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3-D Visualization Techniques for Medical Images: A Comprehensive Study

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ABSTRACT: 3D visualization of medical images refers to the generation of a 3-D representation of examined structure from a series of 2-D slices. 3-D visualization results provide anatomy information that can't be extracted by traditional methods. There are two basic techniques of 3-D visualization namely indirect volume rendering or surface rendering and direct volume rendering. In this paper, a detailed study and evaluation of these rendering techniques is done to facilitate efficient 3-D visualization for better qualitative and quantitative analysis.

KEYWORDS: Surface Rendering, Volume Rendering, Marching Cubes, Ray Casting, Splatting, Shear Warp

I. INTRODUCTION

3-D visualization is an important area of medical image processing because of its huge application in medical diseases diagnosis. The use of 3-D visualization techniques makes direct inspection of the human anatomy in three dimensional visualization feasible and hence facilitates the extraction of quantitative and qualitative information from medical images. All the recent techniques for 3-D visualization of medical images create 3D images from stack of 2D slices. These slices can be recorded by any of the various equipments such as CT, MRI, ultrasound etc. Each type of device has its own characteristics due to the physical principles of image recording for e.g. images of CT scanner are usualy parallel slices with high contrast whereas images of ultrasound scanner may either be parallel or divergent slices with low contrast. The visualization technique to be used depends on the type of data. 3-D visualization is the second step of the two stage 3-D reconstruction process which first involves the arrangement of the 2-D slices exactly with real spatial positions. This results in a data volume. Rendering techniques are then used for 3-D visualization.

II. LITERATURE SURVEY: AVAILABLE TECHNIQUES

There are two basic techniques for 3-D visualization namely Indirect Volume rendering and Direct Volume rendering. A further classification of these techniques is done (Figure 1).

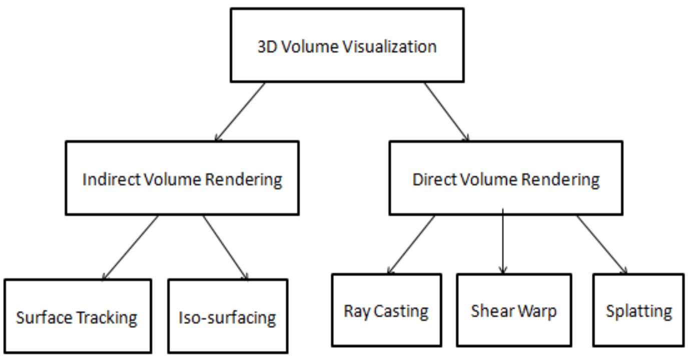

Figure 1: Techniques for 3-D visualization

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(i)Indirect Volume Rendering

Indirect Volume rendering is also known as surface rendering because it generates a geometric surface before rendering the 3-D data. The process consists of classifying each voxel within a volume as belonging to or not to the object being rendered. Identifying all the pixels belonging to an object describes the object surface. It is then modeled as a collection of polygons and displayed with surface shading. Surface rendering algorithms can be classified into two categories:

(a)Surface Tracking: It constructs a geometric surface from a data volume by following the voxel faces residing on the surface boundary. This boundary is defined either by thresholding classification or by surface detection process. A closed contour is traced for each data slice for a given threshold value. The contours in adjacent slices are connected and a tessellation of triangles is performed (Figure 2).

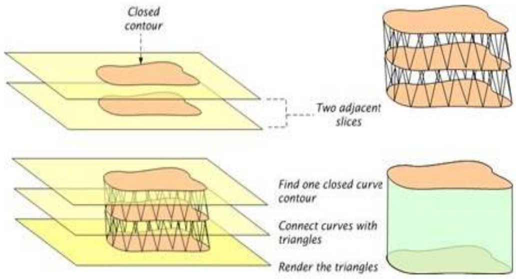

Figure2: Contour tracing

(b)Iso-surfacing: An isosurface is a 3D surface representation of points with equal values in a 3D data distribution. An isosurface can be used to represent all voxels in an image with a given co-localization level. A 3-D surface is formed by joining these points. The most common iso-surfacing algorithm is Marching Cubes. It uses a divide and conquer approach to locate the surface in a logical cube formed by eight pixels, four each from two adjacent slices. The algorithm works by finding out how the surface intersects this cube and then moves on to the next cube. If the value at a cube vertex exceeds or equals the value of surface being constructed, it receives a one. Such vertices are inside or on the surface. Vertices of the cube which have values below the surface are assigned a zero and are outside the surface. The surface is supposed to intersect those cube edges which have one vertex inside the surface and other outside the surface. Since there are 8 vertices in each cube and 2 states, inside and outside, a surface can intersect the cube in only 2^8=256 ways. All these cases can be generalized in 15 families (Figure 3) by rotations and symmetries.

