A Visualization System of Brain MR image based on VTK

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Abstract

VTK is a free but professional development platform for images three-dimensional (3D) reconstruction and processing. It is powerful, open-source, and users can customize their own needs by self-development of great flexibility. To give the doctors more and detailed information by simulate dissection to the 3-D brain MRI image after reconstruction. A Visualization System (VS) is proposed to achieve 3D brain reconstruction and virtual dissection functions. Based on the free VTK visualization development platform and Visual Studio 2010 IDE development tools, through C++ language, using real people's MRI brain dataset, we realized the images 3D reconstruction and also its applications and extensions correspondingly. The display effect of the reconstructed 3D image is well and intuitive. With the related operations such as measurement, virtual dissection and so on, the good results we desired could be achieved.

1. Introduction

The doctors usually diagnose by observing a series of slices of Computer tomography (CT), magnetic resonance imaging (MRI) images in recent decades. It mainly depends on the doctors' experiences in reading slices and maybe cannot get intuitionist information. Three-dimensional reconstruction of medical images provides an effective approach for obtaining more intuitionist and accurate information. With the fast development of computer technology, it is now possible to reconstruct and visualize 3-D medical volume data [1-4]. Three-dimensional reconstruction of medical images is now an important part of biomedical research. It has been widely used for demonstrating lesions and/or their localization in the musculoskeletal system, vascular system, respiratory and alimentary systems. In the area of biomedicine, 3-D data are acquired by a multitude of imaging devices, such as MRI, CT, and 3-D microscopy. In most cases, 3-D images are represented as a sequence of two-dimensional (2-D) parallel image slices [5]. Three-dimensional visualization is a series of theories, methods and techniques, which transform the resulting data from the process of scientific computing to graphics by applying computer graphics, image processing technique and human-computer interacting technique [6-10]. In this paper, a visualization system (VS) of brain MRI image with the three-dimensional reconstruction and interaction of medical images is presented. Firstly, Visual Studio 2010 with VTK was used to reconstruct 3-D images using the MRI slice sequence of human head. The simple interactive operations, such as rotation, zoom and transfer can be realized by user interaction with PC. Secondly, virtual dissection function use virtual normal plane to simulate the dissection on the object after 3-D reconstruction. Real time interaction can be realized by dissecting the reconstruction object. The vector and inner points are set to form the virtual dissection plane, which in turn is used to incise the 3-D object. And the information of cross-section images is obtained, at the same time the correspondent images are displayed on the screen. Therefore, extraction of cross-section images on 3-D medicine image can be realized in any direction. The coordinates can be acquired by setting the value of slider, by which to realize the point mouse pick-up as well interactive quantitative measure the 3-D medicine image. Finally, realization of 3-D brain medical images interaction is done in fields such as basic brain data information, the location of virtual dissection plane.

Section 2 introduces the materials of this system. Section 3 describes our proposed system. Experimental results and discussion are described in Section 4. Finally, a conclusion is described in the Section 5.

2. Materials

2.1 Visualization Toolkit

Conventional 3-D visualization tools usually have important limitations such as low efficient code execution, poor computing capacity. VTK is an open-source software system for visualization, computer graphics and imaging. It is provided as a C++ library with interfaces to the interpreted languages TCL, Python and Java [11]. Object oriented design, high level interface and possibility to write scripted components make it an excellent tool for a wide range of applications, from few lines throw-away scripts, to complex visualization systems. VTK is distributed by Kitware, Inc. (469 Clifton Corporate Parkway, Clifton Park, NY 12065 USA) under an open license that permits free inclusion of VTK components into both commercial and non-commercial applications [11].

The object-oriented visualization Toolkit (VTK) has been widely applied in 3-D reconstruction of medical images. VTK is a visualization library that provides a large number of functions for presenting three-dimensional data. Interaction with the visualized data is controlled with two-dimensional input devices, such as mouse and keyboard.

2.2 VTK Widget Event Handling Mechanism

VTK Widget can be defined as the geometry and behavior control of the displayed object information. It allows the direct interaction of programmer with the data in three-dimensional data field manipulation. The widget control is depending on the mouse click and move triggered. It will receive the activated control of interactive events and generate appropriate behaviors according to the sign given by the users. The VTK widget features are separated into two parts, one part inherited from vtkAbstractWidget class for event handling, and the other part inherited from vtkWidgetRepresentation class for geometry description, as shown in Figure 1. It can be observed that vtkWidgetRepresentation is subclass of vtkProp, and it combines with vtkAbstractWidget subclass to produce a 3D widget. In this system, vtkBoxWidget is used in the display part.

