The University of Michigan NGI Visible Human Project

Quarterly Report
Q1, Y1

April 8, 2000

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Project Director

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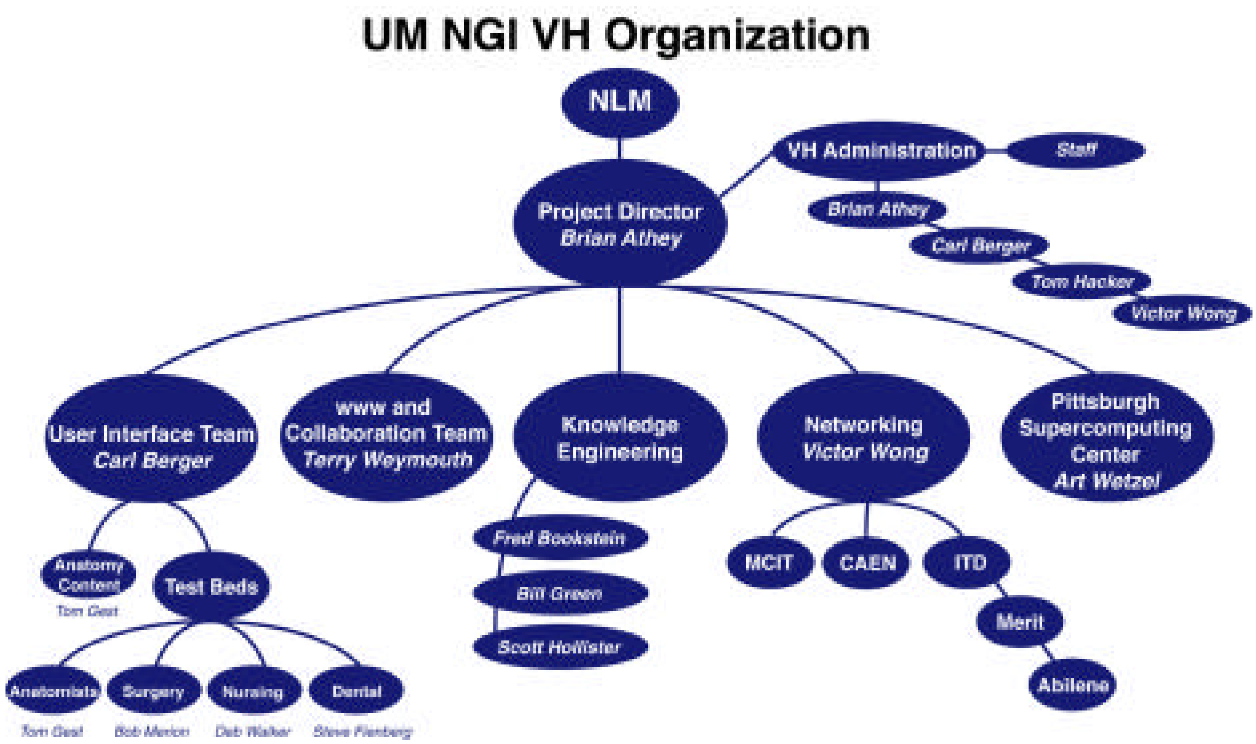
Introduction - Brian Athey

This quarter has been a productive one and has set the stage for a very successful program. We have established 5 teams, which are shown in the organization chart below. Reports from each of the teams are submitted, with some sub-team reports. Highlights of this quarter include: 1) Meeting of all expected milestones for the project to date; 2) Accelerated delivery of several software capabilities such as linking arbitrary cutting of VH volumes for PSC server for loading into the 24-Bit EdgeWarp 3.2 program; 3) The procurement of VH administration and workspace in the Computing Center Annex Building on North Campus and the merger of the Athey administration group with the Wong/Berger Administration group; 4) The procurement of excellent space 2100 sq ft for a surgical test bed for educational development; 5) A very solid plan for the server implementation for the project based upon a heterogeneous Compaq architecture; 6) The "flipping" of all VH data to an orientation most useful for professional educators. This data will be made available to all sites including NLM. This will be coordinated to be at the 3rd VH conference; 7) First cut user requirements from the User interface team; 8) Demonstration of point to point interactive capability of the Abilene link between Ann Arbor and PSC; 9) Aggressive use of collaboration tools and technology and the establishment of strong collaborative ties with Stanford University Medical School; 10) Budgetary conservatism that is fiscally sound and is keeping us within budget.



Applications and User Interaction Group - Carl Berger

First Quarter Goals: Five goals were set for the Applications and User Interaction Group

1. Set up Applications and User Interaction Group
2. Obtain first round of IRB approval
3. Review literature
4. Develop project PERT chart
5. Gather and test tools

Progress: Initial Action Items Completed

1. Set up Applications and User Interaction Group:

Establish team: The team was established consisting of the following members:

- Carl Berger, Education and Office of the CIO
- Tom Gest, Anatomy and Medical School
- Steven Feinberg, Medical and Dental School
- Tom Hacker, Education and Information Technology Division
- Tricia Jones, Education
- Wen-Yu Lee, Education
- Neil Skov, Physics
- Deborah Walker, School of Nursing
- Victor Wong, Physics and Office of the CIO

Clarify goals and roles: Every team member has articulated what goals are under her or his jurisdiction and her or his roles on the team.

