

# Progress in Research of Digital Human in China

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**Abstract**—Human body is a large complex system which is composed a hundred trillion cells. Even though science and technology at 21st century are developing very fast, the human being knows himself very limited. Digital human project aims at building whole human body datasets, from nano to macro, including cells, DNA, tissue, organs and the system. The information may be anatomical, physical and functional, depending on the stage of the development of the database.

The National Library of Medicine's Visible Human Project (VHP) published male data set in 1994, which consists of digital magnetic resonance (MR), computed tomography (CT), and anatomic images derived from a single male cadaver. The data set is 15 gigabytes in size and is available from the National Library of Medicine under a no-cost license agreement. After one year, female data set of VHP finished with 30 GB data.

Considering the race anatomical variance, the dataset of Visible Korean Human was characterized with oriental nationality.

Chinese Digital Human research started in November 2001 as a National High Tech Research and Development Project. The first female data set was completed in February 2003.

A Digital Human Research Consortium of China is responsible for coordinating the research activities about Chinese Digital Human in China. To date, several datasets of the whole human body in China are available. Using these datasets, many research works have been done, including some image processing methods such as multi-slice registration, reduction of noise and artifacts, and color image segmentation techniques. Also some new hybrid volume rendering methods based on parallel computing are developed for high resolution visualization. 3D reconstruction of the most tissue and organs of the female cadaver are completed. Some potential applications of Digital Human are also carried out.

**Keywords**—Chinese Digital Human, Visible Human Project, medical image, anatomy.

## I. INTRODUCTION

The National Library of Medicine's Visible Human Project (VHP) published male data set in 1994, which consists of digital magnetic resonance (MR), computed tomography (CT), and anatomic images derived from a single male cadaver. The data set is 15 gigabytes in size. After one year, VHP female data set was finished with 30 GB data. The VHP datasets have significant effects in medicine

all over the world. The main meanings can be summarized as following four aspects.

### 1. Digitalization of Human Anatomy

Traditional cadaver based experimental human body anatomy which has developed for hundreds of years now has been changing dramatically. Once the anatomical information of the human body is digitalized, it can be interfaced to computer. The following various processing will make the data source very useful.

### 2. Visualization level increased greatly

Human being goes one big step forward in knowing the anatomical structures of human body. By 3D visualization, it can be seen anywhere inside the body. The shapes, sizes, locations of thousands of small anatomical structures can be observed in detail, from any orientation, either in 2D or in 3D. The spatial relationship between different tissues or organs is displayed accurately never before.

### 3. Open virtual environments for medical research

Based on the VHP dataset, many kinds of virtual endoscopies, e.g. virtual colonoscope, virtual laparoscope, have been developed. Since the technique is not limited by tube and cavity, in principle the viewer may fly-thru anywhere within human body. Image-guided surgery planning and navigation system increases safety and success rate greatly. Virtual surgery training system provides valuable opportunity to practice surgery with realistic operations.

### 4. Data share

As a basic medical dataset of high quality, scientists and scholars all over the world share the VHP data for their research work. Since the VHP dataset is available from the National Library of Medicine(USA) under a no-cost license agreement. The anatomical information of VHP are used most extensively in the world. The VHP dataset is a successful example of scientific data share.

Almost at the same time when VHP come forth, a tentative plan of 'Virtual Human' research was proposed by some scientists. One reasonable description sounds acceptable by many scholars: '*Virtual Human* is a computer model that not only look real, but also act like a real body.' As one phase of its development, "*Visible Human*" focuses on the geometric description of the anatomical structures. The

second phase will add some physical attributes to the human model, including kinematics and deformations of the tissues and organs with physical dynamics modeling. Next phase will consider physiologic characteristics of human body, such as Bleeding, leaking bile etc. In the following advanced phases, the model will possess microscopic anatomy and biochemical systems. A more realized human being model with all kinds of functions such as neurovascular, glandular, endocrine system, immune mechanism and so on will be implemented. The model will integrate anatomical, physical, physiological, biochemical features, from macro to nano. This interactive digital human model will impact the medical research and many other areas significantly.