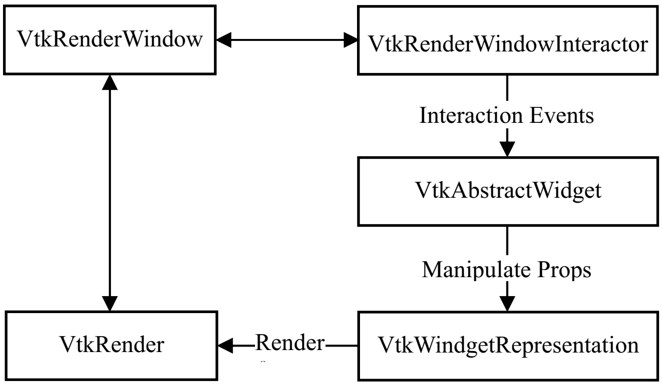


Figure 1. VTK Widget Event Handling Description

2.3 Brain MR Images

The MR images are in the format of DICOM. DICOM is designated medical digital image archiving and transmission standards by the American College of Radiology and the National Electrical Manufacturers Association. DICOM for different manufacturers of medical imaging equipment (such as CT, MRI, ultrasound, etc.) provides a standard interface and interactive agreement; it has gradually developed into an internationally accepted standard in medical imaging. Many consecutive human head MR images (256 × 256) sequence in the DICOM data format are acquired with a spatial resolution of 256 × 256 and scanning interval of 1.2 mm. Figure 2 shows the reader of the MR images with sequences of head.

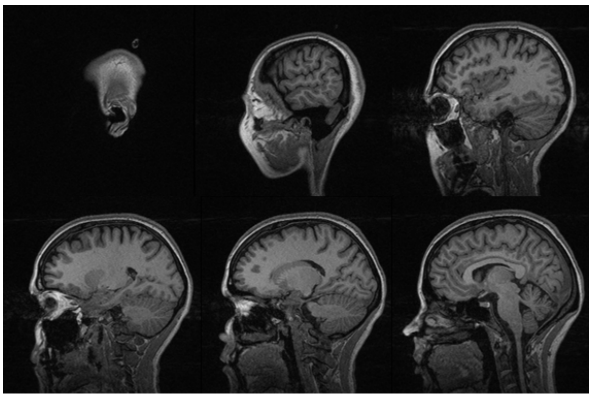


Figure 2. The Original Brain MR images

3. Visualization System

3.1 3-D Reconstructions

In general, there are two main principles of three-dimensional reconstruction and visualization, which are surface rendering and volume rendering. The main pipeline VTK design mechanism for volume rendering is very similar to surface rendering, but it is using the basic unit of volume data and data manipulated by ray casting techniques. The difference of volume rendering in present studies is to express the object's internal information, in this system, multi slices of DICOM brain data were collected for 3D volume reconstructions. The collected DICOM files are stored in 16 bit, and digital unsigned characteristic with the grey scale values between 0 and 255. The total numbers of slices stored are 160 slices. The scanned subject in the present studies is Siemens's Trio Scanner. Figure 3 shows the proposed system flows of the case data to form a three dimensional scalar topology rendering. The vtkImageCase class from VTK is used to receive case data, and retrieved its SetDimensions function is to set the dimension of the data, SetSpacing function set the pixel spacing (pixels interval must be in strict accordance with the pixel interval of the original data set, otherwise it will results visual imbalance). The output of vtkImageCase will access vtkRayCasting, and forming 3D volumetric rendering. In order to show the internal structure of brain translucency explicitly, we have proposed a three dimensional virtual slider dissection plane, using implementation of vtkPlane, as shown in Figure 3. VtkPlane will be implemented as a grid plane with setting x, y, and z values, which indicates the current position of three dimensional grid planes. The movement of virtual slider can be controlled through the interaction of mouse click and movement triggered. To perform this, the algorithms need an extra AddClippingPlane on vtkPlane class. One common use of these arbitrary clipping planes on volume rendering is to specify two planes parallel to each other in order to perform a thick reformatting operation. For unstructured data, clipping planes can be used essentially as cropping planes to view only a sub-region of the data, which is often necessary when trying to visualize internal details in a complex structure.

3.2 Virtual Dissection

There is a lot of method to dissect the data after 3-D construction in VTK. This system uses a free plane clipping method. The key procedure is to keep the part data around the 3-D object and replace another with new value, normally 0 is set.

Application of the VTK vtkBoxWidget class to construct a cuboids region on the screen, as well as in its centre and six surfaces can be controlled to zoom, move or circumrotate by mouse and other operations, which can be very intuitive to dissect 3-D objects. The use of this class, we must designate a class inherit from vtkCommand to deal with the interaction event. Six planes of BoxWidget will be added as a clipping plane in each interaction end. Therefore, clipping result shows 3-D reconstruction objects by cuboids clipping. Subsequent work is the definition of BoxWidget initial position, as well as surface properties, and so on.

