

# An Efficient Virtual Endoscopy System for Stereotactic NeuroNavigation

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**Abstract**— Virtual endoscopy has been used in visualizing human organs such as colons, bronchi and rectums. However it has not been widely applied to the stereotactic neurosurgery. In this research, we have developed an efficient 3D medical imaging system to support stereotactic neurosurgery planning. This system focused on visualizing internal structures of human skull using multimodal images transferred from PACS. We used hybrid volume rendering method with several acceleration techniques and spatial data structures for fast volume data traversal. Our preliminary evaluation study reveals that this system not only provide endoscopic view of internal organ, but helps us to determine the accuracy of surgical path.

**Index Terms**—Virtual Endoscopy, Direct Volume Rendering.

## I. INTRODUCTION

Virtual endoscopy is a non-invasive surgical treatment, which visualize the internal structure of a patient using CT and MRI data. Nowadays, the research on virtual endoscopy is focused on 3D visualization of pipe-like structures such as gullet, colons, bronchi and rectums. In this research, we applied virtual endoscopy technique to the stereotactic neurosurgery, visualizing blood vessels, skin, bone and other brain structures. It helps us to determine the optimal surgical path and guarantees the surgical precision

Stereotactic neurosurgery is a kind of non-invasive surgical method in neurosurgery, which uses CT and MRI data set to minimize the injury to the normal brain. Current stereotactic neurosurgery planning systems focus on the visualization of external structures such as skin and bone. However, it is more important to visualize the internal structures like blood vessels and tumors, and perceive the relative position of these structures. Virtual endoscopy provides endoscopic view of inside of skull and could be stretched to the image-guided neurosurgery application. Unfortunately we could not directly use the well-known acceleration techniques for rendering, since the methods mostly take advantages of the coherence of the volume data

and the image plane. In virtual endoscopy, it's hard to decide which part of volume will be projected to the image plane and endoscopic views should be generated by perspective projection. These characteristics restrict the coherence acceleration techniques being used in virtual endoscopy. The polygonal rendering method is suitable for iso-surface rendering, but not appropriate for multi-structure rendering in our research.

We can get near-realtime endoscopic views using direct volume rendering of perspective projection. In order for near-realtime rendering, we exploited some spatial data structures and preprocessing techniques.

In the following, Section 2 gives a detailed description of our virtual endoscopy system, and then in Section 3 we will present the experimental result and conclude our works in section 4.

## II. VIRTUAL ENDOSCOPY SYSTEM

### A. Overview of Virtual Endoscopy System

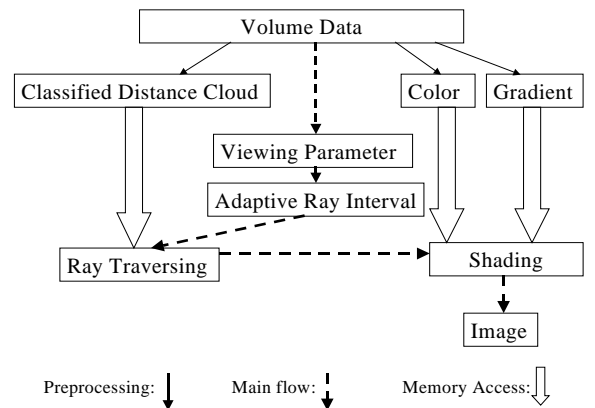


Figure 1. Overview of the virtual endoscopy system

### B. Transmission of Volume Data Using PACS

The CT and MRI data are stored in PACS server via ethernet, and virtual endoscopy system acquires data from the PACS server and generate 3D volume to be visualized.

### C. Preprocessing

The preprocessing of volume data could be divided into three procedures. The first is classification operation of data values using anatomical features. This is based on the fact that different structures such as skin, bone and blood vessels have different intensity, gradient and approximate spatial position. The second is distance transformation and distance cloud generation, which aimed for enhancing the ray traversal speed. Distance cloud is a special data structure in which every voxel contains the length to the nearest boundary. Figure2 depicts the two dimensional representation of a distance cloud. The third is to compute gradient and color value of each boundary voxel. The gradient values could be easily calculated from central difference method and the color values are calculated from dot product of gradient and light vector using Phong Shading method.

