Original

Development of a Human Electric Atlas Database System —Computer Assisted Atlas System—

Masataka SUZUKI¹⁾, Hidemasa OCHIAI¹⁾, Seiichiro INOKUCHI¹⁾,
Isamu MANO²⁾ and Yasuzo SUTO³⁾

Abstract: Recent advances in medical imaging equipment have made it possible to obtain images in any desired plane. However, it is often difficult to visualize these images in three-dimensions. For this reason, we have developed a Human Electric Atlas Database system which permits simulation of cross-sectional and three-dimensional images. This system is suitable for medical education and can be used as a reference during clinical examinations.

A magnetic optical disk (MO) was added to a PC-9801VX2 computer, and C compiler (Turbo C, version 2 for MS-DOS) was used as software. This is the original software to which the assembler (Turbo assembler, version 1 for MS-DOS) is partially linked.

Features of the system are: 1. It uses the original CT image as the image data, whereby the window level (WL) and window width (WW) can be set, and the CT numbers can be found. 2. Three-dimensional reconstruction by the voxel method is introduced, whereby complex configurations can be reconstructed with ease. 3. It has a dictionary of anatomical terms. 4. It can be transferred to other MS-DOS machines, for example, IBM PC-AT or Toshiba J-3100 by slight modification, since the C compiler in MS-DOS is used.

Key words: personal computer, database, reconstruction, computer tomography, head

Introduction

There are many reports of methods to provide comprehension of three-dimensional construction using a computer for surgical planning and determination of configuration. However, there are few reports of an atlas using a computer.¹⁾ In particular, reports of a three-dimensional atlas including anatomical terms have been made by very few groups.

Naoki Suzuki *et al.* have reconstructed the human whole-body using image data obtained from CT, MRI and ultrasound by the wire-frame method.²⁾ Since Mano *et al.* reported the fundamental concept of an atlas in which image and non-image data were combined,³⁾ the following atlas systems have been reported: a) A method to input image data was defined.⁴⁾ b) Image data compression and non-image data filing were defined and an atlas system was demonstrated by minicomputer.⁵⁾ c) An atlas was produced mainly for the thorax.⁶⁾ The following reports of atlas systems using personal computers have been pub-

¹⁾ Department of Anatomy, Showa University School of Medicine, 1-5-8 Hatanodai, Shinagawa-ku, Tokyo 142, Japan.

²⁾ Department of Radiology, Toshiba Central Hospital.

³⁾ Medical System Division, Toshiba Corporation.

lished: a) Display of selected cross-sections of the cerebral cortex and cranial bones.⁷⁾ b) Introduction of the semisolid method.⁸⁾ c) Storage of non-image data in the library.⁹⁾ d) Introduction of the voxel method permits more complex structures to be display than the wire-frame method. There is also a report of an atlas system of the head to which stereoscopic images are added.¹⁰⁾ Thus, composition of equipment, data construction, and software development for atlas systems have been steadily advancing.

In the present paper, we have developed a system whereby original CT images are added to a conventional system using a personal computer, which can be employed by an individual user.

Materials and Methods

1. Image data acquisition

The subject was a healthy adult male. Computer tomography (CT) and magnetic resonance imaging (MRI) were used to obtain cranial images, and CT was used to obtain thoracic images. The slice thicknesses were 2 mm for CT and 2.5 mm for MRI.¹¹⁻¹⁷⁾

2. System composition

Fig. 1. System flow chart.

Photo. 1. Outline of system composition.

Fig. 2. General Flow Chart of Atlas System

The system composition and equipment used are shown in Fig. 1 and Photo. 1.

3. Software composition

The software used in the system includes Editor and Atlas programs as shown in Fig. 2. The Editor program is used for such functions as registration of image and non-image data, and data correction and deletion. The Atlas program includes image and non-image databases, and the Atlas Management File (AMF) which is managed by the Atlas Manager. Information used to manage relations between image and non-image data, and between non-image data items, is written in the AMF.¹⁸⁻²⁰⁾

4. Data input method

1) Image data

The types of image data, and the input and storage methods, are as follows:

- a) Method in which the original image obtained by CT or MRI is used;
 - (1) Data is transferred from the CT system to an optical disk.
 - (2) Data in the optical disk is read by a VAX system.
 - (3) The VAX system is connected to a J-3100 with a telecommunication link and the data is transferred to an MS-DOS file.
 - (4) The 3.5" floppy disk from the J-3100 is read by the PC-9801 and the image data is filed.
- b) Method in which the original image is enlarged to full size and traced;
 - (1) The original image is enlarged to a full-size film using a laser printer.
 - (2) Tracing is performed manually.
 - (3) The running coordinate data is compressed and filed.
- c) Method in which the original image is processed using a digital filter and contours are extracted;

Fig. 3. Operation of the system.

- (1) The original image is processed using a digital filter and contour extraction is performed for the desired region.
- (2) The running coordinate data is compressed and filed.

