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The Visible Human Project ™: A Resource for Anatomical Visualization

Michael J. Ackerman, Ph.D.

Office of High Performance Computing and Communications
National Library of Medicine
Bethesda, MD 20894

Abstract

The National Library of Medicine (NLM) has long been a world leader in the archiving and distribution of the print-based images of biology and medicine. NLM has also been a pioneer in the use of computer systems to encode and distribute textual knowledge of the life sciences. NLM's Long Range Planning effort of 1985-86 foresaw a coming era where NLM's Bibliographic and factual database services would be complemented by libraries of digital images, distributed over high speed computer networks and by high capacity physical media. The NLM Planning Panel on Electronic Imaging recommended that NLM should undertake the building a digital image library consisting of computerized tomography (CT) and magnetic resonance (MR) images, and cryosection images of a representative, carefully selected and prepared male and female cadaver -- the "Visible Human ProjectJ." The male and female Visible Human data sets are now being made available through a license agreement with the NLM. The data sets are supporting a wide range of educational, diagnostic, treatment planning, and commercial uses. The value of this international resource in the public domain increases through its application. Its utility will continue to grow as related databases are attached to it, and as more attributes are given to its image elements.

Keywords

Imaging; Anatomy; Digital Image Library

Background

Images are an important part of biomedical knowledge. Pictures facilitate the understanding of biological structure and function, and are an essential component of education, research, and health care delivery. New computer-based technologies are providing an unprecedented opportunity to supplement the traditional two dimensional images of medicine, such as pictures in textbooks and plain radiographs, with dynamic three dimensional images. These images can be viewed, rotated, and reversibly dissected in a manner analogous to the physical objects they represent, providing valuable instruction to the student, insight to the researcher, and critical treatment planning information to the practitioner.

Planning Panel on Electronic Imaging

Early in 1989, under the direction of the National Library of Medicine's Board of Regents, an ad hoc planning panel was convened to provide the Library with in-depth guidance as to its proper role in the rapidly changing field of digital imaging. The panel recognized that much of our understanding of complicated health and disease processes actually lies in images not text. Over the centuries we have been using text to describe our view of body systems, organs, and molecules because of the difficulty and expense of creating and distributing the images. With this as a background the Panel made the following recommendation:

> The NLM should undertake a first project, building a digital image library of volumetric data representing a complete normal adult human male and female. This "Visible Human ProjectJ" would include digitized photographic images from cryosectioning, digital images derived from computerized tomography, and digital magnetic resonance images of cadavers. [1]

The Panel viewed this project as a cornerstone for a future set of related digital image libraries, including libraries of normal structural variation, collections of diseased and abnormal structures, embryology and pediatrics. The Visible Human ProjectJ could serve as a test platform for developing the methods and standards necessary to acquire, maintain, distribute and efficiently use digital image libraries and as a catalyst for the development of methods to link spatial data consisting of images, and objects within images, to symbolic (text-based) data consisting of names, hierarchies, principles, and theory -- the connection of structural-anatomical knowledge to functional-physiological knowledge. The Panel noted that fundamental research problems remained unsolved in the area of the computerized representation of biomedical structural data and the linkage of such data to related textual and numeric information.

The details of how the images which make up the Visible Human data sets were captured are described elsewhere [2]. The male data set contains 1871 digital axial anatomical images obtained at 1.0 mm intervals and is 15 gigabytes in size. The

female data set contains 5189 digital axial anatomical images obtained at 0.33 mm intervals and is 39 gigabytes in size.

Applications of the Data Set

The data sets are available to researchers from academia and industry who are interested in using the digital image data produced by this project through a non-financial licensing agreement with the NLM. This approach makes it possible for interested parties to help NLM reach a consensus on the collection, maintenance and distribution processes for digital image libraries which will be mutually beneficial. License holders may obtain the data sets by downloading them via the Internet using FTP or by ordering them in 4mm and 8mm tape formats.

The Visible Human ProjectJ data sets are designed to serve as a common reference point for the study of human anatomy, as a set of common public domain data for testing medical imaging algorithms, and as a test bed and model for the construction of digital image libraries that can be accessed through networks. The data sets are being applied to a wide range of educational, diagnostic, treatment planning, virtual reality, artistic, mathematical and industrial uses by over 800 licensees in 27 countries.

