The Explorable Virtual Human

Victor M. Spitzer
Karl D. Reinig
Virtual Anatomy Over the Internet

- Digitized cryosectioned data is like crude oil. It is beautiful to many but not particularly useful until it has been refined.
- Our goal is to create and deliver virtual anatomy to present and future health care providers.
- The internet is a powerful delivery tool for virtual anatomy.
Virtual Anatomy is a Moving Target

- Constantly Improving Segmentation
- Continued Diversity (Gender, Age, Race and Body Habitus)
- Improving Resolution and Tissue Contrast
- Adding Pathologies, Functionality, Physiology
Development and Validation of Knee Anatomy Curriculum

- Nora Hebert and Ruth Heisler, anatomists, and Lucy Eisenhart, instructional designer, developed knee anatomy curriculum.
- Tim Weston of Alliance for Technology, Learning, and Society (ATLAS) headed tests of the EVH on students at Red Rocks community college and the University of Colorado at Boulder.
What We Have Learned

- Physicians and anatomists are eager for virtual anatomy
- Today’s consumer graphics cards can handle today’s virtual anatomy
- The internet is not particularly 3-D friendly
- Neuroradiologists can write robust complex code
Some JAVA Concerns

- Easily Decompiled, Making it Difficult to Protect Proprietary Data
- Not Completely Cross Platform
- Extra Layer of Indirection, Garbage Collection for Example, is a Major Nuisance
- Significant Memory Overhead
The Explorable Virtual Human (EVH)

- The EVH is an authoring and display tool for delivering virtual anatomic curriculum over the internet.
- The EVH requires high-bandwidth but is highly tolerant of latency and other instantaneous interruptions such as packet loss, making it practical for the NGI of today and the near future.
EVH Objectives

- Development of a Network EVH
- Introduce EVH into Anatomy Curriculum
- Assessment for Graduate and Undergraduate Anatomy Students
- Augmentation of EVH for Surgical Simulation
Visible Human Data

- Just a set of pictures?
- Alpha masks give geometric definition
Segmentation and Classification

- Tedious work
- Laplacian Of the Gaussian (LOG) filter can help
Volume Visualization Methods

- Ray-tracing
- Polygonal Texture-Mapped Models
Making Polygonal Models

- Marching Cubes

The Need for Edge Sharing Information
Our Method For Making Polygons

• Alpha data is by nature discrete
• If the smoothing can be accomplished after the polygons are made, then the algorithm for producing polygons is simple: Each voxel face that is not adjacent to a voxel of the same type is given a two triangle representation
Our Method For Making Polygons
Adjacent Structures

- Adjacent structures share surfaces in one of two ways
  - They slide along each other
  - They join each other
- Many structure pairs do both
  - How they share effects the topology
Defining Edge Sharing Types
### Edge Sharing Table

<table>
<thead>
<tr>
<th>Choose ID</th>
<th>Unknown IDs</th>
<th>Attached IDs</th>
<th>Sliding IDs</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Posterior Auricular - Left</em></td>
<td><em>Articulare Ligament Anterior</em></td>
<td><em>Cartilage of the Proximal Tibia</em></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Auricular - Right</em></td>
<td><em>Connective Tissue</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Auricular Nerves - Left</em></td>
<td><em>Bone Femoral Cartilage - Right</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Auricular Nerves - Right</em></td>
<td><em>Fibrous Capsule of the Knee</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Auricular Vein - Left</em></td>
<td><em>Lateral Meniscus - Right</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Auricular Vein - Right</em></td>
<td><em>Medial Meniscus - Right</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Facial Vein</em></td>
<td><em>Removal Centre of the Knee Joint</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Facial Vein - Left</em></td>
<td><em>Muscle</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Facial Vein - Right</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Facial Vein - Right</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Posterior Facial Vein - Right</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Controls:**
- Quit
- Save
- Make Unknown
- Make Attached
- Make Sliding
Smooth and Disjoint
The EVH as a Display Tool

