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Perception-based model simplification for motion blur rendering

Minying Zhang [a,b], Wencheng Wang [a,*], Hanqiu Sun [c], Honglei Han [a,b,d]

[a] State Key Laboratory of Computer Science, Institute of Software, Chinese Academy of Sciences, China
[b] University of Chinese Academy of Sciences, China
[c] Department of Computer Science & Engineering, The Chinese University of Hong Kong, China
[d] School of Animation and Digital Arts, Communication University of China, China

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ABSTRACT

Motion blur effects are important to motion perception in visual arts, interactive games and animation applications. Usually, such motion blur rendering is quite time consuming, thus blocking the online/interactive use of the effects. Motivated by the human perception in relation to moving objects, this paper presents simplified geometric models that enable to speedup motion blur rendering, which has not been tracked in motion blur rendering specifically. We develop a novel algorithm to simplify models with motion-aware, to preserve the features whose characteristics are perceivable in motion. We deduce the formula to outline the level of detail simplification by the object moving velocity. Using our simplified models, methods for motion blur rendering can achieve the rendering quality as using the original models, and obtain the processing acceleration mostly. The experimental results have shown the effectiveness of our approach, more acceleration with the larger models or faster motion (e.g. for the dragon model with over a million facets, the motion-blur rendering via hierarchical stochastic rasterization is sped up by over 27 times).

1. Introduction

Motion blur refers to visible streaks generated by the movement of an object or a camera, resulted from the light integration at the imaging devices during a finite exposure time. It is an important cue in the perception of dynamic objects in motion, and more frequent demand for rendering high-quality animated images. In principle, motion blur rendering needs to draw the object at many different but continuous times and then average the results. By such, the time complexity is quite high. Over years, it has been an active research topic in interactive graphics and virtual reality attempted to speed up motion blur rendering. To address the issue, approaches have been studied, such as investigating visibility coherence and motion hints to simplify the light integration [30], representing the moving objects with static geometry to save time-sampling [9], developing sampling techniques via spatio-temporal coherence or hierarchical structures to accelerate ray tracing of objects in motion [6,27], and optimizing the rendering pipeline to efficiently use caches [27] or GPUs [24]. However, to our knowledge, no method has been proposed to efficiently simplify the moving objects for speeding up motion blur rendering, and determine the level of detail simplification in relation to the motion-blur features in rendering.

In this paper, we propose a motion-aware (direction, speed) simplification method to get the simplified models with which motion blur rendering can be accelerated. As our method is orthogonal to existing techniques for motion blur rendering, it can be easily integrated with existing methods for fast rendering. Here, we mainly focus on two issues with respect to moving objects. First, we simplify the object model with the moving direction aware, aiming to reduce the geometric primitives as many as possible while producing the visible features in motion blur similar

* Corresponding author.
E-mail addresses: zhangmy@ios.ac.cn (M. Zhang), whn@ios.ac.cn (W. Wang), hanqiu@cse.cuhk.edu.hk (H. Sun), hanhonglei@sina.com (H. Han).

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to using the original model. This is based on the observation that the features parallel to the motion direction are blurred and less likely to be observed in the rendered results. Then we deduce a formula to get the level of detail simplification related to the moving speed to simplify the object, by the sensitivity variation map of the human visual system corresponding to the spatial frequency and motion of the object [13]. Afterwards, we examine how to incorporate our algorithms with the rendering pipeline using rasterization or ray tracing, the two popular approaches for motion blur rendering via 3D models, as illustrated in Fig. 1, with our simplified models, the existing methods get acceleration for motion blur rendering, even by an order of magnitude. In general, our main technical contributions are in two aspects:

- An effective approach for producing simplified 3D models especially to speed up motion blur rendering.
- Novel motion-aware algorithms for geometric models to fast perform high quality motion blur rendering.

In the rest of the paper, we briefly outline the most related work in motion blur rendering, level of detail simplification, and perception-based rendering in Section 2. Then, we analyze the motion blur phenomenon and the perception of motion blur in Section 3. Afterwards, we describe direction-aware simplification with object motion in Section 4, and how to determine the level of details in perception-based motion blur rendering in Section 5. Our experimental results and discussion are given in Section 6, and finally conclusions in Section 7.

