THE UNIVERSITY OF MICHIGAN VISIBLE HUMAN PROJECT (UMVHP)
QUARTERLY PROGRESS REPORT: Y2Q2

Brian D. Athey, Ph.D.
Asst. Professor
Director, UMVHP

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UMVHP: SECOND YEAR QUARTER TWO REPORT
TABLE OF CONTENTS

Y2Q2 REPORT, KNOWLEDGE ENGINEERING

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ACCOMPLISHMENTS YEAR 2, QUARTER 2

The principal accomplishment of the quarter just ended was the release of two new versions, EWSH3.2.7 and EWSH3.2.8, of our familiar Edgewarp software product. Releases are in the form of executables for SGI Irix platforms and for Linux machines with OpenGL support.

Features distinguishing EWSH3.2.8 from its predecessors include:

(i) Incorporation of shaded surface representations within both of the main Edgewarp windows. See below.
(ii) Animation of the tie between the Edgewarp section plane and the associated deformed grid in a second specimen. The deformed grid is continually displayed, freely tumbled under user control, in the left window, while the contents of the source image through which the section plane is passing appears in the right window.

       In addition, 3.2.8 incorporates all the new features of the interim release 3.2.7, May 2001, which included --

(i) Construction of a new Edgewarp window that combines the three different playback modes of the current filmstrip editor in a moving trihedron viewed in the global (lefthand) window, where it cuts through surfaces as specified by the user and can be tumbled freely for better viewing.
(ii) Export of filmstrips for playback as .mpg or QuickTime files for other desktop environments.

       Furthermore, 3.2.8 preserves all of the useful innovations of last quarter's (February 2001) release, version 3.2.6:

(i) Automatic loading of the network connection with the PSC chad server, automatic memory filling under ordinary user interactions, automatic image fill at the highest available level of detail
(ii) For filmstrips representing continuously moving Edgewarp scenes, a new browser window, incorporating interactive controls of playback mode

(speed, discrete search, user adjustment of projection orientation) and a complete editing station (insert, delete, replace, intercalate) perhaps via browser window out of a lexicon
(iii) Command-line invocation, as from a browser interface.

The shaded surface rendering in EWSH3.2.8 is somewhat different from other implementations in that it is keyed to the presence of a sectioning plane on which the viewer's attention is presumed mainly to be focused. Surfaces are selected for display as active objects in the left and right Edgewarp windows separately. On the left, all surfaces are opaque, and also the current sectioning plane, on which the usual colored images continue to be painted. On the right, the familiar section image, subject to all of the existing controls, incorporates sections of the surfaces as well; these are implemented as very tightly clipped views of the same polyhedra.
In 3.2.8, surface representation is as simple triangulated polyhedra, without surface normal information, with shading produced by OpenGL utilities. These surfaces are obtained at present using the facilities of the Volume Browser at PSC (see elsewhere this report). The PVB offers windows similar to these Edgewarp windows, though without the surface-sectioning, filmstrip or gridding capabilities, and the two programs have somewhat similar geometric-state parameterizations, though with quite different widget sets for interaction.

PLANS FOR QUARTERS Y2Q3 and Y2Q4

 1. EVALUATION

Completion of the surface rendering facility, along with the filmstrip traverse (Y2Q1), makes EWSH relevant, at last, to the actual context of anatomical education. At least we can begin the long-awaited interaction between our group and the Anatomy Testbed Evaluation Team. To this end, as reviewed under the UIT quarterly report in this document, we have:
(i) selected a specific pedagogic unit of the M1 gross anatomy course for complementation, namely, the Urinary Bladder,
(ii) selected a short list of Curve Traverse features that EWSH will be expected to supply complementing the text and table presentations of the existing syllabus, and

(iii) sketched a desktop protocol by which the student can navigate among the different software products pertinent to this task, specifically, the Pittsburgh Volume Browser (PVB), the Lexical Database, and the Edgewarp Animated Viewer.

As of this writing, we suspect that the PVB and Edgewarp can share a single format of geometry states: window contents for section, surfaces, and global viewing frame. This will permit the student to toggle back and forth between viewing environments that emphasize global structures of reference (skin, skeleton) and others that emphasize dynamical series of sections (the Edgewarp moving trihedron). Where geometry parameterizations are shared, the evaluation group will be able to differentiate user reactions to the sets of interactions required, toward improving the options offered by either browser separately.

