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Real-time rendering of approximate caustics under environment illumination

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ABSTRACT

We present a real-time GPU caustics rendering technique for dynamic scenes under environment illumination taking into account light occlusion. The dynamic scenes consist of caustic objects (reflective and/or refractive objects which produce caustics) and receiver objects (non-reflective and non-refractive), that can be translated and rotated. As the light source, we consider environment illumination (distant lights from all directions) which we approximate as a set of important directional lights. Our rendering technique is able to generate approximate caustics (cast on receiver objects) as well as volumetric caustics. As the preprocessing, we precompute the caustic patterns of caustic objects for several directional lights and store them in caustic images. During the rendering, we interpolate the precomputed caustic patterns based on the important directional lights which approximate the given environment illumination. The important directional lights are obtained by using our proposed environment cube map segmentation technique. Our proposed technique is able to generate real-time caustics which are visually similar to the caustic generated by using a commercial renderer mental ray.

1. Introduction

Real-time photo-realistic rendering is a major goal in computer graphics and entertainment as it enables the audience to experience and immerse into a virtual world as if it is the real world. However, it is computationally expensive to generate photo-realistic images of 3D scenes, especially dynamic 3D scenes (whose objects can be transformed such as by translation or rotation) under environment illumination. Generally, the solution involves the integration of the contributions from all light directions in the environment, with the computation for each light direction needs to take into account several factors, such as reflections and refractions.

One of the important effects in photo-realistic rendering is caustics which are produced by reflective and/or refractive objects (*caustic objects*). Due to the reflective and/or refractive properties of the caustic objects, light arriving on the caustic objects are converged on some locations on surfaces hence producing caustic patterns. Generating caustic effects, however, is also computationally expensive. Thus, it is a challenge to generate real-time caustics in dynamic scenes under environment illumination. There are many researches in generating caustics in computer graphics. However, most of them generate caustic under a single light source, and some of them are not in real-time.

In this paper, we present a real-time caustics and volumetric caustics rendering technique under environment illumination taking into account light occlusion. Fig. 1 shows some examples of our caustics rendering results. In our proposed rendering technique, we firstly precompute the reflective and/or refractive caustic patterns at the surrounding of caustic objects based on a set of directional lights. Afterward, we use the precomputed caustic patterns in the rendering pass in order to efficiently compute the caustic intensities at arbitrary locations. Our proposed rendering technique has some differences with the technique presented by Wyman et al. [1] and we discuss these in Sections 2 and 3. In order to achieve real-time performance for caustics rendering under environment illumination, we approximate the environment illumination as a set of directional lights using our proposed environment cube map segmentation technique (a cube map is a set of six textures, with each texture corresponds to one cube face). We show the main steps diagram of our technique in Fig. 2.

To evaluate the rendering quality of our result, we compare the images generated using our technique with the images generated using mental ray (available in Maya 2010). Mental ray is a famous renderer used by movie industry to generate visual effects in some well-known movies with outstanding visual quality. As we show in Section 7.2, our technique can generate caustics which are visually similar to the caustics generated using mental ray.

The organization of this paper is as follows. In Section 2, we describe the related work. Section 3 explains the precomputation of caustic patterns for a set of directional lights. Section 4 describes how our technique uses the precomputed caustic patterns in the rendering under one and multiple directional lights. Section 5

