Application of Particle Based Rendering to Slice Image with Opacity Map

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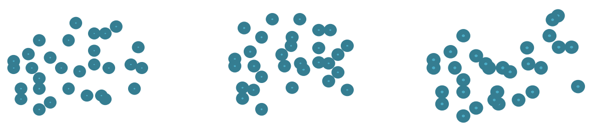
1 Introduction

In medical, scientific, and other fields, transparent surface visualization is used to investigate inner 3D structures. Usually, this type of visualization uses polygon graphics, where the polygons must be sorted along the line of sight. The sorting, however, takes a long computation time for large-scale data. Besides, the order of polygons in the sorting often becomes indefinite, especially for intersecting surfaces.

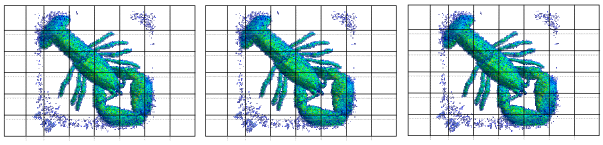
Recently, Koyamada et al. proposed the particle-based volume rendering (PBVR) even though [1], which uses tiny particles as rendering primitives. This method does not require any sorting and applicable to large-scale data. It also enables natural volume fusion [2]. We extend PBVR such that it becomes applicable to surfaces as well as volumes [3]. We call this method "particle-based rendering (PBR)". A great advantage of this extension is that 3D fused visualization of different volume/surface/slice objects becomes possible simply by merging particles prepared for each element to be fused. In the PBR, surface is visualized at constant opacity by applying the uniform sampling method. In this research, the slice image is rendered with the opacity map using the transfer function, that is color and opacity map, same as the volume rendering. Therefor, we propose the sampling technique in order to execute rendering same as volume.

2 Creating Slice Image Using Particle Based Rendering

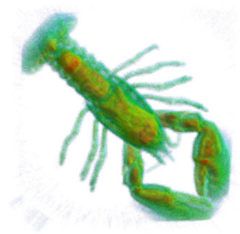
PBR renders 3D scalar fields as particle clouds and incorporates both the emission and absorption effects. The particle density depends on the transfer function and is used to evaluate the number of particles to be generated in the volume data. Because the particles can be considered opaque, no visibility sorting processing is required. PBR has three processes: particle generation, particle projection onto the image, and ensemble averaging of particle luminosities. The first process stochastically generates particles according to the form of transfer function. We repeat to create such particle distribution until L_R statistically independent particle sets are prepared (See Fig. 1(a)). Below we call L_R the 'repeat level'. Such particle projection with the occlusion effect is executed for each particle set prepared in the first process. As the result, L_R similar images are created (See Fig. 1(b)). The second process projects particles onto an image plane. The third process calculates the ensemble average of the L_R images created in the second process (See Fig. 1(c)), which realizes transparent images.



(a)



(b)



(c)

Fig. 1. Schematic View of the PBR. (a) L_R sets of particles, (b) L_R images, (c) Final image.

In order to visualize a surface, we stochastically generate particles on the surface. The number of particles is defined by the following formula:

$$n = \frac{\ln(1-\alpha)}{\ln(1-s_{\mathrm{p}}/s_{\mathrm{A}})} L_R \quad (1)$$

where α, s_{p} and s_{a} are the opacity, the area of the particle and the surface, respectively[3]. The slice plane is drawn same as above technique.

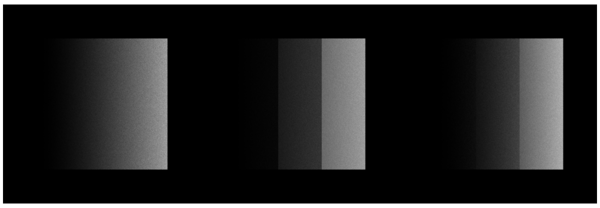
We suggest the technique that applies not only the color but also the opacity to the slice image. In this research, three sampling methods are proposed for applied the opacity:

1. Metropolis sampling whole of the plane
2. Uniform sampling at each grid
3. Metropolis sampling at each grid

First, the Metropolis sampling is adopted same as the particle-based volume rendering. This technique is created the particle on the slice plane, if the opacity is more than that of one step before. If that isn't the case, we randomly decide whether or not to create. Second, we assume that the opacity is constant at each grid, and the number of particles is decided at each grid. The opacity at each grid is decided from the center of the grid. Then the particles are stochastically uniformly generated at each grid. Third is the combined with above two technique that uses the Metropolis sampling at each grid. Here, the number of particles is same as the second technique.

