Abstract: 3D image 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 taken place of very expensive imported facilities and softwares. This paper introduces first step results of mentioned project: implementing fundamental problems in 3D medical image reconstruction for medical imaging such as 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++.

1. Introduction

3D image diagnostic equipments such as CT scanners, MRI, 3D-4D ultrasound etc. have been used widely in developed countries but in Vietnam, they are used just at some high quality hospitals and medical centers. These equipments have been alternatively assisted by information technology, which need strong computers with dedicated softwares. At present, such high-tech equipments are unable to be manufactured with domestic technology, but feasible developing supporting accessories and softwares can enhance their utilization effectiveness 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 softwares. This paper introduces some first step results of building 3D image reconstruction softwares, which are very necessary tools for medical image processing.

2. Fundamental theory

Medical 3D image reconstruction is a part of a field called Visualization. Visualization is the data presentation by pictures in order to helps users to understand and manipulate data by a visually better way [1]. Nowadays, visualization especially with aids of computers has been applied in a lot of fields such as simulation, education, economy etc.

2.1. 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 its 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).
However, the general principle of 3D reconstruction is composed of following steps:

- **Step 1**: 2D data slices need to be read and arranged exactly with the real spatial positions, the result is a data volume. This data volume is saved in any 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).

### 2.2. Rendering techniques

**a) MPR technique**

MPR does not require too many calculations, so it is appropriate for low configuration computers. This technique can be used to reslice structure, i.e. with axial slices we can use MPR technique to reslice according to different directions such as coronal, sagittal or diverse.

**b) 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, blood vessel system from slices of body etc. SR technique is often used for high contrast data.

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 (Keppel, 1975; Fush, 1977; Ekoule, Peyrin, Odet, 1991) [1]
- Voxel based reconstruction: Iso-surfaces are built directly from voxels having identical intensity (iso-value). One of the best algorithms is Marching Cubes (William E. Lorenzen and Harvey E. Cline, 1985) [1]. Some similar algorithms as Marching Tetrahedrons, Deviding Cubes (Cline, 1988) [1] can be considered.

**c) VR technique**

VR technique is used to visualize the entire volume transparency of the object. It is performed by projecting rays through volume data. Along each ray, opacity and color need to be calculated at every voxel. Then information calculated along each ray will 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 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).

### 2.3. Reconstruction from a set of parallel slices

*Figure 1: Parallel (a) and divergent (b) types of 2D slice*
Figure 2. Arrange slices to a volume data

Set of parallel slices can be recorded by CT scanners, MRI scanners etc. In reality, the distance between 2 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.

Usual configuration can be considered is 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 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.

3. Programming

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

3.1. VTK

The Visualization ToolKit (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 Tel/Tk, Java, and Python. Professional support and products for VTK are provided by Kitware, Inc. 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 (Windows 98/ME/NT/2000/XP), and Mac OSX Jaguar or later. [2].

3.2. Programming

a) Structure

Figure 3 illustrates the flowchart structure of the software BKDoctor V.1. It is similar to other VTK and Windows applications.[3]
b) Interface design (fig.4)
The main user interface of the software BKDoctor V.1 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.

![Main screen of BKDoctor V.1](image)

Figure 4. Main screen of BKDoctor V.1

c) Classes

Program contains some main classes as follows (Fig.3):
- CBKDoctor classes: set of functions for starting and terminating program.
- CBKDoctorDlg: set of functions and variables for processing and display. There is the most important class of the program.
- Auxiliary classes: contains functions and variables for communication between users and program.

d) Functions
Main functions of BKDoctor V.1 are:
- Running on Windows operating system.
- Suggested configuration being CPU 2.4GHz, 512 of RAM.
- Reading DICOM image.
- Reconstructing 3D image with techniques MPR, SR, VR.
- Having friendly user interface similarly to popular commercial medical image software.

e) 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.

4. Conclusion
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. Actually main objectives of the project is performing own computer graphics libraries and practical softwares supporting add-on accessories manufactured and used in Vietnam.

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References:
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