2) Non-image data

The registration method for non-image data and the structure of the data file are as follows:

- (1) Anatomical terms are entered in both Latin and Japanese.
- (2) The registration number is determined as internal code.
- (3) Latin and Japanese terms are sorted into separate files.
- (4) The header of each file includes the position in the file where each internal code and term is stored, and relations between the two files. These files thus serve as dictionaries of anatomical terms.

5. Operation of the system

The system is organized the same as a printed anatomical atlas (Fig. 3).

6. Options

The system incorporates several functions in addition to the standard Atlas functions.

1) Three-dimensional reconstruction

Three-dimensional displays can be reconstructed to improve visualization of the three-dimensional configuration and relations between organs and tissues by using the data from a number of images.

- (1) Wire-frame method
- (2) Semi-solid method
- (3) Voxel method
- 2) Image filters
 - (1) Extraction of borders
 - Extraction of vertical and horizontal borders and contours
 - (2) Extraction of vertical and horizontal components
 - (3) Smoothing
 - (4) Noise reduction
 - (5) Filters
 - High-cut, low-cut, and band-pass filters.
- 3) Non-image filters
 - (1) Non-image filters for each system
 - (2) Non-image filters for each function
- 4) Window level and window width
 - The window level and window width can be freely set when the original CT image is displayed.

Results

As of this time, Latin and Japanese anatomical terms have been registered in the system as non-image data. Contour data for the thorax, and both original CT image and contour data for the head, have been registered as image data. In addition, the Atlas Management data, which relates images and anatomical terms, has been registered. The functional capabilities of the system are described below:

- 1) Selection of a file (Photo. 2)
- 2) Display of three-dimensional images for index (Photo. 3)
- 3) Setting of the slice position (Photo. 4)
- 4) Display of cross-sectional images (Photo. 5)
- 5) Atlas function (Photo. 6)

Other examples are shown in photographs 7 and 8.

Discussion

It is clear that using original CT images is easier and more effective than using anatomical illustrations in a computer assisted atlas for training in the reading of CT images.^{3,4)} However anatomical illustrations have been used in most reports^{2,9)} because large capacity support memory is necessary to replace the original CT image data. In the present study, this problem is solved by adding a magnetic optical disk to the system. Our system makes it possible, in the displayed images, to freely set the window level (WL) and window width (WW), and the CT numbers can be indicated.

When a certain region of interest is selected, only ten anatomical terms have been displayed in relation to that region,⁹⁾ because it is difficult to display sufficient information on a screen. In our method, a large quantity of information can be displayed on the limited screen of a personal computer.

The system permits more complex structures to be displayed than was possible using the wire-frame method, because the voxel method is used for three-dimensional display.

The system is able to store data for the entire body because an MO (a recordable optical disk) is now used as an external storage medium. Approximately 3000 CT or MRI source images can be stored on the two sides of the optical disk.

In a previous version of this system, line drawings were used. In the present version, the original CT images can be displayed. This makes the system useful for training in the interpretation of CT images.

[PROBLEMS IN SYSTEM DEVELOPMENT]

1. Problems involving transfer of the system to IBM PC-AT compatible equipment

This system was initially developed on a PC-9801 personal computer (NEC). Since that time, the system has been transferred to IBM PC-AT compatible equipment, the J-3100 series (Toshiba). The Latin and Japanese anatomical terms have all been entered as non-image data.

The sixteen-color display data, which was developed for the PC-9801 and full-color image display, could not be transferred to the CGA or EGA of the IBM PC-AT compatible system. Expansion EGA or VGA for sixteen-color display and a frame buffer for full-color display must be provided. We plan to explore these problems thoroughly to optimize the display capabilities and portability of the system.

2. Hardware limitations

In recent years, the data processing capabilities of personal computers have improved remarkably. However, we feel that the processing speed and capabilities of the current system are still inadequate for dealing with large amounts of image data.

[FUTURE SYSTEM DEVELOPMENT]

1. Cross-sectional image display

Sagittal, coronal, and oblique tomographic images will be added to the system.

2. Expansion of image data

As of the time of this report, most of our efforts have been directed toward system development, and image data registration has been limited to the head and thorax. We would like to register image data for all regions of the body.

3. Expansion of non-image data

Only Latin and Japanese anatomical terms have been registered as non-image data. We plan to register anatomical terms in English and other languages as well. In addition, we would like to add CT numbers and T1 and T2 values.

4. Simulation

We would like to incorporate physiological and pathophysiological simulation functions in the system.

5. Expert system

We would like to develop an Expert System based on artificial intelligence (AI) techniques.

Acknowledgements

We thank Mr. Yoshikazu Kuroiwa of Ten Science Art and Mr. Takanobu Ito of the Information Processing Center of Showa University for cooperation in this project.

