Direct Ray Tracing of Smoothed and Displacement Mapped Triangles

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Abstract.
We present an algorithm for ray tracing displacement maps that requires no additional storage over the base model. Displacement maps are rarely used in ray tracing due to the cost associated with storing and intersecting the displaced geometry. This is unfortunate because displacement maps allow the addition of large amounts of geometric complexity into models. Our method works for models composed of triangles with normals at the vertices. In addition, we present a special purpose displacement that creates a smooth surface that interpolates the triangle vertices and normals. Thus two adjacent triangles which share two vertices and normals will be smoothly interpolated. This displacement can be added to the displacement associated with the object. The combination allows relatively coarse models to be displacement mapped and ray traced with much less storage and fewer artifacts due to tessellation.

1 Introduction

Visually rich images are often generated from simpler models by applying *displacement maps* to increase surface detail (Figure 1). Displacement maps are a special type of *offset surface*, and are usually assumed to perturb surface positions a small distance using some function. Images with displacement maps are usually computed using explicit subdivision [3]. The displacement is often a semi-random procedural function that uses Perlin-style noise [11]. Somewhat surprisingly, displacement maps are almost never used in ray tracing. This turns out to be for entirely technical reasons; a straightforward implementation would need to store more micropolygons than would fit in main memory on most computers [4]. For this reason, sophisticated caching strategies have been suggested [12]. Although caching strategies work well for a variety of applications they are problematic for applications that resist reordering such as Metropolis Light Transport [15]. Alternatively, explicit numeric root-finding can be used, provided the displacements can be nicely bounded [5, 8]. A third approach that could work for displacement mapped surfaces is the recursive subdivision scheme used for procedural geometry by Kajiya[6]. This approach requires knowing tight bounds over each subdivided region of the displacement function in order to be efficient. Because most global illumination algorithms require ray tracing, it is desirable to find a simple way to add displacement maps to ray tracing programs. This would allow realism in both global lighting complexity and local geometric complexity.

We introduce a method for ray tracing polygonal models with displacements that avoids complex strategies by restricting the allowable base geometry to triangle meshes with vertex normals. Although this is a narrow class of modeling primitive, almost all other modeling primitives can be converted to triangle meshes in a practical manner.