3	2	2	2	2	2	2	2	2	2	3	
3	2	1	1	1	1	1	1	1	2	3	
2	2	1	0	0	0	0	0	1	2	2	
2	1	1	0	1	1	1	1	0	1	2	
2	1	0	1	1	2	2	1	1	0	1	2
2	1	0	1	2	2	2	2	1	0	1	2
2	1	0	1	1	1	2	2	1	0	1	2
2	1	1	0	0	1	2	2	1	0	1	2
2	2	1	1	0	1	1	1	1	0	1	2
3	2	2	1	0	0	0	0	0	1	1	2
3	3	2	1	1	1	1	1	1	1	2	2
4	3	2	2	2	2	2	2	2	2	2	3

Figure 2. 2D representation of distance map

### D. Accelerated Ray Casting Based on Adaptive Ray Sampling

Once given the viewpoint, the viewing direction and the image plane, we can easily compute the parameters needed for the ray casting. Since the endoscopic view is a perspective projection, each ray passing through the image plane has different direction. We consider the three dimensional volume data as a cube and compute the intersection point of the ray and the cube. There may be one or two intersection points between the ray and the cube. In our research, we only take into account the case of one intersection point, since the endoscopic viewpoint is inside the volume. Rays are shot from the viewpoint, and read the value of the distance cloud at each sampling point. If the value of distance cloud is higher than 0, ray moves forward by ray interval. If the value is 0, which means the sampling point is at the boundary of surface, we get the color and opacity value from the classified volume and render the pixel. In this way, we can reduce the ray sampling rates.

Nevertheless, if the ray interval is 1 unit distance for all rays, like most ray casting method, it may decrease the acceleration performance of distance cloud. Figure3 shows the inefficiency of constant interval ray casting.

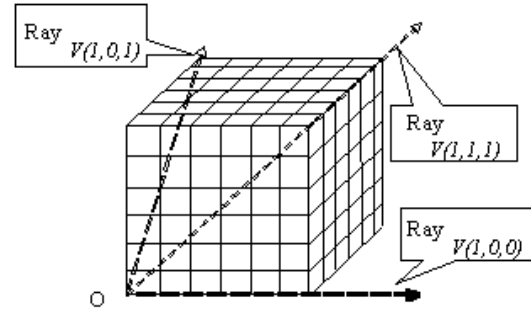


Figure3. The necessity of adaptive interval based ray casting

In figure3, we assume that the distance cloud value of point O is 7, which means there is no boundary voxel in this 6\*6\*6 sub-volume. But the traversal time of rays is different by their directions. The ray V(1,0,0) escapes the sub-volume after one sampling time step, while the ray V(1,0,1) and V(1,1,1) need two or more sampling time slots to escape from the sub-volume. In order to rectify this kind of inefficiency we applied an adaptive ray interval method in which the ray interval is dependent on the ray direction. For example, the interval of ray V(1,0,0) is 1, V(1,0,1) is 1.414 and V(1,1,1) is 1.732. We have minimized the ray sampling rates by the ray casting based on adaptive ray sampling.

### E. Opacity accumulation and shading

If the sampling point is at the boundary of the surface, the algorithm reads the color and gradient value from the classified volume. Then calculate the opacity value from the gradient and composite the color and opacity using equation1. When the opacity is accumulated to some threshold value, stops the ray casting and fires the next ray.

$$final\_Color = C_1 O_1 + .C_2 (1 - O_1) \quad (1)$$

## III. EXPERIMENTAL RESULTS

The platform is 300MHz Pentium PC with Windows operating system. The data used in the experiment is for human head of which the size is 256\*256\*225 byte. The rendering time of the endoscopic image differs by the viewpoint, but for the worst case it is not more than 1.3 second. Table1 indicates the rendering time by the viewpoint. Figure4 and figure5 are sample endoscopic images rendered from the experiment.