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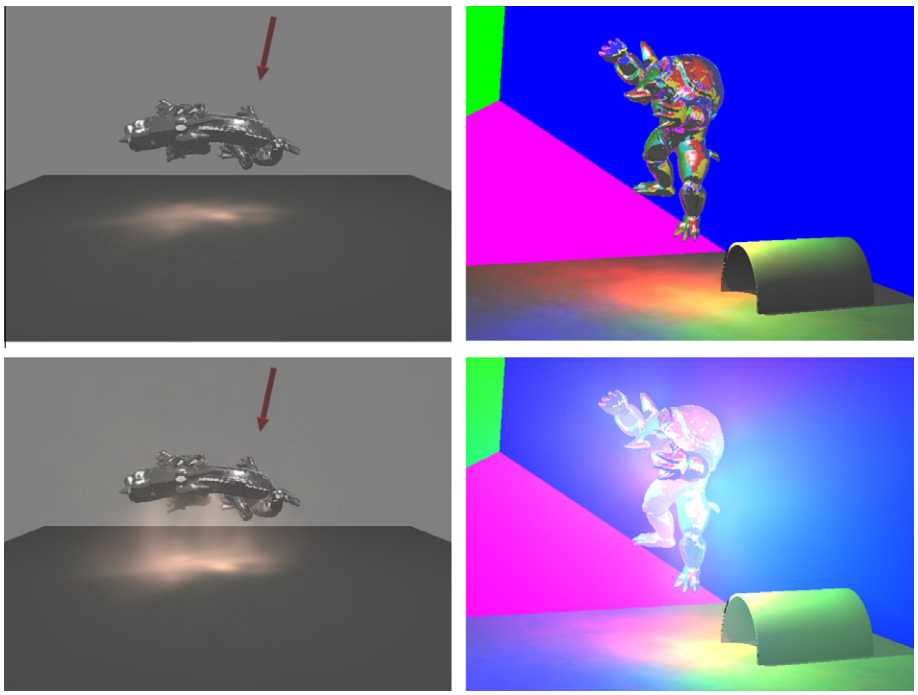

Fig. 1. Caustics rendering using our proposed technique. First column shows caustics under one directional light source (light direction indicated by the arrow). Second column shows caustics under environment illumination. The first row shows only the cast caustics, and the second row shows cast caustics and volumetric caustics.

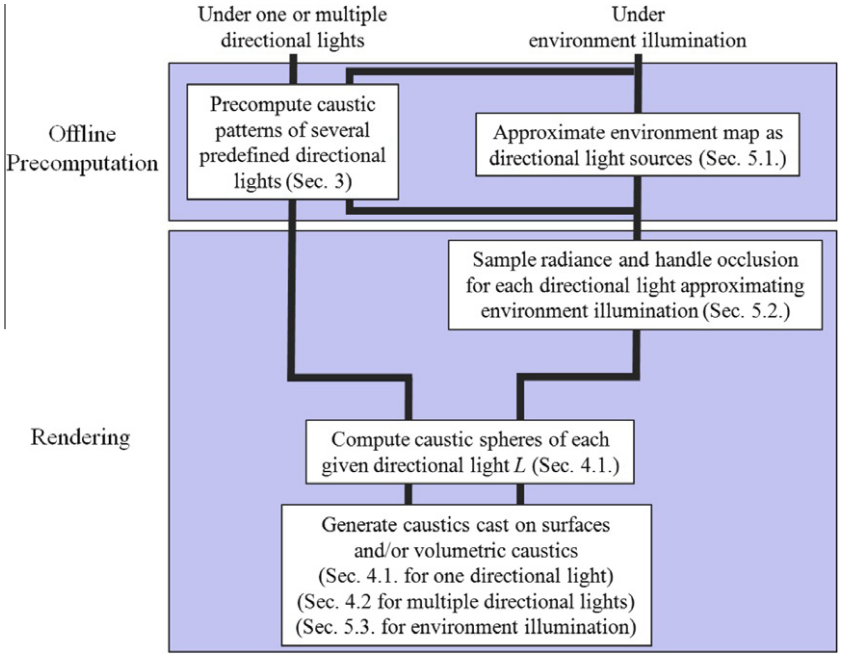

Fig. 2. The main steps of our technique.

explains how we determine light directions to represent an environment illumination and how we render approximate caustics under environment illumination. In Section 6, we present the GPU implementation of our techniques. We show the results in Section 7 and draw conclusions and future work in Section 8.

2. Related work

There are several work in caustics rendering and they can be classified into three categories: offline (non real-time) caustic rendering, real-time caustics rendering of single reflection and/or refraction, real-time caustics rendering of multiple reflections and/or refractions.

2.1. Offline/non real-time caustics

In general, photon mapping [2] is the most commonly used technique in offline (non real-time) caustics rendering. In photon mapping [2], photons (packets of light energy) are shot to the scene and stored in a photon map. The photon map is used during