Staff and Resources: Identify any staffing and resource needs to fulfill these goals. We have identified a new role for an instructional programmer/designer. We will work to fit it into our current budget.

Communication process, team meeting times, and work schedule: The UI team meets biweekly for updates of work in progress and discussion of future assignments/plans. We are using an interactive communication tool, UM.CourseTools to expand our communication process. This is available at https://coursetools.ummu.umich.edu/umaa/soe/projects/vishuman.nsf (although full access is currently restricted to authorized users, some documents are available to anyone with a valid University of Michigan account). This tool allows for schedule, assignments, discussions, announcements and resources for all participants. We also began a PERT chart to identify task and resource alignment.

2. Obtained first round of IRB approval. Applied for and received human subjects approval for user requirements gathering.

3. Review of literature including design processes and problem based learning in the health sciences.

4. Developed project PERT chart from the grant application which guides the current and future work of the User Interaction Team as well as other VH teams.

5. Gather and test tools that include:

Research agenda:

Chose non-experimental approach. We chose a non-experimental approach as our research indicated that an experimental control group style would not yield the results we need.

Designed protocol to gather data from faculty and students.

Identified groups and scheduled meetings of dental, medical and nursing students and faculty.

<u>Problems Encountered:</u>

- Need for Institutional Review Board human subjects approval for user requirements gathering delayed design of test bed facilities
- Need to strengthen interaction, communication, and relationship with other project teams

<u>Resolutions</u>

- Obtained human subject approval for focus groups
- Using surveys to obtain student profiles, not as final outcome measure
- Student background data are needed for learning outcomes assessment
- Questionnaires after tool use are needed for impact assessment

<u>Goals for Second Quarter:</u>

User Requirements Gathering:
We have begun to take an initial assessment at difficulties surrounding anatomy courses. We will gather qualitative data from the following groups:

Faculty:

- Faculty who teach Gross Anatomy to medical and dental students
- Faculty who teach Gross Anatomy to undergraduates in nursing, along with other stakeholders in that program
- Faculty who teach specialized skills to surgical residents

Students:

- Medical school students (first, second, and fourth year)
- Dental school students (first and second year)
- Nursing students (undergraduates)
- Surgical residents
- Kinesiology Undergrad Anatomy (700 students)

These data (together with knowledge gained from the literature review) will allow us to define instructional goals, and identify major problems students have learning anatomical content.

These will help us clarify the requirements for the Visible Human user interface and develop initial prototypes.

The goal is to deliver to the applications group the first cut of user requirements.

Analysis of Results:
Use problem analysis tools to develop themes for user interaction.
Test web programs for possible use for developers, faculty and students.
Develop first draft user requirements for interface tools.
Begin work on manuscript #1; user requirements.

Second Quarter Needs:
Hire an instructional programmer/designer.
Better communicate with application team.
Obtain appropriate web development software and hardware.

Anatomy - Thomas Gest

Progress:
We have received the computer workstations to be used in labeling, and equipped the workstations with Photoshop 5.5. One complete labeling station is in place and in use, with the second to be on-line when additional components arrive. With Art Wetzel of the PSC, we have established a mechanism to retrieve the jpeg versions of the Visible Human images. In order to present the cross-sectional images in the standard radiologic view, we instructed Art to rotate all of the cross-sections 180 degrees, and to flip these images horizontally.

We presently lack some of the necessary materials and services to accomplish our tasks. We have requested these items, and are awaiting their delivery or installation. At the end of January, we met with Chuck Singer of MCIT concerning upgrading the gross anatomy laboratories to 100base/T Ethernet connections, but we have not received notification of completion of this upgrade. We have requested assistance in correlating the Terminologia Anatomica with the UMLS nomenclature. The CD containing the FileMaker Pro version of the Terminologia Anatomica was delivered to Walter Meixner at the end of February. We should soon be contacted by the individuals working with these databases.

Selected Visible Human cross-sections were printed, and we have been working with these print-outs to begin to label the images. The anatomy labeling team has divided the work load so that each anatomist is assigned a tissue group to label: Burkel – bones, joints, & ligaments; Cortright – vessels; Fisher –editorial review; Fischer – viscera; Gest – nerves; Kim – muscles. The anatomists have been meeting on a weekly basis to discuss issues of labeling, nomenclature, and student learning modules. Denis Lee has started to add detail to anatomic features which are less than satisfactory.

A test of the anatomy labeling was sent to PSC at the end of this first quarter. We will adjust our techniques according to the feedback from Art Wetzel.

Goals for Second Quarter:
We will complete the installation of labeling workstations and Ethernet connections and upgrade the anatomy testbed Ethernet connections to 100base/T speed.

With the necessary tools in place, the anatomy labeling team is now labeling the female dataset. We are proceeding with labeling the abdominopelvic cavity, chest, head & neck, and limbs, in that order. The labeling of the female dataset will most likely extend into the third quarter.

The correlation of Terminologica Anatomica and UMLS databases should commence in earnest. Rectifying inconsistencies in the nomenclature and providing correlating clinical jargon will be a long-term project extending throughout the first year and into the second year of this project. Dr. Athey is building a database group with members of the College of Engineering and School of Information staff to augment our efforts.

