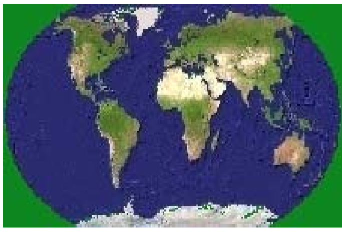

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CT volume rendering

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Abstract

Volume rendering is a set of techniques used to describe and hence represent the visualization of three-dimensional data. Visualizing sampled functions of three spatial dimensions by computing 2-D projections of the entire volume data. Computed Tomography (CT) Volume Rendering, performs rendering of the CT medical data. This paper elaborates the techniques such as maximum intensity projection and shaded surface display that provide added diagnostic capabilities thereby providing much better visualization of the volume data.

The paper also focuses on a new emerging application of the computed tomography volumetric rendering that is 3D CT Volume Rendering. Its implementation involves volume data management including acquisition, resampling and editing, rendering parameters including window width and levels and image display comprising of techniques such as fly-through and fly-around.

Keywords: Volume Rendering, Computed Tomography, Volumetric Data, Three Dimensional Volume Rendering.

1. Introduction

Digital image processing is the use of computer algorithms to perform image processing on digital images. Many of the techniques of digital image processing are medical imaging, character recognition, picture enhancement, etc and extends its role into computer graphics and scientific visualization. In scientific visualization and computer graphics, volume rendering is a set of techniques used to display a 2D projection of a 3D discretely sampled data set. A typical 3D data set is a group of 2D slice images acquired by a CT or MRI scanner [1].

To render a 2D projection of the 3D data set, one first needs to define a camera in space relative to the volume. Also, one needs to define the opacity and color of every voxel. This is usually defined using an RGBA (for red, green, blue, alpha) transfer function that defines the RGBA value for every possible voxel value. For example, a volume may be viewed by extracting isosurfaces i.e. surfaces of equal values, from the volume and rendering them as polygonal meshes or by rendering the volume directly as a block of data [2].

The marching cubes algorithm is a common technique for extracting an isosurface from volume data. The algorithm proceeds through the scalar field, taking eight neighbor locations at a time (thus forming an imaginary cube), then determining the polygon(s) needed to represent the part of the isosurface that passes through this cube. The individual polygons are then fused into the desired surface. This is done by creating an index to a precalculated array of 256 possible polygon configurations ($2^8=256$) within the cube, by treating each of the 8 scalar values as a bit in an 8-bit integer. If the scalar's value is higher than the iso-value (i.e., it is inside the surface) then the appropriate bit is set to one, while if it is lower (outside), it is set to zero. The final value, after all eight scalars are checked, is the actual index to the polygon indices array [3].

2. CT Volume Rendering

Computed Tomography volume rendering performs rendering of CT medical data. Techniques such as maximum intensity projection (MIP), shaded surface display (SSD), volume rendering (VR), and virtual endoscopy (VE) provide added diagnostic capabilities [4]. These techniques permit the exploration of fine anatomical details that would be difficult to evaluate using axial reconstructions alone. These techniques are elaborated as follows:

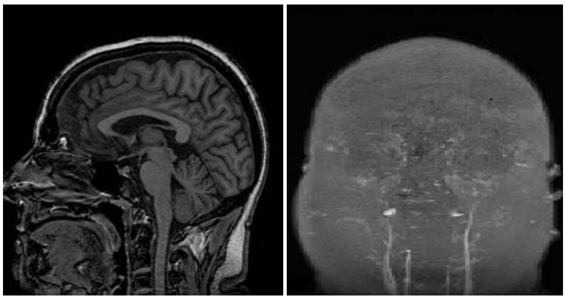
2.1. Maximum Intensity Projection

MIP is a data visualization method that enables detection of highly intense structures. It uses all the data in a volume of interest to generate a single bidimensional image. The MIP algorithm is diagnostically useful because it can readily distinguish structures that are hyperdense with respect to surrounding tissues.