The data sets have their primary application in health care and health education. They are used as a normal reference and as an aid in the diagnostic process. Programs under development will be used to educate patients about the need for and purpose of surgery and other medical procedures as well as to permit physicians to plan surgery and radiation therapy. The images from the Visible Human data sets are used in several prototype virtual reality surgical simulators [3]. A virtual colonoscopy has been demonstrated [4], and a virtual laparoscopic simulator is expected shortly. Educational materials that make use of the Visible Human data sets are beginning to be used by students from kindergarten to practicing health care professionals [5]. The data sets are being used as a starting point by medical illustrators and are serving as a common source of images for the development and testing of rendering algorithms. The value of this international resource in the public domain increases through its application. Its utility will continue to grow as related databases are attached to it, and as more attributes are given to its image elements.

The data sets are also being used in non-health care applications. They are forming the basis of interactive games to entertain as well as to educate. Automobile manufacturers now include passenger injury models based on Visible Human data to their vehicle crash simulation models. Engineers and physicists are creating models to quantify human exposures to various forms of electromagnetic radiation. The data provided by the Visible Human data sets are being used by mathematicians as an application for what were previously only theoretical mapping theories. Several artists are using the data set as the basis for new multi-media art forms. The Visible Human data sets provided the images and the theme for the February 1997 issue of Life Magazine. And the images have appeared in one Hollywood move and a television commercial with a second movie in production.

From Data Set to Data Base

Now that the data collection phase of the initial Visible Human ProjectJ is completed, a second phase has begun - the segmentation, classification, and three-dimensional rendering of the data set. A new research effort is under way. Its ultimate objective is the identification of all the anatomical structures within the Visible Human data sets including the extent of each structure. An initial contract has been awarded for this work to be performed on the male thorax. Each object in each cross-section will have to be labeled. The relationship of each object to the other objects in its cross-section and in the adjacent cross-sections will have to be catalogued. The extent of a single object which spans several cross-sections will have to be noted. In order to accomplish this, information about building geographic data bases and data bases associated with computer aided drafting systems will be used as starting points for development of this unique interactive anatomical digital atlas.

Future Initiatives

A interactive anatomical atlas composed of anatomical objects can serve as the basis for a future set of related digital image libraries. A database of normal structural variation could be created. Preliminary studies of the existing medical literature show that the literature already contains enough information for describing the normal morphological variability present in humans [6]. Each time an anatomical image is rendered from objects contained in the Visible Human database, the objects would be morphed according the statistics contained in the database of anatomical variation, thereby turning a single individual into the normal human family.

But what about abnormalities and pathologies? Three-dimensional image data representing diseased and abnormal structures could be collected and suitable objectized. These pathological objects could then be morphed and substituted for the normal corresponding object contained in the Visible Human database. This would extend the database from the realm of normal variation to the realm of abnormality.

Anatomy is not only three-dimensional, it is also functional. Models of physiological and physical function are envisioned which would animate the anatomy, both normally and abnormally. These models could include descriptive as well as mathematical models. The models would be organized as modules which would be associated the appropriate anatomical objects.

If the objects and modules making up the future Visible Human Data Base are to be easily usable, a set of software tools will have to be built and included with the database. This set of tools will allow the custom rendering of any object in the image data set and the animation of those renderings by the appropriate modeling modules.

Long Term Goal

The larger, long-term goal of the Visible Human ProjectJ is to produce a system of knowledge structures, which will transpar-

ently link visual knowledge forms to symbolic knowledge formats. Methods still need to be developed to link image data to symbolic text-based data which is comprised of names, hierarchies, principles and theories. Although experiments are being done using generalizable linkage methods, like the use of hyper media where words can be used to find pictures, and pictures can be used as an index into relevant text, standards do not currently exist for such linkages. Basic research is also needed in the description and representation of structures, and the connection of structural-anatomical to functional-physiological knowledge. The goal is to make the print library and the image library a single, unified resource for health information.

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Address for correspondence

National Library of Medicine
Visible Human Project
8600 Rockville Pike
Bethesda, MD 20894
U.S.A.
E-mail: vhp@nlm.nih.gov
http://www.nlm.nih.gov