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Guest Editorial

Imaging outcomes from The National Library of Medicine's Visible Human Project®

The National Library of Medicine has since its inception been a leader in the dissemination of medical information. Historically that information has been primarily in the form of paper (books, journals, periodicals, etc.). With the advent of the computer and digital technologies this tradition is changing.

In 1986, The National Library of Medicine's oversight body, its Board of Regents, met to discuss future directions for the Library. Included in the Long-Range Plan, approved at that meeting, was the concept of digital image libraries. In 1989, the Board of Regents convened a special planning committee on electronic imaging. This committee examined an NLM staff proposal to capture a complete, anatomically detailed, three-dimensional (3D) representation of the normal human male and female bodies, in digital format. Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI) were well established and easily obtained modes of whole body imaging, but collection of full-color cross-sections of the entire body had not been attempted. Hence the birth of the Visible Human Project®.

Under contract to The National Library of Medicine, the University of Colorado School of Medicine undertook the task of collecting the image data sets. In November 1994, images for the normal adult male were released to the public, followed in November 1995 by those of the normal adult female. The data sets include standard CT and MR images and color cryosections for the entire bodies. Cryosections were obtained from the cadavers while frozen to -70°C. A specially designed milling device was fashioned as a cryomacrotome. The male was sectioned at 1 mm increments in the axial plane from head to toe (1878 sections) with the female done at 0.33 mm (5190 sections). Following each pass of the macrotome a digital photograph was taken and ultimately cropped to 2048×1216 pixels $\times$ 24-bits of color. Film images in 35 and 70 mm also were acquired.

The data sets are available to the public under license to The National Library of Medicine. Requirements for the no cost license are: submit two signed originals; include a statement of intent indicating how the images are to be used; and provide the National Library of Medicine a copy of any application/product created. License agreement forms are available at the Visible Human Project® website: http://www.nlm.nih.gov/research/visible/visible_human.html or by writing to: The Visible Human Project®, National Library of Medicine, MS-42, 8600 Rockville Pike, Bethesda, MD 20894, USA.

As of this writing there are over 1250 license holders in 41 countries throughout the world.

In October 1996 and again in October 1998, the National Library of Medicine invited license holders to present their findings at scientific conferences held at the National Institutes of Health. At each of these conferences approximately 40 licensees presented papers, and proceedings were published on CD-ROM. These proceedings have subsequently been posted on the Visible Human Project® website (see web address above). Several authors whose work we considered appropriate for publication in Computerized Medical Imaging and Graphics were invited to submit papers for publication, and among those submitted, the seven appearing in this issue were reviewed and accepted. The international scope of involvement with the Visible Human Data Set is illustrated by the authorship of the papers appearing here—in addition to those from the United States are two from Germany, one from France and one from the United Kingdom.

1. Extending existing work/enhancing existing technologies

The Schiemann paper, "Exploring the Visible Human Using the VOXEL-MAN Framework", illustrates how the Visible Human Data Set was used to enhance an existing radiological image based 3D atlas. Using Visible Human color cryosections, the authors at the Institute of Mathematics and Computer Science in Medicine at the University Hospital Hamburg-Eppendorf, Germany were able to create a more realistic atlas. In addition, they have developed what they refer to as "Intelligent Movies" using QuickTime VR technology, thus permitting user manipulation of 3D images on standard PC platforms.

A second example of using Visible Human data to extend existing technologies is illustrated in the Robb paper, "Virtual Endoscopy: Development and Evaluation Using

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the Visible Human Data Sets". At the Mayo Clinic in Rochester, Minnesota, the Visible Human Data Set has been used in the development and evaluation of simulated visualizations of patient specific organs. Virtual endoscopy (VE) using 3D reconstructions from non-invasive imaging techniques such as CT and MRI are being validated. Just as conventional X-ray technology permits virtual diagnosis of bone fracture, more advanced virtual technologies for medical diagnosis, such as colonoscopy, are being validated.

A technique for extending the information found in patient-specific CT data is developed in the Kerr paper, "'True' Color Surface Anatomy: Mapping the Visible Human to Patient-Specific CT Data". Using the Visible Human male data set as a model, a color lookup table is created for well-defined structures and organs. RGB color values from the cryosection data are compared to Hounsfield units in the CT data to create color maps. The work reported here also includes techniques for texture mapping in an attempt to create more lifelike patient-specific information from CT data. This effort was undertaken at Engineering Animation, Inc., Ames, IA.

The Sachse paper, "Numerical Calculation of Electrical Fields in Models of the Human Body", further illustrates how Visible Human image data can be used to enhance techniques previously employing CT and MRI technologies. At the University of Karlsruhe, Karlsruhe, Germany investigators are modeling the distribution of electrical fields throughout the human body. From the Visible male color cryosections they begin with segmentation and classification of tissues, determine muscle fibre orientation, assign conductivity values to tissues in the creation of conductivity models, and ultimately define a model illustrating the distribution of bioelectrical fields throughout the body as they emanate from the heart.

2. Segmentation

An image segmentation technique studied collaboratively at the Stevens Institute of Technology, the University of California, Berkeley, and Stanford University is reported in the Imielinska paper entitled "Semi-Automated Color Segmentation of Anatomical Tissue". The technique combines an iterative automated approach using Voronoi diagrams with optional human refinement to extract anatomical structures from the Visible Human color cryosection data. This color-based method facilitates segmentation of soft tissues.

The Marquez paper, "Radiometric Homogenization of the Color Cryosection Images from the VHP Lungs for 3D Segmentation of Blood Vessels", describes a method for segmenting small anatomical structures from the Visible Human male data set. The technique addresses problems of discontinuous, inter-slice radiometric variations through the use of an adaptive correction propagated across a series of parallel slices. This work was done at the Ecole Nationale Superieure de Telecommunications, Paris, France.

3. Warping

The final paper, "3D Shape Recovery of A Newborn Skull Using Thin-Plate Splines", authored by Lapeer, reports on an approach for analyzing the deformation of a newborn's skull when subjected to the trauma of labor. Using a 3D model of the adult skull (constructed from CT scans of the Visible Human male), thin-plate spline and ray-casting warping techniques, and the creation of a finite element mesh model using Delaunay Triangulation, the investigators create a model suitable for analyzing external forces. Engineers at the Cambridge University, Cambridge, England developed this technique.

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