2. Related work

Motion blur rendering. Efficient rendering of motion blur effects has been a long-standing problem in interactive graphics. Recent progress can be referred in the survey paper [22]. Here, we do not cover the work on using image processing techniques for rendering blurring effect, such as [26,18,2], which is out of the scope of the paper, as our approach is aimed at using 3D models for motion blur rendering. The works with 3D models for motion blur rendering need to compute samples from the moving object for light integration, which are generally treated via rasterization or ray tracing.

The rasterization-based methods work by rasterizing the object in multidimensional spaces. These are easy to utilize graphics hardware for acceleration, such as using hardware frame buffers and GPUs. Some methods render the object in the spatial domain many times respectively and then combining the results with weights [11]. Other methods form a geometric representation for a moving primitive and rasterize the geometric representation, including oriented bounding box (OBB) in the 2D homogeneous space [1], the convex hull in the screen space [19], and temporal bounds for a tile of triangles [20].

Ray tracing has also been studied for motion blur rendering. The key computation here is to get the track for a ray from a pixel to intersect the object during a time period. With respect to this, distributed ray tracing methods have been investigated, where each ray is stochastically allocated so all dimensions are simultaneously sampled [5]. For high efficiency, different sampling techniques were proposed, such as minimum distance Poisson or jittered sampling [4], pre-computed sampling patterns [4], adaptive sampling in the Euclidean domain [10], or in the wavelet domain [23]. Recently, there are physically-based smart reconstruction methods to reason about the anisotropy of the underlying space–time imaging process [16] or samples [23,32,31], to improve the rendering quality.

Unfortunately, these rasterization-based methods and ray tracing methods did not take into account using simplified moving objects. In this paper, we mainly address this challenge to reduce the computing cost on sampling for light integration, by providing the motion-aware simplified models to the rendering methods.

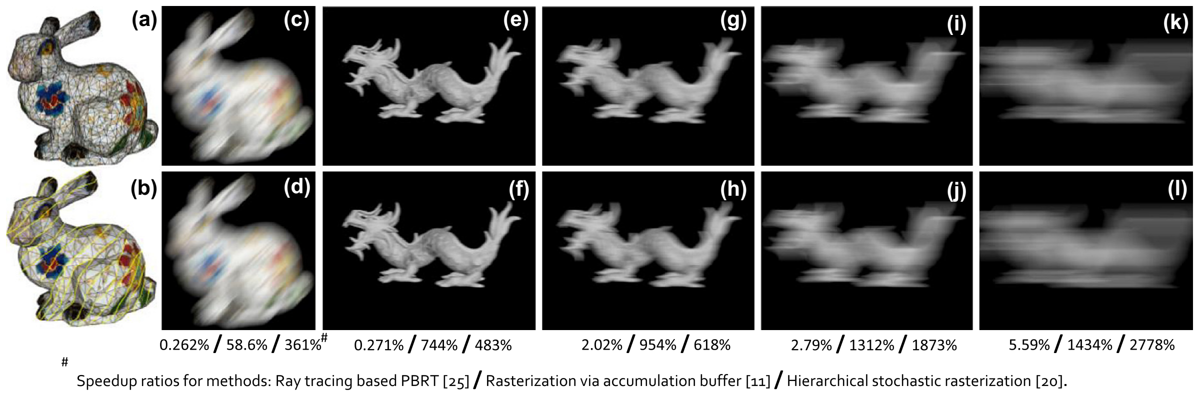

Fig. 1. Comparison of motion blur rendering results with original models and our simplified models. The percentage of computational speed-up for ray tracing, accumulation buffer and stochastic rasterization are listed at the bottom of the images. In the first row, it displays the original Bunny model and the rendering results with the original models of Bunny and Asian Dragon. In the second row, it displays our simplification manner with motion direction aware, illustrated in yellow lines here, in (b), and the rendering results with our corresponding simplified models for getting similar results as using the original models for different motions. The speedup ratios show that our method can effectively speed up existing methods for motion blur rendering, and achieve more acceleration with the larger models or faster motion. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)