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THREE-DIMENSIONAL MEDICAL CT IMAGE RECONSTRUCTION

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Abstract**—**In this paper, it is provided to reconstruct three dimensional(3D) models of human body by using CT slices and digital images and precisely finding locations of pathological formations such as tumours.3D image CT reconstruction is an attractive field generally in digital image processing techniques, especially in biomedical imaging. It has been strongly developed and practically implemented in almost every modern tomographical modalities but there are many problems which still remain unresolved or can be improved. A project in such area has been alternatively developed in order to master mentioned technology and to develop domestic products partially substituted for very expensive imported facilities and softwares. This paper introduces the implementing fundamental problems in 3D medical image reconstruction for medical imaging such as Marching Cubes （MC） algorithms, usual rendering technique, etc. and designing a software for reconstructing 3D image from a set of CT images, which was built on VTK (Visualization Toolkit) and Visual C++. The result show that the reconstruction program can help to reconstruct series of 2D segmented binary images and display the 3D image of the target object.

Keywords**-**CT Image; Marching Cubes; 3D-reconstructio; VTK.

I. INTRODUCTION

Medical Imaging techniques are used for diagnosing and treatment of many diseases as well as surgical operations. CT and MR imaging techniques are the mostly used ones[1-2]. Reconstruction of 3D volume and surface models of the tissues, by using 2D image slices, provides many advantages to medical doctors. For a long time, 3D models have being used in medical applications in many countries, which are used just at some high quality hospitals and medical centers. These equipments have been indispensably for doctors' diagnosis assisted by information technology, which need strong computers with dedicated software. At present, such high-tech equipments are unable to be manufactured with domestic technology, but feasible developing supporting accessories and software can enhance their utilization effectivity and reduce the dependence on foreign maintenance system with high cost. On the other hand, medical information system does not shape clearly; medical units in national health care system have not united yet in any standard process to operate image diagnostic equipments or to manage patient data. Therefore, a project making facilities for medical information system in general and for medical imaging in particular has been alternatively developed in order to master mentioned technology and to develop domestic products partially taken place of very expensive imported facilities and soft wares[3-4]. This paper introduces our building 3D image reconstruction software with MC algorithms on PC, which are very necessary tools for medical image processing.

II. FUNDAMENTAL THEORY

A common approach to stereo reconstruction is the optimization of a cost function, computed by solving the correspondence problem between the set of input images. The matching problem involves establishing correspondences between the views available and is usually solved by setting up a matching functional for which one then tries to find the extrema. By identifying the matching pixels in the two images as being the projection of the same scene point, the 3D point can then be reconstructed by triangulation, intersecting the corresponding optical rays. Our proposed method differs from this approach by projecting all the images into a common space prior to analysing the correspondence between the images. The matching problem is then solved not as a correspondence problem between images, but as a matching functional, computed for each voxel in the volume. This functional is optimised through segmentation to recover the 3D structure of the scene.

A. Medical images and 3D reconstruction

All recent medical 3D image reconstruction techniques create 3D images from sets of 2D slices, which can be recorded by various equipments such as CT, MRI, ultrasound etc. Each type of scanner has his own characteristics due to physical principles of image recording, e.g. images of CT scanner are often parallel slices with high contrast, images of ultrasound scanner are either parallel or divergent slices with low contrast etc. Thus there are different 3D reconstruction techniques for each type of data (fig. 1).

Generally, the general principle of 3D reconstruction is composed of following two steps:

Step 1: 2D data slices need to be read and arranged exactly with the real spatial positions, the result is a data volume, which is saved in memory of computer.

Step 2: use rendering techniques to visualize data volume as 3D image. Usual rendering techniques for medical image are multiplanar rendering (MPR), surface rendering (SR) and volume rendering (VR).

B. Rendering techniques

1) MPR technique. MPR does not require too many calculations. So it could run on some low configuration computers. This technique can be used to reslice structure, i.e. with axial slices we can use MPR technique to reslice

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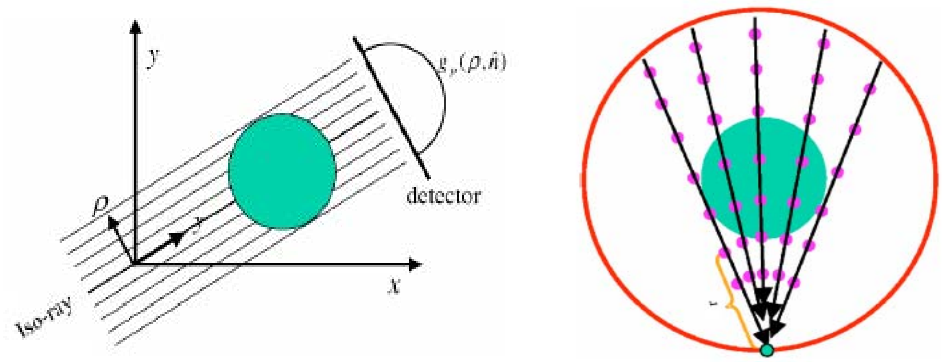
according to different directions such as coronal, sagittal or diverse .

