Distance Based Enhancement for Focal Region Based Volume Rendering

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Abstract. This paper proposes a method to control the object enhancement in context region in focal region based volume rendering. The proposed method uses the distance as a factor to control the volume features in the context region. The main contributions are as follows: To introduce the distance into the rendering pipeline for volume feature enhancement; To demonstrate the implementation of how to use distance in focal region based volume rendering; And to show the important capabilities of distance based enhancement in focal region based volume rendering for 3D data interpretation.

1 Introduction

With the development of 3D data recording techniques (e.g. CT, MRI), very large data volumes are created in medical imaging. In real applications, on the one hand, the volume of interest only occupies a small percentage of all data volumes, on the other hand, the object of interest (e.g. tumors) is often resided inside of the volume and it is difficult to visualize this kind of object based on the traditional volume rendering methods because of the overlapping. To solve these problems, a new approach named *focal region based volume rendering* was proposed in our previous research for 3D data analysis [5]. The focal region based volume rendering divides the volume data into two parts: focal region and context region. The user needs to emphasize the object and show details in the focal region. At the same time, because the objects far away from the focal region are not the volume of interest, they are not needed to be shown in details and needed to be faded out. In some cases, the objects of interest have similar scalar data values with their surrounding structures. It is difficult for the user to recognize the objects of interest and their surroundings. These surrounding structures often disturb the interpretation of object details in the focal region. The goal of this paper is to develop a method to move out or de-emphasize the unimportant objects in the context region and emphasize the objects in the focal region for 3D data analysis.

This paper proposes a method to control the object enhancement in the context region in focal region based volume rendering. The proposed method uses the distance as the main factor to control the volume features in the context

region. The main contributions are as follows: To introduce the distance into the rendering pipeline for volume feature enhancement; To demonstrate the implementation of how to use distance in focal region based volume rendering; And to show the important capabilities of distance based enhancement in focal region based volume rendering for information extraction.

2 Related Work

Intensity depth-cuing is a well known technique for enhancing the perception of depth in a scene [1]. This technique dims the color of objects far from the viewer, creating an effect similar to viewing the scene through haze. Rheingans et al. [4] adapted this technique for volume rendering, dimming volume sample colors as they recede from the viewer. Lu et al. [3] introduced a method to use distance as one of the factor to create the nonphotorealistic volume stippling. This technique enhances depth perception by using the position of a voxel within the volume box to generate a factor that modifies both the point count and the size of the points. It uses a linear equation with different powers to express the function of the distance attenuation to generate this factor. Kanda et al. [2] introduced a method using the distance which is defined using gradient between adjacent voxels to render volume data. The visualization is performed by rendering the volume where the initial voxel values are replaced with the distances (gradients).

The distance based viewing is accordant with the real human viewing. The previous researches showed that distance or voxel positions can be used in volume rendering to depict the data information in a different way. In our approach, we pay more attention to the power of distance for analyzing volume data to provide additional information – the importance of the current voxels. This method is exactly matching the needs for context rendering in our focal region based volume rendering approach [5].

3 Distance for Focal Region Based Volume Rendering

The initial idea of distance based enhancement for focal region based volume rendering is that we want to control what to be shown and what not to be shown or to be shown with less details depending on the voxel positions. The voxels near the focal region should show the details of the object and the voxels far away from the focal region are needed to be faded out. In order to combine the voxel position into the rendering pipeline, a criteria need to be set up to measure the effects of voxel positions on the rendering. The relative position information of a voxel can show the importance for a specific organ or position. So the distance between the current volume sample position and a specific position specified by user (in this paper, this position refers to the focal region center) is introduced into the volume rendering pipeline to depict the importance of the current volume sample for the whole rendering.

The distance is an important factor that helps us understand the relationship between elements within the volume. To combine this distance into rendering

pipeline, a mechanism is defined to use the distance to modulate the optical properties (e.g. opacity) of each volume sample position and give different patterns for the modulation. One way to combine the distance information into the rendering pipeline is to modulate the object original opacity with distance coefficients and can be realized from the following equation:

$$\alpha_d = \alpha_0 \left(k_{d0} + k_{de} \left(1 - \frac{d_i}{d} \right)^{k_{dn}} \right) \tag{1}$$

where α_d is the enhanced opacity and α_0 is the original object opacity, k_{d0}, k_{de}, k_{dn} are coefficients to control the contributions of the different parts, d is the diameter of the whole volume and k_{di} is the distance from the current volume sample position to the focal center.

The basis of the method is to use the distance to modulate the opacity of each volume sample position and apply different functions for the modulation. The procedure of volume rendering in the proposed method is as follows:

1. Setting a focal region center and focal region radius;
2. Calculating the distances between the focal region center and the current volume sample position;
3. Modulating the opacities of volume samples based on the calculated distances using specified functions;
4. Rendering the whole volume using texture based volume rendering with register combiners mechanism;
5. Changing the focal region center and focal region radius to start another rendering process.