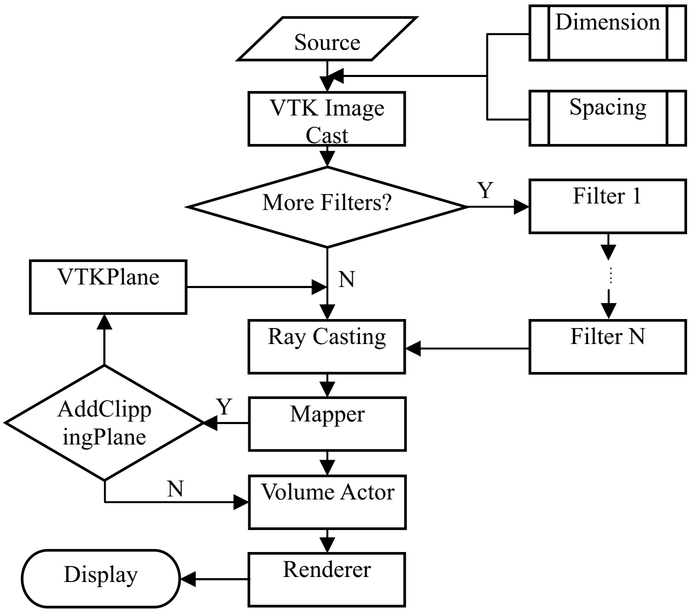
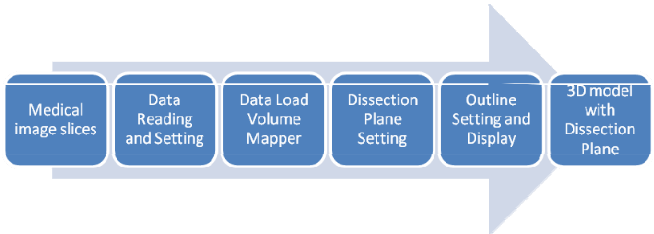


Figure 3. System Flow Chart

3.3 System Structure

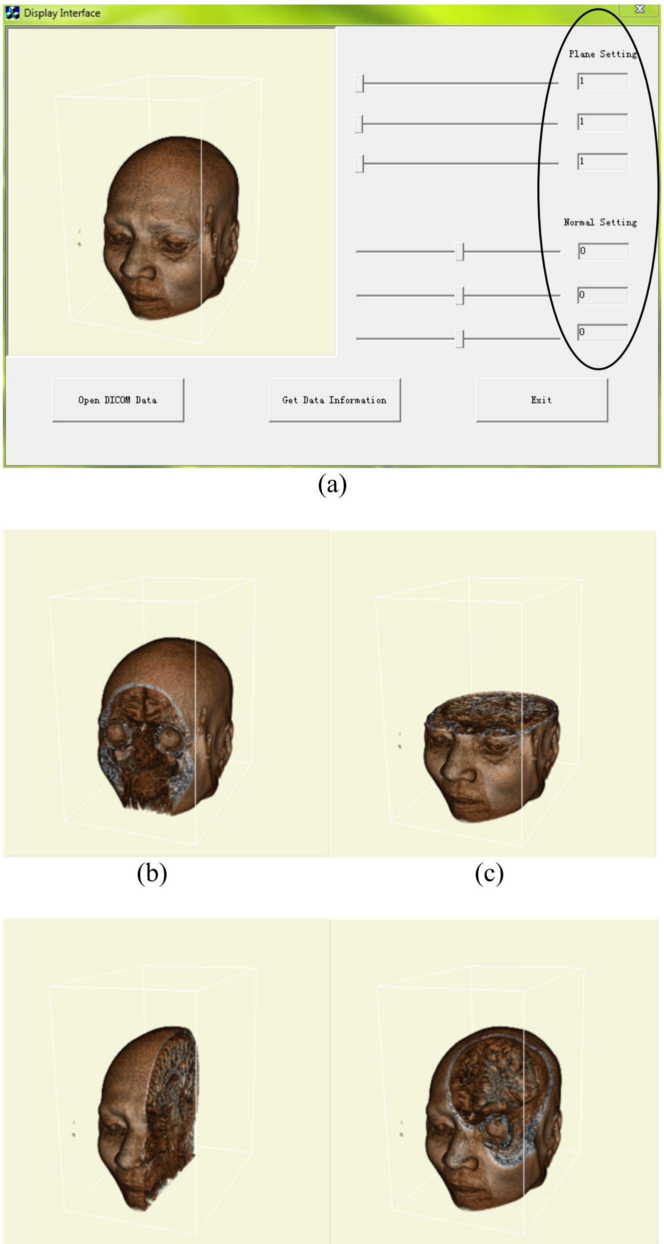


4. Experiment

Based on the VTK platform, through Surface Rendering and Volume Rendering methods, this system realized medical brain images 3D visualization. The display effect of the reconstructed 3D image is well and intuitive. With the related operations such as measurement and virtual dissection, the good results we desired could be achieved.