2) SR technique. SR technique visualizes a 3D object as a set of surfaces called iso-surfaces. Each surface contains points which have the same intensity (called iso-value) on all slices. This technique is used when we want to see the surfaces of a structure separately from near structure, e.g. skull from slices of head, tooth,blood vessel system from slices of body etc. SR technique is often used for high contrast data.



(a) *(b)*

Figure 1. Parallel beam x-ray projections and mathematical notations to label them (a) and divergent-beam weighted back-projection (b) types of 2D slice

Two main methods for reconstructing iso-surfaces can be considered as follows:

-Contour based reconstruction: Iso-contours, which are extracted from each slice can be connected to create iso-surfaces [5-7]

- Voxel based reconstruction: Iso-surfaces are built directly from voxels having identical intensity (iso-value). One of the best algorithms is Marching Cubes [8] . Some similar algorithms as Marching Tetrahedrons, Deviding Cubes [9] can be considered.

3) VR technique. VR technique is used to visualize the entire volume transparence of the object. The images will be performed by projecting rays through volume data. Along each ray, opacity and color need to be calculated at

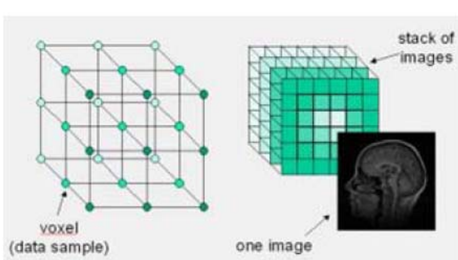


Figure 2. Arrange slices to a volume data

every voxel[10]. Then information calculated along each ray will to be aggregated to a pixel on image plane. This technique helps us to see comprehensively an entire compact structure of the object. One of disadvantages of this technique is enormous amount of calculations, which requires strong configuration computers. This technique is appropriate for low contrast data.

Two main methods for x- or γ-rays projecting can be considered as follows:

-Object-order method: Projecting rays go through volume from back to front (from volume to image plane).

-Image-order or ray-casting method: Projecting rays go through volume from front to back (from image plane to volume).There exists some other methods to composite image, appropriate methods depending on the user's purposes. Some usual methods in medical image are MIP (maximum intensity projection), MinIP (minimum intensity projection), AC (alpha compositing) and NPVR (non-photorealistic volume rendering).

C. Reconstruction from a set of parallel slices

Set of parallel slices can be recorded by CT, MRI scanners etc. In fact, the distance between two consecutive slices is about 0.5 to 2 mm. Reconstructing 3D image from CT data is easier than other types of data because of high contrast of CT images[11]. Usual configuration can be considered isometric volume data (fig. 2), in which the distance between two successive slices is equal to real distance. Value of each voxel is the value of the correlative

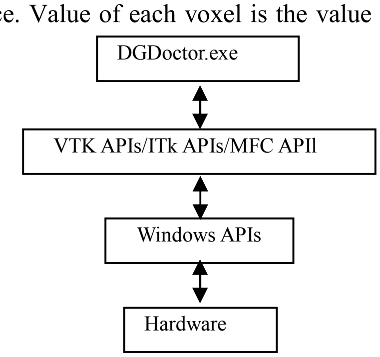


Figure 3. Structure of software

pixel, which is often the gray level of pixel. After arranging of parallel slices, rendering techniques will be selectively use to perform the volume data.

III. PROGRAMMING

Software for reconstructing 3D image from a set of CT images was built on VTK and Visual C++ 6.0. VTK has been chosen because of its open source toolkit professionally designed for computer graphics purposes.

A. VTK

VTK is an open source, freely available software system for 3D computer graphics, image processing, and visualization used by thousands of researchers and developers around the world. VTK consists of a C++ class library, and several interpreted interface layers including Tcl/Tk, Java, and Python. Professional support and products for VTK are provided by Kitware, Inc. VTK supports a wide variety of visualization algorithms including scalar, vector, tensor, texture, and volumetric methods; and advanced modeling techniques such as implicit modelling, polygon reduction, mesh smoothing, cutting, contouring, and Delaunay triangulation. In addition, dozens of imaging algorithms have been directly integrated to allow the user to mix 2D imaging or 3D graphics algorithms and data. The design and implementation of the library has been strongly influenced by object-oriented principles. VTK has been installed and tested on nearly every Unix-based platform, PCs(Window), and Mac OSX Jaguar or later. [12].

B. Programming

1) Structure. The flowchart structure of the software DGDoctor V.1.0 is illustrated in Fig.3, which is similar to other VTK and Windows applications[13].

2) Interface design. The main user interface of the software DGDoctor V.1.0(fig.4) is functionally similar to some commercial medical image softwares. It contains a screen on the right to display original and processing images. This screen can be displayed with different modes. General toolbar is placed on the top and control panel on the left. However, due to the main educational and training purpose of the software, it contains some more control components which are not necessary in commercial software.

3) Example. Through this structure, a reconstructed triangle was stored in memory in the form of a bidirectional linked list, which could reconstruct a 3D shape. We use MC to reconstruction CT data of tooth,with gray CT images($404 \times 279 \times 156$), showed as fig.5. The source is PAT format image to reconstruct 3D image with techniques MPR, SR, VR with MC algorithm. Experimental data is 256 serial images which were transformed PAT(for Protein Analysis Toolkit) format.