2. TOWARD EWSH3.3

Progress to date highlights five distinct directions of EWSH development that are most pressing at this point in the contract: compression of image data, a generalized facility for multiple spectra with multiple content styles, incorporation of surface traverses, desktop invocations other than by command line, and simplified widget sets for the majority of users.

i. Over the coming quarter, PSC will begin serving chads in compressed form. The EWSH kernel will be modified to accept these in either lossy or lossless versions, with appropriate user control. Image quality at 90% compression appears undetectably altered, and we expect this to be the normal setting for everything except final "filmstrip production" runs. The net effect of compression will be to speed up the tie with the server by a substantial factor and thus to permit a classroomful of students on wireless laptops to browse Eve over the same server bandwidth presently required for the single user.

ii. One general goal of this project is the incorporation of additional generalized spectra in Eve's "volume" beyond the familiar three eight-bit channels of color. Production of a 48-bit data resource that adds MR and CT contents to RGB is dealt with elsewhere in this progress report. A second augmentation, which may be dealt with by a subordinate server at PSC, would provide a lookup capability linking every single voxel of Eve to

one or more of thousands of associated text strings. The geometric pre-images of these lexical entries will in some cases be regions of voxels and in other cases two-dimensional surfaces, one-dimensional curves, or discrete points. Entries that are themselves dynamically renderable (curves or surfaces) will be linked to the corresponding Edgewarp filmstrips. Back in the Edgewarp windows, a subset of these links may be active in the geometry windows in the form of abbreviations that serve analogously to labels in textbook illustrations (but move with the geometry); by this means the user can pass, for instance, from an interesting-looking chunk of tissue in a section to the database entry for the structure sectioned there and immediately, through another invocation of Edgewarp, to a filmstrip for the pedagogically more relevant view of this same novel structure. In other applications, additional colors might represent other
 specimens deformed into Eve's coordinate frame (see under "Lucy" below). EWSH3.3 will incorporate user control of the byte(s) intended for display from these or similar multispectral resources.

iii. Curve Traverse mode was completed in Y2Q1. Now that surface rendering is available in the EWSH environment, we can turn our attention to Surface Traverse mode. While Curve Traverse is dominated by the natural ordering of dynamics by the single parameter of position, Surface Traverse can be ordered by a greater variety of display strategies, including rotating a single normal plane around the surface normal, marching a section plane down the normal, and passing tangent planes along the surface on geodesic paths. We will experiment with these on suitable prototype organs in Eve and package them with other pedagogic materials for evaluation in anatomy teaching as for curves. The earliest prototypes will probably follow cardinal traverses of surfaces (e.g., the "midline" of the bladder) or the ridge curves, such as the bottom of the Pouch of Douglas, at which surfaces are locally most folded.

iv. Generalized invocations. Toward ease of interaction with the other software products of the Evaluation Testbed (see above), changes will be made to the EWSH save file structure to permit unambiguous instantiation from either of two contexts: the project database of lexical terms and curricular contents, or the companion browser just delivered by PSC, which specializes in color space work, segmentation, and construction of the surfaces that EWSH3.2.8 is now able to use.

v. Widget masking. The current EWSH main windows have 43 buttons, and the filmstrip editor, 13. Systems will be produced in which this number is reduced considerably below the range required for editing, to the minimum number needed for playback or free tumbling of archived structures. The sophisticated user will be able to restore the full toolbar via a toggle.

3. DOCUMENTATION

Documentation has been produced of the filmstrip editor, in a form suitable for use by members of the UIT team of this contract. Geri Pelok is responsible for implementation of this feature in the context of the specific anatomy laboratory sequence selected (the urinary bladder, see under UIT, this report). Additional documentation will be produced for the various levels of users encountered on the pedagogical platforms, from those simply reading QuickTime filmstrips to those wishing to explore the full volume of Eve on their own.

ADDITIONAL IMAGE VOLUMES

Over the next quarter we will go forward with the loading of Lucy2.0, the Stanford female pelvis data resource, into EWSH, along with the associated visualizations and lexicons. The comparison of Eve with Lucy is a promising new testbed for software development. Initial experiments will use the current "unwarping" module of EWSH to bring Lucy into Eve's coordinate system. The current visualization system allows for the simultaneous inspection of surfaces traced on Lucy and homologous surfaces traced on Eve after they have been warped into a common coordinate system; the discrepancies should be very instructive.

