Anisotropic Volume Rendering Using Intensity Interpolation

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1 Introduction

In medical applications, anisotropic volume data sets are commonly used, of which the resolution in an axial plane is higher than that in the direction perpendicular to it. In this paper, we propose an efficient anisotropic volume rendering method based on intensity interpolation that obtains the intensity value at an interpolated position lying between voxels in two consecutive slices from the intensity values of the voxels. Unlike density interpolation method, it does not require long preprocessing time and extra memory for storing the interpolated slices. Experimental results show that this method improves rendering speed without significantly sacrificing image quality.

2 Anisotropic Volume Rendering Using Intensity Interpolation

In order to manipulate the anisotropic volume in rendering time, intensity calculation on missing voxels is required. Fig. 1 compares our method with a conventional density interpolation method to compute the intensity of an interpolated sample v_i divided internally as $m : (1-m)$ between the voxels in two adjacent slices, v_k and v_{k+1} . In the figure, $d(v_i)$, $N(v_i)$ and $I(v_i)$ is a density value, a normal vector and an intensity value of v_i , respectively. Since the conventional method computes $I(v_i)$ from

Fig. 1. Comparison of intensity calculation process.

$N(v_i)$ obtained by interpolating density values of v_i and its neighbors, the normal calculation, with additional density interpolation is required for each interpolation position. On the other hand, intensity interpolation method computes $I(v_i)$ from $I(v_k)$ and $I(v_{k+1})$. It is not necessary to compute density values and normal vectors for intermittent samples. The normal calculation is only performed on the original voxels.

Consider the equation $I(v_k) = K_a I_a + K_d (L \bullet N(v_k))$ where K_a is an ambient-reflection coefficient, I_a is an ambient-light intensity, K_d is a diffuse-reflection coefficient, L is a light vector. Equation (1) proves that the intensity value $\tilde{I}(v_i)$, computed by intensity interpolation is equivalent to the intensity value calculated from the normal vector $\tilde{N}(v_i)$:

$$\begin{aligned} \tilde{I}(v_i) &= I(v_k)(1-m) + I(v_{k+1})m \\ &= (K_a I_a + K_d (L \bullet N(v_k)))(1-m) + (K_a I_a + K_d (L \bullet N(v_{k+1})))m \\ &= K_a I_a (1-m) + K_a I_a m + K_d L \bullet (N(v_k)(1-m) + N(v_{k+1})m) \\ &= K_a I_a + K_d L \bullet (N(v_k)(1-m) + N(v_{k+1})m) \\ &= K_a I_a + K_d (L \bullet \tilde{N}(v_i)) \end{aligned} \quad (1)$$

Compare the normal vectors along Z-axis of these methods. Following equations represent the normal vectors $N_z(v_i)$ and $\tilde{N}_z(v_i)$ (by equation (1)), which are for the conventional method and the intensity interpolation method, respectively.

$$N_z(v_i) = \frac{2(d(v_{k+1}) - d(v_k))}{\lambda} \quad (2)$$

$$\begin{aligned} \tilde{N}_z(v_i) &= N_z(v_k)(1-m) + N_z(v_{k+1})m \\ &= \frac{(d(v_{k+1}) - d(v_{k-1}))(1-m) + (d(v_{k+2}) - d(v_k))m}{2\lambda} \end{aligned} \quad (3)$$

In the equations, more samples are referenced for calculating $\tilde{N}_z(v_i)$ compared to $N_z(v_i)$. Thus the smoother images are obtained by the intensity interpolation.

3 Experimental Results

To evaluate the performance of our method, we compare it with other approaches [1]–[3] such as interpolating density values in the preprocessing step (P-Interp), interpolating them in the rendering time (R-Interp) and transforming the anisotropic volume to isotropic one by scaling matrix (S-Matrix). These are implemented on an 800 MHz Pentium III PC with 512 MB of main memory. As a rendering algorithm, the scanline-based shear-warp factorization [1] is used.

Table 1 compares processing time and storage. Among these methods, only P-Interp requires preprocessing time for creating missing slices, and it increases rendering time due to the memory access overhead. R-Interp takes longer time than our method due to the conventional interpolation process. S-Matrix is the fastest because of the long sampling distance. Table 2 shows that our method is much more efficient than R-Interp in the images requiring a lot of samples.

Fig. 2 shows the image quality. Compared to P-Interp and R-Interp, our method alleviates staircases while preserving detail information. On the other hand, S-Matrix produces excessive staircase artifacts, thus it is not practical in medical applications.

Table 1. Comparison of time and storage.

Data	Performance Test	Ours	P-Interp	R-Interp	S-Matrix
Airway	Pre-interpolation Time (ms)	–	12684	–	–
	Average Rendering Time (ms)	1108	1486	1513	673
	Storage (MB)	71.8	240.8	71.8	71.8

Table 2. Comparison of average rendering times between our method and R-Interp according to the number of contributed samples (colon data with $512\times512\times141$ resolution).

Structure	Samples	Ours (ms)	R-Interp (ms)	Speedup
Colon	0.6 M	1362	1992	1.46
Skin and Bone	8.1 M	5235	8802	1.68
Semitransparent Skin	13.3 M	8230	15047	1.83

Fig. 2. Comparison of image quality on detailed parts (airway data): (left) our method; (middle) P-Interp and R-Interp; (right) S-Matrix.

4 Conclusion

We have presented an efficient way of calculating the intensity value on each sample in visualizing anisotropic volume data sets. We are currently extending our approach to avoid overblurring on high frequency area.

References

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