network traffic for this type of activity compared to the full arbitrary plane mode.

The two modes will operate seamlessly to the user and the mode switching will be automatically taken care of by the browser.

We are currently running the mesh and other http based services from the single processor XP1000 but would like to migrate all of this to the ES40 during this quarter. This would free up the XP1000 for use with more extensive ray casting experiments and as an emergency backup server for the compressed volume data. We are also planning to retire the old bounding box based uncompressed chad servers as that function is now replaced by the new server which operates in both compressed and non-compressed modes. This is significant for reducing the current memory contention that is occurring by having multiple 24Gbyte volumes mapped into the server virtual memory space.

As usual time management continues to be a challenge. We have made great progress and have completed all of the major items but still have many "wish list" features that we would like to implement as time permits.

Y3Q3 REPORT: GEOFFREY C. HENNY 10/8/2002

ACCOMPLISHMENTS OF THE QUARTER JUST ENDED:

During the last three months I have focused on two main items:

(1) **UMVHP Website**

At the request of Dr. Athey, I coordinated the re-organization of our UMVHP website Integrating Digital Anatomy for the 21st Century (see <http://vhp.med.umich.edu/index.html>). As part of this exercise we established a team that included myself, Walter Meixner, Alex Terzian, Paul Trombley, Amy Hilbelink and Aaron Bookvich to develop and implement a visual, navigational and content strategy. The objective was to retain the best done so far, while integrating the exciting new projects underway in an appealing and accessible manner. My role, apart from guiding the team to a successful product and evolving a development strategy, was to produce text on each of the new projects. The current site reflects this approach and was well received by UMVHP stakeholders at the recent Quarterly meeting. The new areas presented under projects – some of which are discussed in this report - are the following:

- Pre-professional and K-12 Learning Platform
- Collaborative Internet 2 based Health Sciences Training
- Medical Education, Virtual Reality Surgical Simulation and Emergency Preparedness
- The Digital Human Project
- Emergency Preparedness

(2) **Special Projects – Digital Human, Pre-professional and K-12 Learning Platform, Virtual Reality and Surgical Simulation**

Digital Human

As part of an ongoing commitment on the part of UMVHP to advance the development of the Digital Human Project (see <http://www.fas.org/dh/index.html>), I participated in that project's Unified Ontology Planning Workshop at the National Institutes of Health July 25-26, 2002, which focused on the development of strategies for establishing a unified Anatomy/Physiology testbed and common conceptual framework for simulation, education and research. In collaboration with Drs. Athey, Bird, Higgins and Kelly, I helped place UMVHP in a leadership role for operationalizing an international collaboration to exchange software, ontologies and databases between Visible Human players as well as to begin serious fund raising. Since that meeting I have been working on organizing background material on existing human simulation technologies and planning a meeting at UMVHP of key players for end 2002 or early 2003 as well as exploring fund raising materials and funding sources to be contacted.

(Note: The Digital Human Project is an international group of academic, government and private sector organizations committed to in silico modeling of the human body. The consortium aims to use 21st century information technology tools to simulate the functions of genes and proteins, cells, tissues, organs, and systems. It is expected this work will provide unprecedented understanding of the human body over the next decade.)

Pre-professional and K-12 Anatomy Learning Platform

Current programs at the University of Michigan Visible Human Project are focused on the development of Internet-enabled visualization tools and navigation technologies that enhance anatomy education and research. These tools include the development of organ models, labeling, 3D volumes, whole body flythroughs from a variety of perspectives, and courseware. All of these resources are being actively used and evaluated in testbeds at the University of Michigan Medical and Nursing Schools. During the current quarter, I have been working actively with Drs. Athey, Walker and Hilbelink (see previous quarterly report) and Walter Meixner to extend this work to an interactive online course program for pre-professional, and K-12 education. This has involved contacting on a temporary basis an Anatomist assistant with a strong background in Anatomy, Physiology and Biology teaching at the undergraduate and community college level to assist UMVHP with additional female reproductive system segmentation and annotation. It has also involved coordinating with NLM, Ferris, UMVHP and other organizations on the strategic development of the program, writing planning documents, developing a fund raising strategy and helping to define a prototype module – the female reproductive system – (target completion is end first quarter 2003). In doing this UMVHP intends to extend the benefits of its work to a much larger audience and make it self sustaining while helping to further stimulate the digital transformation of healthcare education.

Medical Education, Virtual Reality Surgical Simulation and Emergency Preparedness

In the spirit of extending the work it has done to date and plans to do if the new NLM grant application is funded, UMVHP is planning to develop advanced interactive online healthcare training programs with its partners at the UM College of Engineering Virtual Reality Lab (see [The Virtual Reality-Enhanced Medical Readiness Trainer - MRT at the University of Michigan Virtual Reality Laboratory](#)), the Uniformed University of the Health Sciences National Capital Area Simulation Center and Simquest Inc.; including virtual reality projections of human anatomical/physiological information combined with haptic feedback. This collaboration will use the Visible Human data sets as well as other anatomical and physiological data sources to develop the equivalent of a flight simulator for the medical/surgical professions and for emergency preparedness. During this quarter, with advice and support from Dr. Athey, I have been coordinating a core group of experts from these groups and others to define some exciting fundable projects and funding strategies.

Y3Q3 REPORT: ANATOMY/UIT/NURSING

ACCOMPLISHMENTS OF THE QUARTER JUST ENDED:

1. Evaluation of PSC - VB “paper-and-pen” Evaluation; User Testing/Logging, M1 and M2:

Usability tests (PSC-VB v.460) were performed on 10 Second Year Medical (M2) Students (8 novice, 2 expert). User task conducted over 15 minutes with follow-up. Tasks involved a “treasure hunt” for a specified view (targets: kidney, fundus of uterus). Server logs (PSC-VB v.467_14): Two sources, user logs and anatomy website user logs are being used to evaluate activities of the M1 gross anatomy coursework. (See Abstract 1.)

2. Observations:

“Paper-and-pen” methodologies aided in iterative design from PSC-VB v.440 to v.460 t There is an increase in recognition through bookmark labels and “optimal view” of structure (view plane + magnification). A decrease in M1 user skill necessary to select and display VHF data through implementation of browser plug-in. A decrease in time and steps necessary to reach target structure through implementation of browser plug-in.