Y2Q2: DESIGN AND IMPLEMENTATION OF THE U OF M VISIBLE HUMAN DATABASE
Alex Ade

Description
The database design supports the information content defined by the UIT concept map (see report Q1 Y2), including but not limited to 'is a' queries and structural ('is part of', 'is composed of'), connection (blood supply, nerves, and lymphatics), clinical (e.g. function and dysfunction), and boundary relationships. The database supports multiple lexicons (e.g. Terminologia Anatomica and Latin), synonyms, and multiple character sets (e.g. US English and Japanese). This combination allows for the addition of new lexicons derived from nearly any language. The database also supports geometric information, including points, lines, and surfaces that represent anatomical landmarks. Queries may be made against the geometric mappings.

The database framework supports the concept of learning modules, a set of data and their relationships usually grouped by Anatomy lesson. Users log in to the system and are granted privileges based on their role. Currently, there are two roles, author and student. An author may create new modules which are then populated manually or inherit the content of a parent module, or may edit any existing module which she previously created. The module's content may be based on regional or systemic anatomy, if desired, and may include any combination of lexical terms. Students, viewing as read-only clients, may query as many modules as have been assigned to them.

Recognized multimedia content types are text, including anatomical descriptions, lesson plans, and quizzes; movies, both binary files and URLs to streaming media; JPEG and GIF images; 3D models in binary or ASCII format; and audio files in MP3 format. Hyperlinks are included as needed. Multimedia content may be stored in the database as binary or text data. Conversely, URLs to web-based media may be stored for access to content created by our collaborators. Additional media types will be supported as required.

The database design includes both a relational and an object relational architecture underlying an object oriented application layer. The

database, an application server, and a web server form a three tier production system. The application server contains the logic used to query, data-mine, and format the resulting information. Java is the language of choice for communication between the different services. Information is outputted as XML or HTML which can be read by any web-enabled client.

Foreign languages and non-latin character sets are supported by the use of the Unicode standard.

Y2Q2 – UIT/ANATOMY TEAM

Progress in Second Quarter:

An article has been submitted to the Journal of the American Medical Informatics Association. This article was based on the information derived from previous interactions with focus groups and summarized the principal user requirements.

Modifications to the original Institutional Review Board (IRB) request were successfully completed. This allows videotaping and direct observations of student evaluation groups during software demonstrations and its use by students. Also, draft protocols and questionnaires for evaluations have been developed and cleared.

Student evaluations of (a) browsers and (b) scenarios for the presentation of course material has begun. Three groups, each consisting of four pre-M2 medical students, have participated in the evaluation sessions. Analysis of the videotapes and student responses is presently underway. Preliminary data from these sessions has been placed before the software/database development groups to direct development efforts.

Variations of the Graphical user interface (GUI) layout, which presents standardized 'look and feel' to the student have been created and will be presented for evaluation during the third quarter. In conjunction with this effort, the information flow of an example anatomy lesson (bladder, pelvis) have been charted, as well as application-function requirements (see Appendix 1) and will be folded into a new student evaluation session. This will permit the students to understand how all components in development will be integrated.

The PSC segmentation tool was put into service and several test models were created.

Plans for the Third Quarter:

Groups of pre-M1 students will be shown the same evaluation sessions as were presented to the pre-M2s of the second quarter. In separate sessions, both pre-M1 and pre-M2 students will also evaluate the example anatomy lesson scenario with integrated component/information flow.

Segmentation will continue into the thorax with a new team member, Dr. Heping Chau.

Y2Q2 REPORT: NETWORKING
Thomas J Hacker

This quarter, efforts were focused on improving the ability of Visible Human project applications and infrastructure to move large amounts of data across local area networks and the Abilene network. This effort was leveraged to provide assistance in the network performance area to several other large projects at the University of Michigan and at Stanford University.

The first area of work was the successful use of the Web100 application under development by the NSF sponsored Web100 project. The Visible Human project is an alpha user of the Web100 software, and has been engaged with the Web100 development team at PSC to provide feedback on the software. Using the Web100 software, the Visible Human project has been able to improve end-to-end network performance by a factor of 20 for local area networks and by a factor of 75 for wide area networks. This success was demonstrated in June at the NASA NREN workshop at NASA AMES Research Center.