Figure 4 (a-d) shows the 3D reconstruction model and the virtual dissection results in each signal direction (x, y and z). By setting both plane values and normal values, the dissected brain model in free direction can be displayed in the Figure 4 (e).

Figure 4 (a) describes a whole vision of this system. It displays the original 3D reconstruction brain model and original state of dissection option. Plane setting section will be used in getting the location of x, y and z planes, while normal setting section will be used in fixing dissection direction. Figure 4 (b-d) shows the dissection effect of three basic directions respectively. This system can show the dissection model in basic x, y and z direction meant it only needs to modify the value of one normal direction. If this system modifies more than two values in the normal setting option, a free dissection plane can be achieved in Figure 4 (e).



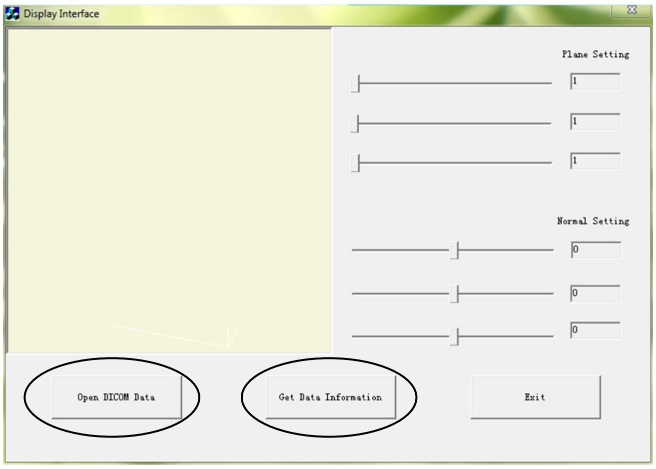
(a)

(b) (c)

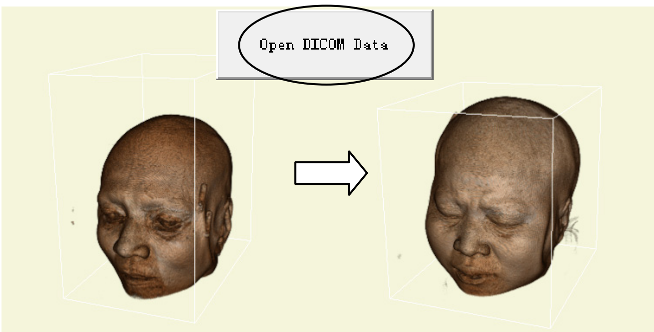
(d) (e)

Figure 4. Display Effect of VS: (a) Original 3D Reconstruction (b) X Plane Virtual Dissection (c) Y Plane Virtual Dissection (d) Z Plane Virtual Dissection (e) Normal Plane Virtual Dissection

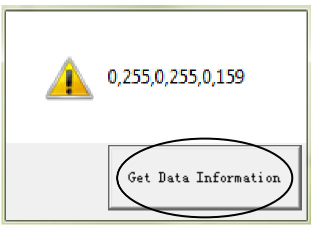
Figure 5 (a) describe the interface of this system. In Figure 5 (b), through Open DCIOM File Icon, a new brain DICOM file can be loaded into Mapper and reconstructed 3D model which instead of the original 3D brain. The DICOM data can be measured by clicking Get Data Information Icon in Figure (c). This feature can achieve the maximum and minimum value of x, y and the number of slice. Virtual dissection can be achieved by setting initial plane and normal direction.



(a)



(b)



(c)

Figure 5. Interface Description of VS: (a) Display Interface (b) Open a New DICOM File (c) The Size of Brain MR Images (X_{min}, X_{max}, Y_{min}, Y_{max}, Z_{min}, Z_{max})

5. Conclusion

In this paper, a visualization system is applied to reconstruct the 3-D brain images for the MRI image sequence in DICOM format under the Visual Studio 2010 and the visual package VTK platform. This system can help the doctors to acquire the position information of disease by the dynamic dissection of 3-D object.

With the help of 3-D measurement, doctors can acquire the detail information of disease and increase the position accuracy of the treatment or surgery, decrease the pain of patients. In the future, this system will be improved by combining VTK with QT. It can also add more medical image process application, such as segmentation and real time interaction etc. About Data, this system can extend to any parts of human body, such as human ankle, knee, pelvis etc. In addition, dissection plane setting method can be improved and virtual scalpel can be created for virtual surgery.

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