Surgical Simulation Test Bed Site - Steve Feinberg

Progress:

The NGI/VH surgical simulation facility/test bed was able to identify physical space (the Northern Brewery) to house our operation. Our group at present consists of myself (Stephen Feinberg) a maxillofacial surgeon, Robert Merion, a transplant surgeon, and Scott Hollister, a biomechanical engineer with expertise in modeling and simulation. In the near future a software programmer and a post-graduate student will be identified to assist our collaborative activities.

Problems Encountered:

The cost of the rent for the Northern Brewery was a concern. We were able to obtain the indirect costs for Dr. Feinberg to assist in this endeavor. In addition, Drs. Merion and Athey have agreed to contribute funds as well to cover the rent.

Resolution:

At present we do not have any hardware to place in our surgical simulation test bed. Drs. Merion and Feinberg went to the IEEE VR2000 meeting held in New Brunswick, NJ to develop a collaborative interaction between the University of Michigan NGI/VH surgical simulation group and the following three companies: ReachIn Technologies (www.reachin.se), SensAble Technologies (www.sensable.com), and Teneo Computing (www.teneocomp.com). The result of the meeting ended in a positive note and our purchase of a 6 DOF haptic device with companion software (the 6 DOF magma software from ReachIn will be developed in the next 6 months).

In addition, Teneo Computing and Dr. Feinberg submitted a SBIR proposal (April 1, 2000) on development of a virtual reality model for tooth extraction. If this is funded the indirect costs will assist in rent for the Northern Brewery and allow us to pay for software development for the 6 DOF haptic Phantom device.

Goals for Second Quarter:

1. To get a 3 DOF haptic device and software as a loaner while the 6 DOF haptic software is being developed.
2. Coordinate our "game plan" for development of a VH TMJ animation model, with associated bones and muscles, to use as a deliverable for the NGI/VH (this venture will be directed by Dr. Hollister).
3. Bring Tim Posten, initial developer and consultant of ReachIn Technologies, and John Ranta, Teneo Computing (a "spin-off" company from SensAble Technologies), to the University of Michigan for a workshop on the use of the 6 DOF haptic device and software for virtual surgery using VH datasets.
4. Implement Thoracic and VH data obtained by Dr. Gest and Art Wetzel into the surgical testbed.
5. Link efforts with Department of Energy and Medical School Simulation efforts to link VH into that Graduate Medical Curriculum.

Collaboration Activity - Terry E. Weymouth and WWW Site Team

<u>Progress:</u>
During the first quarter, we had two primary activities with respect to the adaptation of collaboration web-based technology.

First, we set up a web server that to serve the SPARC framework for user-configurable, shared web pages. This required the installation and configuration of Apache and the installation of the Jserv server-side plugin. We also installed the class library for the Java servlets that implement the framework.

Second, we have worked out a plan for getting a full web site up and running. This is primarily a "chalk and talk" stage of getting people connected. The resulting plan is to implement a web interface that is (essentially) a portal to the resources of the project. There are web resources being developed by various groups (e.g. the Pittsburgh sub-group, the Educational Evaluation sub-group). The intent, for the next quarter, is to establish a central gateway to all the resources of the project.

The SPARC project is discussing collaboration with Dr. Ken Klinginstein of I-2 relating to the NSF middleware 'Early Adaptors' program. The collaboration and WWW group will expand its activities to bridge into useful areas where these initiatives will overlap.

Knowledge Engineering - Fred Bookstein

Fred L. Bookstein, Project Director
William D. K. Green, Senior Scientific Programmer

Over the first three months of this Phase II NGI VH development project, progress related to the Knowledge Engineering theme has been as follows:

<u>Progress:</u>
This project was committed to implement a 24-bit version of the current EdgeWarp DIG3 sectioning engine by the end of Y1Q1 and to demonstrate its timing in native mode on SGI machines with Impact graphics hardware. This system also runs on PSC under the Linux OS.7. Implementation and demonstration were achieved by running the new executable module live on a randomly selected Indigo2 machine at the University of Michigan Media Union, on March 9, 2000 at the quarterly progress meeting; also, to deliver the kernel of this engine to Pittsburgh for them to inspect and begin to modify. Delivery was on or about March 20, 2000.

Separately, in view of the very satisfactory performance of the PSC site at bringing the actual VH data resource on line, we agreed to modify this implementation so that the 24-bit volumes to be loaded could be retrieved dynamically from PSC whenever such a server became operational. That server came up on March 8, well ahead of the anticipated Y1Q3 date, and so the stand-alone EWSH implementation was correspondingly modified in late March. For more on this server resource, see the PSC progress report elsewhere in this document.

