Advances in Visible Human Based Virtual Medicine

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Abstract. In this paper, important virtual medicine research related to visible human data sets would be outlined. In particular, latest visible human related research carried out in the Visualization, Virtual Reality and Imaging Research Centre of the Chinese University of Hong Kong (CUHK) will be discussed in detail, while related applications such as virtual acupuncture, virtual anatomy, and virtual orthopedics training briefly shaped our current and future research and development on visible human-related virtual medicine. Our latest advancement in segmentation, imaging, user-interface design as well as surgical education and training will be discussed.

Keywords: Visible Human data, visualization, surgical simulation, virtual reality.

1 Introduction

As the importance of digital images in medical research increases, construction of standardized human body datasets has been indispensable. Being proposed by the National Library of Medicine of United States, the Visible Human Project (VHP) was carried out at University of Colorado, Denver, Colorado [1]. Complete digitized datasets for normal male and female, which consist of cryosectional photographic images as well as the corresponding computerized tomography (CT) and magnetic resonance images (MRI), were collected in 1994 and 1995 respectively. This accomplishment symbolizes a new era in virtual medicine with an in-depth understanding of human anatomy and systematic application of computational techniques in clinical medicine and biomedical research.

Motivated by VHP, the Chinese Visible Human (CVH) Project was started in 2001 while the first male dataset was collected in 2002 at the Third Military Medical University, Chongqing, China [2]. Up to now, five CVH datasets have been successfully collected, representing a diversity of Chinese population [3]. Compared to the US visible human, the CVH data features a higher resolution of images; this provides a clearer identification of blood vessels, for example. The Visible Korean Human (VKH) project was started in 2001 at Ajou University, Suwon, Korea, which is another visible human representing East Asian [4]. This dataset contains CT, MRI and cryosectional photographs of a complete male cadaver.

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One natural application of visible human data is virtual anatomy where the rich anatomical information contained in the VH datasets enables the construction of informative anatomical atlases for anatomy education [7], this gives a convenient way to view structures from different directions. Voxel-Man project built photorealistic anatomical atlases for the brain, internal organs [8], and small organs like the hand [9]. Virtual anatomy complements the traditional cadaver dissection by constructing 3D models using the cryosectional images such as the visible human data, and it serves as a powerful and flexible way to learn human anatomy [10].

A concept extended from “visible human” is “virtual human”, which integrates static anatomical data with dynamic physiological properties. Once such a virtual human is constructed, it can serve as a test-base for the simulating and validating human anatomical functions. The Oak Ridge National Laboratory (ORNL) proposed the Integrated Respiratory System Model [13] that uses the virtual human to simulate the generation and transmission of lung sounds. Another direct application of virtual human is surgery simulation, which simulates surgery to estimate the effect on a patient [14].

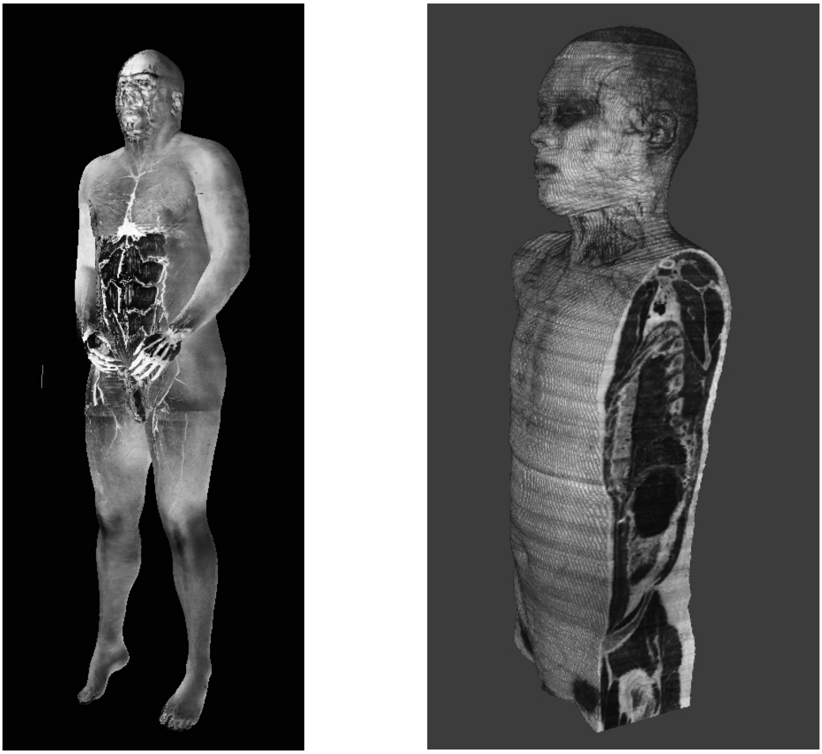
As a repository of medical images, the visible human dataset can be used to test different image processing and analysis methods. The Biomedical Imaging Resource (BIR) at the Mayo Clinic have been using the visible human dataset extensively for testing image visualization, segmentation, registration, classification, and modeling algorithms [5]. The Anatquest project aims at building a universal platform for visual and textual queries to the VH dataset and investigating the image segmentation techniques tailored for the VH cryosectional images [6].