The second area of work was to use the knowledge gained from network tuning activities to improve the end-to-end performance of Visible Human applications. The tuning work performed was written as a research paper "Experiences Using Web100 for Application Tuning" that has been submitted to USENIX LISA for publication.

The third area of work is in establishing network "beacons" at critical points in the network. Three network beacon hosts were built and deployed across the U-M campus. As the result of a meeting with Stanford University in late June, U-M will work with Stanford University to improve network performance between U-M, Stanford, and other key sites on the Internet using these network beacons along with software developed by the Network Weather Service project sponsored by NPACI at San Diego Supercomputer Center. This infrastructure will provide Visible Human project applications the ability to predict the amount of network bandwidth available between any two points in the Visible Human collaboration.

Finally, a second paper was accepted for publication in the 2nd International Workshop on Grid Computing to be held on November 12, 2001, in Denver, Colorado, in conjunction with Supercomputing `01. This paper describes a mechanism for dynamically allocating accounts for access to resources. This research will be essential for managing the stream of users that will be using Visible Human software.

PSC VISIBLE HUMAN SUBCONTRACT STATUS REPORT Y2Q2

1) Description of progress towards completion of quarterly milestones & deliverables:

Primary areas of progress during the quarter include construction and display of surface mesh models, extension of the platform independent Volume Browser (VB), compressed volume delivery from the volume server, and continuing improvements to network connectivity.

Our work on production of surface meshes for segmented organs and tissues is greatly enhanced by the addition of new staff member Demian Nave. Demian's areas of interest and expertise include mesh construction methods and parallel computation. Given that we have access to and make use of consulting from additional PSC staff and student aids we do not anticipate further staff changes for the duration of the project.

Using the program "powercrust" by Nina Amenta for surface mesh generation we have been able to use all of the hand segmentations produced by the Michigan team to produce first level meshes for the objects segmented. Some of these have arrived in the form of a compacted run length coding, which we were able to use with no difficulty, while others were delivered as a variation of photoshop layer files. We have revised the layer extraction process written earlier in the project to handle both photoshop formats. Additional computed segmentations at PSC produced a full resolution skin surface mesh useful as an enclosing context model.

Powercrust implements a provably good algorithm for generating approximating surfaces from dense point sets. Most of the current hand-segmented organs are not sufficiently dense in the vertical direction, so some of the models produced from this input have regions of incorrectly placed surfaces and related artifacts. Problems also arise from manual contours which are not oriented relatively normal to the local surface. These problems will be eliminated by 3D computational segmentation for areas between manual guide contours coupled with the ability to rapidly produce contours at arbitrary well chosen orientations by means of PVB segmentation features. Even with these temporary restrictions, the end results are found to be quite useful as navigational aids in both VB and EW viewers.

Raw surfaces generated by the existing process and its planned enhancements tend to be large because the meshing algorithm inserts additional points at intermediate positions to define the approximating surfaces. The number of triangles used in practice generally has to be reduced before viewing for efficiency of display and good user response time. Because the great detail in completed models such as the skin exceeds visible resolution more usable simplified meshes were generated using Michael Garland's "qslim" program which was highly recommended by Muriel Ross. Qslim transforms the fine surface mesh composed of vertices and triangles into a topologically consistent but coarser mesh containing a user-specified number of triangles. The program was used to simplify several of our surface meshes. The largest model, the skin, which had already been partially simplified during production contained 381,138 vertices and 762,000 triangles. For use as a navigational context surface this was successfully reduced to 7,500 triangles to allow rapid transmission and display with no significant change from the topology of the original surface.

During the quarter we have looked at additional tools for Visible Human segmentation from outside the UMICH NGI VH project. Work in the Segmentation and Registration Toolkit (SRT) is progressing and should eventually be able to handle a number of the processes we need. Bill Lorensen has indicated that the SRT may be available in alpha release for our group in September but that it will require a significant learning period. We also evaluated the IsoView program from John Stewart. This program can produce very nice results given enough effort but can be very slow in operation and is limited in the size of the data volume that can be manipulated at any one time.

Because restrictions in using these alternate tools do not fit all of the time constraints of our project we have been adding segmentation capabilities into the VB framework. We consulted with Brad Smith and other members of the Michigan team to determine key areas where a combination of manual input and computational aids would produce the greatest benefits toward rapid 3D model construction.