References

- 1) Sigal R, Halimi Ph, Francke JP, Tardivon A, Doyon D, Sigal F, Beja D, Lefevre JE, Zerah M, David Ph, Mauroy B and Pruvo JP: Computer-Assisted Atlas of the Brain. XIII Federative International Congress of Anatomy (abstracts), 57 (1989)
- 2) Suzuki N and Ito M: Keitai kensaku no tameno jintai 3jigen-zou shisutemu no kaihatu. *Image*

- Technol. and Inf. Display. Med.*, **18**: 1211–1217 (1986) (in Japanese)
- 3) Mano I, Yoshida H, Itsushima H, Suto Y and Suzuki M: Kyoiku-shindan you, seijou-zou seijou-chi shisutemu no kaihatu dailhou: gainen to shinzou no sanjigen moderu. *Jap. Radiol Soc*, **47** (extra issue): 285, 1987 (in Japanese)
 - 4) Suto Y, Mano I, Itsushima H, Suzuki M, Kotake T, Koh T, Okubo H and Furuhashi K: Development of normal image and normal database system. *Med. Imaging Technol.*, **5**: 229–230 (1987) (in Japanese)
 - 5) Suto Y, Mano I, Okubo H, Terakado Y, Furuhashi K, Kotake T and Suzuki M: Development of human atlas database. *Japan J Medical Informatics*, **8**: 311–322 (1988) (in Japanese)
 - 6) Mano I, Suto Y, Suzuki M, Okubo H, Kikuchi K, Furuhashi K and Koh T: Sanjigen denshi kaibou-zu no sakusei—Kyoubu wo chuushin to shite—. *Innervation*, **3**: 2–7 (1988) (in Japanese)
 - 7) Suzuki M, Mano I, Suto Y, Furuhashi K, Oubo H, Koh T and Inokuchi S: Database system in the human normal anatomy and normal values. *Acta Anat Nippon*, **63**: 126 (1988) (in Japanese)
 - 8) Suzuki M, Ochiai H, Inokuchi S, Mano I and Suto Y: Development of data base system of atlas in the human anatomy—head part. *Acta Anat Nippon*, **63**: 385 (1988) (in Japanese)
 - 9) Suzuki M, Mano I, Suto Y, Okubo H, Terakado Y, Furuhashi K, Kotake T and Inokuchi S: Human atlas data base system—No. 3: Library of anatomical term. *Acta Anat Nippon*, **64**: 95 (1989) (in Japanese)
 - 10) Tamai H, Akimoto M, Suzuki M and Mano I: Pasokon ni yoru gazou shindan shien shisutemu—Denshi atarasu to 3jigen hyoji shisutemu—. *Medic*, **1**: 18–21 (1989) (in Japanese)
 - 11) Laan AC, Lamers WH, Huijsmans DP, Kortschot AT, Smith J, Strackee J and Los JA: Deformation-corrected computer-aided three-dimensional reconstruction of immunohistochemically stained organs: Application to the rat heart during early organogenesis. *Anat Rec*, **224**: 443–457 (1989)
 - 12) Heuck AF, Steiger P, Stoller DW, Gluer CC and Genant HK: Quantification of knee joint fluid volume by MR imaging and CT using three-dimensional data processing. *J Comput Assist Tomogr*, **13**: 287–293 (1989)
 - 13) Hemmy DC and Tessier PL: CT of dry skulls with craniofacial deformities: accuracy of three-dimensional reconstruction. *Radiology*, **157**: 113–116 (1985)
 - 14) Naidich DP, Zinn WL, Ettenger NA, McCauley DI and Garay SM: Basilar segmental bronchi: Thin-section CT evaluation. *Radiology*, **169**: 11–16 (1988)
 - 15) Smith DK, Berquist TH, An K, Robb RA and Chao EYSC: Validation of three-dimensional reconstructions of knee anatomy: CT vs MR imaging. *J. Comput Assist Tomogr*, **13**: 294–301 (1989)
 - 16) Vannier MW, Marsh JL and Warren JO: Three dimensional CT reconstruction images for craniofacial surgical planning and evaluation. *Radiology*, **150**: 179–184 (1984)
 - 17) McLean M, Ross MA and Prothero J: Three-dimensional reconstruction of the myofiber pattern in the fetal and neonatal mouse heart. *Anat. Rec*, **224**: 392–406 (1989)
 - 18) Ito N and Ito K: 3D super graphics for PC-9800 series. Shuwa System Trading Co., Tokyo, 1986 (in Japanese)
 - 19) Takahashi Y and Takano S: Macro assembler. Shuwa System Trading Co., Tokyo, 1988 (in Japanese)
 - 20) Yamaguchi F: Computer graphics, Nikkan-Kogyo Shinbunsha, Tokyo, pp 26–95 (1981) (in Japanese)

[Received September 1, 1989: Accepted October 20, 1989]

Photo 2. Screen for selection of file.

Photo 3. Screen for display of images for index.

Photo 4. Screen for setting of slice position.

Photo 6. Screen for performing Atlas functions.

Photo 7. (Example 1) The sulci and gyri of the superior cerebrum can be seen.

Photo 5. Screen for displaying cross-sectional image.

Photo 8. (Example 2) Cross section in which bullet fragments can be seen at the right.