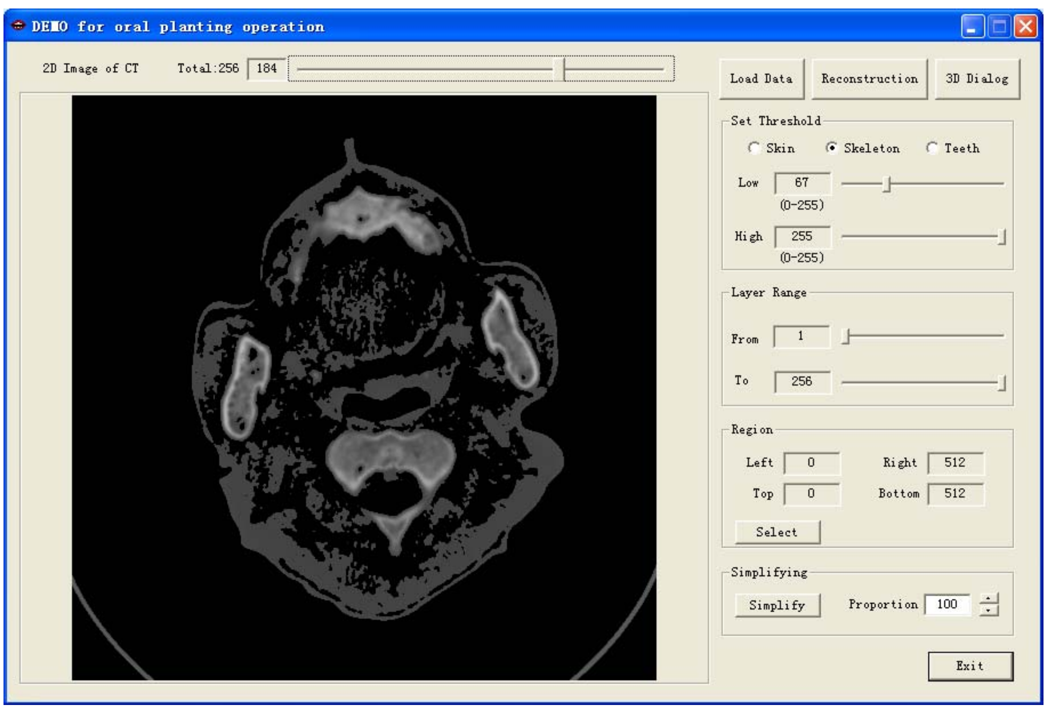


Figure 4. Main screen of DGDoctorV.1.0

PAT, for Protein Analysis Toolkit, is an integrated biocomputing server. PAT is able to read and write data in many bioinformatics formats and to create any desired pipeline by seamlessly sending the output of a tool to the input of another tool. PAT can retrieve protein entries from

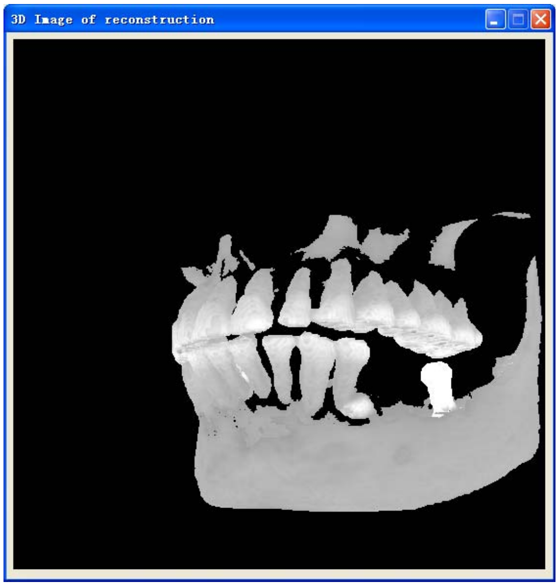


Figure 5. Result of teeth reconstruction

identifier-based queries by using pre-computed database indexes[14].

4) Problems.Program runs slowly with VR mode and there are not a lot of functions yet, e.g. no function for data pre-processing, for selecting regions of interest etc. Resolving mentioned problems needs to study more about computer graphics, VTK and to improve programming skills.

IV. CONCLUSION

By using 3D models, it is easy to diagnose pathological formations and preparing the treatment plans. With 3D models, it will be possible to trace the progress of the diseases. Thus, for many diseases such as Parkinson, new treatment methods may be developed. On the other hand, a such system may be used in plastic surgery or in dental diagnosis and treatments.

The project of designing medical image domestic software has been developed in order to master biomedical image processing technology and to develop domestic products partially taken place of imported softwares. This paper introduces first step results of partially mentioned project: implementing fundamental problems in 3D medical image reconstruction for medical imaging such as algorithms, usual rendering technique, etc. and designing software for reconstructing 3D image from a set of CT images. The software is still in development stage, achieved just some fundamental functions corresponding to educational and training purposes.

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