Hybrid Focal Region-Based Volume Rendering of Medical Data

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Abstract In this paper we advocate the use of a hybrid focal region-based volume renderer that offers an alternative for visualization of internal structures of medical image data. We describe this promising technique for communicating the first impression of object shape, while at the same time providing detailed information of volumetric data with the use of a lens-like focal region. This is to better communicate the existence, form, and location of underlying targets while minimally occluding them.

1 Introduction

Recent developments in image modalities, such as Multislice-Spiral CT in medical imaging, have led to a substantial increase in resolution in slice direction. On the other hand, the structure of interest (tumours, lesions, etc.) occupies a percentage which is often below 10% of all voxels. In practical applications, the large number of slices per study require fast, versatile and efficient methods for reducing the data for information extraction. However, the analysis of such structures needs context information like locations within a specific organ or nearness to sensitive structures (nerves, vessels). All these require an alternative rendering approach which integrates both: on the one hand, focusing on a specific structure and, on the other hand, context information.

In this paper, we propose a new approach to volume rendering: *Hybrid Focal Region-Based Volume Rendering* (*HFRBVR*). We describe this technique for communicating the first impression of object shape or contour while at the same time providing detailed information of volume data with the use of lens-like focal region. Inspired by the nonphotorealistic rendering (NPR) to define an object with just a few contour lines with less redundant information, we designed a method for generating object contours of the volume data to depict context information out of focal region. In the focal region, we render interesting volume data using a direct volume rendering method. The connection between the structure of inside of focal region and outside of focal region gave a better understanding of spatial relationship.

2 Related Work

Recently, nonphotorealistic rendering, which originally has been used for computer graphics in general, has been proposed for volume rendering [1, 2, 3], definitely extending the abilities for the investigation of 3D data. Rheingans [2] introduced the volume illustration approach to enhance important features (boundary enhancement, sketch lines, etc.) using nonphotorealistic rendering techniques. Hauser [1] presented a two-level volume rendering to allow for selectively combining different rendering techniques for different objects within a common data set. Csebfalvi [3] developed an

NPR technique for volumetric data to visualize object contours depending on the magnitude of gradient information. Although all these approaches can provide promising visualization results to some degree, they all lack in providing volume of details and context information at the same time and thus lack a flexible understanding of volumetric data.

3 Approach

In this section, we will present our hybrid focal region-based volume rendering approach which combines nonphotorealistic rendering and volume rendering into one renderer to investigate volumetric data.

3.1 Outline of HFRBVR

The *hybrid focal region-based volume rendering (HFRBVR)* approach uses a lens-like geometry to divide volumetric data into two parts: in the focal region and out of the focal region. Because the volumetric data in the focal region is the main area of interest, it is rendered with DVR or surface rendering. The area out of the focal region, which is rendered to show volume context information, is rendered with nonphotorealistic rendering (e.g. contours, silhouettes). Fig. 1 shows the main idea of HFRBVR.

3.2 NPR for Volumetric Data

For a full depiction of 3D objects, contour lines are particularly important in the perception of surface shape and have been utilized in surface illustration and surface visualization rendering. Similarly, contour volumes increase the perception of volumetric features. Our approach sets up aN NPR model which is used to render the contours of the objects within the volumetric data set out of the focal region.

Model for Contour Volumes The nonphotorealistic rendering model for contour volumes can be expressed as:

$$I(P,V) = WF(\nabla(P)) \cdot W(P,V) \cdot DepthW(P) \tag{1}$$

where P is voxel position, V is viewing direction, *I(P,V)* is the intensity at the voxel position P, *WF(* ∇*(P)* is the windowing function for the gradient at P as indicated in Fig. 2 and is used to determine the range of interest in the domain of gradient magnitude, *W(P,V)* is used to introduce the viewing direction into the model and gives high weights to the voxels which belong to an object contour, *DepthW(P)* is the depth-weighted coefficient at P and is introduced to overcome the limitation of MIP, which can not depict depth cueing of objects and is used later for compositing the image.

