Ray Casting for 3D Rendering – A Review

Dr.M.Mohamed Sathik
Principal
Sadakthullah Appa College, Tirunelveli, Tamilnadu, India

R.Mehaboobathunnisa
Research Dept. of Computer Science
Sadakthullah Appa College, Tirunelveli, Tamilnadu, India

A.A.Haseena Thasneem
Research Dept. of Computer Science
Sadakthullah Appa College, Tirunelveli, Tamilnadu, India

Dr.S.Arumugam
Principal
Nandha Engineering College, Erode, Tamilnadu, India

Abstract – 3D modeling of images provide better visualization in all aspects. Medical data, which is available in CT or MRI slices shall be composited to render the 3D view. This makes diagnosis more accurate. Researchers have come up with many techniques for 3D visualization of medical dataRay casting is one such where rays are "pushed through" the object and the 3D scalar field of interest is sampled along the ray inside the object. The focus of this paper is the Ray casting method for 3D rendering and some of its issues and improvements over years.

Keywords: 3D Reconstruction, Direct volume rendering, Ray Casting

I. INTRODUCTION

Image analysis and diagnosis is always an inevitable part in the medical field. Human anatomies are visualized using many modalities from the older X-rays to the recent MRI and others. All of these techniques capture the 2D view of the internal organs. It is the doctors, who mentally interpret these 2D images into 3D volumes for their analysis. Better diagnosis results from the availability of 3D images than from 2D.

The advent of research in image processing has introduced many algorithms for converting sequence of 2D data into 3D. These algorithms generate the 3D view in two steps - converting the 2D data into 3D volume data and then rendering it for visualization. Several works have been reported in both the streams and the focus of this paper is on the second step of 3D reconstruction. The techniques for volume rendering come under two broad categories – Indirect volume rendering or Surface rendering and Direct volume rendering. The indirect volume rendering methods generate a geometric surface prior to rendering the 3D data and hence called Surface rendering. Direct rendering methods involve no such intermediate surfaces. They directly render the volume image from the 3D data. Some of the direct volume rendering techniques are ray casting, shear warp and splatting. This paper reviews the widely used ray casting technique of volume rendering and a few of its enhancements.

II. DIRECT VOLUME RENDERING

A. The earliest and easily implementable direct volume rendering method was proposed in [1]. The technique works by shooting a ray through an image plane into the 3D volume and determines the accumulated color of a few equidistant sample voxels via which the ray traverses. The formulae for color and opacity computation are given in (1) and (2) respectively.

$$C_{out} = C_{now}(1- \alpha_{in}) + C_{in} \qquad (1)$$
$$\alpha_{out} = \alpha_{now}(1- \alpha_{in}) + \alpha_{in} \qquad (2)$$

where C_{out} is the output color

C_{in} is the accumulated color

C_{now} is the current voxel's color
α is the opacity factor

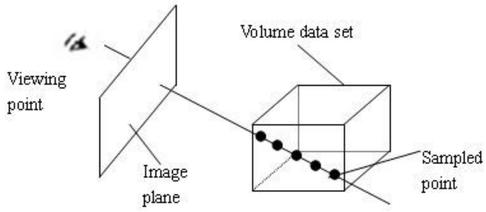
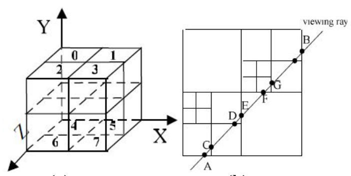


Figure 1. Ray Casting scheme

Resampling is performed within the equidistant samples using trilineaar interpolation to further increase the rendering quality. Inspite of its simplicity and efficiency, this technique is so straightforward that it processes all the voxels irrespective of their contribution and thus consumes more time. Many worked to increase the rendering speed in several ways and a few improvements are discussed below.