3. User testing (preliminary):

Expert (M2) user: correlation between 3-D model landmarks and ease of navigation. Novice (M2) user: difficulty in navigation of 2-D plane and structure orientation. Both Expert and Novice expressed possible uses in radiology, MRI, and CAT clinical correlates. Additional use as interactive substitutes for anatomical diagrams and illustrations.

4. Bookmarking the Visible Human Female Dataset:

Intermedia: QTVR and the Visible Human Data Set (see Abstract 2). Prototype: linking of “hot spots” to bookmarks (see Abstracts 3 and 4). Linking didactic terms and concepts with specific, customizable views of the VHF. Bookmark = x-y coordinates + label + magnification + orientation.

UIT Nursing testbed:

Activities during this quarter included the preparation and submission of 3 abstracts to the Fourth Visible Human Conference (see Abstracts 5, 6, 7). All three abstracts were accepted and preparation for the presentations is in progress. A paper was also accepted to the ICLS conference of Oct. 2002 (see paper 1). Plans were developed during this quarter and are underway for beginning to test the PSC Volume Browser tutorial with undergraduate nursing students. Collaboration began and continues with Don and Amy Hilbelink on the development of the Pelvic module for anatomy education.

PLANS FOR QUARTER Y3Q4

1. User testing and server logs to provide input for more iterative design throughout Fall Semester 2002. There will be an increase in the number of internal users to include the

Learning Resource Center and CAI lab. Tracking of internal and external users through server logs.

2. Support of Lecture-Lite philosophy by expansion of bookmarks throughout the Gross Anatomy Dissector.

3. Expansion of intermedia by the linking of current digital media and bookmarks.

(See Appendix 1 for abstracts mentioned in the above Anatomy/UIT/Nursing Report)

APPENDIX 1

Abstracts

Abstract 1.

Evaluation of a Volume Browser: PSC-VB

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*University of Michigan, Ann Arbor, Michigan; +Pittsburgh Supercomputing Center, Pittsburgh.

Introduction

The purpose of this paper is to evaluate the Pittsburgh Supercomputing Center Volume Browser (PSC-VB) as an educational tool that is cost-effective in learning time, easily integrated into current curricula, useful and usable.

The PSC-VB (Fig. 1) is a stand-alone, cross-platform application and plug-in that currently links it to the Internet browser Microsoft Explorer (future versions will also link to Netscape and other browsers). Designed by the PSC Visible Human team and implemented by Stuart Pomerantz, the PSC-VB supports interactive navigation through the Visible



Human datasets with anatomical bookmarks (labeling along with the information necessary to recreate a particular view). The bookmark file (XML format) is linked to a term or object in a web-based curriculum. This file is created by the instructor, or a user, using the Bookmark function provided in the application menu. By clicking on the link, the user is presented with the labeled and navigable structure in the PSC-VB, thus integrating the Visible Human data set directly into a didactic. A 3-dimensional database currently containing thirteen anatomical structures may be downloaded into the Volume Context window.

In order for software applications and content to be accepted and used by medical instructors and students, the applications must be perceived as:

1. Cost-effective: in terms of time spent learning how the application works versus how much medical content is learned. If the student perceives an application to be too complex to quickly learn in order to find anatomical structures like vessels in the celiac trunk, that student will be more likely to spend the extra time in searching for acceptable structural diagrams in textbooks (sometimes several); their perception being that the textbooks are less stressful (i.e. easier to use), more useful, more reliable.
2. Able to be integrated into current and customized didactic: the Lecture-Lite philosophy has been shown to be highly successful in raising overall student learning. Linking the Visible Human data directly to anatomical terms and concepts is in keeping with this philosophy. Direct integration increases the usage of such materials as well as reinforces the concepts being illustrated; for

example, the presentation of text explaining the subtle differences between the left and right sides of the heart (primarily muscle wall thickness), illustrated by a bookmark file producing the best labeled aspect of the Visible Human heart.

3. Usable as well as useful.

Methods

The methodology utilized a heuristic evaluation checklist (modified, Xerox Corporation, 1995) cognitive walkthrough, modified GOMS (Goals, Operators, Methods, Selection Rules; see Table: Pirolli and Rao, 1996, Relevant perceptual, cognitive, and motor time-cost parameters) and user survey and testing. Ten second-year medical students were recruited to complete the anatomy orientation task using the PSC-VB.

Parameter	Value	Source
visual scan to target (1° arc $\sim .25''$ @ 15" eye-screen distance)	4 msec/degree of visual arc	OO
Mentally compare two words	47 msec	CMN
Point mouse at target of size S at distance D	$1030 + 960 \log_2(D/S + .5)$ msec	CMN
Read a word	300 msec	CMN
Mouse click	70 msec	CMN
Mouse gesture	70 msec	CMN
Keystroke	372 msec	CMN
Perceptual Judgement Time	92 msec	OO
Execute Mental Step	70 msec	OO
Retrieve from Memory	1200 msec	OO

Results

Results of the first four methods show the PSC-VB to be easy to learn (thus cost-effective) due to its minimalist design and simple menu, useful in its ability to be integrated via bookmark files into website content, and usable with its 3-dimensional models for navigational and relational orientation, as well as providing user freedom in manipulating the image once directed to the point of interest. Initial user testing and surveys point to the significance of integrating content, such as the Visible Human data, directly into the course didactic, as well as providing insight into student views on the usage of such content in their learning. Further studies will be conducted in the Fall semester at the University of Michigan as the PSC-VB is integrated into the full gross anatomy website and provided to first-year medical students in and outside the gross anatomy laboratory.

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Abstract 2.

Creation of an educational visual module: integration of QTVR and the Visible Human Data Set

Geri Durka-Pelok¹, Thomas Gest¹, Gary Nieder², Terry Weymouth¹, Jie Huang¹, Art Wetzel³, Stuart Pomerantz³, Demian Nave³, Brian Athey¹ - ¹University of Michigan, Ann Arbor, Michigan; ²Wright State University, Dayton, Ohio; ³Pittsburgh Supercomputing Center, Pittsburgh.