Viewing Weight In order to strengthen the features provided by contour volumes, we set up a weighting function which enhances the intensity of volume samples where the

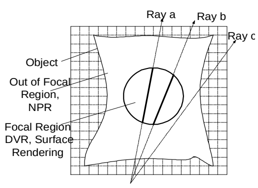

Fig. 1. Outline of Hybrid Focal Region-based Volume Rendering

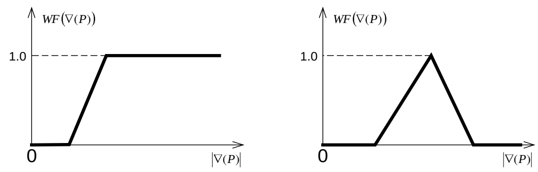

Fig. 2. Different Windowing Functions

gradient direction is almost perpendicular to the viewing direction, indicated by a dot product between gradient and viewing direction which nears zero (Fig. 3). This weighting function is:

$$W(P,V) = \left(1 - k\left|\hat{\nabla}(P) \bullet V\right|\right)^n \tag{2}$$

where n is the exponent which controls the sharpness of the contour lines, k is used to control the effect of viewing direction, $\hat{\nabla}(P)$ is the normalized gradient direction at P.

Depth Weight Using depth-weighted coefficient *DepthW(P)* is originated as an intuitive view of the natural visual characteristics that are evident when envisioning sight as a group of progressive planes. This scenario gives the front visual plane the greatest intensity and gives diminishing intensity to planes as they go into the distance. Depth-weighted coefficient *DepthW(P)* of intensity can be modelled as:

$$DepthW(P) = \frac{d_{\max} - d_i}{d_{\max}} \tag{3}$$

where d_{max} is the distance from the first plane to last plane, d_i is the distance between the first plane and the i plane.

3.3 Combining NPR with DVR

After creating the intensity of each sample position along a viewing ray, an image is produced in a compositing step by our depth-based maximum intensity projection or alpha blending to show context information. The focal region can be obtained with ray-bounded DVR. The idea is shown in Fig. 4. As shown in Fig. 4, only the bounded thick parts of rays are traversed during ray casting, and thus we only render the volumetric data in the focal region, instead of all of the volumetric data. In the final step, we have a rendering mixture of NPR and DVR. The use of a Z-buffer algorithm to solve this mixture problem is straightforward. In our approach, the contour lines for context of focal region are rendered first. Subsequently, the focal region is rendered with DVR. This is rendered in front-to-back order. In this way the correct depth ordering of all contributing entities is preserved and the use of the over operator to composite them creates correct colors in the final image pixels.

4 Results and Discussion

The renderings we generated provide a good representation of volume data features. Using medical data as an example we show the aggregate utility of a hybrid renderer and its ability to provide different focal region-based views of the volume data. We

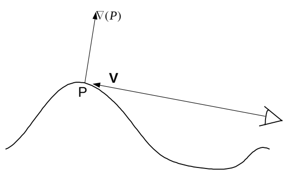

Fig. 3. The contour is the set of points for which the gradient direction is almost perpendicular to the viewing direction

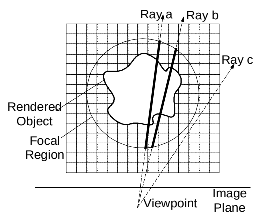

Fig. 4. A 2D example of ray bounding during ray casting

applied our method to CT data of head for the representation of bones and its surrounding tissue sketches at the same time (Fig. 5). This gives a good understanding of tissues in the focal region. The connection information between focal region and out of focal region is very important. The results have shown that such a hybrid focal region-based volume rendering can differentiate the focal region-based view of medical volume data for representing volume of interest. Fig. 6 shows the result of rendering of liver for its focal region and out of focal region. Rendered images are rich in densitometric information as well as in geometric information concerning local shapes and the spatial interrelations of structures.

In our research, we aimed at realizing the approach presented in this paper, but did not aim at interactive rendering. The resources and time consumed by rendering in this approach mainly depend on the size of dataset, the size of focal region and the gradient computation method. One of the means to improve rendering performance in our approach is to optimize the gradient computation method.

5 Conclusions and Future Work

In this paper, we have presented the approach of hybrid focal region-based volume rendering for visualizing medical image data. This technique uses different rendering methods for different regions to show more details. We have shown that combining NPR with volume rendering produces more information and provides the viewer with a better understanding about volumetric data. Our future work will focus on introducing segmentation information into our approach to enhance our algorithm.

References

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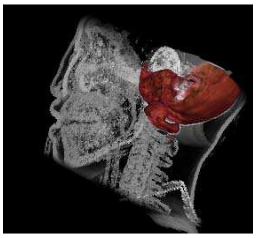

Fig. 5. Focal Region-based Rendering of Head

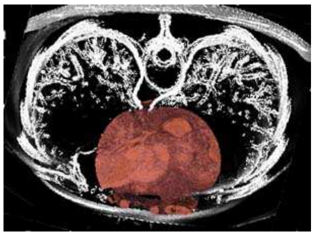

Fig. 6. Focal Region-based Rendering of Liver