<u>Demonstration:</u>
The following is a discussion of a demonstration of actual program window contents from a run of the current EdgeWarp3.2 release using a 256^3 set of voxels of the Visible Female centered in the cardiac septum:
The volume, retrieved prior to the activation of the PSC URL, was preloaded, but it is identical to what would now be dynamically accessed. The demonstration involves running a tangent plane over a wholly arbitrary "anatomical structure" that was simply the surface of a cylinder (axis vertical) centered at the middle of the volume. In the left (guide) view you can follow the progress of this tangent plane (this window was freely manipulable during the circuit); on the right, the volume is resampled corresponding to the moving position of the slice. The navigation begins in pericardial fat, wanders into the marrow of the sternum, briefly explores the tip of a left lung lobe, then curves back in to section the aorta and two cardiac chambers (including a very nice short-axis view of the left ventricle). With the sectioning engine set to rendering at 256^2, the sequence ran at 5.8 frames per second on a 1997 SGI Indigo2 with Maximum Impact hardware.

<u>Notes:</u>
(1) What you see is what you got: the new Y1Q1 EdgeWarp 24-bit sectioning engine running underneath the old EdgeWarp screen interaction protocol. While the display is real (i.e. not a simulation), it was not intended to anticipate the ultimate user interface currently being designed. It is expected that this will involve three windows, not two. The right-hand window here will be

flanked by a global scout view and also an oblique representation of the slice in situ with translucent representation of neighboring surfaces and their labels. (2) Although this moving tangent plane is a prototype for the "surface traverse" mode to be delivered Y2Q1, none of the tools have yet been prototyped by which navigations like these will be attached to actual curvilinear structures in Visible Human data sets. (3) Likewise, in this demonstration, the EWSH kernel has no structure corresponding to the dynamics of the traverse ("going around the cylinder"). The movie was implemented by a crude wrapper outside of EWSH – a TCL "calling program" -- rather than the smoothly interpolated internal implementation intended for delivery Y2Q1. (4) The traverse demonstrated here is entirely internal to the loaded volume, and so did not require (and hence does not prototype) the server interactions that would obtain additional subvolumes of the specimen as navigation requires. (5) All these limits notwithstanding, we believe that the combination of the old EdgeWarp user interface with the new sectioning engine may already be a useful tool in the hands of others than its developers, and so we have posted it, in SGI and Linux versions, on the project's FTP site for software, ftp://brainmap.med.umich.edu/pub/edgewarp3.2.

Goals for Second Quarter:

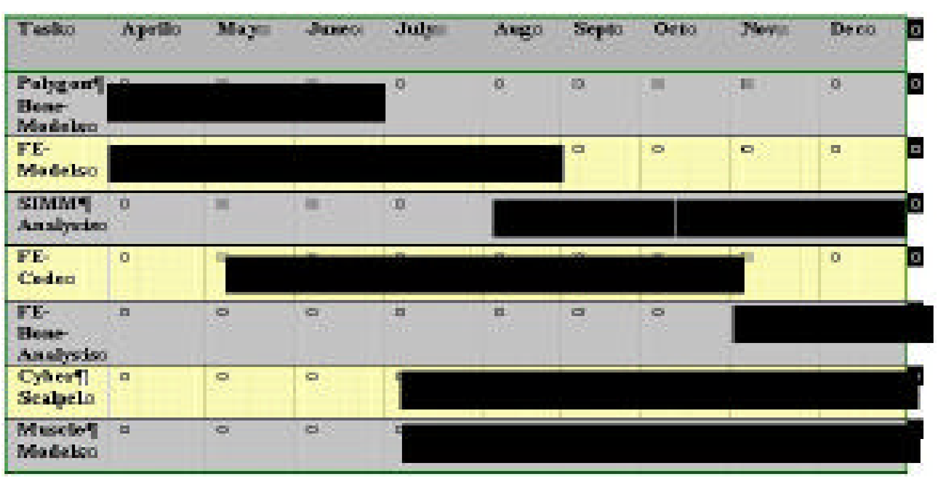
The next milestones for the Knowledge Engineering project include: A script handler and browser, along with preliminary implementations within the kernel for the two cases we expect users to invoke most frequently: point traverse (rotating around a fixed axis) and line traverse (passage along the tangent developable of a space curve). A preliminary version of the surface overlay and the anatomical labeling overlay should be available from the PSC site by Y1Q4 for experimental incorporation into the same user window system (perhaps implemented as an ancillary "volume" one bit deep to be managed by the same sectioning engine).