B. Gong and Wang in [2] have proposed an accelerative ray casting algorithm to overcome the problem of slower image rendering of the basic ray casting technique. The crossing area technique uses a bounding box and octree data structures to cut and compress volume data respectively. The process of linear octree is as such: choose a color threshold E_1.The cut volume dataset is considered the root node of octree represented by 0.The state of root node might be any of the three states, Full (F),Partial (P),Empty (E).F implies similar color value for all pixels, P implies similar color value for some pixels, and E represents empty nodes. Divide the node into eight squares and code it as 0, 1,2,3,4,5,6,7 as in Figure.2(a). Leaf nodes with same color and empty nodes are omitted from resampling thus avoiding duplication, trilinear interpolation and ray compositing operations. Resampling process computes the intersection A,B between the viewing ray and bounding box and distance between them are calculated. Adjacent nodes are found along the ray starting from node A recursively as in Figure.2(b) The octree coding uses the six sets of neighborhood nodes defined as Northern set N={0,1,4,5},Southern Set S={2,3,6,7},Western Set W={0,2,4,6},Eastern Set E={1,3,5,7},Up Set U={0,1,2,3},and Down Set D={4,5,6,7} for judging the neighborhood.



(a) (b)

Figure 2. (a) Octree Encoding (b) sampling method

Average rendering time and image quality are the criterion used for comparison and analysis and it depends mainly on the chosen color threshold value.

C. The algorithm in [3] improves the classic ray casting in a variety of ways. It first extracts the foreground voxels from the background using an appropriate threshold. The foreground voxels are resampled by the joined application of nearest neighbor interpolation and trilinear interpolation for more detailed display. The optical factor (opacity) in traditional ray casting is assigned to voxels using a simple transform function with one freedom degree even before resampling is done. This results in a poor opacity value and when low pass filter is applied during resampling, the visual quality gets degraded. This is rectified using a method involving a multi degree freedom and multi factor of the form (3) to determine opacity, C(x).

$$C(x) = t_1 f(x) + t_2 D_1(x) + t_3 D_2(x) \qquad (3)$$

where f(x) – resample value

t_1, t_2, t_3 – weight factors such that $t_1 + t_2 + t_3 = 1$

D_1 – Euclidean distance between the resample and viewpoint

D_2 – Euclidean distance between the resample and lightsource

As the equation (3) implies, this technique considers the distance between the resample and both the viewpoint and the lightsource individually for opacity and thus ensures higher quality. The background voxels are rendered at the same time using a very fast space leaping resampling, thus generating the 3D view of the whole volume data at a greater speed.

D. Another paper which deals with the shortcomings of traditional Ray Casting has been reported in [4]. Here, the re-sampling speed and the efficiency of ray casting are improved by taking advantage of segment composition method. Using the bounding box technique, the 3D data field alone is extracted. Instead of determining the intersection of the ray with all the planes (slices), only those planes with the highest vertical extent along the ray direction are considered for intersection. Thus the projection ray is fragmented, which implies sampling points between two adjacent planes have similar optical properties. This segment composition reduces the number of trilinear interpolation required. The fundamental equation (1) and (2) for calculmmating the color and opacity of each point has been rewritten as:

$$C_{out}=C_{now}(1-\alpha_{in})\sum_{k=0}^{n_i-1}(1-\alpha_{now})^k+C_{in} \quad (4)$$

$$\alpha_{out}=\alpha_{now}(1-\alpha_{in})\sum_{k=0}^{n_i-1}(1-\alpha_{now})^k+\alpha_{in} \quad (5)$$

where,

n_i =length of the segment.

The term $\sum_{k=0}^{n_i-1}(1-\alpha_{now})^k$ implies the significance of fragment based rendering.

E. The high computation time of the classic ray casting algorithm is reduced by compacting the 3D data within a bounding box. There are possibilities of increased overhead when the 3D data are not evenly distributed and hence the bounding box numbers may increase as a result. [5] proposed another accelerating algorithm using the ray correlation technique. Voxels which do not contribute to volume rendering are considered as empty voxels and others as non empty or opaque. Whenever a ray strikes an empty voxel, it is forwarded to the nearest voxel using the incremental step as in (6).