Our resulting solution is implemented as an extension to the current Volume Browser which lets us take advantage of its existing code and the networked interface to work with an entire visible human dataset with no

restrictions on memory or region size. The primary segmentation facility is based on Catmul-Rom spline segments with movable control points to let anatomists sketch contours in any planar orientation. For best results anatomy markup should be done in an orientation that is close to perpendicular to the anatomical surfaces being outlined. During processing a spline simplification process is used to minimize the number of control points needed to maintain an accurate description of the contour.

Rather than force users to precisely paint contours to voxel precision we provide computational aids to reposition contour control points based on template matching from a very small number (typically 1 to 4) of carefully positioned points which represent characteristics of the local surface. One of these template points should be provided for each type of surface interface such as bone to fat or fat to muscle etc. Our implementation applies each template over the context to which it applies and tries to avoid using a template on an inappropriate area. Contour refinement within the viewing plane is instantaneous from the human time scale. Users can also copy contours from layer to layer and use the previous templates to quickly adjust each new contour according to the (usually small) changes from slice to slice. When the user sees leaks or other aspects of the contour that they do not agree with the have the option to redraw any portion of the contour as a manual override or select new template points as the working context changes.

We have now provided a means for the VB client, functioning in this case as an anatomy labeling workstation, to send completed contour data back to the ES-40 server where we will use the additional computational power to fill regions between contours using the manually produced contours as both geometric guides and a source of statistics on voxel characteristics inside and outside of the contour. The fill in process that we are producing
generates a complete 3D voxel level point cloud to define the surface and hence closes all gaps left from the users manual contours. These dense point sets fit all of the criteria for surface generation by powercrust. Models from this process will be inserted into the web accessible model collection so they are available by the anatomist and other users to view and revise almost immediately.

Additional features of VB, including a measurement ruler and color space display, are described in a user manual and from the web site, http://vhserv.psc.edu:8000/volume_browser/index.html,
we have set up to make the program available to the rest of the project team and other members of the VH community. A major benefit of VB is that it now supports all major
platforms including UNIX, Linux, Windows 95/98/ME/NT/2000 and Mac OS X. Additional support for Mac OS 9 and BeOS can be produced if there is user interest. Operating as a browser VB accesses the same ES-40 volume server at PSC that is also used to feed Edgewarp. VB provides the essential framework for us to quickly test implementation methods and produce code modules that will be released to the rest of the project.

Important features which have been demonstrated at the quarterly meeting, the NREN workshop and at Stanford include interactive arbitrary orientation slice browsing, display of shaded surface models, use of a 3D context window to supplement slice views, linkage to web browsers, linkage to Alex Ade's database at Michigan and use of a new 3D point identification service from PSC. Michael Gill from the NLM was able to be at both the NREN and Stanford demonstrations and expressed interest in arranging a large multiuser demonstration which can be accomplished with the current level of system development. During the Stanford demo we were also able to show concurrent operation by Steve Senger from his facilities at Wisconsin. Parvati Dev plans to use both VB and Edgewarp with the NLM VF data and Stanford's Lucy2.

The new point identification server at PSC uses data from segmented models to produce a translation from XYZ position to the nearest enclosing segmentation represented as a sequential model number. The model number then allows reference to an http based web server and to the anatomy database at Michigan. The database provides additional information about further levels of anatomical hierarchy and descriptive text. Since 3D surface models were being supplied from the XP1000 http web server at PSC portions of the recent demonstrations accessed two different servers at PSC along with the database server at Michigan. VB does not include the morpohometric features of Edgewarp but to the extent possible we have agreed to share common descriptions of orientation, position and scale so that each of these tools can be used to best advantage as needed.

These recent demonstrations included operation from the compressed service port coming from the ES-40 at PSC. We are currently running the original uncompressed data service along with a relatively simple block of voxels compression and the more complex hierarchical compression. These services run on ports 8694, 8695 and 8696 of the ES-40 and allow us to test and tune proper compression levels according to user feedback and types of use. It is apparent that one level of compression does not simultaneously optimize users on low speed and high speed links. Anatomy users have also shown a strong preference to work mostly in the 3 primary planes rather than at arbitrary orientations. Consequently we will be further optimizing compression and server modes to optimize those views. Tests of compression show visually lossless operation at 10:1 compression ratio but much higher ratios are usable with slightly reduced quality and on platforms with fast processors to allow for the more demanding decompression codes. Lossless overlay at the final level operates at a 3:1 compression ratio limited by the data SNR.