Modeling and Simulation Group - Scott Hollister

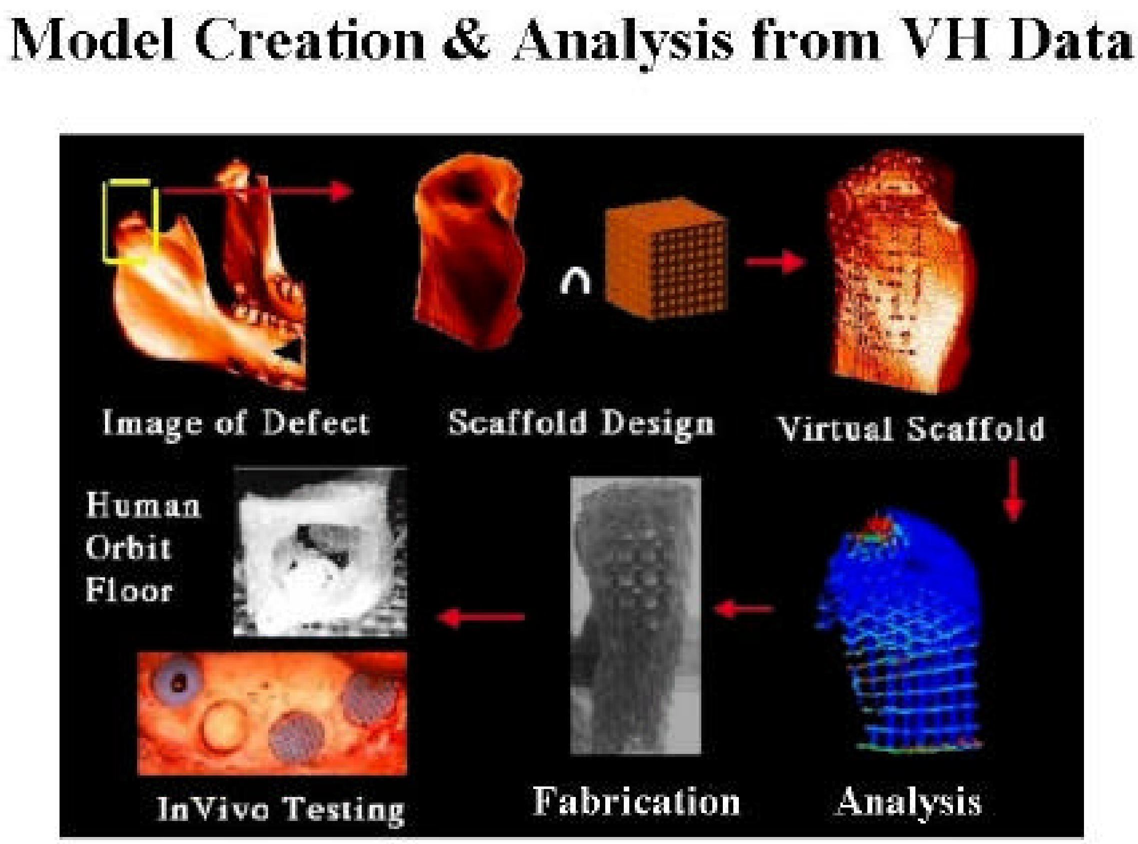
1st Quarter Goals:
The overall goal of the modeling and simulation group is to enhance the current Visible Human data with functional information (software, charts, servers, and networks), and to serve this functional information using the same data format and over the same Web infrastructure as the current Visible Human Data. Our specific goals for the next three quarters are outlined below:

1. Create Anatomically Realistic Rigid Body Models of Bone and Muscle from Visible Human Data and Simulate Movement using SIMM software.
2. Create Anatomically Realistic Finite Element Models of Bone, Muscle, and Tendon From VH Data.
3. Perform Finite Element Simulations of Tissue Deformation and Anatomic Movements using Voxel Model.
   a. Initial Targets – Craniofacial Deformation/Motion.
   b. Muscle/Bone Combination Models.
4. Implement Cyberscalpel (Murial Ross formerly from NASA Ames and now of the University of Mexico).
5. Package resulting simulation data so that it may be served over the net for navigation using EdgeWarp software.

Timeline:
Our timeline for achieving these goals is given below text format, followed by a timeline chart:
1. April-August: Create Polygon models of different refinement for all bones and muscles that are segmented (we will use VHCT data).
2. April-October: Create Anatomically Realistic Finite Element Models of Bone, Muscle, and Tendon From VH Data.
3. May-October: Update Parallel FE code to accommodate VH Data.
4. July-November: Implement muscle model in Voxel FE Code.
5. November: Begin FE Analyses of Bone/Muscle.
6. July: Begin Implementing Cyberscalpel using polygon models.

