UNIVERSITY OF CALIFORNIA,
IRVINE

Microscale-based Macroscale Rendering and Its Inverse Rendering

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Computer Science

by

Yu Guo

Dissertation Committee:
Professor Shuang Zhao, Chair
Professor Gopi Meenakshisundaram
Professor Charless Fowlkes

2021

DEDICATION

To Myself and My Family

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

ACKNOWLEDGMENTS

I would like to thank my advisor Shuang Zhao for his patient guidance and unconditional support.

I am sincerely grateful to Miloš Hašan for his inspiration and offering me opportunities for my internships in Autodesk and Adobe. I would also like to thank my other committee members Gopi Meenakshisundaram and Charless Fowlkes for the constructive advice they have provided.

I want to thank all the collaborator from my publications. And my intership mentors.

I would like to thank my labmates and other friends.

Finally, I thank my wife and my parents.

This work was supported in part by NSF grant IIS-1813553, Autodesk Inc., Adobe Inc., University of Zaragoza (Spain) and Department of Computer Science, UC Irvine.

Chapter 3 is based on the material as it appears in ACM Transactions on Graphics, 2018 ("Position-Free Monte Carlo Simulation for Arbitrary Layered BSDFs", Yu Guo, Miloš Hašan and Shuang Zhao). The dissertation author was the primary investigator and author of this paper.

Chapter 4 is based on an under reviewing paper ("Beyond Mie Theory: Systematic Computation of Bulk Scattering Parameters based on Microphysical Wave Optics", Yu Guo, Adrian Jarabo and Shuang Zhao). The dissertation author was the primary investigator and author of this paper.

Chapter 5 is based on the material as it appears in ACM Transactions on Graphics, 2020 ("MaterialGAN: Reflectance Capture using a Generative SVBRDF Model", Yu Guo, Cameron Smith, Miloš Hašan, Kalyan Sunkavalli and Shuang Zhao). The dissertation author was the primary investigator and author of this paper.

Chapter 6 is based on the material as it appears in Computer Graphics Forum, 2020 ("A Bayesian Inference Framework for Procedural Material Parameter Estimation", Yu Guo, Miloš Hašan, Lingqi Yan and Shuang Zhao). The dissertation author was the primary investigator and author of this paper.

This dissertation is based on a LaTeX template for thesis and dissertation documents at UC Irvine [4].

VITA

Yu Guo

EDUCATION

Doctor of Philosophy in Computer Science — **2016 – 2021**
University of California, Irvine — *Irvine, CA, US*

Master of Science in Computational Sciences — **2010 – 2013**
University of Chinese Academy of Sciences — *Beijing & Shenzhen, China*

Bachalar of Science in Applied Mathematics — **2006 – 2010**
Central South University — *Changsha, China*

RESEARCH EXPERIENCE

Research Associate — **2013 – 2016**
Nanyang Technological University — *Singapore*

REFEREED PUBLICATIONS

Position-Free Monte Carlo Simulation for Arbitrary Layered BSDFs **2018**
ACM Transactions on Graphics

MaterialGAN: Reflectance Capture using a Generative SVBRDF Model **2020**
ACM Transactions on Graphics

A Bayesian Inference Framework for Procedural Material Parameter Estimation **2020**
Computer Graphics Forum

Beyond Mie Theory: Systematic Computation of Bulk Scattering Parameters based on Microphysical Wave Optics **2021**
In submission ...

ABSTRACT OF THE DISSERTATION

Microscale-based Macroscale Rendering and Its Inverse Rendering

By

Yu Guo

Doctor of Philosophy in Computer Science

University of California, Irvine, 2021

Professor Shuang Zhao, Chair

The abstract of your contribution goes here.

Chapter 1

Introduction

In this dissertation, we first address a more general but efficient way to handle complex surface reflectance and volumetric scattering,

Next, we present an optimization based method for SVBRDF reconstruction and then extend it to bayesian inference.

To summarize, we develop a smart technique to render layered material, a framework to compute scatterings in participating media based on wave optics, and given a number of images, how to estimate the material properties. These techniques were presented at multiple conferences [2, 3, 1]. Our specific contributions include:

Position-free Monte Carlo simulation for arbitrary layered BSDFs. Real-world materials are often layered: metallic paints, biological tissues, and many more. Variation in the interface and volumetric scattering properties of the layers leads to a rich diversity of material appearances from anisotropic highlights to complex textures and relief patterns. However, simulating light-layer interactions is a challenging problem. Past analytical or numerical solutions either introduce several approximations and limitations, or rely on ex-

pensive operations on discretized BSDFs, preventing the ability to freely vary the layer properties spatially. We introduce a new unbiased layered BSDF model based on Monte Carlo simulation, whose only assumption is the layer assumption itself. Our novel position-free path formulation is fundamentally more powerful at constructing light transport paths than generic light transport algorithms applied to the special case of flat layers, since it is based on a product of solid angle instead of area measures, so does not contain the high-variance geometry terms needed in the standard formulation. We introduce two techniques for sampling the position-free path integral, a forward path tracer with next-event estimation and a full bidirectional estimator. We show a number of examples, featuring multiple layers with surface and volumetric scattering, surface and phase function anisotropy, and spatial variation in all parameters.

Chapter 2

Background

Chapter 3

Microscale Based Surface Rendering

Chapter 4

Microscale Based Volumetric Rendering

Chapter 5

Inverse Rendering for Macroscale Material Parameters

Chapter 6

Inverse Rendering for Microscale Material Parameters

Chapter 7

Conclusion and Future work

Bibliography

[1] Yu Guo, Miloš Hašan, Lingqi Yan, and Shuang Zhao. A bayesian inference framework for procedural material parameter estimation. *Computer Graphics Forum*, 39(7):255–266, 2020.

[2] Yu Guo, Miloš Hašan, and Shuang Zhao. Position-free monte carlo simulation for arbitrary layered bsdfs. *ACM Transactions on Graphics (ToG)*, 37(6):1–14, 2018.

[3] Yu Guo, Cameron Smith, Miloš Hašan, Kalyan Sunkavalli, and Shuang Zhao. Materialgan: reflectance capture using a generative svbrdf model. *ACM Transactions on Graphics (TOG)*, 39(6):1–13, 2020.

[4] Lars Otten. LaTeX template for thesis and dissertation documents at UC Irvine. `https://github.com/lotten/uci-thesis-latex/`, 2012.

Appendix A

Appendix Title

Supplementary material goes here. See for instance Figure A.1.

A.1 Lorem Ipsum

dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

"I am glad I was up so late,
for that's the reason I was up so early."
William Shakespeare (1564-1616), British dramatist, poet.
Cloten, in Cymbeline, act 2, sc. 3, l. 33-4.

Figure A.1: A deep quote.