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Review

Visible Human Project^a: From Data to Knowledge

In 1989, the U.S. National Library of Medicine (NLM) Board of Regents empowered an ad hoc panel of experts to recommend the position that NLM should take in the rapidly evolving field of electronic imagery. They recommended that NLM proceed with the proposed Visible Human Project (VHP) [1]. In August of 1991, the University of Colorado School of Medicine was awarded a contract that resulted in the acquisition of the NLM Visible Human Project male and female data sets. NLM made the data sets available under a no-cost license agreement over the Internet (Figure 1). The VHP male data set contains 1971 digital axial anatomical images obtained at 1.0-mm intervals (15 Gbyte) [2]. The VHP female data set contains 5189 digital anatomical images obtained at 0.33-mm intervals (39 Gbyte). Since the introduction of the data sets, NLM has signed over 1400 licenses with participants in 43 countries. In addition, three VHP Conferences have been hosted by the NLM [3]. These Conferences have highlighted research and applications based on the Visible Human data sets.

Despite the unprecedented detail in the VHP data sets and its demonstrated utility in conveying information about gross anatomy, deficiencies

in the data compromise its use in the focused teaching of specific areas of human anatomy. In February 1998, a workshop sponsored jointly by NLM and National Institute of Dental and Craniofacial Research explored the growing needs of the research

and education community for more powerful digital tools and higher resolution models of human anatomy [4]. The workshop focused on an in-depth analysis of the existing male Visible Human data, specifically on the anatomy of the head and neck.

The workshop participants recommended the development of a multimedia, web deployable head and neck atlas created from the existing male data set as a proof of educational and technical concept, the pursuit of advanced image processing software tools to accommodate future higher resolution data, and the development of better tissue fixation and staining techniques to minimize tissue artifacts and maximize the visibility of anatomical objects.

The NLM in partnership with six other U.S. government agencies is sponsoring research and development which will further the core goals of the VHP in three areas:



Fig. 1. Reconstructed frontal section through the Visible Human male and female.

1) the creation of a Visible Human Project Atlas of the Head and Neck; 2) the development of a software tool kit (Insight) capable of automatically performing many of the basic data handling functions required for using Visible Human data in applications, e.g., segmentation and alignment; and 3) the development of better tissue fixation and staining techniques to rectify the anatomical problems associated with the tissue methods used during the creation of the Visible Human data sets.

Visible Human Project Atlas of the Head and Neck

The purpose of this project is to develop a public domain NLM hosted web site portraying human anatomy based primarily on the VHP male data set. The goal is to create a landmark functional and clinical anatomy atlas of the head and neck human body regions - a prototype for a new wave of educational applications based on the integration of the VHP data sets with other ancillary human imagery sources. The project is designed to demonstrate the utility of the existing data and will provide a platform for new directions in education and medical research. The NLM commissioned the VHP Head and Neck Atlas to the University of Colorado Health Sciences Center through a competitive, peer-reviewed contracting process.

A series of clinically relevant functional anatomy modules are being created as part of the Atlas. These educational modules are being designed to demonstrate the functional processes involved in facial expression, mastication and deglutition, phonation, hearing, and vision. The Atlas web site will allow the user to interact with the appropriate imagery in order to demonstrate functionality,

for example, the function of the muscles that control and move the mandible bone during the chewing (mastication) reflex. Magnetic resonance interferometry (MRI), computerized axial tomography (CAT), and other radiology image modalities as well as conventional anatomic graphic materials will be integrated into each module. The modules will demonstrate normal musculo-skeletal system function as well as abnormal functional deficits including clinical signs and symptoms. They will illustrate neurovascular relationships through the interactive dissection of anatomic structures and fly-through views. For example, the student will be able to experience a walking tour of the optic nerve and view of the distribution of the ophthalmic artery and its tributaries. These web accessible modules will emphasize interactivity over passivity (Figure 2).

Equally important to the educational success of this project is the achievement of an element of novel entertainment quality that will form

a creative prototype to stimulate and encourage the interactive learning process. The Atlas web site is being designed to meet the needs of a wide ranging audience including: medical, dental, and nursing students with an emphasis on normal anatomic structure and function; practicing health care professionals with an emphasis on clinical relevance; and the general public's need for reference materials to better understand a health concern.