There has been many virtual medicine applications implemented using visible human data, including surgical planning and rehearsal, as well as virtual endoscopy. To assist surgical planning and intraoperational navigation, 3D organ models built from the VH data are registered with the patient MRI data. The visible human data have also been used to build phantoms for radiation treatment planning [11]. The Monte Carlo method is used to calculate the maximum radiation dose for a tumor while minimizing the exposure of normal tissue. Virtual endoscopy broadens the accessibility of endoscopic examination and minimizes the uncomfortable experience of patients by generating simulated visualizations of patient anatomy. Visible human datasets have been used to produce simulated endoscopic views of the stomach, colon, spinal column, esophagus, trachea, and heart [12]. By mapping textures onto the cryosectional images of visible human datasets, the simulation of endoscopic views can be vividly generated.

In this paper, some of the latest research and development projects carried out in our research centre, the Virtual Reality, Visualization and Imaging Centre, CUHK will be discussed in detail. The rest of this paper is organized in this way. First, the visible human visualization will be discussed. The use of Visible Human Project data as well as the Chinese Visible Human data on virtual medicine research, for example, in the application of virtual acupuncture, virtual anatomy shall be discussed next. Finally, conclusion will be drawn.

2 Visible Human Visualization

Visualization, Virtual Reality and Imaging Research Centre has started medicine-related research on the visible human project since 1999. **Fig. 1** (a) shows our

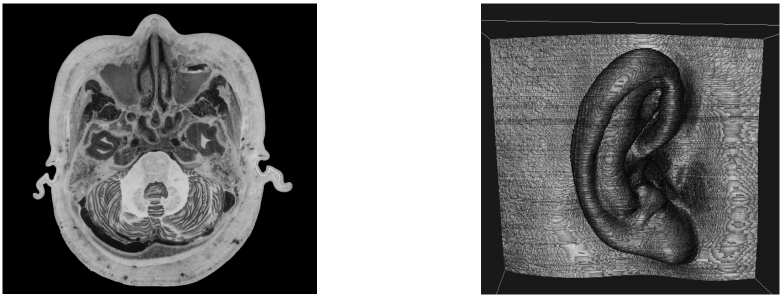


(a) (b)

Fig. 1. Screenshots of the real-time visible human visualization are shown. (a) The VHP data, having segmented into different tissue layers, can be interactively viewed. (b) The highest resolution Chinese Visible Human data can be visualized with multi-planar reconstruction.

real-time rendered shots on a multi-layer VH visualization. Since the Third Military Medical University in Chongching started the CVH project in 2002, we have been collaborating with the CVH project team in the development of 3-D visualization techniques [15]. A depiction of the early work on CVH data visualization can be observed in Fig. 1 (b).

Gelatin is injected into the body in order to prevent the collapse of the respiratory system or the digestive system at the abdominal region. The milling process is carried out inside a cold chamber in order to avoid dropping of smaller structures. Compared to the American visible human data, the CVH dataset can be said to be more complete in terms of the anatomical system being preserved [16]. CUHK, as one of the important collaborators in the CVH project, has been devoted into the imaging, visualization as well as virtual surgery research on the CVH data in these few years. Innovative techniques in these areas have been proposed in order to handle these precise but huge data sets.



(a) (b)

Fig. 2. (a) A processed Chinese Visible Human cryosectional slice is shown. Preciseness of the tiny details, such as blood vessel or nerve can be observed in the dataset. (b) The volume rendered view of the ear from the second female Chinese Visible Human dataset is shown.