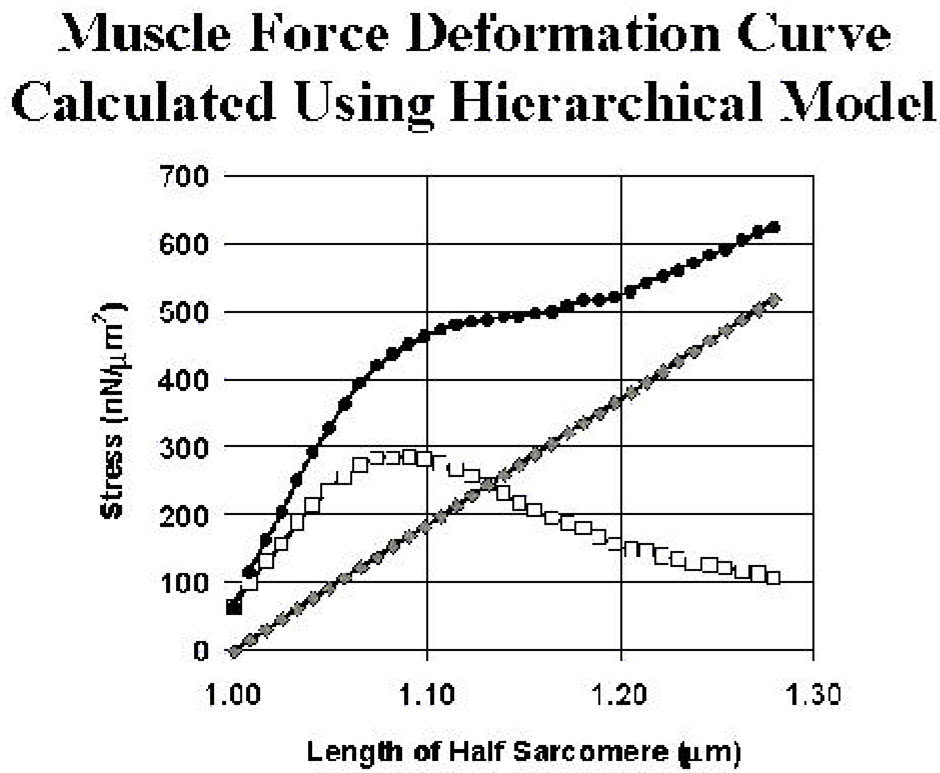


Progress:
We have been laying the groundwork for implementing the tasks given in the Goals section. We have the software in place and have tested it for creating voxel models. We have been able to run these voxel models on systems ranging from a PC to the SP2 parallel computer. We have also shown the ability to create polygon models from voxel data and use the VH data to design tissue replacements. This is illustrated in the figure below:

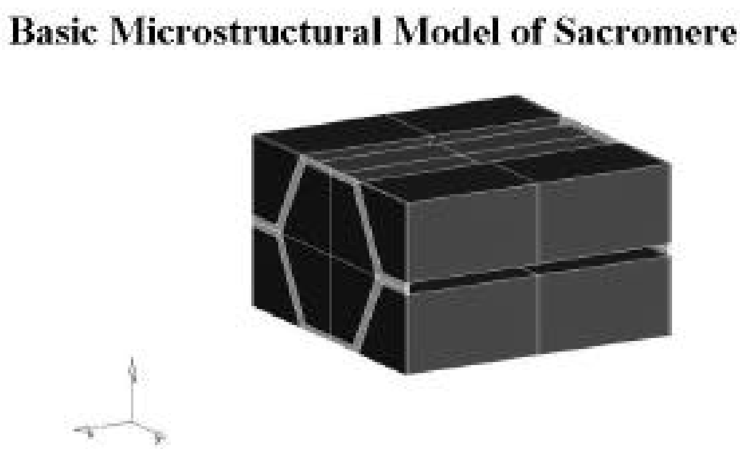


In addition to polygon models we have created, we can actually build physical replicas of Visible Human anatomy using solid free-form fabrication techniques. The orbit floor in the picture was built from patient CT data. Similar models have been built using VH data.

Finally, Mark Palmer, a MD-PhD student working with Dr. Hollister and Dr. Hollister have formulated and implemented a model of muscle contraction using a homogenization model of tissue hierarchy. With this model, we have been able to show that global level force displacement curves that match experimental results can be computed using the actin-myosin equations for muscle physiology proposed by Huxley, as shown in the figure below:



This presents a new dimension to the Visible Human dataset, the ability to incorporate microscopic physiologic dynamics into hierarchical computational models that can predict the affects of the physiologic dynamics on the global anatomic data. The computational model for the sarcomere is shown below:



<u>Goals for Second Quarter:</u>
In summary, during the first quarter we have laid the groundwork in terms of implementing formulations and software for the modeling that we will perform starting in April. In addition, we will implement software obtained in collaboration with Dr. Muriel Ross and NASA that will allow simulation of surgery on polygon models. This, along with our modeling, will supplement other VH data used in the testbeds.

User Interface Design and Implementation - Alex Ade

Progress:

During this report period, I began designing and developing an enhanced graphical user interface (GUI) around the EdgeWarp kernel. The current EdgeWarp tool bar has been reconfigured and simplified for ease of use. A full-featured menu system is under development. I've added the ability to include three-dimensional objects in the rendered scene and to clip through them in any orientation. I've developed and begun to implement a display system for the hierarchical listing of anatomical terms which link to elements in the 3D world. Finally, I've begun exploring and evaluating network technologies for client-server communication and data interchange.

A combination of menu buttons in the tool bar and a more comprehensive pull-down menu system will make the EdgeWarp interface more manageable and easier to use. Menu buttons can be used to collapse mutually exclusive button groups into one functional GUI element.

The user must be able to view and interrogate 3D objects in the rendered scene. Therefore, I've developed a system to import, embed, and illuminate 3D anatomical objects within the cardinal planes. These objects can be toggled on or off and have a user defined transparency setting. A clip plane can "cut" through the object exposing the surface underneath.

A two-way system, connecting labels in the scene to anatomical terms, will allow the user to find objects based on names, or names based on objects. I've begun to extend the current EdgeWarp interface to allow this interactivity.

Finally, I've been evaluating technologies such as Extensible Markup Language (XML) and CORBA for client-server communication and data exchange.

Problems Encountered:

I began programming the interface using Java and its associated APIs. My thought was to use Java because of its platform independence and integration with the World Wide Web. I developed a GUI prototype and tested it. While there were many benefits to using Java, it became clear that the performance hits would be unacceptable. Therefore, Java and its APIs will be used in the project, but will not be the primary programming language for the interface. Java cannot provide the degree of interactivity the project demands.