- HTML
  - Text
  - Audio
  - Movies
  - Links

- Interactive Anatomic Animations (IAAs)

- Haptics
The EVH as an Authoring Tool

- Create/Edit
  - IAAs
  - HTML
- Create and Import Sound Clips
- Import Movies
IAA Editing

- Select Structures
- WYSIWYG Spline Path Camera Motion
- Toggle
  - Transparency
  - Highlighting
  - Visibility
- 3-D Painting
Editing
3-D Painting Allows Delineation of Surface Features

The Explorable Virtual Human

4 Bones: Femur: Proximal epiphysis

The proximal epiphysis of the femur has a head which is a ball-like structure that articulates with the coxal (hip) bone. Articular cartilage covers the surface of the head and acts to reduce friction during movement. Examine the femoral head.

A ligament runs from the coxal bone to the femur, attaching at a pit in the head called the fovea capitis. Examine the fovea capitis.

The head of the femur narrows as it approaches the shaft; this part is called the neck.
Questions Are Added that Depend On the 3-D Surface Painting
Soft Tissue Deformation
Haptics

- Haptics Run in Native Code (C++)
- Supports Either GHOST or Our Own API
- See Video
Hardware Controlled Knee Joint (HCKJ)

- An Input Device for Simulated Arthroscopy
- Measure:
  - Flexion
  - Varus / Valgus Forces
  - Tibial Internal / External Rotation
Hardware Controlled Knee Joint (HCKJ)
HCKJ Hardware
HCKJ Electronics
Latest Incarnation
The Next Step
Derivative Applications

- Interactive Atlas (Obliquemaker)
- Multimedia for the VH Dissector™
- Clinical Specialty Projects
On-Line Interactive Atlas
VH Dissector™
Explaining Subtleties of the Flexion Axis

This IAA illustrates the difference between the two axes, which are neither colinear nor parallel.

The following IAA shows that the corresponding two planes are neither coplanar nor parallel.

The angle between the two axes is 6.76 Degrees.

For the CT knees, the angle between the two axes were:

<table>
<thead>
<tr>
<th>Knee</th>
<th>Angle (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>knee 1</td>
<td>3.6</td>
</tr>
<tr>
<td>knee 2</td>
<td>10.7</td>
</tr>
<tr>
<td>knee 3</td>
<td>14.2</td>
</tr>
<tr>
<td>knee 4</td>
<td>7.1</td>
</tr>
<tr>
<td>knee 5</td>
<td>1.11</td>
</tr>
<tr>
<td>knee 6</td>
<td>1.83</td>
</tr>
<tr>
<td>knee 7</td>
<td>9.02</td>
</tr>
<tr>
<td>knee 8</td>
<td>1.23</td>
</tr>
</tbody>
</table>
Sacral Stimulation

This image demonstrates the point of entry via the third sacral foramen. As shown here, the needle tip reaches the third sacral nerve.

This is a transverse section of the Visible Human taken at the level of the S3 foramen.

The line represents a needle trajectory perpendicular to the skin, reaching the S3 root.

In this specimen, the spinous part of the coccyx shields the S4 and S5 roots from needle trajectories that are perpendicular to the skin.

Note the unusual presence of the right pubic ramus in the sacral canal, as well as the larger amount of bone in the coccyx compared to the male. The coccyx is more pronounced in the female.
Sacral Stimulator Simulator
Sacral Stimulator Simulator
Neurosurgery Simulator
Significant Impact On

- Anatomy - Medical & Undergraduate Education
- Orthopaedics - TKA basic research
- Orthopaedics - Surgical Simulation
- Urology – Sacral Stimulation Simulation
- Gastroenterology – Planer Anatomy
- Neurology – Needle Insertion Simulation
Where Must We Go From Here

- Develop anatomy curriculum for the rest of the body.
- Develop an economic model for delivering this to the health professional world.
- Grow from anatomy to medicine!