Slices pre-processing is one of the essential process before actual visualization can be done. Since the overall milling process has been carried out for a number of weeks, the photo capturing condition is altering from slice to slice, color or contrast balancing as well as accurate alignment between multiple slices is thus necessary. One of the processed CVH slices is shown in **Fig. 2** (a). Having processed every slice, the slice reconstruction comes next.

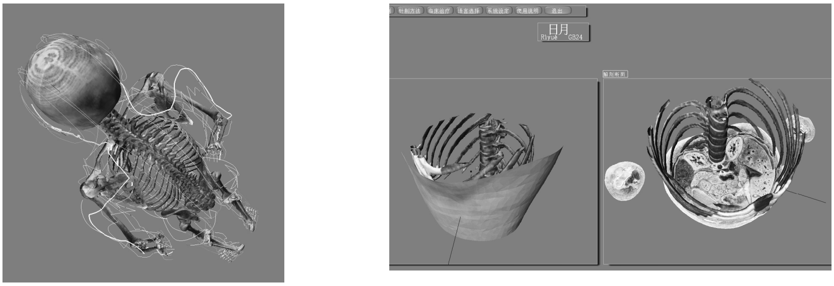
Slice reconstruction is relatively more straight-forward, slices in different axial order are re-arranged and then the volume texture is being compressed in way which conforms to the graphics pipeline in personal computer grade video accelerator. In this sense, the reconstructed volume can be visualized by deploying advanced shader-based rendering tactics. **Fig. 2** (b) shows the screen shots of our CVH visualization application, which incorporates the second female CVH data set which is composed of 131G data size in total. Such dataset can be presented in real-time stereoscopic rendering too. This application has won the Credit of Merits in RSNA'04 [17] and is now being shown as a permanent exhibition in the Hong Kong Science Museum.

3 Virtual Medicine with Visible Human datasets

In this section, we introduce some of the visible human based virtual medicine projects being conducted in our research centre. These projects include virtual acupuncture, virtual anatomy and virtual orthopedics training.

3.1 Virtual Acupuncture

Virtual Acupuncture is one of our early works based on VHP data. As a key component of traditional Chinese medicine, the therapeutic effectiveness of acupuncture on various diseases by stimulating acupoints using needle has long been appreciated. However, incorrect needle penetrations may lead to serious complications, in this sense, extensive training is essential for acupuncturists to build up their skill, virtual



(a) (b)

Fig. 3. (a) The meridian system can be shown interactively. The brighter white line is showing the highlighted meridian when other dimmer lines are showing the rest of the system. (b) The user interface for displaying every acupuncture point is shown. In addition to the external skin surface, bony tissue as well as the cross-sectional anatomical details can be observed simultaneously with the selected acupoint. The line is showing the location of the selected acupoint.

reality training is an elegant choice. CUHK has collaborated with the Nanjing Chinese Medical School of China in the virtual acupuncture project aiming at delivering a user-friendly environment for learning acupuncture therapeutic concept and knowledge as well as a virtual puncturing training system for acquiring needle lifting and thrusting operational skills.

Fig. 3 (a) shows our virtual acupuncture application. Based on the Chinese Visible Human dataset, the data is first semi-automatically segmented into different tissue: the skin layer (including the dermis and hypodermis), the muscle and the bone [13]. The skin and bone is crucial for locating acupuncture points while hypodermis and muscle contributes to a successful realistic tactile modeling of needle puncturing simulation. **Fig. 3** (b) shows how our system can assist the learning of the 3-D location of acupoints and meridians. Acupuncture novice can acquire the knowledge of acupuncture points or meridians, while practitioners can further research the correlation between these acupoints and underlying anatomical structures. In other words, our intuitive learning platform can foster scientific research on traditional acupuncture.

Fig. 4 shows the haptic needle puncture training system. Based on a multi-layer model obtained through segment visible human, physical tissue properties have been incorporated in order to constitute a bi-directional needle thrust and uplifting force model for realistic haptic rendering [14]. With such a tactile simulation, users can practice their needle manipulation skill including thrusting depth and frequency as if they were puncturing real patients.