## II. DIGITAL HUAMN RESEARCH IN CHINA

Considering the race anatomical variance, after the dataset of Visible Korean Human was characterized with oriental nationality and reported in 2001, Chinese Digital Human (CDH) research started in November 2001 as a National High Tech Research and Development Project.

In the 174<sup>th</sup> Xiang Shan Science Conference, the highest academic meeting in China, 46 scientists and professors of cross-disciplines from mainland of China and overseas discussed the issue and put forward the proposal. This meeting was a milestone of Chinese digital human research.

### A. General strategy of Chinese Digital Human

CDH dataset is based on the Tomography technique. Human body is scanned slice by slice. Each slice is composed of several million minimum image elements (pixels). A volume dataset of high quality and most accuracy is the basis of the digital human research.

1. CDH data should include multi-modality images, such as digital magnetic resonance (MR), computed tomography (CT), and anatomic images derived from a single cadaver.
2. A Compromise is made between the image accuracy and ease of processing. The slice thickness is 0.2 mm.
3. Besides the whole body data acquisition, some additional datasets of small anatomic structures, such like eye, ear etc., should be acquired separately.
4. Collaboration between physicians and computer specialists is necessary for the image segmentation and reconstruction.

5. Considering the multi-phase task of digital human project, CDH dataset should consist of both structural and functional information. The latter one can be acquired from PET, SPECT, fMRI and Optical Intrinsic Imaging, then integrated with the structural information.
6. Study on computing medicine. The processing of CDH dataset needs high performance computer which involves many kinds of mathematic tools and physics methods, e.g. linear algebra, differential geometry, partial differential equations, bio-mechanics and Finite Elements Method, advanced fluid mechanics, etc.. Currently, The study of accurate image registration and complex deformation of the object should be emphasized.

### B. Implementation of VCH-Female



Fig. 1. Reconstruction of VHP female (left) and VCH female (right).

Table 1. Main parameters of VCH

	anatomic image	CT	MRI
Number	8556	1718	801
thickness	0.2mm	1mm	2mm
size	3024*2016	512*512	512*512
data	149.2GB	429.5MB	200.5MB

The first female data set was completed at February 2003, which was called 'Virtual Chinese Human-female', VCH-F for short. Compared with the VHP female dead at 58 years old whose main sex feature degenerated significantly because of atrophy of both uterus and ovary. But the VCH female was a generative young lady dead at 19 years old. The VCH female data set is valuable for study of oriental female anatomy (Fig.1).

The VCH cadaver was frozen at  $-70^{\circ}\text{C}$ , then cryomacro-tomed into 8556 slices. The thickness of each slice is 0.2mm. The VCH data set consists of digital anatomic im-

ages, magnetic resonance (MR), and computed tomography (CT) images. Total amount of data is 150GB.

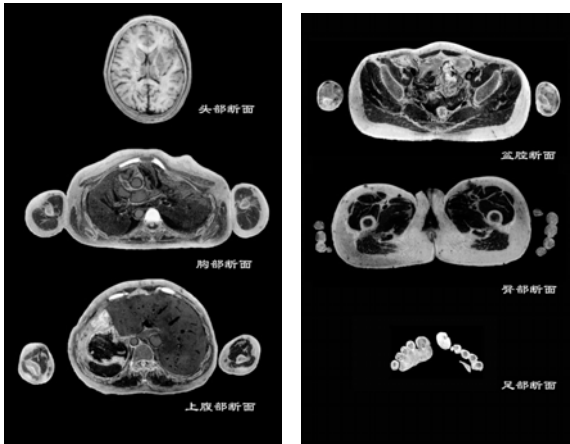


Fig.2 The anatomic images of VCH dataset

The post-processing of images includes image registration, background removal, image segmentation and ROI extraction, and 3D reconstruction of tissues and organs.

After a long time of data acquisition, many factors may cause misalignment of the images such as slight moving of the milling tool or digital camera, minute changes of illumination. Using marks on slices, a coarse registration was completed with affine transformation (Fig.3). Then a more elaborate multi-slice registration based on mutual information was implemented.