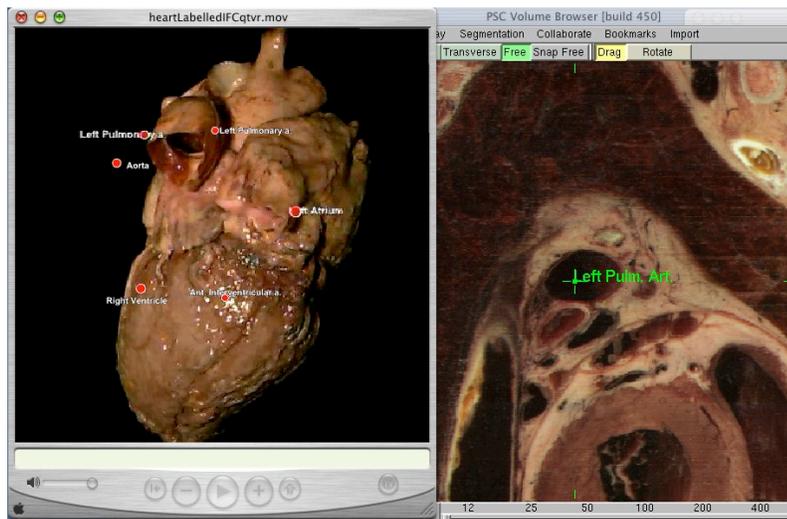
Multimedia Interactions: importance of interactive learning

Only 10% of what is read is retained; 20% of what is heard. However, 90% of what is learned through active participation is retained (Edgar, 1969). Interactive multimedia, such as QuickTime VR, and image-generating applications, such as the Pittsburgh Supercomputing Center Volume Browser (PSC-VB), offer quickly accessible information within teaching modules to illustrate complex and, possibly, confusing anatomical relationships (Carter, 1999).

The Division of Anatomical Sciences, University of Michigan Medical School, and the Department of Anatomy, Wright State University, are engaged in developing interactive intermedia, linking QTVR with the Visible Human data through the use of bookmark files. QuickTime VR (QTVR) media provide excellent “whole” objects, such as the heart, that may be rotated 360 degrees showing the surface features including arteries, veins, and real surface textures. The QTVR object may use wired sprites to link to other content, in this case, to bookmark files, generated and read by the PSC-VB. While QTVR may be ideal for illustrating 3-dimensional anatomy of an object, by itself, it does not illustrate relationships to surrounding structures. With its ability to obliquely cut through a structure and surrounding organs and tissues, the PSC-VB offers a highly detailed view of surrounding and internal anatomy. By combining the strengths of both digital images through labeling and linking, an anatomical relationship such as the subtle differences between the left and right sides of the heart (primarily muscle wall thickness) may be easily illustrated.

The wiring of QTVR

All QuickTime VR Object movies were created by Dr. Gary Nieder and associates at Wright State University, Dayton, Ohio, as part of a National Library of Medicine grant. The movies were downloaded from the QTVR Anatomical Resource website at <http://www.anatomy.w>



right.edu/QTVR

QTVR object movies were imported into Macromedia's Flash MX. Labels were applied as animation sprites that were then wired to bookmark files generated in PSC-VB.

Heart Module

The current prototype involves the linking of clickable labels created to identify surface structures of the heart, to corresponding labels in the Visible Human data as displayed in PSC-VB (see Figure above). By utilizing the bookmark file (XML format), queries may be sent to a linked database of anatomical terminology, through which other types of content (e.g. clinical concepts, quiz questions, multimedia) may be accessed.

The success of electronic information depends on three factors (Oliver, 2002):

1. How easy the interface(s) involved are to control and operate.
 - Both QTVR and the PSC-VB use minimalist interface design and simple menus.
 - User testing showed that students are able to operate both in a reasonable amount of time.
2. Is the student able to move between the two interactions (QTVR and PSC-VB) with minimal confusion?
 - The corresponding labels and any additional web content should prove adequate.
3. Is the student able to understand the connection being made between the corresponding labels, i.e. is the concept being explained adequately by the "whole" object in conjunction with the 2-dimensional plane?
 - To be evaluated as modules are made available to students in Fall 2002.

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Abstract 3.

Bookmarking the Visible Human Dataset

Gerri Durka-Pelok*, Terry Weymouth*, Thomas Gest*, Stuart Pomerantz+, Demian Nave+, Art Wetzel+, Wen-Yu Lee*, Brian Athey* - *University of Michigan, Ann Arbor, Michigan; +Pittsburgh Supercomputing Center, Pittsburgh.

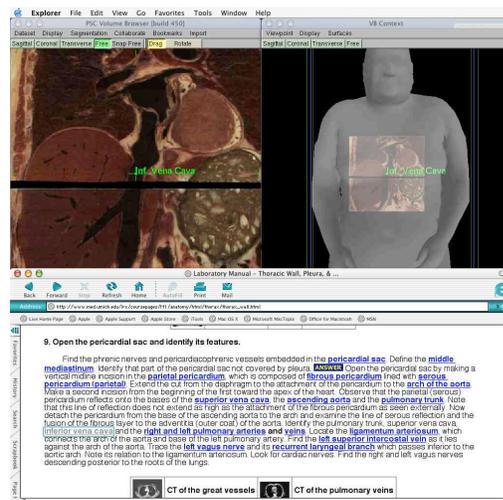
Introduction

One of the main difficulties in integrating content has been the lack of linking didactic terms and concepts with specific, customizable views of the Visible Human data set. To address this problem, a Bookmark function has been integrated into the Pittsburgh Supercomputing Center Volume Browser (PSC-VB). This function allows the user (i.e. instructor) to create a customized view of a structure (specific x, y, z coordinates and magnification) and generate an xml file. This file may then be embedded into a link on a website, or placed in a database cell (Weymouth, 2002). By clicking on the link, PSC-VB may be launched, the file loaded, and the specific image viewed by the user. By integrating the Visible Human data directly into a didactic lesson, a student may be initially directed to a structure and then allowed to navigate freely around that structure to study relationships between surrounding structures as described by the didactic.

