Fast Rendering of Reflections in Non-uniform Surfaces Using a Multi-Scale Environment Map

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1 Introduction

Various techniques are used for rendering virtual objects in a virtualized real scene under arbitrary illumination conditions. Especially, an environment mapping [Blinn and Newell 1976] has been developed to render glossy objects in real time. However, this technique can only render an object consisting of smooth surfaces such as a mirror. To overcome this problem, various improvements have been performed to an environment mapping [Cabral et al. 1999; Kautz et al. 2000]. However, these methods can support only uniform surface reflectance properties. So, it is difficult to render surfaces with non-uniform reflectance properties in real time. In this paper, we propose a real time rendering method for surfaces with non-uniform reflectance properties. The proposed method is based on computing a multi-scale environment map.

2 Rendering using a multi-scale environment map

In our method, a filtering of an omnidirectional real image is performed to create an environment map according to multiple roughness of surfaces in advance. This map is called *a multi-scale environment map*. We employ the Phong model to calculate reflections, and we apply an approximation to the Phong model. The multi-scale environment map is created as a 3-dimensional voxel data. The distance from the center of the voxel data corresponds to the surface roughness parameter. The more far from the center the distance is, the more smooth the object surface is. The direction corresponds to the reflection vector.

Here, the geometry and the reflection image of a rough surface should be low resolution than those of a smooth surface. Therefore, we employ a pyramidal image data structure and multi-scale geodesic domes to reduce computation (See Figure 1). Moreover, the filter processing is performed only on pixels within omnidirectional images which significantly influence rendering results. Calculations are also accelerated by using a table which holds weights of the filter.

Finally, reflections in surfaces are rendered in real time using the multi-scale environment map as a texture. The texture coordinates $\vec{t}$ are determined as $\vec{t} = \vec{r} \cdot n$, where $\vec{r}$ and n are a reflection vector against a viewing vector and a surface roughness parameter, respectively. Additionally, the 3-dimensional texture mapping function which is ordinarily supported by a graphics hardware can also accelerates the texture mapping of a voxel data.

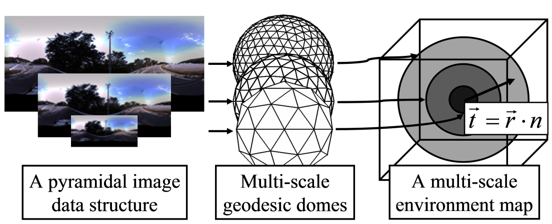

Figure 1: A summary of generating a multi-scale environment map.

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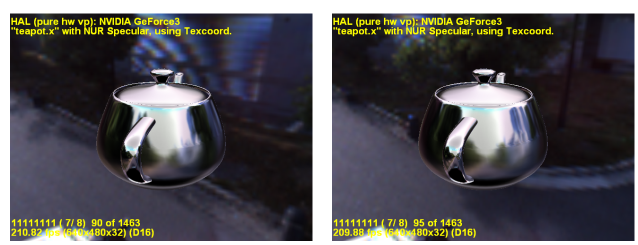
3 Experiments

In experiments, we first verify that the proposed method can well approximate the Phong model. Figure 2(c) illustrates the differences in rendering results between the Phong model (a) and the proposed method (b). The average of the differences of all pixels is only less than 1 in regard to each RGB channel. With respect to rendering time, rendering of each frame takes about 2 hours with the Phong model. On the other hand, the proposed method can render in real time.

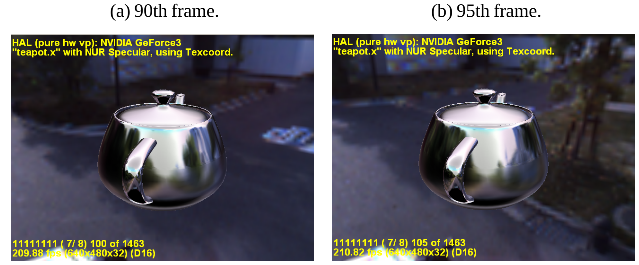
In the next experiment, we show some rendering results for non-uniform glossy objects in a virtualized dynamic environment which consists of an omnidirectional image sequence captured by an omnidirectional multi-camera system. Figure 3(a)-(d) show the rendering results from the 90th frame to the 105th frame. These results are rendered at over 60 fps.

(a) Rendered by the Phong model (b) Rendered by the proposed method (c) Differences between two methods

Figure 2: Comparison of the proposed method with the Phong model rendering.



(a) 90th frame. (b) 95th frame.



(c) 100th frame. (d) 105th frame.

Figure 3: Rendering of a glossy object in a dynamic environment.

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