4 Hardware-Based Implementation

Because of the expensive computation of the distance when combining distance into the rendering pipeline, the hardware based approach is used to implement the distance enhancement for focal region based volume rendering to improve the rendering performance. The presented approach is implemented on Windows XP platform on a standard PC with single 2.40 GHz Intel Pentium4 CPU and 1.0 GB memory. The graphics board is NVidia GeForce 4 Ti 4200 processor with 64 MB of data RAM. To provide the programmer with a mechanism to explicitly control the per-fragment information, NVidia has introduced the OpenGL extension `NV_register_combiners`. The register combiners provide a flexible way to control the rendering pipeline.

The core of setting up distance based enhancement using register combiners is to create a *position texture* PT and load it into Texture Unit 1. The texture values in PT represent voxels positions as RGB values. PT is used as a helper texture in the subsequent operations. The main advantage of using PT is that it is only created one time before rendering and never changed afterwards. It is not necessary to reload the distance texture every time when some parameters of the focal region are changed.

The following equation is used to compute a distance based factor to modulate the original texture:

$$v = (\overrightarrow{(p_{PT} - p_{FC})} \cdot \overrightarrow{(p_{PT} - p_{FC})}) - r \tag{2}$$

where p_{PT} is the value of the position texture, p_{FC} is the focal center position and r is the focal region radius. All values of p_{PT}, p_{FC} and r are normalized to $[0, 1]$.

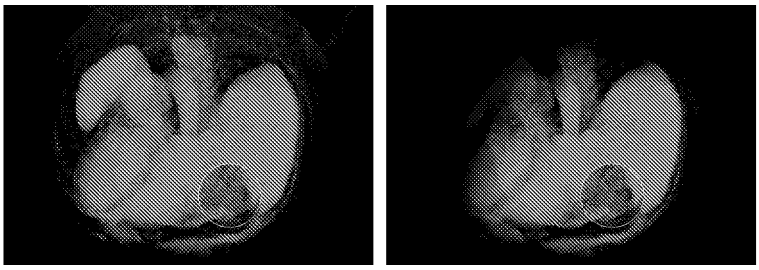
Firstly the position of the focal center is transformed to texture coordinates through dividing the focal center position coordinates (x, y, z) by the size of the volume. The result is stored in the register of Constant Color 0. Secondly the position of the focal center is subtracted from PT. In this way, we get vectors from the texture position to the focal center. Afterwards, the dot products between these vectors themselves are calculated. These dot products are the distances we are interested in. In the third step the focal radius r is subtracted from the dot products as shown in Equation 2. The final calculated factor v is inverted and used as a modulation factor for $RGBA$ values of the original volume texture.

The factor v calculated from Equation 2 can be used in Equation 1 to substitute the distance factor $\frac{d_i}{d}$ to combine the influence of distance into the rendering pipeline. Furthermore, other type of enhancement functions can be used to combine distance factor into the rendering pipeline to show the effect of distance on rendering.

5 Results and Discussion

The proposed method has been applied to the liver data to explore the liver tumor information to show its usefulness for 3D data analysis. Usually, when rendering the liver for information extraction, the other structures surrounding the liver are often displayed because of the similar scalar data values with the user interested objects. Using distance based enhancement for focal region based volume rendering, the unnecessary objects surrounding the objects of interest can be removed or de-emphasized from the scene and this makes the user concentrate more on the objects of interest and focal region. The results in Figure 1 show that the distance based enhancement for focal region based volume rendering is a powerful tool for 3D data analysis. From the comparison in Figure 1 we can see that when the distance based enhancement is applied to the volume data, the surrounding redundant information is removed out or de-emphasized and the objects of interest (e.g. liver and tumors) are shown in details. This method allows the user to flexibly control which part should be emphasized or de-emphasized. A very similar method for removing redundant information in volume rendering is volume clipping using geometric planes. The geometric plane based volume clipping is not flexible like distance based enhancement. The geometric plane based volume clipping is a binary operation, it just removes the selected objects all out or not. Distance based enhancement can alter the overall look-and-feel of the data set in a continuous fashion. It can provide different enhancement operations for the selected objects.

Fig. 1. Liver data focal region based rendering without distance enhancement applied to it (left) and with distance enhancement applied to it (right).



6 Conclusions and Future Work

We proposed an approach to emphasize and de-emphasize the different regions in focal region based volume rendering using a distance based approach. This approach was applied to the liver data for analyzing tumor information. The results showed that the proposed approach is useful for enhancing context region depending on the enhancement functions. Because the presented approach used a fixed distance enhancement function, this is not flexible in applications other than in focal region based volume rendering. For example, the user wants to make the regions near a specified point with less details and the regions far away from the specified point with details on the contrary or enhance the different object parts according to the user's specification. To solve these shortcomings of the presented approach, our future work will focus on the development of extending the distance based approach to be a transfer function mechanism to enhance the volume and the user pre-specified point can be generalized to be any feature point but not only the focal center.

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