Computational 3D Ultrasound Volumetric Rendering; an Object Oriented Open-Sources Approach

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Abstract: - On account of the advanced technology in recent years, the increasing demand for an effective medical imaging system has addressed its significance in diagnosis especially in the development of three-dimensional medical image reconstruction. Of the various software that have been investigated, none of them show efficiency in terms of cost and computational performance. Owing to this fact, a method of 3D reconstruction using VTK has been proposed in this paper. The 3D reconstruction has been achieved through a series of processes includes DICOM sources manipulation, gray interpolations, ray casting and volume rendering. The result obtained indicates that VTK is an efficient open source library in performing 3D reconstruction especially in the matter of volume rendering. The method proposed has shown its future utilities in clinical application especially in CT, MRI and Ultrasound image volume rendering in providing a more informative view in order to assist the personnel in hospital to perform significant diagnosis.

Key-Words: - three dimensional, reconstruction, VTK, volume, rendering, medical imaging

1 Introduction
With the rapid development of advanced technology in the current health care environment, requirements in diagnosis technology are becoming tremendously demanding. Especially while MRI, CT and other large equipments [1-4] which are widely used in the medical environment, image-based diagnosis and processing [4-7] has been developing from the traditional two-dimensional diagnostic imaging X-ray film in reading digitized DR-chip technology to the current development of the three-dimensional diagnostic imaging technology [8].

Since the American College of Radiology (ACR), the National Electronics Manufacturers Association (NEMA) proposed the standardized and uniform information exchange, the DICOM 3.0 in medical image [9], the obstacles and difficulties where different imaging devices have different image formats in image exchange has been solved and can now processed with the standardized format.

Currently, in many large-scaled hospitals, DICOM images are embedded in three-dimensional reconstruction software which is similar to a class of large-scale image processing workstation system or treatment planning system. A major drawback of the workstation system is the great consumption of computing processing and thus demanding hardware configuration is needed to perform the task. Therefore, prices are usually very high and consequently the establishment of such workstation is not affordable for small-scaled hospitals. Obviously the software is not cost effective, moreover, only the related companies who developed the software are able to carry out the routine maintenance and this has created many difficulties and inconvenience.

Therefore, the development of smaller and efficient standard DICOM 3.0 medical image reconstruction system can be utilized to overcome the limitations mentioned above, at the same time, medium and small hospitals will own three-dimensional diagnostic imaging standards
themselves [10]. This implementation can surely enhance the accuracy of the current diagnostic imaging system and perform further improved treatment for patients.

2 Methodology

2.1 DICOM Sources

DICOM is also known as Digital Imaging and Communications in Medicine, which is specially used for medical digital imaging and communications. DICOM standard is jointly developed by the American College of Radiology (American College of Radiology, ACR) and the National Electrical Manufacturers Association (National Electrical Manufacturers Association, NEMA). In this project, multi frames of DICOM ultrasound data were collected for three dimensional volume reconstructions. The collected DICOM file is stored in 8 bit, and digital unsigned characteristic with the gray scale value between 0 and 255. The maximum number of frames stored is 256 frames, as shown in figure 1 below. The order of these 256 ultrasound images need to be arranged according to their priority in advanced. The scanned object in the present studies is carotid arteries, with the resolution 641 x 598 using transabdominal 3.5 MHz ultrasound transducer.

Fig. 1 Multiples slices of two dimensional ultrasound images arranged in order

2.2 Volume Rendering

In image pre-processing, the raw data used in volume rendering is the DICOM format [12-15]. Volume rendering is similar to the basic flow chart as shown in figure 3, but it is slightly more complicated than the surface rendering. Its main difficulty is to set different transparency and colour for each different gray value of image voxel. VTK uses class vtkPiecewiseFunction to set the transparency, such methods can be achieved using Add Point (gray value, transparency). This method requires only a few setting of discrete gray value of transparency, where the value changing continuously between the gray values. However, to know the gray value in different structure is not an easy task, it requires thorough trial and error to find suitable range of gray values.

vtkColorTransferFunction class is used to set the colour, which actually provides a gray value to the RGB values of the map. It is used to add colour to voxel with different gray scale value for visual effect enhancement. VTK volume rendering method is implemented by the vtkVolumeRayCastFunction. It consists of three sub-categories: vtkVolumeRayCastMIPFunction, vtkVolumeRayCastCompositeFunction, vtkVolumeRayCastIsosurfaceFunction.