3.2 Virtual Anatomy

The CVH dataset have been utilized as the basis of our virtual anatomy application, different regions of interest are segmented for different anatomical education platforms. In our virtual anatomy platform, interactive user control such as multi-planar

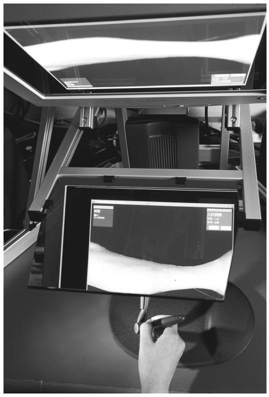
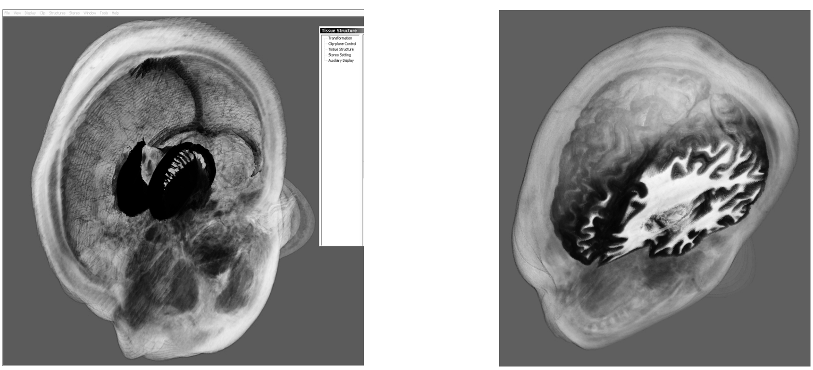


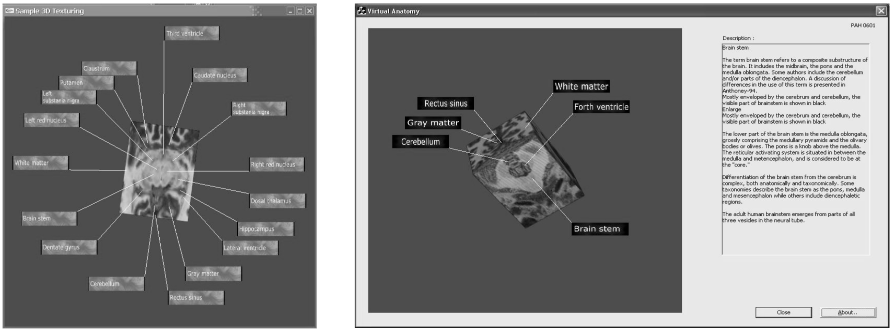
Fig. 4. The user interface for needle puncturing training can be observed. Reach-in display system is deployed in order to provide a more immersive environment. Users can freely practice needle thrusting or uplifting within this virtual environment.

reconstruction (MPR), translucency visualization, and pseudo-color highlights can be applied to the structures in a real-time manner. 3-dimensional stereoscopic visualization, informative anatomical descriptions, selective functional structure display can help medical student shortening the learning curve in acquiring anatomical knowledge. The preciseness of the data set equipped with interactive visualization delivers a completely new learning experience on anatomy. One of our virtual anatomy series, virtual neuroanatomy, central nervous system structures in the head and neck region for example, cerebrum, cerebellum, ventricles, diencephlons, bascal ganglia and nerves etc are identified. This application has been shown in the RSNA'05 InfoRAD Exhibits [18].



(a) (b)

Fig. 5. (a) The user interface of the virtual neuroanatomy is shown. Different tissue can be visualized selectively, for example, the cerebrum has been set totally transparent so that the limbic system can be observed clearly. (b) Multi-Planer Reconstruction is one of essential visualization mode in virtual anatomy applications.



(a) (b)

Fig. 6. (a) the automatic anatomic annotation result (b) detailed anatomical information will be shown when user clicks on one of the labels