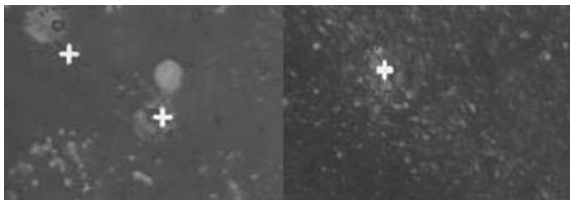


Fig. 3. Slice registration with marks. Left: before registration Right: After registration.

Filtering noise and removing background, some regions of interest were extracted with homemade image segmentation software. Some manual editing is needed when ambiguous boundary exists between ROI and neighboring areas. A new hybrid volume rendering method based on parallel computing was also used for high resolution visualization of the large dataset of VCH.

The parallel system consists of two dual-CPU(main frequency 2.4GHz), 2GB memory SMP workstation, which implements a COW+SMP hybrid parallel system by 100MHz Ethernet.

The anatomic structures of the whole body were reconstructed, including skin, bones, muscles. Almost all the major organs such as brain, heart, lung, liver, kidney, intestines, stomach and uterus, were segmented and 3D rendered. All the organs can be viewed separately or in any combination. Within the rebuilt ovary about 20 follicles can be seen distinctly, out of them the biggest one has length of 13 mm that means the lady dead before her ovulation duration.

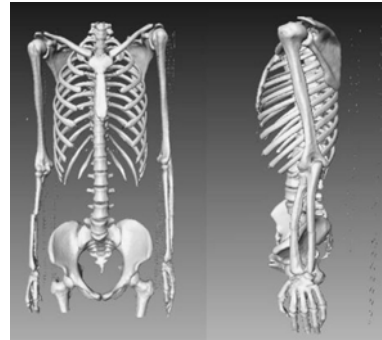


Fig. 4. Reconstruction of skeleton.

Since the girl dead of eating poisonous mushroom, clyster treatment made her intestines empty which means that virtual endoscopy will be very difficult from organs with so flat lacune.

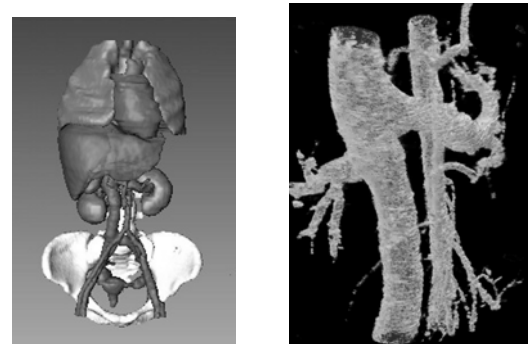


Fig. 5. Left: reconstructed 3D Organs of thorax and pelvis. Right: reconstructed 3D blood vessel

### III. CONCLUSIONS

Based on the real human body, a 3D anatomic data set was completed. Since the slice is very thin, voxel size reached  $0.2 \times 0.2 \times 0.2 \text{mm}^3$  that allows high resolution of anatomy. With the flying-through browser, we can observe minute anatomic structures from any angle of view, even inside the object. The realistic appearance of the reconstructed tissues

and organs is suitable for a 3D anatomy study of high quality. Besides, the VCH data set has a lot of potential uses in many areas. For example, we designed a motion analysis system which makes the skeleton of the VCH female



Fig. 6. VCH walking

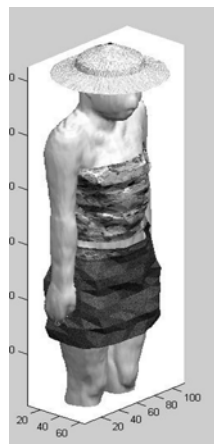


Fig. 7. VCH fashion show

walking on marble floor freely (Fig.6). And the VCH girl wearing a fashion skirt is mostly possible walking on a T-table in the near future (Fig.7). The meridian lines have been superimposed on the skin surface of the VCH female for the research of traditional Chinese medicine.

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