We have continued to make improvements to the delivered network performance of the volume server based on PSC network upgrades, software tuning and network scrubbing with the help of Web100 tools, enhancements to the server programs and operating system upgrades. The most important improvement to Web100 which has let us uncover bottlenecks is the support for SMP configurations such as our 4 processor ES-40. The server was initially constrained to operation from a single processor but now uses all 4 according to system usage. Web100 modifications were also made to prepare for the next
level of Linux upgrade which further improves SMP support. A paper being prepared by Tom Hacker at Michigan outlines the use of Web100 in conjunction with the volume server to tune the network and application software.

2) Problems encountered during this quarter:

Other than the time difficulties involved in juggling priorities to make even and rapid progress on all of the technical fronts given the budgeted staff level there were very few significant problems during the quarter. Most of the problems that did occur have already been mentioned in the earlier description of progress such as new photoshop layers descriptions, and limitations due to spacing of manual contours, powercrust limitations. It

has become clear that the current widget set used in VB needs to be replaced or at least supplemented to handle some of the requests from the UIT group and the demands of the segmentation and labeling role. The only other difficulty was scheduling of PSC network upgrades associate with the Terascale Computing System (TCS) installation.

3) Resolution of problems:

Resolution of most problems has been described earlier. The remaining problems with surface construction will be greatly reduced by 3D point cloud completion and mesh generation that is a major part of the work continuing into the new quarter. Problems with network structure upgrades were resolved by cooperation of additional network and support staff beyond those already on VH project. This cooperation provided a temporary work around network path that was used in preparation for and during the NREN demonstrations at NASA. Permanent network upgrades taking place during July and August and will remove the need for these short-term measures and will be the final PSC network configuration provided for the current project. To assure reliable operation during recent demos and also for the increasing usage of the volume server we have added a third power supply so we can now continue to operate through any single power supply failure. (Tests from the TCS project show this as the single most likely hardware failure.) Additional tuning of the user interface controls for VB and compression levels will be done based on feedback from the user interface team (UIT).

4) Goals for the next quarter & action plan for their completion:

Many of the goals for the next quarter have already been discussed as continuations of work from the previous quarter. Increasing portions of the new work will be based on feedback from the UIT test results. UIT feedback will be most useful to adapt the underlying technical structure that has been developed to the educational mission
of the anatomy lab.

However, independent of UIT results, it is clear that the largest work item continues to be anatomy segmentation and labeling. Our work in this area includes the anatomy labeling workstation extensions to VB as well as 3D surface completion and meshing at the ES-40 server. Production of skeletal models is a high priority and we will provide service of the CT

data to support that work during July. Work is underway to provide rapid user feedback from initial manual segmentations by transmission to the ES-40 server with model sign-out by simultaneous users operating in parallel from PC and Mac clients. Partial replacement of the VB widget set will streamline user operations during segmentation and labeling as well as in the educational user interface. Besides the template matching mode we will be supporting additional modes for user directed segmentation using textures and colorspace markups.

Although we have demonstrated initial linkage of web browsers, VB, Edgewarp, the point identification service and the anatomy database, there is a great deal of additional work during the next quarter to enhance and streamline that linkage and to provide uniform modes of operation. That linkage is the foundation of flexible label display that will be shown during the new quarter. Additional areas of work include the export of VB components for use in Edgewarp and to support Java based interfaces, zooming in the VB context window, support for NURBS surface descriptions in the form of OBJ files, more interaction with the Stanford group, implementation of collaborative operation features, color and contrast transforms to approximate the 70mm film response and general performance improvements from code optimizations and special treatment of primary viewing orientations.

An operating system upgrade to the Linux 2.4 kernel will be done on both the ES-40 and XP-1000 servers. Besides general bug fixes and performance improvements the most important aspects of the upgrade are the significantly improved multiprocessor support, better virtual memory implementation and improved multi-threaded network stack. This will translate directly into better support for more users at higher rates of network traffic which will let us take advantage of the network upgrades coming from the TCS project.

5) Next quarter needs:

In addition to developing new features we need to be sure to allocate enough time for optimization and completion of debugging of existing features that have been demonstrated in prototype but are not yet in finished form. We will be purchasing replacements for borrowed network cards that have been used during development and demonstrations as well as Nvidia based PCs for continued development and testing.