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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Acknowledgements

Firstly, I would like to express my sincere appreciation to my supervisor, Prof. WU Enhua, not only for his professional guidance and valuable advices throughout the whole seven years during my master and PhD study, but also for his kind support and constant encouragement. His conscientious attitude at work impressed and influenced me a lot. I am grateful to him for leading me to such an exciting research area in computer science: Computer Graphics. I am also grateful to my two co-supervisors: Prof. PhengAnn Heng and Prof. HanQiu Sun from CUHK.

In particular I would like to express my great thanks to Prof. LI Yiping, Ms. LIANG Shouzhuang, and my mathematics teacher Mr. ZENG Chuping in No.2 Middle School of ShaoYang, for their kind concern, help, trust, and encouragement all the time. Special thanks are given to Dr. PUN Chiman, who taught me a lot about image processing. I worked as his teaching assistant for more than two years, and we collaborated very well. I am also grateful to other teachers who taught me the master courses. They are Prof. GONG Zhiguo, Dr. XU Qiwen, Dr. SI Yain Whar, Prof. LI Xiaoshan, Prof. THAM Yiu Kwok and Dr. SIMON Fong.

Thanks should go to Donald Lam WengHong, the lab technician who helped me a lot in my daily work. I have also benefited from time spent with the following colleagues and students: CHANG Yuanzhang, GUO Qinghui, CAI Zhongmou, CHEN Yadang, HAO Chuanyan, YANG Lijie, ZHANG Shixue, SHENG Bin, YAO
Wenli, and LI Dong. I also would like to thank my roommates. They are ZHU Haitao, ZHENG Haibin, ZHENG Chenpei, CHEN Shipo, and ZHANG Bin.

My thanks also extend to the professors and students from the State Key Laboratory of Computer Science, Institute of Software, Chinese Academy of Sciences, Beijing. They are Prof. WANG Wencheng, LIU Xuehui, CHEN Yanyun, LIU Youquan, LI Sheng, Dr. BAO Kai, HUANG Peijie, JIAO Shaohui, CHI Xiaoyu, CHEN Xin, YANG Liming, MENG Weiliang, HUANG Mengcheng, LIU Fang, PhD candidates YANG Meng, WU Xiaolong, LIU Feitong, WANG Shandong, XIE Guofu, LI Xiaosheng, SUN Gang, MA Ziyang, Master students LIU Ming, LIU Yang, ZHANG Man, CHEN Shunbin, LIU Le, LU Jian, et al.

I am grateful to my parents for their selfless and endless love to me. They are not highly educated persons, but they educated me a lot. I am so grateful for my upbringing. Most important of all, the deepest thanks go to my wife and my little one year old daughter. I owe them too much. Without my wife’s big consideration and encouragement, I am afraid I cannot finish the study. My gratitude is far beyond the words I can express. They are most precious to me in the world, and they are the motivating force that makes me go forward.

Finally, I would like to express my appreciation to University of Macau for the support of postgraduate studentship to me.
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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Figure 5-14: As the wood decomposes gradually, the gold characters (i.e., CASA2011) inside the wood show up.