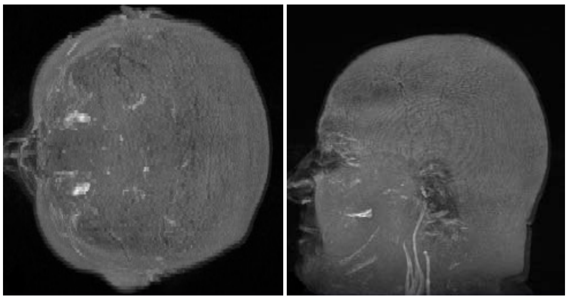
Detecting voxels with higher density enables the radiologist to better understand the extension and morphology of some structures, such as vessels, nodules, calcifications, surgical clips, foreign bodies, etc., and significantly reduces the time needed to analyze complex structures in different planes and with a non-linear course [5]. MIP images have proven to be faster and more sensible than standard viewing of axial images for detecting small lung nodules.

Algorithm:

- Let **I** be an input 3D image.
- Let **X**, **Y,** and **Z** be the output 2D images representing the maximum intensities in *x*, *y*, and *z* directions.
- **X** is a 2D image of size (*y** *z*) formed by viewing along the *x*-axis and selecting the highest intensities in the *y*-*z* plane.
- **Y** image is of size (*x***z*) formed by viewing along the *y*-axis and selecting highest intensities in the *x*-*z* plane.
- Similarly, **Z** image is formed by viewing along the Z axis and selecting highest intensities in the *x*-*y* plane and is of size (*x* * *y*).



(A) Original Image **(B) X-axis**

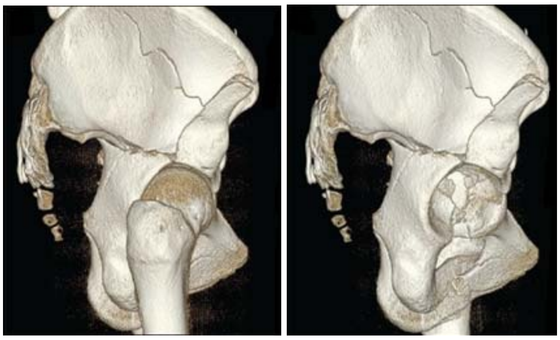


(C) Y-axis **(D) Z-axis**

Fig 1: Application of MIP

2.2. Shaded Surface Display

Shaded surface display volume rendering (SS-VRT) is a technique that creates a 3D visual illustration of CT volumetric data for display from any desired perspective. This technique typically select voxels to be included in a surface rendering based on a selected range of Hounsfield values. By properly choosing the Hounsfield range, different types of tissues can be selected: parenchyma, bone, airways, and vessels. By analyzing a combination of Hounsfield ranges, a volume of CT data can be segmented into several of these tissue types. These techniques then calculate the location of surfaces separating tissue types. The surface information is then used to calculate a perspective visualization based on selectable observer position and light source positioning (ray-tracing techniques).



(A) Original Image (B) Image after SSD

Fig 2: Application of SSD

2.3. Curved plane reconstruction

Curved plane reconstructions are a subcategory of multi-planar reconstructions. Instead of representing a plane oriented in one specific direction, they display all voxels contained in a user-selectable curved surface as a single bidimensional image.

This technique is particularly apt for study of the vascular system. It is used to display a winding vessel as a straight line and thereby facilitates the identification of vascular defects, stenoses, and dilations. It is also well suited to depict the winding course of the mandibular canal, along with the nearby structures, in dental applications. This method is often used to obtain zoomed images that are cut perpendicularly to the canal course, depicting dental roots, and their relationship with the mandibular nerve [6].

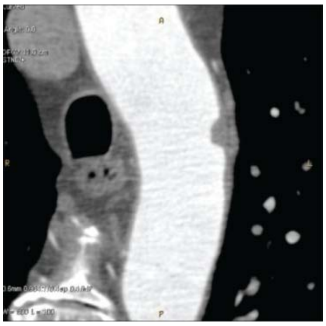


Fig 3: Curved Plane Reconstruction

3. 3D Volume Rendering

Three-dimensional medical images of computed tomographic data sets can be generated with a variety of computer algorithms. An understanding of both the theory and method of 3D volume rendering is essential for accurate evaluation of the resulting images. 3D volume rendering is useful in a wide variety of applications and medical imaging.