3 Experiments

Consider the following the test volume data for simplicity. The number of grid is $4 \times 4 \times 4$, and the scalar value ρ of this data is defined as $\rho(x, y, z) = 85x$, $(0 \le x \le 3)$. Fig.2 shows the slice image at $z = 2$ using three sampling technique: Metropolis sampling whole of the plane (See Fig. 2(a)), uniform sampling at each grid (See Fig. 2(b)), Metropolis sampling at each grid (See Fig. 2(c)). This figure shows that the pixel color vary smoothly in the case with the technique 1. On the other hand, we have a clear view of the grid line in Fig. 2(b) since we assume the opacity is the constant at each grid. And Fig. 2(c) is the same shown in Fig.2 (b) even though the pixel color vary smoothly in the each grid. The pixel value at $z = y = 2$ is shown in Fig. 3. The pixel value increases linearly with x in the case of the technique 1. On the other hand, at the borderline rapid changes in pixel value occur in the case of the technique 2. In the technique 3, the pixel value increase linearly with x only if $x < 310$ and then the rapid changes occur. This is because the gap of the number of the particles between each grid is wide. The sampling time



(a) (b) (c)

Fig. 2. Slice image of the test volume data ($z = 2$). (a) Metropolis sampling, (b) uniform sampling at each grid, (c) Metropolis sampling at each grid.

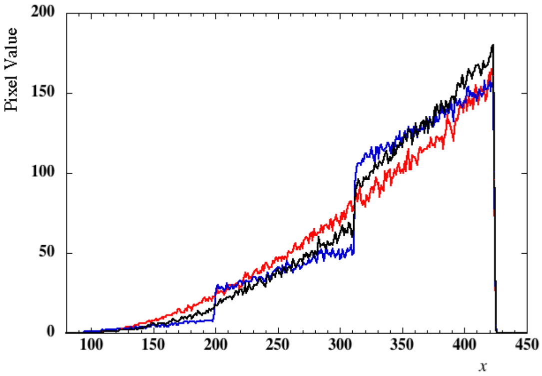


Fig.3 Pixel value on the slice plane at $z = 2$, $y = 2$. Red line: Metropolis sampling, Blue line: uniform sampling at each grid, Black line: Metropolis sampling at each grid.

Fig. 4-6 shows the slice image with color and opacity maps same as Fig. 1. The technique 1 makes it possible to create the smooth image shown in Fig. 4. However, the enlarged view is indicated the patchy pattern because the particles dose not tend to create around the low-opacity area. In the technique 2, the borderline is clearly shown in the low-opacity area (See blue or green color area in Fig. 4). On the other hand, in the technique 3, the borderline is clearly shown in the high-opacity area (See red or yellow color area in Fig. 5).

4 Conclusion

We proposed the following three sampling technique to display the slice image with opacity map using the PBR: 1. Metropolis sampling whole of the plane, 2. uniform sampling at each grid, 3. Metropolis sampling at each grid. The result show that the technique 1 created the smooth image even though the image had the patchy pattern at the low-opacity area. The borderline is clearly shown in the low-opacity area by using the technique 2 and is clearly shown in the high-opacity area by using the technique 3.

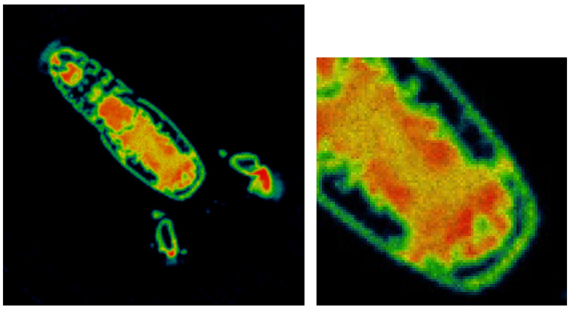


Fig.4. Slice image at $z = 18$ using the Metropolis sampling whole of the plane (Right-had side is the enlarged view).

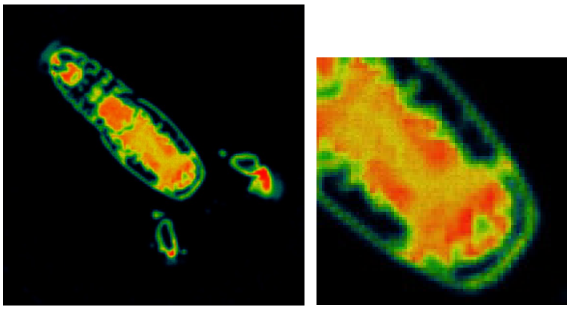


Fig.5. Slice image at $z = 18$ using the Uniform sampling at each grid (Right-had side is the enlarged view).

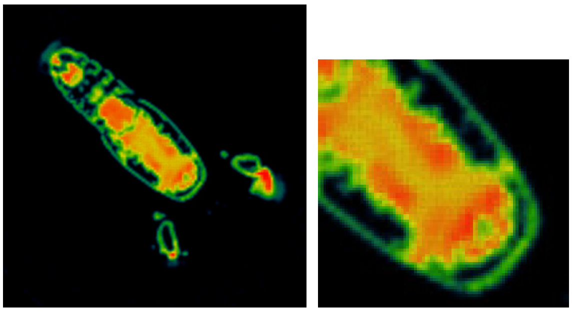


Fig.6. Slice image at $z = 18$ using the Metropolis sampling at each grid (Right-had side is the enlarged view).

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