GPU Acceleration of Improved Particle-based Volume Rendering for Irregular-Grid Volume Data

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Abstract— **In this paper, we apply an improved particle-based volume rendering (PBVR) technique for previewing large irregular-grid volume data using current programmable GPU architecture. This technique allows opaque and emissive particles rendering of translucent volumes without visibility sorting. In our new GPU acceleration of PBVR, we provide a scalability feature by developing cell-by-cell particle generation during rendering, so that the user can alternatively switch to particle pre-generation mode for higher speed rendering. We also reduce the memory cost required for storing all sub-pixel values by proposing a pixel-superimposing technique for the large sub-pixel level. By adjusting the repeat level we achieved a very smooth level of detail (LOD) control to exchange quality with speed. As another improvement, we enhanced the image quality by introducing a post-rendering filter, which degrades the speckle artifact derived from particle sampling. Our work demonstrates a full detail rendering rate from 5 to 10 fps for irregular-grid volume data with mega-scale amounts of cell on NVIDIA GEFORCE 8800GTS.**

I. Introduction

MANY volume rendering methods have been developed over the last twenty years. Even now, the development of techniques for irregular volumes has remained a challenging area in the visualization community. Such datasets consist mainly of scalar data defined on collections of irregularly ordered cells whose shapes are not necessarily orthogonal cubic. Data of this type can be found in the results of finite element method (FEM), which is widely used in computational mechanics and computational fluid dynamics (CFD).

High performance computing results in a huge FEM model, which cannot reside in a single computational node and is thus distributed to multiple computational nodes. To evaluate whether the computation has been done successfully or not, a fast preview is necessary. For previewing such dataset, a volume rendering technique is suitable since the entire volume space can be visualized. Splatting may be used for this purpose, but it requires visibility sorting in which all the volume cells need to be processed in advance at each viewing point. In this regard, our particle-based volume rendering (PBVR) technique is suitable for previewing a large irregular volume dataset since it requires no visibility sorting process. The technique represents a given volume dataset as a set of particles which are emissive and opaque based on a particle model from which Sabella's density emitter model [14] is derived. Once a volume dataset is converted to a set of particles, the rendering process is efficient regardless of the visibility order. Recently, a particle modeling for the improved PBVR was given in [7].

In this paper, we focus on addressing the GPU implementation of improved PBVR. In order to preview a huge irregular volume dataset, our improved PBVR includes two features. The first generates particles in a cell-by-cell manner by developing a particle density estimation technique. The second mixes the sub-pixel processing with a pixel-superimposing technique, which decreases memory cost considerably in rendering a large scale volume. In section 3, we briefly introduce the principle of the particle model in PBVR. In section 4, we distinguish proposed techniques as switchable pipelines for different rendering performance requirements. A smooth level of detail control feature is demonstrated in the particle pre-generation mode. To enhance the image quality, we also introduce a post-rendering filter to suppress the rendering artifacts effectively. Finally, in section 5, we demonstrate rendering of several mega-scale irregular volumes with average frame rate above 5 fps, and we discuss the rendering performance and image quality of improved PBVR in comparison with HAVS approach.

II. Related Works

The recent development of programmable graphics hardware offers wider a view for rendering acceleration. A vast work of ray casting has been done on GPU primarily using 2D or 3D texture [10]. Unfortunately, rendering irregular-grid volumes is an intricate issue when using this approach.

Meredith and Ma [9] developed a technique that involves approximating irregular volumes as an octree structure and rendering it using hardware-assisted splats. Wylie et al. [16] proposed hardware-accelerated methods to improve the performance of the PT algorithm by mapping the volumetric cell using shaders. However, with current graphics hardware, still no more than approximately 490K tetrahedral cells are possible to process (timings do not include sorting). Roettger et al. [13] proposed an algorithm without visibility ordering for irregular volume cells. Volume rendering methods are, in

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