GPU-Assisted Techniques for Image-based Rendering and Physically Based Computer Animation

by

Jian Zhu

Doctor of Philosophy in Software Engineering

2012

Faculty of Science and Technology

University of Macau

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Abstract

For a long time, real-time rendering of highly realistic scene has been a goal pursued by computer graphics researchers. The parallelism of programmable graphics hardware provides us a way to accelerate the simulation and rendering speed. In this thesis, we present two GPU-assisted techniques for image-based rendering and physically based computer animation, respectively.

In Chapter 3 of this thesis, we present a real-time depth image-based rendering algorithm by GPU acceleration. By the algorithm, we uniformly sample an object in all directions in a polar coordinates system, to construct a *Spherical Depth Image*. With two deduced Warping Equations, we then pre-warp the image onto a view-dependent plane to get an intermediate image, which is further rendered onto the target image plane using standard texture mapping. By exploiting the inherent parallelism of modern programmable GPU, we transport the pre-warping process into vertex shader. Furthermore, the hardware pipeline's rasterization function is utilized to conduct the image re-sampling efficiently to generate hole-free rendering results.

Significant achievements have been made in the past two decades to model the dynamic behavior of fire, but almost none of them have addressed the decomposition process of the solid objects under combustion. In Chapter 5 of this thesis, we present a realistic, fast, and controllable model to simulate burning solids on GPU. A hybrid structure of grids is employed to simulate the whole process efficiently. The fuels inside the solid are consumed in a physically based way based on combustion theory, and fire is physically simulated by solving the fluid dynamics equations. They are well coupled by treating the solids as part of the fluid with high viscosity. Fire

propagation along the burning surface is well simulated with level set method. With proposed GPU-based ray-marching and multi-textures methods to visualize the turbulent fire and burning solid respectively, convincing results are produced. To achieve interactive simulation speed, a few acceleration techniques are employed, including a moving grid to dynamically track the fire propagation, a refined Marching Cubes method to reconstruct the burning surface, and a hardware-implemented fluid solver with CUDA.

Keywords: GPU, Image-based rendering, Depth image, Hardware acceleration, Pre-warping, Pixel Shader, Vertex Shader, CUDA, Physically based animation, Fluid simulation, Navier-Stokes Equations, Fire propagation, Object decomposition, Level set, Moving grid, Marching cubes

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