Resolution:

I'm currently using a combination of programming languages to develop the interface. The resulting application will run natively on the computer and will not be inhibited by interpretation through any "Virtual Machine". The Linux operating system will be used for platform portability. MAC and PC's should be able to run the interface.

Goals for Second Quarter

During the Second Quarter I plan to continue developing and improving the user interface. I will develop a method to include complex textures with the 3D models. The interaction between textual and graphical elements will be expanded. I will also continue some early work in network programming using XML and/or CORBA to exchange data between client and server.

Second Quarter Needs:

I will need access to R&D machines for all platforms we choose to support. These machines must be configured to run their respective operating systems (e.g. MacOS on a Macintosh) as well as Linux. They also must have state-of-the-art graphics cards and a fast network connection.

Dr. Athey and Mr. Hacker are working to obtain these resources.

Pittsburgh Supercomputing Center – Art Wetzel

Progress:

The first 3 months of PSC work has been primarily devoted to setting up the underlying computing and technical base for the rest of the project. In particular, we have concentrated on setting up the data repository and access services for the project along with baseline work on the network connectivity to project members. Initially, the anatomy group in Ann Arbor has had the most urgent need to access image data for manual labeling and seed segmentation. Work on 3D-EdgeWarp was also to the point where it needed to tie into a remote online source of volumetric image data. Because of these needs we adjusted the priorities for the PSC subcontract by moving up some of the data delivery tasks in exchange for moving data compression and image analysis tasks into the next quarter.

Our first task was to set up a server machine "vhserv.psc.edu" with disk storage for all of the visible human data from NLM. This machine is a 500MHz Compaq XP1000 using the 21264 Alpha processor and with 500MBytes of memory. We installed two 50GByte high performance disk drives and house the machine in the PSC graphics lab at Mellon Institute adjacent to the SGI Onyx system "trinity.psc.edu" which is also used for parts of this project. All of the data from the NLM visible human FTP server was downloaded to "vhserv" including optical, CT and MRI data for both the male and female. In order to provide immediate access by project members in Ann Arbor we have hooked into the existing graphics lab network connectivity rather than waiting the higher performance tuned connection that will be used later in the project.

The anatomy and EdgeWarp groups first needs have been for the optical VH data rather than the CT and MRI. To provide this as quickly as possible we initially reformatted the NLM transverse slice data for both the female and male from its NLM R/G/B format into PPM slices which were then JPEG compressed for better network delivery. This data was further processed into 2, 4 and 8X scale reduced versions for quicker visual access and slice selection. An initial web accessible browser interface was set up at the URL "http://vhserv.psc:8000/browser/" and a parallel directory access mechanism at "http://vhserv.psc:8000/slices/". This met the first level requirements of the anatomy team so they were able to begin their work. At the request of the anatomists. who are trained to view data from the bottom looking towards the head and with the ventral side to the top of the screen, the slices were reoriented.

Over a few weeks time the data service from "vhserv" was expanded to include all three-principle axis views over both optical data sets of the whole body. Rather than producing these coronal and sagital sections directly from the slice data we took to opportunity to repackage the uncompressed data into a form that would fit into the needs for volume data delivery and hierarchical compression trees. The new disk organization is based on "cubed" data files which are each 64*64*64 voxels. This organization is a step on the way to the RAM based compressed cublet representation that will be used in the final project server. The optical female data which was originally in the form of 5180 slices of 7.4Mbytes each now occupies 49248 cube files in a 3D organization of 32 cubes wide by 19 deep by 81 high. The cube size of 768Kbytes was chosen as a trade-off between too many very small files and the inefficiency of extremely large cubes with respect to arbitrary slice and volume generation. The eventual RAM based mechanism will use smaller cubes.

The cube representation is the basis for our prototypes of arbitrary slice and volume extraction are also available over the web from "vhserv". In operation these programs use a 3D array of 49248 cube pointers and a cache-like mechanism to dynamically access cubes which intersect a users slice or volume request. Similar to virtual memory operating systems paging mechanisms, unused cubes are removed from memory to make room for new data as needed. This concept will be directly expanded into the future RAM based compressed volume implementation. Both the slice and volume extraction programs operate by stepping across the target data region and reaching into the cube data representation to fetch individual voxels on demand. Currently the volume extractor retrieves any volume but the axes remain in the original data orientation. The slice extractor provides the ability to generate slices in any orientation axis aligned or not. These prototype facilities are currently available via web "forms" at "http://vhserv.psc.edu:8000/slices/get_fem_volume.html" and "http://vhserv.psc.edu:8000/slices/get_fem_slice.html". An example of off axis aligned slicing to view the optic nerve can be seen at "http://vhserv.psc.edu:8000/slices/demo_optic.html". An extension to the browser mechanism at "http://vhserv.psc.edu:8000/browser/index2.html" shows a visual navigation approach to volume selection. A direct hook from 3D-EdgeWarp is being provided by a direct access to the volume extraction program without going through either the browser of form-based interfaces.

Our other major activity has been in the area of networking to characterize and improve the connectivity between all project locations and specifically the access to our data service on "vhserv". We are primarily using tools under development by the Networking Group here the PSC, allowing us to leverage ongoing research efforts in this area. The "TestRig" software package has been ported to many of the target platforms involved and is instrumental in detecting network performance issues and ultimately in the network protocol tuning.