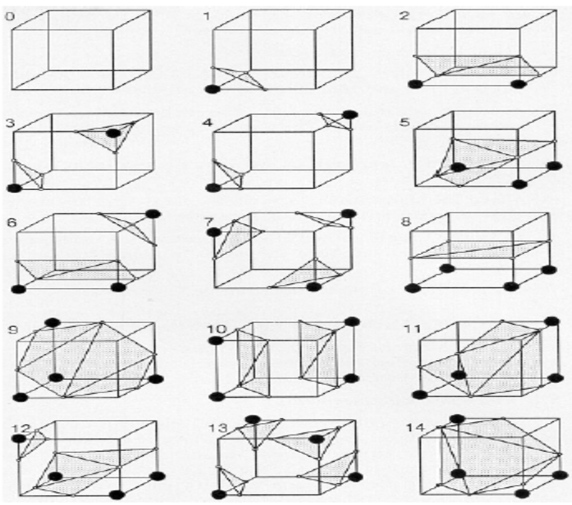

Figure 3: Triangulated Cubes

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(ii)Direct Volume Rendering

The basic idea of Direct Volume Rendering is to get a 3D representation of the volume data directly. It displays the entire 3D dataset by tracing rays through the volume and projecting onto a 2D image, without computing any intermediate geometry representations. The approaches in DVR are based on the laws of physics (emission, absorption, scattering). The volume data is used as a whole. The main advantage of direct volume rendering is its ability to preserve the integrity of the original data throughout the visualization process. The main techniques of direct volume rendering are:

(a)Ray Casting: Rays are cast from the view-point into the volume through the view-plane. Along their way through the volume, data are defined at the corners of each voxel. At evenly spaced intervals along the ray, sample values are computed using trilinear interpolation within a cell of eight voxels (Figure 4). A local gradient is combined with a local illumination model at each sample point to provide a realistic shading of the object. Final pixel values are found by compositing the colour and opacity values along the ray.

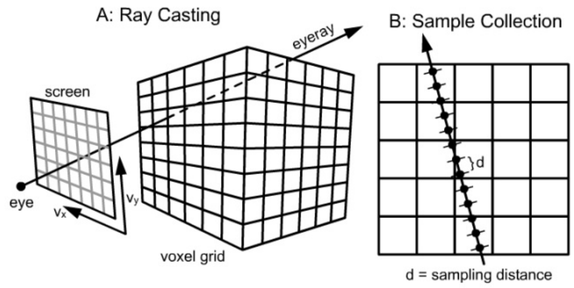

Figure 4: Sample collection after Ray cast in data volume

(b)Shear Warp: Shear Warp is the fastest volume renderer. This is achieved by performing a run length encoding (RLE) compression of the volume to allow a fast streaming through the volume data. It uses object order and image order traversal simultaneously, thus combining their advantages, to rapidly splat entire slices of volume onto image plane. Firstly, the volume data is transformed into sheared object space by translation and resampling each slice. The resampled slices are composited together in front to back order. This projects the volume into a 2D intermediate image in sheared object space. The intermediate image is then transformed to image space by warping (Figure 5).

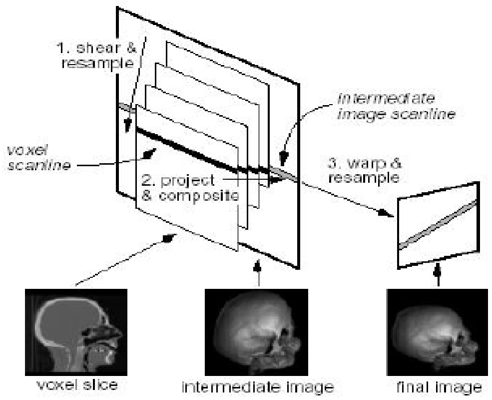

Figure 4: Process of Shear Warp

(c)Splatting: Splatting is an object order method that distributes volume data values across a region on the rendered image in terms of a distribution function. The basic idea of splatting is to project each sample (voxel) from the volume onto the image plane, which can be understood in such a way that each voxel is thrown on a plane and leaves it's footprint on it. For each thrown voxel we have to compute, which part of the image plane could be included (Figure

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5).The voxels are represented by 3D reconstruction kernels, with amplitudes scaled by the voxel values. Footprints, are formed as a result of integration of these kernels along the line of sight. These footprints on the drawing plane represent the visualization. The size and shape of kernel is critical for the quality of result. The compositing process can either be done back to front or front to back. Front to back compositing is faster whereas back to front compositing guarantees correct visibility.

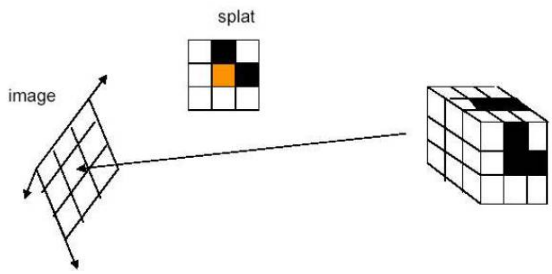

Figure 5: Splatting throws voxels on the image plane

III. CONCLUSION AND DISCUSSION

We have studied the various rendering algorithms. Each has its own advantages as well as limitations. Surface rendering algorithms operate very rapidly on modern computers because they reduce original data volume to a compact surface model. They, however, suffer from a very serious drawback of providing poor imaging fidelity. Volume rendering, on the other hand, produces high quality images, hyper realism unmatched by surface rendering. It provides physically realistic depiction of volume data. But it is difficult to find good transfer function to depict volume samples. Also, the computational cost is high and 3D relationships in very transparent volume rendered images cannot be depicted properly. Ray casting produces images of highest quality but is not an interactive technique. The major advantage of splatting that only voxels relevant to image are projected and rasterized. This reduces the volume data that needs to be processed and stored. Shear Warp generates images of data volumes at interactive frame rates. Thus we conclude that keeping in view the advantages and limitations of each of the rendering techniques, they can be used for 3-D visualization of medical images as per requirement.

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