Lecture-Lite and the Pittsburgh Supercomputing Center Volume Browser

A long-standing goal in medical education is to promote self-directed learning. This is the basis for the Lecture-Lite philosophy (Gest et.al., *in press*) that drives integration of the classical lecture materials and innovative digital content together to form the gross anatomy website at the University of Michigan Medical School. With the reduction of lecture times to 20-40 minute “lab overviews”, the focus of the learning experience has been shifted from the passive lecture method to active involvement of the learner. Students are responsible for the prelab preparation which involves extensive utilization of the web dissector, review tables, and interactive multimedia. Gross anatomy learning is now focused on the human body in the gross anatomy lab, where small groups of students meet to solve the daily problems assigned.

To assist the active learning process, the Pittsburgh Supercomputing Center Volume Browser (PSC-VB) will be made available in the gross anatomy laboratory which is equipped with 32 iMacs on the OS X platform (one computer per student table). The integration of the Visible Human data with the gross anatomy dissector via PSC-VB bookmarks will provide the student with the ability to recall and review intact anatomical relationships. This has been a consistent problem in gross anatomy as blood vessels, muscles, nerves and other structures are removed during the dissection process, leaving



gaps in physical relationships, preventing the reinforcement of concepts being taught (Carter, 1999).

Bookmarks

A bookmark is an x - y - z coordinate to which a text label is attached. This text label may be a term or a string of terms. A bookmark is saved as an .xml file similar in text form to the following example:

```
<vbbookmarks>
  <bookmark>
    <name>
      Coronal Plane
    </name>
    <m1>
      1 0 0 1502 0 6.12323e-17 1 438 0 -1 6.12323e-17 2412 0 0 0 1
    </m1>
  </bookmark>
</vbbookmarks>
```

This file is given the .vbk extension. This extension is recognized by the PSC-VB plugin. Clickable links connect terms and objects in the gross anatomy website to the Visible Human data at specified coordinates and magnifications (see Figure).

Integrated Content

Student surveys point to the need to integrate course content and descriptive digital materials, such as the Visible Human data labeled through the use of bookmarks. Student scores point to the success of web-based learning in conjunction with practical applications. The demand for labeled, accessible, interactive structures has been increasing as more course content is processed through the web. Difficult anatomical relationships, such as the perineum (often pictured as a 2-dimensional flat space, but actually a triangular 3-dimensional space), may be illustrated by multimedia interactions, such as QuickTime VR and the PSC-VB, linked together by bookmarks. Customized learning modules are currently being developed that will provide the student the opportunity to explore these difficult anatomical concepts, as well as the most basic anatomical concepts (e.g. anatomical orientation). These learning modules will be integrated into the gross anatomy website, Fall 2002. Evaluation of student use and learning will be conducted over the course of the semester.

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Weymouth, T. et.al. Using a Knowledge Base: The University of Michigan Visible Human Project". 2002. *This Proceedings.*

Abstract 4

Using a Knowledge Base: The University of Michigan Visible Human Project

Terry Weymouth*, Geri Durka-Pelok*, Thomas Gest*, Jie Huang*, Stuart Pomerantz+, Art Wetzel+, Carl Berger*, Brian Athey* - *University of Michigan, Ann Arbor, Michigan; + Pittsburgh Supercomputer Center, Pittsburgh, Pennsylvania

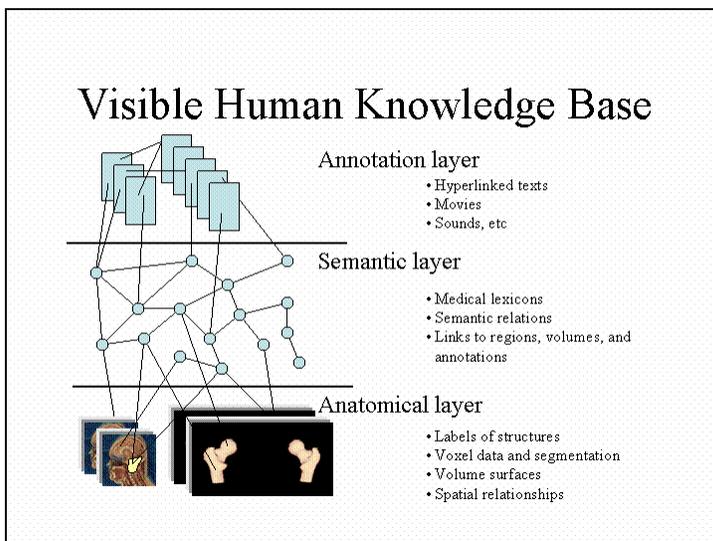
Background

The University of Michigan Visible Human Project is, in part, a project to put augmented visible human data on line in the direct support of clearly defined educational goals: instructional modules in Nursing, Anatomy, and Medical Training. This effort is supported by work on: a Visible Human Browser, an Anatomy Knowledge Base, and a systematic evaluation of the resulting Anatomy Modules.

Visible Human Browser (Figure) is a combination of a stand-alone application and a plug-in that links it to a browser. Designed and coded by Stuart Pomerantz, the Visible Human Browser (officially the PCS-VB, Pittsburgh Supercomputer Center Volume Browser) supports interactive navigation through the Visible Human datasets with anatomical bookmarks (labeling along with the information necessary to recreate a particular view).



The Knowledge Base



The VH Knowledge base (Figure) is an augmented database; conceptually, it consists of three layers: the Anatomical Layer (the VH Datasets + a Visible Human Browser with anatomical bookmarks), the Semantic Layer (a linked database of anatomical terminology), and the Annotation Layer (an indexed set of pedagogical material: lectures, tours, modules, procedures, quizzes, and the like). The core of the Annotation Layer, and the presentation of the knowledge base to users, is a series of Anatomy Modules. These are

sequences of learning tasks, quizzes, and supporting multi-medial material (such as labeled Quick Time VR's of organs, movies of dissection procedures, labeled images of important anatomical features).

We are currently in the middle of a series of design and implementation tasks involving the Knowledge Base. Our plan is to:

- (1) design and build the relational database of bookmarks, terminology, modules (done)
- (2) design, build and evaluate a prototype with specific modules; evaluate both the GUI and effectiveness of content (current)
- (3) design, build, deploy, and evaluate an in-class set of modules

This plan will provide a clearly define path for the development of useful annotations to the basic Visible Human dataset. The initial context for the development of modules is a series of stand-alone modules to augment introductory anatomy classes.

