Plasma based Particle Acceleration Data Modeling by Using Alpha Shapes

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Abstract

Plasma based particle accelerator has mainly used in nuclear field only because of the large scale of the facility. However, since laser-plasma particle accelerator which has smaller size and spends less cost. Developed, the availability of this accelerator is expended to various research fields such as industrial and medical. In these, real-time and interactive applications, accelerating the compute time is a critical problem. We conduct a simulation discussed the method of visualization of multivariate data in three dimensional space by using colored volume rendering and surface rendering. We also suggest new method to visualize plasma data by using alpha shape to achieve a different level of detail for the given plasma based particle acceleration data. In this paper, alpha shapes method is applied for the shake of multiresolution visualization. Level of detail increases the efficiency of rendering by decreasing the workload.

1. Introduction

Plasma-based particle accelerators can produce and sustain thousands of times stronger acceleration fields than conventional particles accelerators, providing a potential solution to the problem of the growing size and cost of conventional particle accelerators. A central challenge in the analysis of complex particle simulation data arise from the fact that while millions to trillions of particles are required for accurate simulation., only a small fraction of the particles from particle features of interest.

Oliver Rubel and his colleagues have a chance to describe a novel approach for automatic detection and classification of particle beams and beam substructures due to temporal differences in the acceleration process, here called acceleration features [1].

Many different phenomena in natural sciences and engineering exhibit multiple levels of details. Among the wide range of examples are transport processes in fluid flow, where finer details of free turbulences may be due to irregular vortex motions or the evolution of shock fronts. To represent the mathematical model at the relevant range of scales, multi-resolution methods are required.

The concept of alpha shapes formalizes the intuitive notion of “shape” for spatial unorganized point set data. An alpha shape is a concrete geometric object that is uniquely defined for a particular point set. Alpha shapes are generalization of convex hull. Given a finite point set S, and a real parameter α, the alpha shape of S is a polytope, which is neither necessarily convex nor necessarily connected. The set of all real numbers α leads to a family of shapes capturing the intuitive notion of “crude” versus “fine” shape of a point set. As α value decreases, the shape shrinks and gradually develops cavities. These cavities may join to form tunnels and voids.

2. Problem description

Trivariate scattered data interpolation from $\Re^3 \rightarrow \Re$ consists of constructing a function $f=(x,y,z)$ such that $f(x_i,y_i,z_i)=F_i$, i =1, 2, 3, ………. ,N where $V=\{v_i=(x_i,y_i,z_i)\in\Re^3, i=1,\dots N\}$ is a set of distinct and non-coplanar data points and $F=(F_1,\dots\dots\dots,F_N)$ is a real data vector as shown in Figure 1. The quality of a piecewise linear interpolation in space can be improved by considering not only positional information, but also intensity gray values for the given volumetric scattered data points [2]. Data size is $241\times401\times401$ in 3-D grid and represented as 32 bit float point. Electron and proton density data are stored in grid as shown in Fig 2

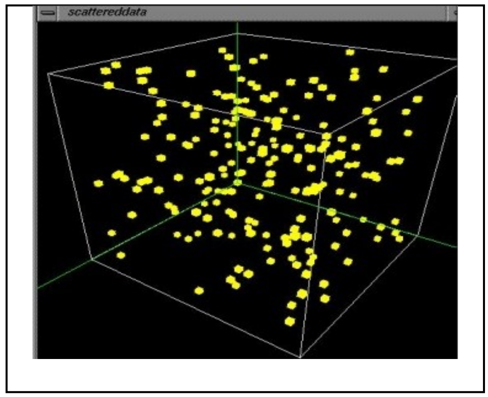


Figure 1.Trivariate Scattered Data.

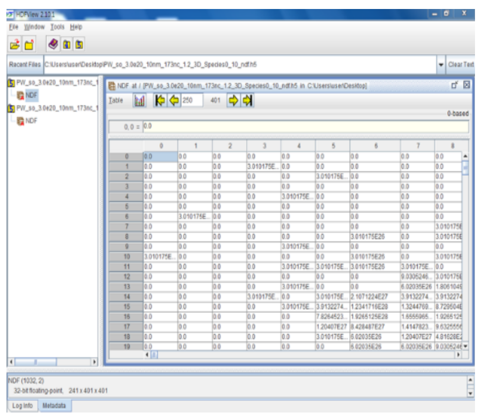


Figure. 2. Three Dimensional grid data of electric charge density

Also, volumetric scattered data properties are described in table 1.

Table 1. Data properties.

Type	HDF5 Scalar Dataset
No. of Dimension	3
Dimension size	241 x 401 x 401
Data type	32-bit floating-point

3. Alpha shapes

The α-shapes of finite point set are a polytope that is uniquely determined by the set and a real number α. There are two definitions, which are depended on α [3][4].

Definition 1: Let α be a sufficiently small but otherwise arbitrary positive real. The α-hull of S is the intersection of all closed discs with radius 1/α that contain all the points.

Definition 2: For arbitrary negative real α, the α-hull is defined as the intersection of all closed complements of discs (where these discs have radii – 1/α) that contain all the points of S. It is a polytope in a fairly general.

Alpha shapes provide a mathematical framework to make the geometric shape of a set of points in three-dimensions. However, α-shapes give good results for point sets of roughly uniform density, it does not give for non-uniform point sets. In order to be effective in non-uniform point sets, it needs to change the value of alpha (squared radius of sphere) locally depending on the intensity of a point set

4. Plasma based particle acceleration data visualization

Plasma-based particle accelerators can produce and sustain thousands of times stronger acceleration fields than conventional particle accelerators. To facilitate scientific knowledge from the ever growing collections of accelerator simulation data generated by accelerator physicists to investigate next-generation plasma-based particle accelerator designs. Because of plasma-based particle acceleration data are also categorized as a volumetric scattered data, suggest the method of visualization of multivariate data in three dimensional space by using colored volume rendering and surface rendering real-time volume rendering [5][6].