	Viewpoint	Viewing direction	Time(ms)
Nasal cavity	$O(138,102,108)$	$V(-11,-34,-2)$	736
Spine	$O(156,133,104)$	$V(39,5,,7)$	831
Skull	$O(94,148,106)$	$V(-23,-60,-12)$	1372

Table 1. Rendering time of different viewpoints

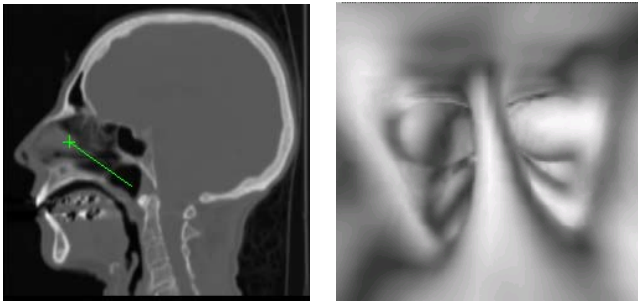


Figure 4. Endoscopic view of nasal cavity

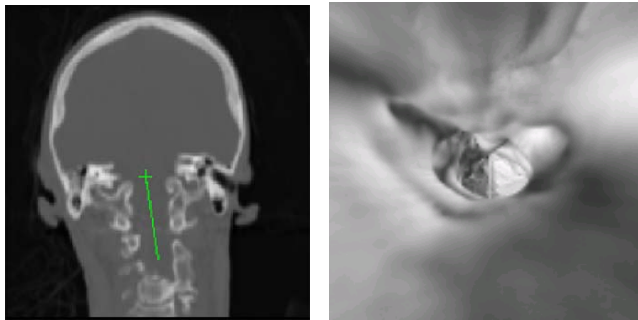


Figure 5. Endoscopic view of spine

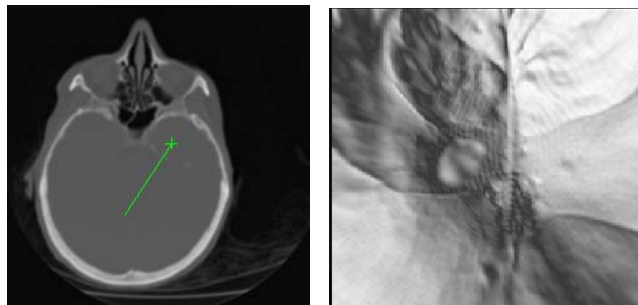


Figure 6. Endoscopic view of skull

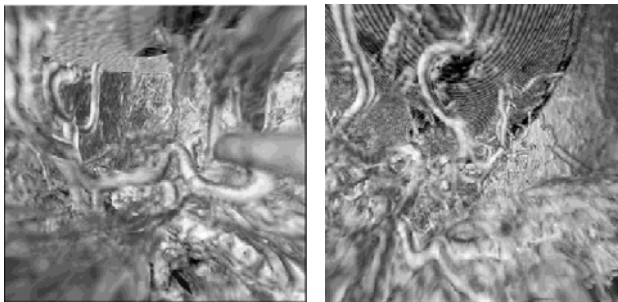


Figure 6. Endoscopic view of blood vessels

#### IV. CONCLUSIONS AND FUTURE WORKS

In our system, we provided endoscopic view of the anatomical structures in brain using CT and MRI slice data, which helps to determine the relative spatial position of different structures in the surgical path. We present an efficient virtual endoscopy method using perspective ray casting. A distance map data structure is used to accelerate rendering speed. We also provide an adaptive ray interval scheme in traversing through the distance map. An image coherency between successive images is considered in rendering rotational images. Experimental result shows that

our method is efficient in rendering endoscopic images both in image quality and rendering speed. Which meets the semi-real time visualization of internal human organs.

The future work is to find out more efficient and accurate classification method and to provide the realistic endoscopic view applying deformation and stereoscopic methods.

#### REFERENCES

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