The Database

The database includes schema for a relational structure of terminology. This is, essentially, terms, and relational tables (such as sub-term) for their relations. Also, there is a web interface to the database, so that links can drive queries. Finally, there is a set of scripts that supports the building of pages that contains links to the database. In this way, a term can link, through the database to all its related terms.

Linking

The linking supported is the essential structure that supports the access to knowledge base. The supported relationships include structural information, the relational tables that describe the connections between terms and leaning objects, and the anatomical bookmarks. Modules in the Annotation Layer are linked to the Semantic Layer via links to anatomical terms. In each module, as it is written, we insert links (that are essentially database queries) into the text of the modules and quizzes. In addition, we are constructing a number of Quick Time VR views of organs and clusters of related organs which are labeled; the labels in the VR files can be hyperlinks; hence, they can be queries to the terminology in the database. We are also planning to make links from the terminology back to the modules that include the terms.

In addition to the links into and out of the database, the modules are linked to the Visible Human data to view anatomical bookmarks. With the plugin for the Visible Human Browser, the anatomical bookmarks can be uploaded as links. Such links are in both the relational tables (related to the terms) and in the modules (pedagogical material) as in-line links. Each such anatomical bookmark, when linked, drives the Visible Human Browser to a view of the organ, concept, or term in the Visible Human Data.

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Abstract 5

Investigating User Requirements: Design of Computer-based Anatomy Learning Modules for Multiple User Groups

Deborah Walker, Wen-Yu Lee, Neil Skov, Carl Berger, & Brian Athey
University of Michigan, Ann Arbor

Introduction

A key objective of the Visible Human Project at the University of Michigan is to facilitate the use of medical images from the Visible Human (VH) Dataset in anatomy learning. It is our observation that anatomy teaching differs from one group to another in health sciences due to their unique requirements in the class and professional goals in the field. We are interested in how appropriate and useful content can be provided in the specific context where anatomy is learned. The intent is to use user data of contextual information about anatomy education to improve iterative design (Boyle, 1997), and thus create a learning environment that is efficient and effective.

However, no efficient methods of transforming user requirements to concrete designs have been suggested in previous research. Hence, this study attempts to begin to fill an important void by describing how user requirements, associated with users' learning experiences, were systematically collected and analyzed and then transformed into guidelines informing the iterative design.

Methods

One or multiple focus group (Morgan, 1997) sessions were conducted with each group of target users: students and faculty in professional schools of nursing, medicine, dentistry, kinesiology and surgery. All eleven researchers then met as a group to share and discuss information gathered in the different focus group sessions. One team member created a matrix for pooling user requirements from all focus groups. After each researcher rated the matrix independently, a summary containing the mean rating from all evaluators for each cell was generated. Examination of these rating data using cluster analysis and multidimensional scaling (MDS) (SYSTAT, 1989) was performed to find target groups who received similar scores in all requirements. Two kinds of hierarchical algorithms, the Complete Linkage and Ward's Method, were used to compare the similarity of all requirements across different users and further group comparable requirements into clusters.

Results

The results from the MDS (see Fig. 1) show that different user groups are distributed into the four quadrants based on their requirements. We observed that users who share similar experience and training objectives in their health care education became a natural group. The two optimized dimensions were interpreted by comparing the attributes of the groups on the opposite ends along each dimension. Thus, the vertical dimension was conceptualized as anatomical scope or breadth of focus; the horizontal dimension was interpreted as level of professional development, novice versus expert (right versus left). These results indicate at least four clusters of users that the design should accommodate.

Results from the hierarchical algorithm show clusters of similar requirements. Each cluster of requirements was composed of numerous related functions and features that should be integrated simultaneously into the learning environment. To make the results in the summary matrix more informative to the interface design, clusters were categorized by level of demand and correlated with characteristics of the users who requested them (see Table 1).

Conclusions

In interpreting the requirement clusters and user clusters resulted from the analysis, we suggested at least two sets of functions and features should be used in the anatomical learning modules. One set of core components used as the base design and framework would be common across groups. Their content was identified in the focus groups as important requirements for learning anatomy by faculty and students across the different disciplines. The second set of functions and features would not be universal across all groups but would fulfill the needs of self-selected users groups that parallel their specialties. To design learning modules with both unified core components and user-specific applications, the program should be flexible, allowing for dynamic insertion of different learning tools for different users. One possible way to achieve this goal is to provide an interface that users can employ to select and enable suitable learning materials.

Interpretations of ideas and feedback from users are powerful in designing and polishing the VH user interface system. In this study, the research design combines both quantitative and qualitative research methods and does not rely solely on one or the other. Through these methods, we were able to (1) identify the group of users who share similar content, (2) suggest the general design framework and special components suitable for specific users, and (3) discern the priority of implementing each requirement. The design described in this paper will continue to evolve throughout the software development process, enabling the research team to link users' needs with the ability to construct an appropriate and customized instructional design.

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Figure 1. Multiple dimensional scaling: natural groups of target users with like requirements. The vertical dimension was conceptualized as anatomical scope or breadth of focus; the horizontal dimension was interpreted as level of professional development, novice versus expert (right versus left).

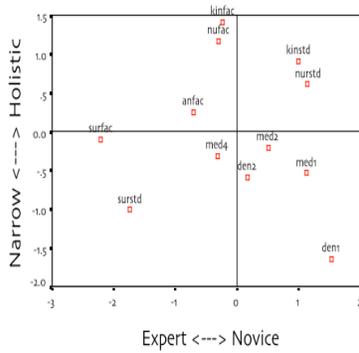


Table 1. Clusters of user requirements sorted by level of demands, design categories and theme of clusters.