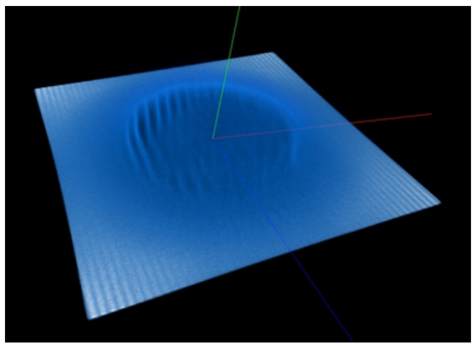


Figure 3. Visualization of electron data

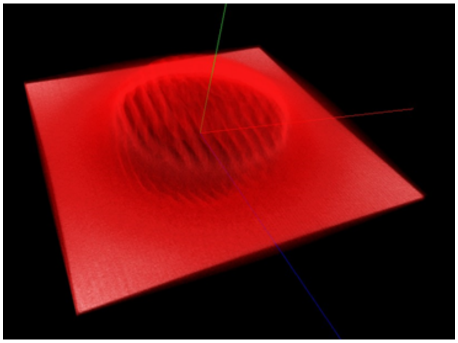
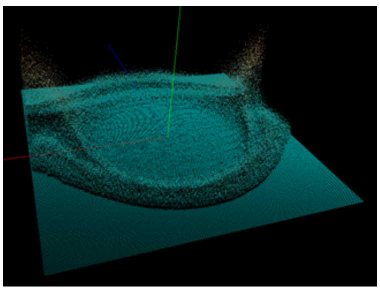
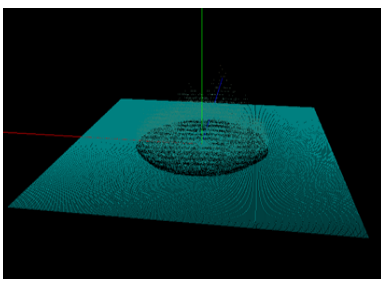


Figure 4. Visualization of proton data

Plasma volumetric data of electron and proton are rendered and visualized , as shown in Figure 3 and 4, respectively.

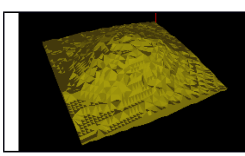
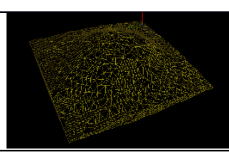


(a)



(b)

Figure. 5. Density variation on X-Z plane (a) y=50 and (b) y=100.

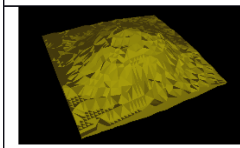
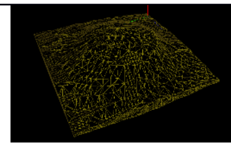
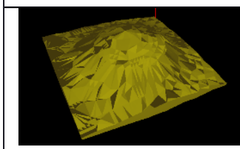
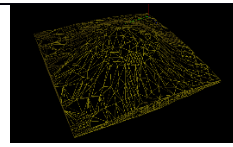
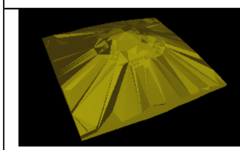
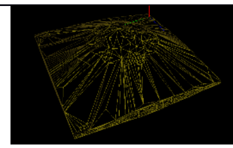
Alpha = 32	
	
Alpha = 64	
	
Alpha = 128	
	
Alpha = 256	

Figure.6. Alpha shape of proton data

If y value is fixed, then the density data can be visualized on the x-z plane as shown in Figure 5 Visualizing of each alpha value are shown in Figure 6. The original alpha values are normalized in the range from 0 to 256. The left column is the rendering of the alpha shapes and the right column is the wireframe of the results of alpha shape. We can observe that the small alpha values (i.e. value = 32, 64) provide the fine shape of a point set that develop the hole and disconnected in sparse region. Conversely, the large alpha values (i.e value = 128, 256) provide the crude shape of a point set that hide details in dense region.

5. Conclusions

In this paper, we discuss how to model and visualize the plasma based particle acceleration data. To facilitate scientific knowledge discovery from the collection of accelerator simulation data, real-time and interactive visualization are demanded. The common problem of visualizing the plasma based particle acceleration data is that the amount of data is too much. In the modeling of acceleration data, the computation time is a critical problem. To reduce the computation time, multiresolution method is very much appropriate. In this paper, alpha shapes method is applied for the shake of multiresolution visualization. Level of detail increases the efficiency of rendering by decreasing the workload. The alpha complex is a subcomplex of the Delaunay triangulation. For a given value of the alpha complex includes all the simplices in the Delaunay triangulation which have an empty circumsphere with squared radius equal or smaller than α. For further research, We are trying to apply this proposed method to the various trivariate scattered data.

We use the package CGAL (Computational Geometry Algorithm Library). In CGAL, the α -complex of *S* is a subcomplex of this triangulation of *S*, containing the a -exposed *k*-simplices, $0 \leq k \leq d$. A simplex is a -exposed, if there is an open disk (resp. ball) of radius *sqrt* (α) through the vertices of the simplex that does not contain any other point of *S*, for the metric used in the computation of the underlying triangulation.

For further research, weighted alpha shapes will be applied to achieve the non-uniform multiresolution visualization rather than uniform multiresolution visualization

Acknowledgments

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