Three dimensional CTVR is a solution to a greater range of problems. One great advantage is that it provides all the necessary information in a single radiologic study in cases that previously required multiple studies. Without extensive editing, 3D CTVR provides clinically accurate and immediate images from full CT data [7].

Implementation of 3D volume rendering involves volume data management, rendering parameters and image display.

3.1 Volume Data Management

Data management relates to operations including acquisition, resampling and editing of data set. Data movement and formatting have direct implications for utility of 3D volume rendering. Its goal is to maintain the fidelity and usefulness of patient data and to make it more interactive. It can reduce both, the computing overhead and increase real-time interactivity by conforming the volume data set to the capabilities of a particular computer platform.

3.2 Rendering Parameters

Rendering parameters are applied to the full volume data set and affect the appearance of the image to be displayed. The window width and level functions are similar to windowing parameter settings on standard CT scanners or workstations [8].

Opacity and brightness are unique functions of 3D rendering that allow the user to selectively reveal the structures that would otherwise be obscured. The percentage classifier combines these functions with the color function and enables more discrete interactions with volume data set.

3.3 Image Display

Image display relates to the process by which a 3D representation of a volume data set is flattened onto one or more 2D planes and to how the resulting images are made accessible to the user. A well designed user interface enables to interact dynamically with images of volume represented in computer memory [9]. Higher level functionalities of 3D volume rendering workstations include methods for ‘flying-through’ and ‘flying-around’ the volume, displaying multiple views and representing depth in a volume.

A **Fly-Through** function reproduces the complex rotation, required for an extended camera shot. The computations that guide the motion of a robot controlled camera sweeping over a scale model also guide the dynamic point of view representing a virtual volume. Rendering parameters are determined for each discrete point defined on the curve, and each sequential image represents a single use of general routines for 2D projection from the 3D volume. The fly-through function has proven useful in clinical applications such as virtual endoscopy, evaluation of stent placement and robot-assisted surgery.

The **Fly-Around** is a function that can effectively isolate a structure within a volume for protracted viewing. The interface requires that the user first places an anchor point of interest within the volume. The distance from the region can be adjusted and, the clip plane and perspective are also variable [10]. The image projected on the display represents a view from the surface of a sphere that has the region of interest at its center. This function of volume data has proven useful for evaluation of complex local anatomy such as carotid artery stenosis and vascular anomalies.

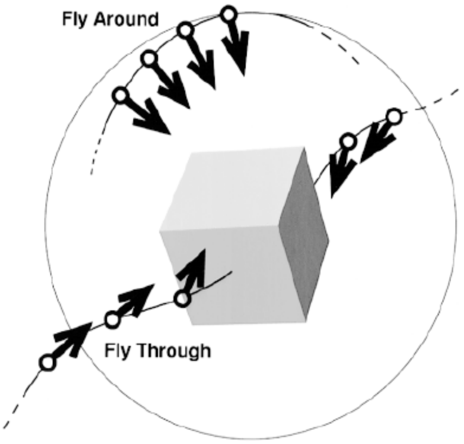


Fig 4: Fly-through and Fly-around

4. Concluding Remarks

Volume rendering is a flexible, accurate and highly efficient 3D imaging technique that can aid help to the medical field and medical applications to more effectively interpret the large volumes of data generated by modern CT scanners. It is a group of 3D image processing techniques and methods with highly improved applications for various CT clinical fields such as high resolution vascular image diagnosis, craniofacial anomalies, etc. The ability to review CT image data in three dimensions facilitates an understanding of the normal anatomy and helps characterize the scope of pathological processes in this field.

To obtain accurate results, however, one must understand the effect of data acquisition, volume data management, rendering, image display and parameter selection on the resulting image. Thus with the availability of such set of rendering techniques that can support 3D CT volume rendering, many new clinical applications can be developed along with the modernization and improvement of the existing ones, thereby innovating us with such an emerging promising technology.

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