<i>Requirement Clusters</i>	<i>Degree of Request</i>	<i>Design Guidelines</i>
<ul style="list-style-type: none"> • 2D – 3D Mapping • 3D Visualization • Whole-Part Integration by Location • Relationship among Parts 	Strongly Required	<u>General features and functions</u> Theme: 3d visualization /relationship reconstruction
<ul style="list-style-type: none"> • Knowledge Integration • Problem Based Learning • Structure- Function 	Required	<u>General features and functions</u> Theme: Knowledge inquiry
<ul style="list-style-type: none"> • Navigation Map • Concept Map • Connection to other Coursework • Multilevel of Support • Macro-Micro 	Required	<u>General features and functions</u> Theme: Information navigation
<ul style="list-style-type: none"> • Innervation • Follow Structure • Blood Supply • Dynamic Visualization 	Degree of request diverse among users	<u>Domain specific applications</u> Theme: Visualization and simulation
<ul style="list-style-type: none"> • Simulate Surgical Procedure • Haptic Interaction • Tactile Feedback • Dissection Process • Dissection Skills 	Degree of request diverse among users	<u>Domain specific applications</u> Theme: Professional skills
<ul style="list-style-type: none"> • Learning to learn • Pronunciation • Mnemonic Devices • Support for team interaction 	Degree of request diverse among users	<u>Users' Tool</u> Theme: Learning aids
<ul style="list-style-type: none"> • Instructor selectable modules and features 	Degree of request diverse among users	<u>Users' Tool</u> Theme: Instructor's Tools

Abstract 6

Visible Human Browsers: Formative Evaluation Based on Student Feedback

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Introduction

The University of Michigan Visible Human Project (UM-VHP) includes a team of faculty and student's whose main purpose is to evaluate and assist in developing the user interface of the Visible Human dataset. The purpose of this investigation, part of the formative evaluation for the Visible Human (VH) instructional system, was to evaluate students' use of the current browser software. The goal was to gain insight into how students interact with the software interface, and also how students perceive the usability of the different types of browsers. The research questions addressed by this project were:

1. What is the most effective way for student users to interact with VH browser interfaces?
2. What are students' perceptions of the usefulness of the VH software for learning anatomy?

Background Information/Literature Review

Formative evaluation emphasizes collecting information in the early design stages in order to improve the design, achieve greater effectiveness and efficiency, and test usability and acceptance. Recognizing the drawback of summative evaluation, which is focused on the end product, research in the past three decades increasingly focused on formatively evaluating instructional materials and generating products which significantly improve students' performance. Having the potential users experience and evaluate the product can provide information that may not be found by expert review. At early stages of the instructional design process, before the system is ready for larger scale field testing, small group evaluation generates information to support design decisions.

This study employed focus groups to test software usability. The usability testing allowed the researchers to observe users' immediate responses to the software. The focus group method afforded the opportunity to observe participants' interactions with each other and to discuss design issues directly with the participants.

Methods

Research participants were 2nd year medical students who had just completed a year of gross anatomy study. IRB approval was obtained from the University of Michigan before data collection occurred. Three, semi-structured group interviews (focus groups) were videotaped for subsequent analysis.

After informed consent was obtained, a member of the research team demonstrated features and controls of each software program followed by the students having the opportunity to 'take the controls'. Then one student volunteer operated the software controls, with the other three students coaching the operator, while the students carried out an anatomy 'assignment' to find a particular anatomical structure. The students were encouraged to converse and think out loud as they explored the database using the browser software. After this exercise was completed, a member of the research team led a discussion with the participants regarding their thoughts about how they felt the software could best be used in learning anatomy and elicited their opinions about the software's user interface.

Software used in the study included the Edgewarp program and the PSC Volume Browser (PVB), a web interface to an anatomy content database as well as a simulation of an Edgewarp fly-through (movie) that was well populated with pop-up labels.

Data Analysis

Qualitative methods were used to analyze the data. Two investigators together studied videos of group interview sessions. The investigators took meticulous notes on their observations and

recorded quotes and event descriptions. Investigators worked through the videotapes in sections, repeatedly viewing and discussing each section in order to reach a consensus understanding of that section. From their notes and observations, the investigators extracted salient utterances, behaviors, and events, and looked for themes or patterns.

Results

Inferences and themes were drawn from the data important to the future development of the VH based tools for anatomy instruction. In total 12 students participated in the research project: 3 groups of students with 4 students in each group. The data were organized according to the following framework:

1. Interactions with VH software
 - 1.1 Inquiry into: functions, controls and display
 - 1.2 Interpretation of orientation and anatomic information
 - 1.3 Strategies for recognizing structures, finding structures and recognizing relationships
2. Vision for learning anatomy with the VH software
 - 2.1 Student requirements: Integration with other materials from the class. Links among anatomy information sources.
 - 2.2 Use of the software: learning curve, learning styles
3. Suggestions for: control devices, new functions and anatomy topics

Major themes included: students preference for a familiar interface, consensus that the browsers would be most useful for study of the head-and-neck and pelvis regions, thoughts that the VH browsers would be a supplementary learning tool in first-year anatomy, and not replace the resources they already use and that labels of anatomical features in the browser window were important. All students agreed that the VH browser views would become increasingly valuable as they advance in their studies and become more dependent on images from radiology (CT, MRI, Ultrasound). Student research participants experienced several difficulties while working with the volume browsers. For example, slow performance resulted in the image breaking up (become coarsely pixilated) until new data were downloaded. This loss of resolution made it impossible for students to tell how far they had moved the cut plane. They consistently undershot or overshot their intended endpoint and often became lost or disoriented. Students also got disoriented while translating or rotating the cut-plane view, even when the displacements were small.

Conclusions

These data point out the importance of integrating the VH browsers into a comprehensive set of anatomy learning resources. Students are already accustomed to approaching anatomy study in a particular way, using texts and dissection as primary resources. This orientation may change as other resources are polished and made available. The 3D models seem to be very important as local frames of reference for the students. There is a general consensus that browsers should have student or instructor adjustable preference settings to select levels of complexity and power in the user interface (controls): beginner, intermediate, advanced.

Medical Students are strongly accustomed to canonical, orthogonal cutting planes, and seemed uncomfortable when viewing arbitrary, oblique sections for very long. The ability to jump back to a preset view (sort of a home button) should be a standard feature of any VH browser.

Students also requested that labels of anatomic structures be provided in some form.

Observation of browser image break-up implies that high data throughput is essential for the volume browsers to be of any use in an instructional setting. It is also essential to provide student users of VH browsers with an orientation support system. The expressed sentiment that students would not use the current browsers may be related to the complexity of the user interfaces of the demonstrated versions, which required too high a time and effort investment in learning to use the software before they could be fluent enough to begin thinking about anatomy. A simple, intuitive user interface may be the key to student acceptance and use of a VH browser in learning anatomy.

