Interactive Sampling and Rendering for Complex and Procedural Geometry

Marc Stamminger, George Drettakis
iMAGIS / GRAVIR - REVES - INRIA Sophia-Antipolis
{Marc.Stamminger|George.Drettakis} @sophia.inria.fr, http://www-sop.inria.fr/reves

Abstract. We present a new sampling method for procedural and complex geometries, which allows interactive point-based modeling and rendering of such scenes. For a variety of scenes, object-space point sets can be generated rapidly, resulting in a sufficiently dense sampling of the final image. We present an integrated approach that exploits the simplicity of the point primitive. For procedural objects a hierarchical sampling scheme is presented that adapts sample densities locally according to the projected size in the image. Dynamic procedural objects and interactive user manipulation thus become possible. The same scheme is also applied to on-the-fly generation and rendering of terrains, and enables the use of an efficient occlusion culling algorithm. Furthermore, by using points the system enables interactive rendering and simple modification of complex objects (e.g., trees). For display, hardware-accelerated 3-D point rendering is used, but our sampling method can be used by any other point-rendering approach.

1 Introduction and Motivation

The complexity of virtual environments has grown spectacularly over the recent years, with the advent of high performance, but affordable, graphics hardware. The paradox is that the majority of objects in such scenes often covers only a few, or even fractions of, pixels on the screen. The traditional advantage of polygon-based scan-line coherence is thus lost, while resources are wasted by transforming and clipping geometry which is either invisible, or is smaller than a pixel. This has led to the investigation of alternatives to pure polygon-based rendering in recent research. Several researchers have turned to ray-tracing based approaches (e.g., [14, 24]); an interesting recent alternative is point-based rendering [4, 16, 19], which is actually an old idea revisited [6].

Point based rendering methods represent the scene's geometry as a set of point samples, that is object space position, surface normal and material data. Usually, the point samples are obtained from images of the scene that include depth and material information, but they are rendered and lit as independent small polygons or oriented disks. It has been shown that such point sample representations are well suited both for fast rendering of extremely complex geometry [19] and for high-quality visualisation [16]. These methods however generate samples as a pre-process, thus restricting their use to static, unmodifiable scenes.

In this paper, we focus on points as a primitive well adapted for interactive applications and non-static scenes. We believe that points are particularly well suited for such applications for the following reasons:

- Objects can be represented at different levels of details very efficiently, by properly choosing point densities (e.g., [19]). When we interactively modify procedural objects, sample recomputation is necessary for all levels of detail, at every
frame. Most level of detail techniques create coarse levels bottom-up, resulting in computational expense proportional to the object’s complexity. In contrast, point samples can be generated top-down, so coarse representations are obtained very quickly. In addition, a coarse representation of an object can be refined incrementally, for example for a closer view, by adding new points. If the object does not change, all old samples remain valid.

- Rendering procedural and dynamic objects requires adaptive refinement in critical regions. With points this can be easily achieved in a straightforward manner by adding additional points locally. Since point representations do not require the maintenance of topological information, object topology can be trivially changed. Examples are CSG models or geometry modifiers such as the wickerwork or holes modifier used in Fig.1. In contrast, the use of meshes (e.g., of triangles), to represent dynamically changing procedural objects or non-standard topologies requires intricate book-keeping when adaptively subdividing, and careful processing to avoid cracks and other artifacts. This leads to complex implementations and numerical robustness problems.

- Points representing a single object or surface are independent, so they can be generated in parallel, in contrast to polygonal meshes. As we shall see, points also lead to simple solutions for visibility culling, and can take advantage of hardware acceleration more easily than for triangles, which require the use of triangle-strips which are non-trivial to generate adaptively.

We present an integrated system which incorporates the above advantages, and can be used for applications such as interactive procedural modelling for design of outdoors or indoors scenes, or VR/game type interactive viewing and manipulation. To achieve sufficiently rapid generation of point samples in this context, we introduce $\sqrt{5}$ adaptive sampling. Our new scheme allows us to hierarchically generate new samples locally, in the regions they are required, according to the current viewpoint. We apply this approach to procedural models, including displacement maps and terrains. For complex objects such as trees, we use quasi-random sampling to generate points. The continuous level of detail property of points allows smooth frame rate control. Finally, the use of a hierarchical caching mechanism, parallel computation and an direct mapping to graphics hardware vectors, significantly increases the efficiency of rendering. Examples of our approach are shown in Fig. 1.

2 Related work

Levoy and Whitted [6], were the first to explicitly investigate the use of points as an alternative to traditional geometry; They treated issues of displacement mapping and texture filtering. In the last few years, there has been significant interest in point-based