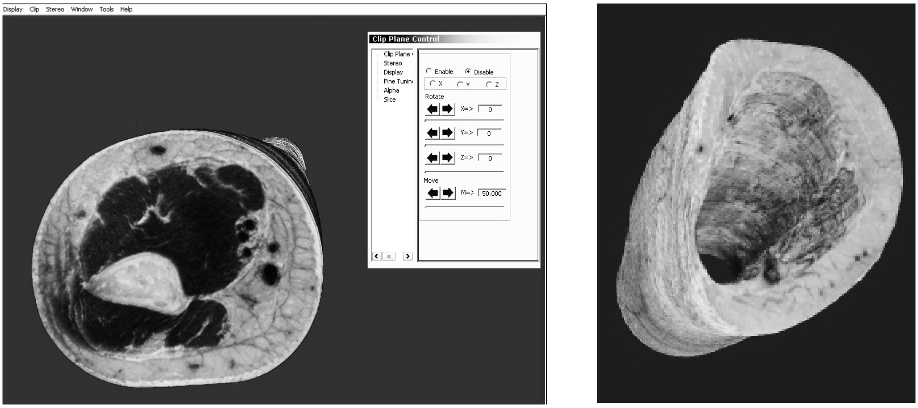
Fig. 5 (a) shows the user interface of the virtual neuroanatomy application. Translucent visualization and pseudo-color highlight are supported. Interactive planar reconstruction (**Fig. 5** b) and level of details are two other important features of the software. In addition, a novel computing tool for annotating anatomical structures in virtual anatomy applications has been proposed. The automatic labeling algorithm can also be applied to other related applications, e.g. virtual acupuncture, which involves similar anatomic annotation requirements. A real-time interactive application which will automatically generate tissues labels was developed. The user can gain further description of a tissue by clicking on the corresponding label and also drag the labels to desired positions.

Although the data size is huge with respect to normal personal computer, for example, the total data size of the virtual brain is over 4G bytes, shader-accelerated dependent texture lookup is being exploited in order to achieve interactive user manipulation of such a huge volume texture.

3.3 Virtual Orthopedics Training

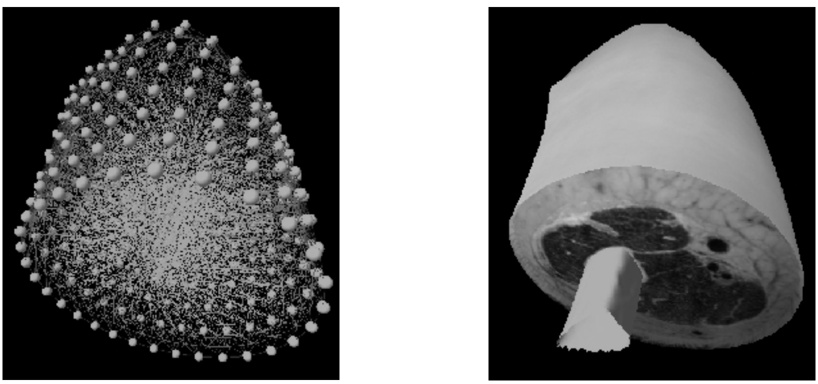
The Orthopaedics trainer is another visible human based surgical education and training system we developed under collaboration with the Department of Orthopaedics and Traumatology at the Prince of Wales Hospital, Hong Kong [19]. The upper limb region of the selected CVH data is segmented into dermis, hypodermis, fascia, deltoid muscle, brachial muscle, triceps brachii muscle, biceps brachii muscle, coracobrachialis muscle, extensor carpi radialis longus muscle, artery, vein, nerve, bone and bone marrow. **Fig. 7** (a) shows the user interface of the orthopaedics training application while another selected shot is shown in **Fig. 7** (b).

Realistic dermal deformation has been researched so that the simulation environment copes with orthopaedics training. A relatively new multi-core hardware accelerator called Physics-Processing Unit (PPU) has been exploited for efficient modeling of volumetric mass-spring system. Microscopic computational parameters of the non-linear spring and damper model are learned through a simulated annealing engine



(a) (b)

Fig. 7. (a) The user interface of the orthopaedics training application is shown. The upper limb region obtained from the second Chinese Visible Human dataset is utilized, (b) The subcutaneous fatty tissue is shown.



(a) (b)

Fig. 8. (a) The mass spring model of the upper limb model (b) the deformed limb

through inputting the macroscopic biomechanics properties of various dermal tissue, like epidermis, dermis, hypodermis. In this sense, real-time physiological deformation of skin tissue can be achieved for assisting surgical education and training.

Fig. 8 shows the mass-spring volumetric model being generated for realistic soft tissue simulation. The multilayer topologic structure can be automatically extracted from segmented CVH datasets. Interactive deformation can be computed using the PPU mass-spring framework while visualization can be done at interactive frame-rate.

4 Conclusion

In this paper, important virtual medicine researches related to visible human data sets have been outlined. In particular, the Visible Human related research in carried out in CUHK has been discussed in detail, while related applications such as virtual knee arthroscopy, virtual acupuncture as well as virtual anatomy briefly shaped our current and future research and development on visible human-related virtual medicine.

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