Abstract 7

Defining Individual Learning Styles for Learning Anatomy in a Technology-enhanced Learning Environment

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Introduction

This exploratory study was part of the contextual analysis of anatomy teaching and learning for the Visible Human Project at the University of Michigan. Research has shown that differences in learning styles exist among students in the same class and also between students in different disciplines (Kolb, 1984). Understanding learning styles can help teachers design curriculum suitable for students' needs, and consequently enhance students' learning, retention, and knowledge retrieval (Federico, 2000). Studies about learning technology have aimed at examining the relationship between the effectiveness of different instructional mechanisms and students' learning styles (e.g., Ross & Schulz, 1999; Ross & Robert, 1999). However, very few studies have been performed to discuss learning style surveys focusing on students' perceptions and experiences gained in an actual learning process. In some research, students answered the survey questions designed out of the learning context (e.g., Grasha, 2000); in some others, the researchers only provided one-time experiential treatment for their participants (e.g., Ross & Schulz, 1999). Thus, using survey analysis and case studies, the goal of this study was to describe the association between different learning styles and students' perception of computer use for learning anatomy.

Methods

The study was conducted in a medical school with 21 students in the pre-matriculation program. The first part of the survey was constructed around five attributes of learning styles: 1) focus on big picture versus focus on details, 2) prefer to follow procedure versus prefer to work at personal pace, 3) need hints and help for problem solving versus prefer to solve problems by myself, 4) define self as a verbal person versus define self as a visual person, and 5) prefer to work alone versus prefer to work in group. All data from the survey was then input into SPSS for Multi-Dimensional Scaling (MDS) analysis.

A semi-structured, individual interview was conducted with two students in one selected group that had been observed by the first author throughout the whole program. The students were asked about their perceptions of 1) how they studied for the gross anatomy class, 2) how they perceived their use of a computer to complete class assignments, and 3) their suggestions regarding the online materials available for the course. Interview data were then compared and contrasted with the results of MDS analysis. In combining quantitative and qualitative methodologies, the analysis focused on how different attitudes toward the five attributes in the survey related to students' perspectives.

Results

1. Individual and collective learning styles

The results of MDS by category (see Figure. 1) shows that the five attributes, representing five distinct aspects of students' learning, distributed evenly along the two dimensions. Individual student's learning styles are presented in Figure 2. The diagram shows that the major learning styles are defined in the first quadrant ($n = 5$), the second quadrant ($n = 7$), and the fourth quadrant ($n = 6$). The two selected students, Terry* (case 13) and Jen* (case 11), fall in opposite quadrants of the MDS chart.

2. Students' perceptions about using computers to learn anatomy

In Figure 3, the distinct profiles of the two students' learning styles are shown. Terry's learning style is characterized as focusing on general ideas, recognizing and working at a personal learning pace, solving problems by himself, and preferring to learn verbally. On the other hand, Jen strongly relies on details, likes to follow set procedure, needs hints to solve problems, and prefers to learn visually.

Interview data revealed that Jen and Terry used computers by following different learning agendas and in different learning situations. Jen tried to use as many on-line materials as possible, and she was persistent in using computer applications even when some technical problems occurred. On the other hand, Terry preferred to use the computer as a supplement to other materials, usually the textbook. To him, computer problems were unbearable and technical problems alienated him from further usage. Nonetheless, Terry used a computer in the actual dissecting work when he could apply the computer information to the practical situation.

Terry and Jen had is their different perspectives about information presentation. Terry felt that the Anatomy Table (Gest & Burkel, 2000) was the most useful material and he liked its short statements explaining the vocabulary and highlighting what is important to learn. By contrast, Jen felt that the short statements in the Table were too “concentrated,” and she only used them for review purposes.

The two students also provided different suggestions for how to organize information computer-based materials. Jen expected a *systemic* way to organize the details across different regions of the body. While to Terry, he found it difficult to learn from the instruction presented linearly and was confused by the different presentation styles in different learning materials.

Discussion and Conclusion

Jen tried to integrate all computer materials into her study sequentially and systematically across different labs. This finding is similar to Gregorc’s (1985) research of sequential students who like to follow procedure and focus on details. As for Terry, he highly integrated computer use into dissection and he flexibly used computer-based materials according to his personal preference for learning. Terry’s learning styles are similar to those exhibited by random learners (Butler, 1994). Butler believed that random learners need a more flexible environment to better support their learning.

Findings of contextual and temporal differences in using computer between the two students provide educators an example to consider whether structures and scaffolds should be applied to computer use. For example, students who focus on details of the learning materials may need more learning materials while students who focus on the big picture found the volume of information creates confusion. An instructional design that may benefit both types of learners is to implement a meta-structure to the learning materials. Meta-structure can be a concept map that shows the relationships between different concepts or it can be meta-cognitive scaffolds (Hannafin, Land, & Oliver, 1999) that lead the students through certain pathways. Students will see and control the levels of details that they would like to explore to.

It is worth noting that the tendency of using a computer is not only guided by learning styles but also related to students’ access to computers, level of comfort with computers and attitude toward technology. Terry defined his general learning style as oriented by experiential experience of solving problem. However, he did not perform as an active learner exploring different online materials. He relies more on guidance from the instructor and the facilitators. While it is believed that the Internet can encourage self-directed learning in medical education (Anderson, 2000), there are certain factors that should be taken into account by educators. It is important to orientate students to be an active learners and realize the value of information for learning. For students in the health-care system, this may be the first step of preparing them to face a technology-enhanced career environment.

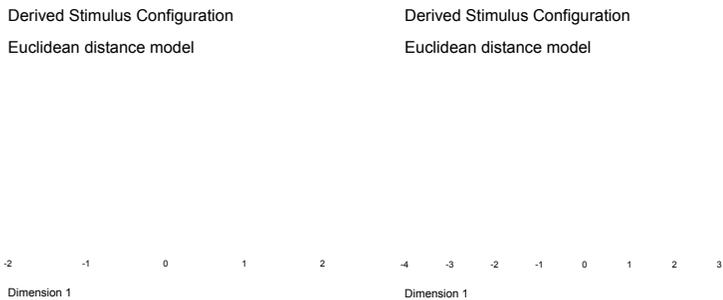


Fig. 1 Multi-dimensional scaling by categories

Fig 2. Multi-dimensional Scaling by cases

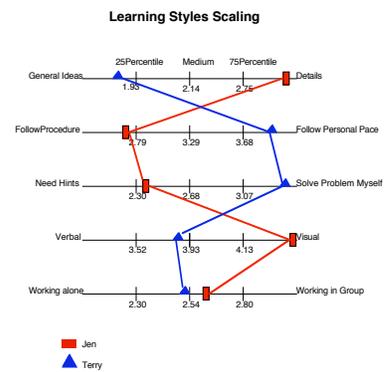


Fig. 3 The scores of each attributes were compared to the medium, 25 percentile, and 75 percentile of the whole class.