Performance testing and analysis between several combinations of machines at multiple locations within the PSC, the University of Michigan, and UC San Diego have been used to profile transmission characteristics. Tests to hosts including the Pittsburgh Visible Human image server have exposed undesired performance constraints within the local network. Currently the resolution of these issues is under way and will likely involve logically relocating the machine with respect to an internal firewall as well as other potential hardware configuration changes. Additionally the TestRig software has enabled a series of data transmission simulations for the benefit of (TCP) protocol parameter "tuning". While the results of this effort are promising, they will have to be verified after the hardware and configuration changes have taken place.

The ongoing efforts in this area will directly support both the network "tuning" functionality in the ultimate Visible Human software system and the increased throughput of the image server within the PSC to the University of Michigan, NIH and other NGI partner institutions. Identifying and relieving the detected bottleneck impeding the image server will allow faster image data serving to remote collaborative parties. This will support the upcoming volumetric data serving to remote EdgeWarp based clients at the University of Michigan. In a complementary fashion, the tuning parameters will feed into the software client and server development to ensure enhanced network utilization.

Additional work during this quarter which will accelerate during the next quarter is the evaluation and design of high performance server architectures to satisfy the 40 seat anatomy lab goal. Currently the most likely option is a heterogenous server taking advantage of very high speed Compaq Alpha machines for compute and memory intensive operations and network connection coupled with high end PC machines using eNvidia graphics cards for server side image generation.

Also during the last month we have officially attached this project as a subject of study with the PSC NCRR Collaboratory Tools grant. This will provide increased ties with the collaboratory work at Michigan and exchange of collaboratory tools and methods.

Problems Encountered:

As reported in the above sections, the major problems during this first quarter were primarily the network performance and the rapid setup of the "vhserv" machine to serve the project. At the end of the quarter we received the first sets of labeled and seed segmented images back from the anatomy group. These have not been processed yet as we are trying to locate tools to convert from the Photoshop layers format into a more computational format. Due to the number of images to be processed this should be a batch rather than an individual manual solution. Also, due to the need to process uncompressed data as well as serve it from the "vhserv" machine we have still been disk limited most of the time.

Resolution:

We expect to resolve the networking and "vhserv" disk problems by identifying and installing the appropriate additional hardware and making changes to the firewall and routing mechanisms. The biggest problem, which is still unresolved, is getting the Photoshop layered anatomy data into a workable computing format.

Goals for Second Quarter:

With the exception of swapping the order of data delivery and image processing tasks across the 1st and 2nd quarter we will continue to follow the original action plan. That plan includes additional network tuning, server architecture selection, analysis and correction of data exposure in consistencies, implementation of volumetric compression and anatomy data segmentation. These should all proceed on schedule provided that we find a solution to the anatomy data representation problem.

Second Quarter Needs:

The top priority is software for converting the layered anatomy data into a simple computational form. If that is available commercially at an acceptable price then we will buy it. If not, then we are collecting specifications on how to write it ourselves.

On the equipment side we will need two additional disks to handle the data processing in addition to the existing data server roles. Also, as we determine the candidate architectures for the eventual high performance server we will need to be getting small quantities of that equipment in house for development and testing. This will include additional Alpha, PC and graphics devices.

Networking Update - V. K. Wong

Progress:

In fall 1999, the University of Michigan Ann Arbor campus was connected (OC-12) to the Michigan GigaPoP, which in turn is connected (OC-12) to Abilene (OC-48). Thus in principle, OC-12 connectivity to Abilene is provisioned; but before this OC-12 connectivity to Abilene can be fully utilized, several bottlenecks at the University of Michigan (UM) must be addressed.

First the UM backbone needs to be upgraded to be consistent with OC-12 connectivity to Abilene. UM has in fact three backbone rings: the CAEN ring which serves the engineering college; the MCIT ring which serves the medical center; and the ITD ring which serves the rest of the Ann Arbor campus. Because of the inter-disciplinary nature of our NGI Visible Human Project, all three rings are essential to the Project. Last year the CAEN ring was upgraded to OC-12 and the MCIT ring was upgraded to Gigabit Ethernet. In February 2000, the ITD ring was upgraded to an ATM mesh with throughput equivalent to three OC-12s. Thus at the end of this first quarter, the backbone network of The University of Michigan has all been successfully upgraded to be consistent with OC-12 connectivity to Abilene.

There is still a bottleneck at the interface, called the UM-BIN, between the UM backbone rings and the UM OC-12 connection to the Michigan GigaPoP. The plan is that the UM-BIN interface will be upgraded to OC-12 by summer 2000. This bottleneck notwithstanding, a demonstration last month using the existing connectivity between UM and the Pittsburgh Supercomputing Center proved successful.

The final and most difficult bottleneck to address is the last mile connectivity. Work is now underway to identify the connectivity at each of the Project's numerous sites on the UM campus. Not all of the sites need to have the same high bandwidth. The last mile connectivity will range from 10 Mbps, 100 Mbps, to OC-12- 655 Mbps). The plan is that by the second quarter, we will have all the sites' connectivity identified and prioritized. Discussions are currently underway to install a prototype VH server directly on Abilene by Y1 2Q.