Practical Logarithmic Shadow Maps

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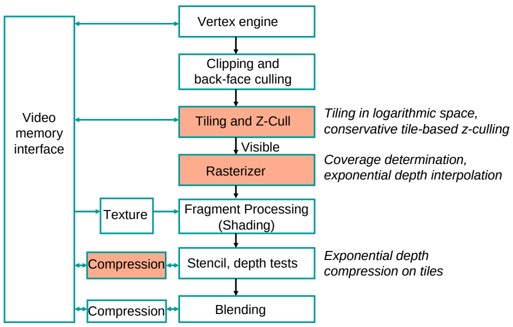

Figure 1: **Shadow Mapping Architecture**: *This figure shows our enhanced graphics pipeline for high-quality shadows based on logarithmic rasterization. We highlight the different stages involved in the rasterization of primitives and the incremental enhancements (shown in orange) to perform logarithmic rasterization. This practical architecture can save memory bandwidth by* $5-6$ *times.*

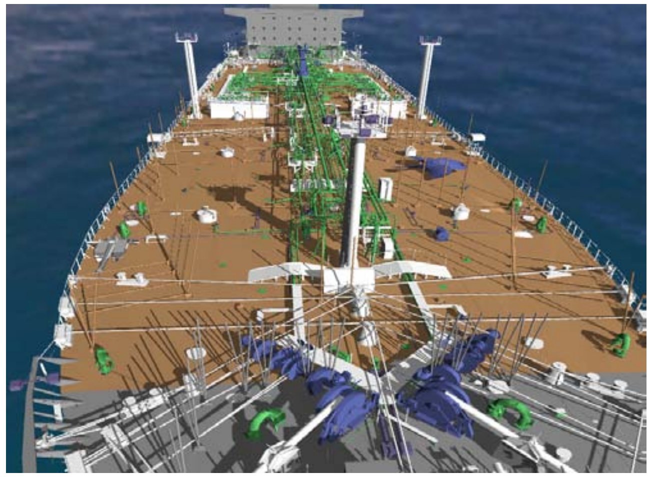

Figure 2: **Tanker model**: *We highlight the high quality shadows generated using logarithmic shadow maps with* $1.5K \times 1.5K$ *resolution. This CAD model has* 82 *million triangles with many complex piping structures and a very high depth range. Logarithmic shadow maps result in much lower perspective aliasing error as compared to prior techniques that are based solely on projective transformations.*

1 Introduction

Computer games and simulators are among the most demanding real-time computer graphics applications. In these applications, shadows greatly contribute to the visual realism and provide important depth cues. However, computing high-quality shadows at interactive rates in a complex and dynamic environment remains a challenging problem.

In this paper, we restrict ourselves to generating hard shadows from point light sources. One of the popular techniques for interactive shadow generation is shadow mapping [Williams 1978]. A major disadvantage of shadow maps is that they are prone to aliasing artifacts if they have inadequate resolution. Aliasing error can be classified as perspective or projection aliasing [Stamminger and Drettakis 2002].

Current practical shadow mapping solutions reduce perspective aliasing by reparameterizing the shadow map to allocate more resolution to the undersampled regions of a scene [Stamminger and Drettakis 2002; Wimmer et al. 2004]. These algorithms use the 4×4 projective transformation matrices available on current GPUs to obtain a non-uniform parameterization. The optimal shadow mapping parameterization, however, involves logarithmic transformations. Since perspective and logarithmic functions can diverge significantly, approximations with projective transformations can require much higher shadow map resolution to avoid perspective aliasing.

Main Results : In this sketch, we present a new logarithmic shadow map parameterization and investigate the feasibility of supporting it in hardware. We first analyze the shadow mapping aliasing problem to derive the parameterization for both point and directional light sources. Then, we present a shadow mapping parameterization composed of a perspective projection followed by a logarithmic transformation. Our parameterization can significantly reduce aliasing error for a given resolution, or equivalently, can reduce the size of the shadow map required for a given amount of aliasing error.

In order to make these bandwidth savings practical, we propose enhancements to several stages of the current rendering pipeline to support optimal logarithmic mapping at current GPU rasterization and fill rates. These enhancements include modifying the rasterizer to support parallel evaluation of nonlinear edge equations and depth functions and a compression algorithm suited to logarithmic depth images. Our modified rasterization pipeline can generate high quality shadows with significantly lower storage and bandwidth requirements than current shadow mapping algorithms. We demonstrate a simulation of our shadow mapping architecture on several complex and demanding scenes: a powerplant model (13M triangles) with thin pipe structures, an oil tanker model (82M triangles) with high depth range, and a scanned statue model (372M triangles). Our simulation results indicate a $5-6$ times reduction in shadow map depth size compared to prior techniques that are based solely on projective transformations.

Overall, we show that a logarithmic parameterization produces high quality results and is practical to implement in hardware. Although our modifications increase the amount of arithmetic in the GPU rasterizer, we note that such changes align well with current hardware trends. The cost of on-chip arithmetic is decreasing rapidly, almost at the rate of Moore's Law cubed, whereas the cost of off-chip bandwidth and storage are decreasing much more slowly. Off-chip bandwidth and storage are key limiters in GPU performance today. More details are given in [Lloyd et al. 2006].

References

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