P(x,y,z) represents empty voxel coordinates and (x_L, y_L, z_L) represents ray vector.

$$\text{Ray step length } d = |x_L| + |y_L| + |z_L| \quad (6)$$

The ray advance step at P(x,y,z) , is

$$N=\frac{D_P}{d} \quad (7)$$

where D_P represents minimum distance

The coordinates of $P'(x', y', z')$ from P is

$$x' = x + x_L.N,$$
$$y' = y + y_L.N$$
$$z' = z + z_L.N$$

Each jump increment is determined by (8).

$$\Delta x = x' - x, \Delta y = y' - y, \Delta z = z' - z \quad (8)$$

The process is repeated until a nonempty voxel is reached. Since empty voxels are skipped in the process, it is referred as a space leaping technique. Even though the speed of rendering has been increased considerably in this method, the image is not as smooth as the traditional algorithm.

F. In addition to the improvements made in the classic ray casting technique, a few variants of it are also available [6] which work at a better speed. They are Maximum Intensity Projection(MIP) and Local Maximum Intensity Projection(LMIP). These techniques project the voxel characteristics into a projection plane. As the names mean, the MIP technique projects only the voxel with maximum intensity along its direction. This suits better to render the high intensity structures from the volume data.

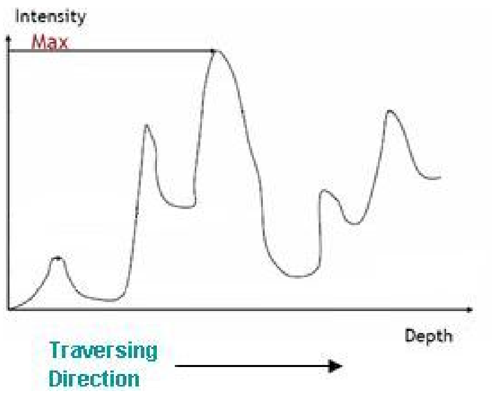


Figure 3. MIP technique

The LMIP, an extension to MIP technique fixes a threshold and projects the first hit voxel with greater intensity than the threshold. LMIP is direction specific.

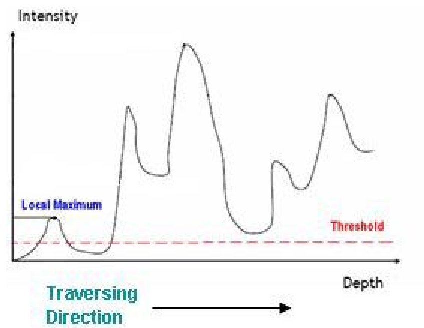


Figure 4. LMIP technique

Another difference between these two techniques and ray casting is that MIP and LMIP project the volume data into the projection plane whereas the ray casting method shoots rays from the image plane to record the colors in the volume data. Hence the former is referred to as object order method and the later as image order method.

III. DISCUSSION

Although each of the volume rendering methods produce results of their own kind, some issues still remain unresolved. The opacity factor taken into account by the ray casting technique is purely an assumption based calculation and does not match with that of the human eye perception, thus compromises with quality to some extent.

REFERENCES

[1] Marc Levoy, " Display of surfaces from volume data", Journal on Computer graphics and applications, IEEE 1988.

[2] Faming Gong, Hongnan Wang," An Accelerative ray casting algorithm based on crossing-area technique", International Conference on Machine Vision and Human-machine Interface,2010.

[3] Yun tian, ming-quan zhou, zhong-ke wu, "A rendering algorithm based on ray-casting for medical images", Proc.of Intl. Conf. on Machine Learning and Cybernetics, 2008.

[4] Tao Ling, Qian Zhi-Yu,"An Improved Fast Ray Casting Volume Rendering Algorithm of Medical Image" , 4th International Conference on Biomedical Engineering and Informatics, IEEE 2011.

[5] Yu Shicai,Wu Qianjun,Lu Rong,"An high efficient and speed algorithm of ray casting in volume rendering", IEEE 2011.

[6] Thean Wui Ooi, Haidi Ibrahim, Kenny Kal Vin Toh, "Implementation of Several Rendering and Volume Rotation Methods for Volume Rendering of 3D Medical Dataset", Proceedings of the 2008 IEEE Conference on Innovative Technologies in Intelligent Systems and Industrial Applications Malaysia, 2008.