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Constructing Anatomy Literacy: How Students Use Computer-based Media in a Dissecting Lab

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Abstract: The purpose of this study is to investigate how computer-based media were used in a dissecting lab to promote the construction of anatomy literacy. By applying ethnographic and discourse analytic methods, the study approaches anatomical literacy as a socially constructed phenomenon. The conversation was not only a means for students to synchronize their understandings but also a research instrument to understand the pedagogical strength of using computers in a socially constructed situation.

Introduction

In a report about literature of computer-aided instruction in relation to medical education, Adler and Johnson (2000) suggested new research evaluating how computers are integrated into medical curriculum and incorporated into different learning environments. However, few studies have provided a descriptive profile of the actual utility of a computer application and have not characterized the learning processes of knowledge building. Based on the above observations, this study is to describe the situation in which students use a computer in a dissecting lab for anatomy literacy building. My analysis was guided by the following three questions: 1) What computer applications and anatomical content were used and how were they used by students in the dissecting lab? 2) What kind of learning opportunities emerged in socially constructed situations when students used computers in the lab? 3) How did computer use in the anatomy lab contribute to knowledge building that led to anatomical literacy?

Theoretical Lenses

The perspective of literacy as a social phenomenon and the conceptual framework of intertextual knowledge building were my analytical tools for observing the meaningful relationships between what group members said to each other as they socially constructed anatomy learning. Literacy is composed of a set of social practices which link people, media objects and strategies for meaning making (Lemke, 1992). Roseberry, Warren and Conant (1992) argued that scientific literacy is not just acquisition of facts and procedures but a socially and culturally produced way of thinking and knowing. Seen through the frame of social construction, intertextuality occurs when members in a learning group act and react to each other in ways that acknowledge and refer to texts to accomplish a socially agreed upon purpose (Bloome & Egan-Robertson, 1993). In this study, I described students' social involvements with computer-based media toward anatomy literacy. What counts as *media* includes images, illustrations, charts, tables, and computerized video clips. I used *intermediation* to describe intertextual meaning-making with various types of media. I illustrated how through their social interactions as they talked to each other, students and facilitators made linkages between information in the media (e.g. a computer graph) and anatomical perspectives gained from other learning methods (e.g. what a professor said in a previous lecture).

Methods

Data for this study was collected from six medical students in the Prematriculation Gross Anatomy class. In the dissecting lab, students worked in groups to share one dissecting table and one computer station. Data collection focused on students' interactions with a computer in the lab and semi-structured interviews with students. One camera was set up next to the dissecting table to capture as much as possible students' conversation and interactions during dissecting (i.e. class video). One video recorder was connected to the computer to record all video output signals directly from the computer screen (i.e. process video). The interview data served as an alternative resource that can be compared to test assertions made from observational data.

Process video and related class video were transcribed. The coding scheme was based on the research question of what learning opportunities emerged when students used computers in the dissecting lab. I selected two representative cases for illustrating how intermediation occurred in different situations of computer use and how each of them was socially significant. Each case represents a series of turns of talk in relation to the learning methods, intermediation, and the anatomical literate practices being socially accomplished.

Findings

Among fourteen events of utilizing a computer, students tended to use computer-based media at the beginning of the lab sessions. In particular, they preferred visual information (i.e. the dissecting video and images) and indications of the dissecting process (i.e. the dissecting video and the on-line lab manual). Information organized in short statements (e.g. Anatomy Table) was used when all the dissecting works were finished.

Case 1: Developing visualization through intermediation

Three students concentrated on viewing anatomical images in *ATLASplus*. In this case, students co-constructed the sequence of learning and made the computer image meaningful to them in the process of knowledge building. They conceptualized an anatomical structure that was not available on the screen by providing to each other their own perspectives developed in the lecture and in preparation for the lab. A pattern emerged in this conversation in that the students alternatively switched between the two important literate practices: identifying structures and defining structures. This process is particularly important for recognizing the same structure in different anatomical presentations (e.g. illustration, medical image, and the real human body).

Case 2: Facilitating meaning-making through the use of computer-based media

A facilitator, Melissa, was involved in the conversation of intermedia meaning making. Melissa recognized the confusion occurred in the conversation and highlighted information in the Anatomy Table on a computer for them. She led the conversation to a comprehensive discussion of the anatomical concepts with deliberation of the short statements shown on the computer screen. The group interactions allowed students to pose further questions to Melissa beyond what was shown on the computer and provided an opportunity for the students to correct the misconceptions that otherwise could not be easily recognized. In this case, the intermediation occurred *through* the facilitator. Melissa located the information on computer but also re-presented it in a way through her own understanding.

Conclusions and Implications

Although students have access to all of the computer-based media individually, this study suggests that it is important to provide these media in a collaborative purposeful, need-to-know environment as well. As demonstrated, learning anatomy is not just about memorizing scientific and medical facts. Rather it involves the application of pertinent knowledge at applicable moments. Some students found the construction of anatomy knowledge confusing and difficult because they had to negotiate and relate information from multiple materials. When students talked about the content on the computer they made the translation and connections between visual and verbal resources, between logic and practical information, and between definitions and identifications of the same structure. In this setting, the computer was a resource for both practice-situated and practice-generated knowledge (Roth & Roychoudhury, 1994). As constructing complex knowledge collaboratively, students help each other interpreting the different presentations and also reflecting on the multiple perspectives emerged from the process by which meaning is made (Koschmann, 1994). Hypermedia and computer multimedia are capable of presenting information in various ways in alternative learning environments (e.g. the dissecting lab). In the future, more research in medical education should be done to examine the impact of intermediation in complex concept development and clinical problem solving.

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