Insight Software Research Consortium

The initial emphasis of this effort is to provide public software tools in 3D segmentation and deformable and rigid registration for medical images Visible Human Project data. The goal is for the consortium to provide the cornerstone of a self-sustaining software community in 3D, 4D and higher dimensional data analysis. The consortium is committed to public, open-source software code including

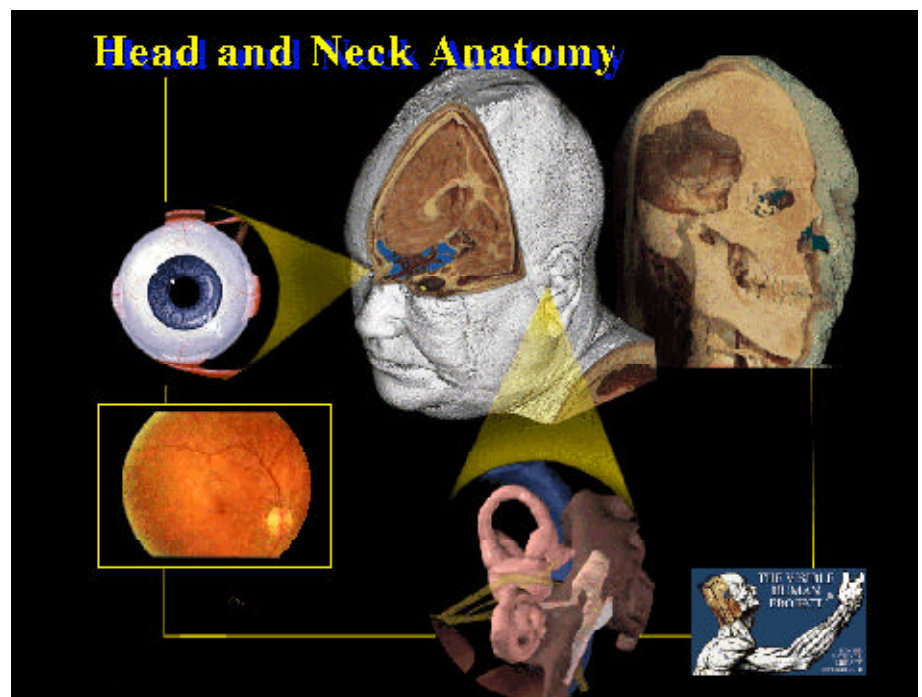


Fig. 2. Proof of concept page from the web based Visible Human Atlas of the Head and Neck.

open interfaces supporting connections to a broad range of visualization and graphic user interface platforms. The goal is the development of a public domain software resource that will serve as a foundation for future medical image understanding research. The intent is to leverage the investment being made through the VHP and other medical image analysis programs by reducing the re-invention of basic imaging algorithms.

The Insight Software Research Consortium which includes partners in academia and in industry has been formed to carry this work forward. The Consortium has completed the design and development of an initial version of a public medical image segmentation and registration toolkit known as **the Insight ToolKit (ITK)**. The goal is to create an application programmer's interface (API) which can be used by developers of medical programs and software products wherever the problems of image or volume segmentation and registration exist (Figure 3). Unlike previous software development efforts, the goal is specifically NOT to create a single monolithic program, but rather a software foundation from which a broad range of programs can be supported.

The ITK API has undergone continuous review and modification by the expert developers on the programming team. The software toolkit is being designed to support a variety of visualization and/or rendering platforms and to be easily integrated into existing processing, visualization and presentation systems. The completed software toolkit, including all source code and



Fig. 3. Current bitmap version of the Visible Human data set (data) on the left versus the future object version (knowledge) on the right.

extensive documentation consisting of manuals, tutorials and examples, will be made available in the public domain by the NLM through a controlled Internet site.

Visible Human Project Anatomical Methods

This initiative is directed at the methods that were utilized to stabilize the anatomical materials used in making the Visible Human data sets. The work is focused on three methodological areas. The first concentrates on the elimination of the freezing and embalming artifacts that can be seen in the data set images. Methods need to be found through which tissue can be fixed without deformation, swelling or misalignment. The second will identify histological staining and wide-spectrum

methods that will enhance the contrast between nerves and their surrounding tissues. This will allow the visualization of the branching of nerves as they reach their target organs. The third involves the identification of vascular structures by the application of dye materials, or by the injection of materials for vascular luminal filling adapted to VHP cryosectioning methodology.

References

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