2.2.1 The concept of voxels

Voxel is the basic unit in three-dimensional where it can be formed by four points in each corresponding slices into a cube [16]. It has the shape of a hexahedron on each side of the orthogonal axes; voxel uses the defined points to coordinate the direction of gradually increasing order, as shown in figure 2.

Fig. 2 Definition of voxel in three dimensional

2.2.2 VTK use of image interpolation

In general, image data slices obtained by medical imaging equipment always contains a gap in space direction, the gap is much larger than the distance between the pixels extends. For example, slice CT, the layer pixel pitch is usually between 0.5 ~ 2mm, while the spacing between the range of 1 ~ 15mm. Therefore, we need to generate new sections by interpolation between the layers when we performed 3D image reconstruction. In the present ultrasound image, the value is set to 3.57. Interpolation methods are mainly divided into two types [11,17]: the first type are based on image gray value interpolation methods, such as neighbouring method, linear interpolation [18], spline interpolation [19-21], and etc. Another type is based on matching interpolation method. These methods are essentially for the gap which contains images from the adjacent common feature extraction. Image interpolation based on gray-based interpolation is the most common and simple method, as discussed below.
2.2.3 Gray interpolation

Gray interpolation is the method that will add a number of "missing" slice images in original tomography images sequences [22-23]. Existing interpolation methods are mainly gray neighbour interpolation, linear interpolation and high order nonlinear interpolation. Linear interpolation is often assumed the gray value in the Z direction changes linearly through two adjacent sections, corresponding to the pixel interpolation intercropping to estimate the corresponding point on the new gap gray. Identification of a new gray value of pixel images needs to use information of corresponding points on several layers of gray level.

Suppose the known tomography image \( V (x_i, y_j, z_k) \) and \( V (x_i, y_j, z_k +1) \) interpolation between them out in a new layer of the image \( V (x_i, y_j, z) \). Interpolation algorithm using Nearest Neighbour, the new image \( V (x_i, y_j, z) \) of the gray scale value:

\[
V(x_i, y_j, z) = \begin{cases} 
V(x_i, y_j, z_k) & d \leq 0.5 \\
V(x_i, y_j, z_{k+1}) & otherwise
\end{cases}
\]  

(1)

Where \( d = z - z_k \) as the distance between point \( (x_i, y_j, z) \) to \( V (x_i, y_j, z_k) \).

3 Result

The usefulness of two-dimensional image plane often depends on the physical structure for the region of interest approach. However, for most of the existing medical imaging systems, it is difficult to generate the best spatial orientation two-dimensional image directly. This is because the structures of positioning and scanning orientation are generally subject to the structure and other physical limitations. Therefore, three dimensional imaging have higher value for the clinical application. In many occasions, it is crucial to identify and display the best two dimensional image plane from the three dimensional model.

Figure 4 shows the resultant three dimensional volumes rendering without interpolation. Therefore it can be observed that the results are poor in quality especially in the matter of z dimensional or space direction. The area of carotid arteries, which is the region of interest in this case are hardly to distinguish from the three dimensional model. Nevertheless, within appropriate parameters adjustment using the sub-library \texttt{vtkOpacityTransferFunction}, and \texttt{vtkColourTransferFunction}, it can be greatly
improved and the internal image areas of carotid arteries are shown clearly, as shown in figure 5.

Fig. 4 Three dimensional volumes rendering with default values

Fig. 5 Three dimensional volumes rendering after adjusting specific volume property, however, the round area of carotid area still contains background cloud

Fig. 6 The background cloud can be removed by tuning additional filter, 3D anisotropic diffusion

4 Discussion
The complexity of volume rendering algorithm are including large amount of data storage and slow computation time. It is always a difficult problem for three-dimensional visualization. In the present project, the focus of the volume rendering synthesis is to define the different gray value of image voxel with different transparency setting. Within different transparency settings, the effect of final displayed image is different.

5 Conclusion
In summary, we have proposed a three dimensional reconstruction for volume rendering using VTK
library. The volume rendering is applicable to multiple organ with CT, MR, or ultrasound scan image reconstruction, it is more beneficial to observe the lesion and the normal organ or tissue between the spatial relationships, and it have a greater significance in practical clinical applications. Findings showed that the system is able to produce promising results.

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References:


