Exploring Micro-geometry for Microfacet-based Normal Mapping

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CONTENT

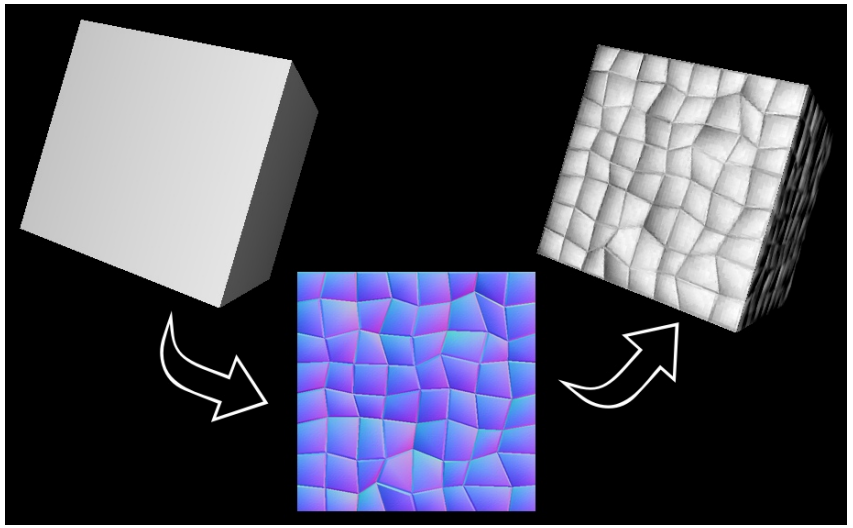
- Introduction
- Related works
- Problem Statement
- Suggestion
- Difficulties
- Progression
- Schedule & Role

Introduction

Normal Map

Normal Map

- Technique that enhances visual details of surface
- Use shading normals that deviate from geometric normals

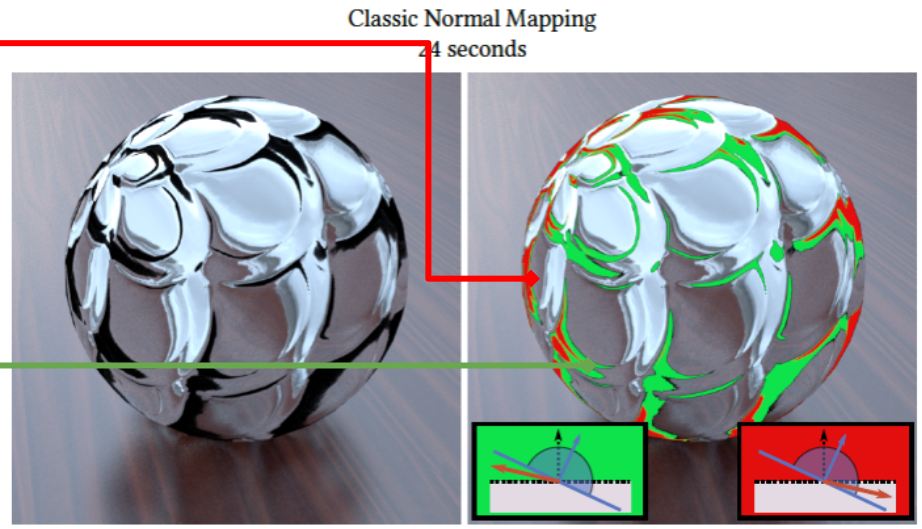


Introduction

Problem of Normal Map

Problem : Breaks the consistency of light transport

- Non symmetry due to shading normals
- Black fringes on surfaces
- Violation of energy conservation



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Problem of Normal Map

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- Black fringes on surfaces
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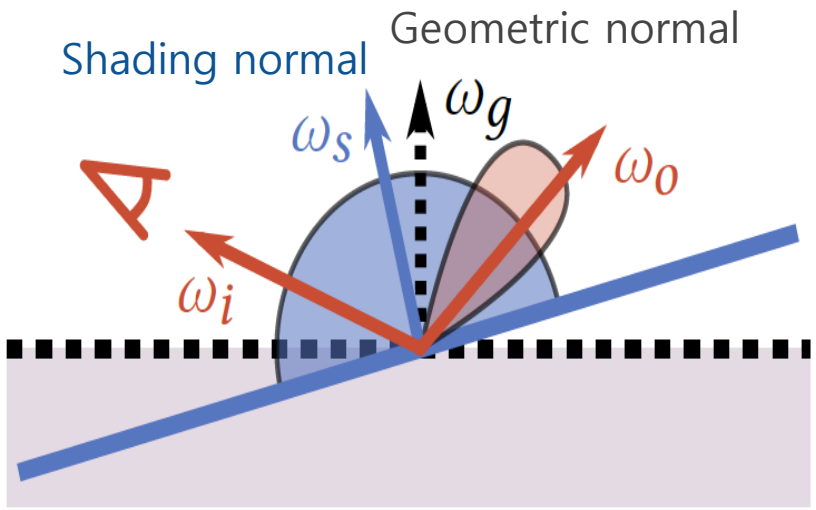

Use of ω_s instead of ω_g reweights BRDF and importance sampling equation

$$\bar{f}(\omega_i, \omega_o) = f_{\omega_s}(\omega_i, \omega_o)\frac{\langle \omega_o, \omega_s \rangle}{\langle \omega_o, \omega_g \rangle}$$

Not symmetric!

Cause High variance

$$\bar{f}(\omega_i, \omega_o)\langle \omega_i, \omega_g \rangle = f_{\omega_s}(\omega_i, \omega_o)\langle \omega_i, \omega_s \rangle \frac{\langle \omega_o, \omega_s \rangle \langle \omega_i, \omega_g \rangle}{\langle \omega_o, \omega_g \rangle \langle \omega_i, \omega_s \rangle}$$

Can only Importance Sample

Introduction

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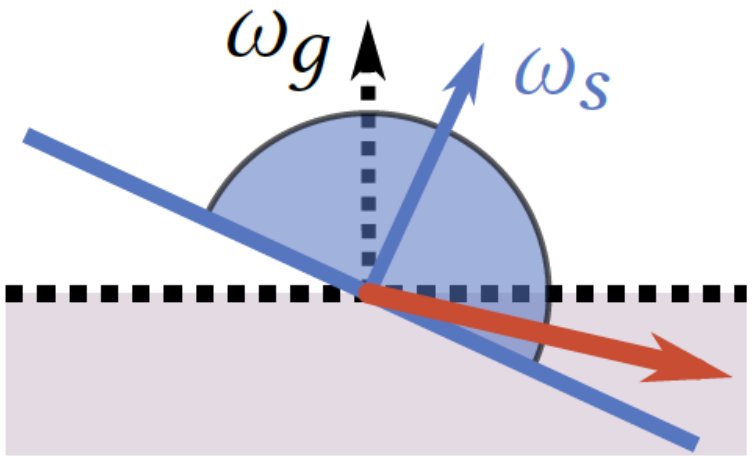
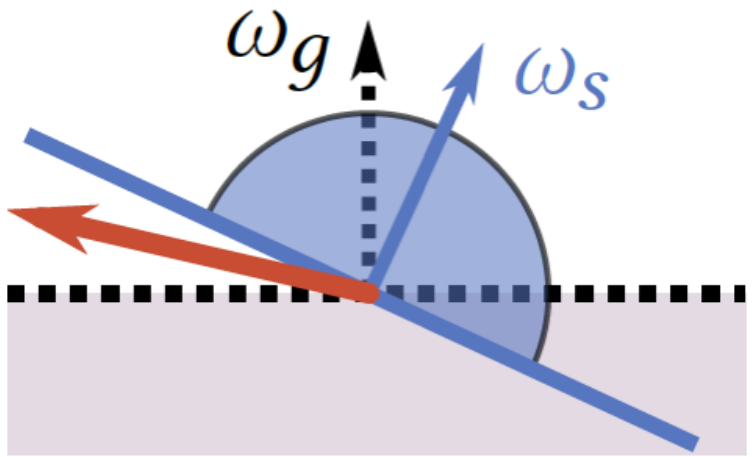


Light leaks through surface



BRDF is undefined

Introduction

Problem of Normal Map

- Non symmetry due to shading normals
- Black fringes on surfaces
- **Violation of energy conservation**

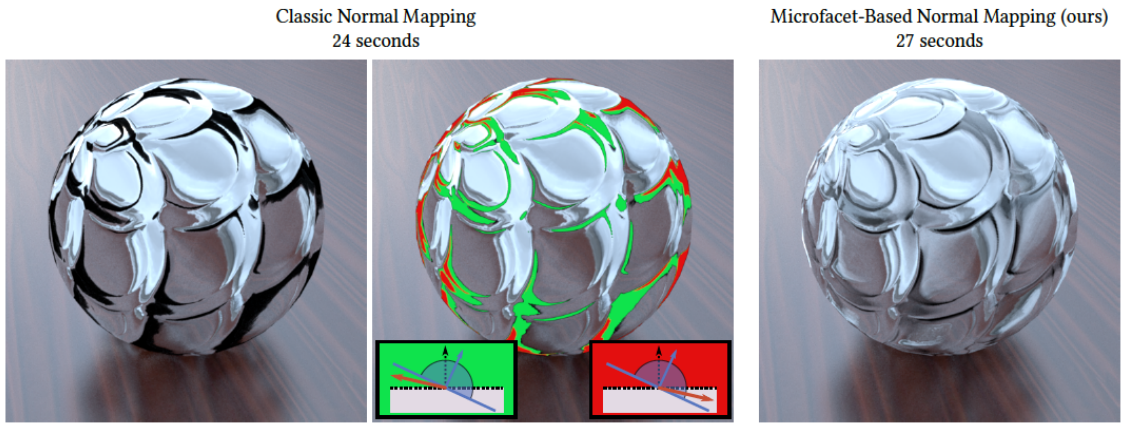
> Use of reweighted BRDF violates consistency equation

$$1 \geq \int_{\Omega} \bar{f}(\omega_i, \omega_o)(\omega_i \cdot \omega_g)\, \mathrm{d}\omega_i$$

$$= \frac{\omega_o \cdot \omega_s}{\omega_o \cdot \omega_g} \int_{\Omega} f_{\omega_s}(\omega_i, \omega_o)(\omega_i \cdot \omega_g)\, \mathrm{d}\omega_i$$

Can be arbitrarily large

Related works

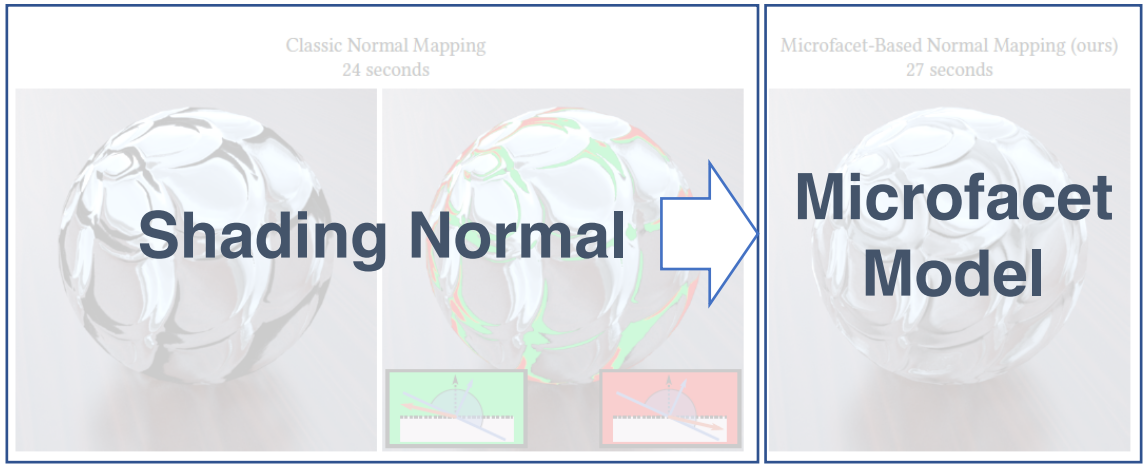


Microfacet-based Normal Mapping for Robust Monte Carlo Path Tracing

VINCENT SCHÜSSLER, ERIC HEITZ, JOHANNES HANIKA, CARSTEN DACHSBACHER

SIGGRAPH Asia 2017

Related works



Microfacet-based Normal Mapping for Robust Monte Carlo Path Tracing

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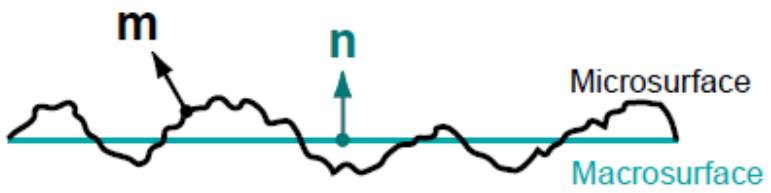
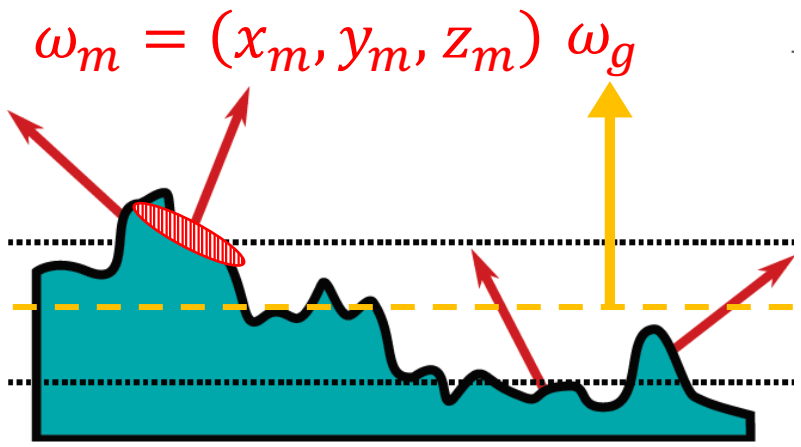
Related works

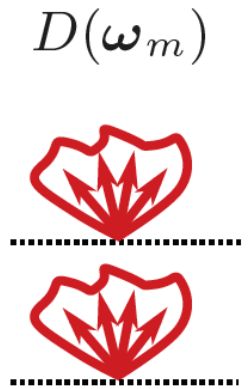
Microfacet theory

Microfacet Theory: Surface light transport framework

- Surface is made up of tiny flat microfacets
- Surface normal ω_g is average of microfacet normals ω_m
- Defined by normal distribution function (NDF) $D(\omega_m)$







Related works

Microfacet theory

Microfacet-based BRDF

$$f(\omega_i, \omega_o) = \int_\Omega f_m(\omega_i, \omega_m, \omega_o) \langle \omega_i, \omega_m \rangle \frac{G_2(\omega_i, \omega_m, \omega_o)}{G_1(\omega_i, \omega_m)} D_{\omega_i}(\omega_m) d\omega_m$$

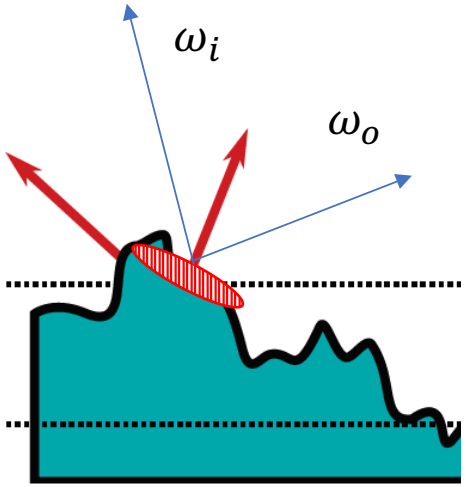
Related works

Microfacet theory

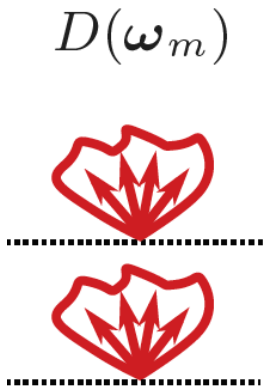
Microfacet-based BRDF

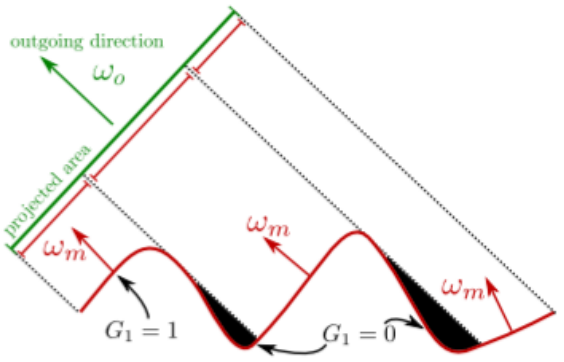
$$f(\omega_i,\omega_o) = \int_\Omega f_m(\omega_i,\omega_m,\omega_o)\left\langle \omega_i,\omega_m \right\rangle \frac{G_2(\omega_i,\omega_m,\omega_o)}{G_1(\omega_i,\omega_m)} D_{\omega_i}(\omega_m)\, d\omega_m$$

Micro-BRDF



Visible Normal Distribution Function





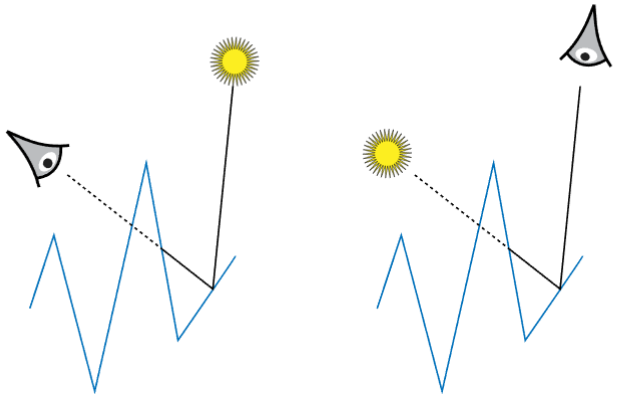
Related works

Microfacet theory

Microfacet-based BRDF

$$f(\omega_i,\omega_o) = \int_\Omega f_m(\omega_i,\omega_m,\omega_o)\left\langle \omega_i,\omega_m \right\rangle \frac{G_2(\omega_i,\omega_m,\omega_o)}{G_1(\omega_i,\omega_m)} D_{\omega_i}(\omega_m)d\omega_m$$

Geometry Function



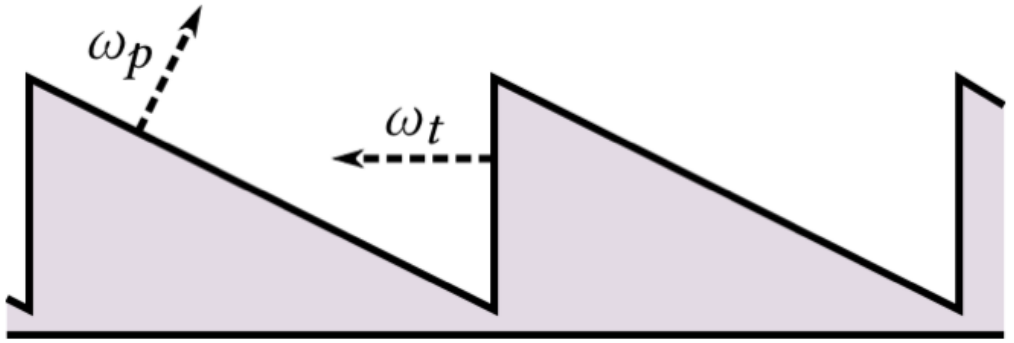
Masking function
Visibility to viewer

Shadowing function
Visibility to light

Related works

Microfacet-based Normal Mapping

Main Idea *by SCHÜSSLER et al. [2017]*



Microsurface consists of two normals:

- Perturbed normal
- Tangent normal:
  - Compensates so that the average normal of the microsurface remains the geometric normal

Related works

Microfacet-based Normal Mapping

Development *by SCHÜSSLER et al. [2017]*

Mathematically formulate microfacets using ...

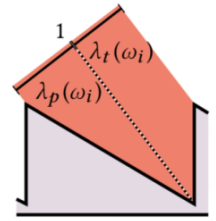
- NDF(Normal Distribution Function)
- Intersection prob.
- Masking-shadowing function
- Derive BRDF
  - single scattering

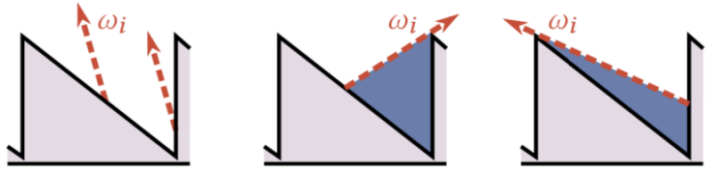
    multiple scattering using random walk

$$D(\omega_m) = \frac{\delta_{\omega_p}(\omega_m)}{\omega_p \cdot \omega_g} + \frac{\delta_{\omega_t}(\omega_m)\sqrt{1-(\omega_p \cdot \omega_g)^2}}{\omega_p \cdot \omega_g}$$

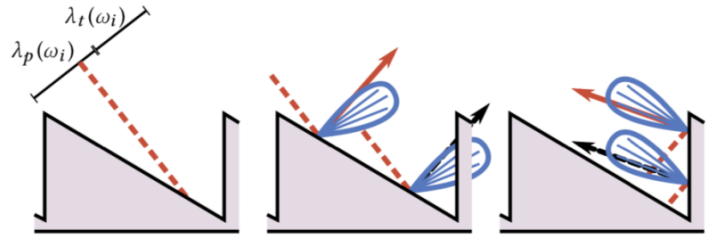
$$a_p(\omega_i) = \frac{\langle \omega_i, \omega_p \rangle}{\langle \omega_p, \omega_g \rangle},$$

$$a_t(\omega_i) = \frac{\langle \omega_i, \omega_t \rangle \sqrt{1-\langle \omega_p, \omega_g \rangle^2}}{\langle \omega_p, \omega_g \rangle}$$





$$G_1(\omega_i, \omega_m) = H(\langle \omega_i, \omega_m \rangle) \min\left[1, \frac{\langle \omega_i, \omega_g \rangle}{a_p(\omega_i) + a_t(\omega_i)}\right]$$



Related works

Microfacet-based Normal Mapping

Result *by SCHÜSSLER et al. [2017]*

1. Resolved violation of energy conservation problem

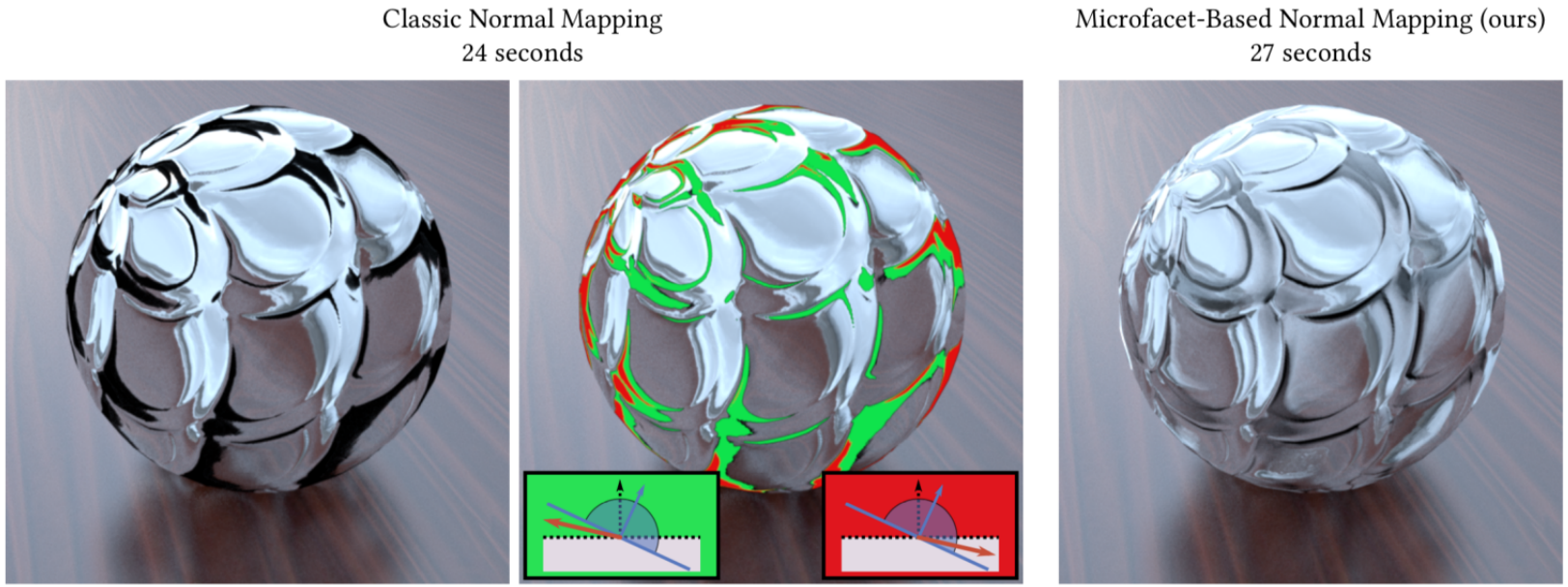
2. Resolved violation of symmetry of light transport problem

Related works

Microfacet-based Normal Mapping

Result *by SCHÜSSLER et al. [2017]*

1. Resolved violation of energy conservation problem

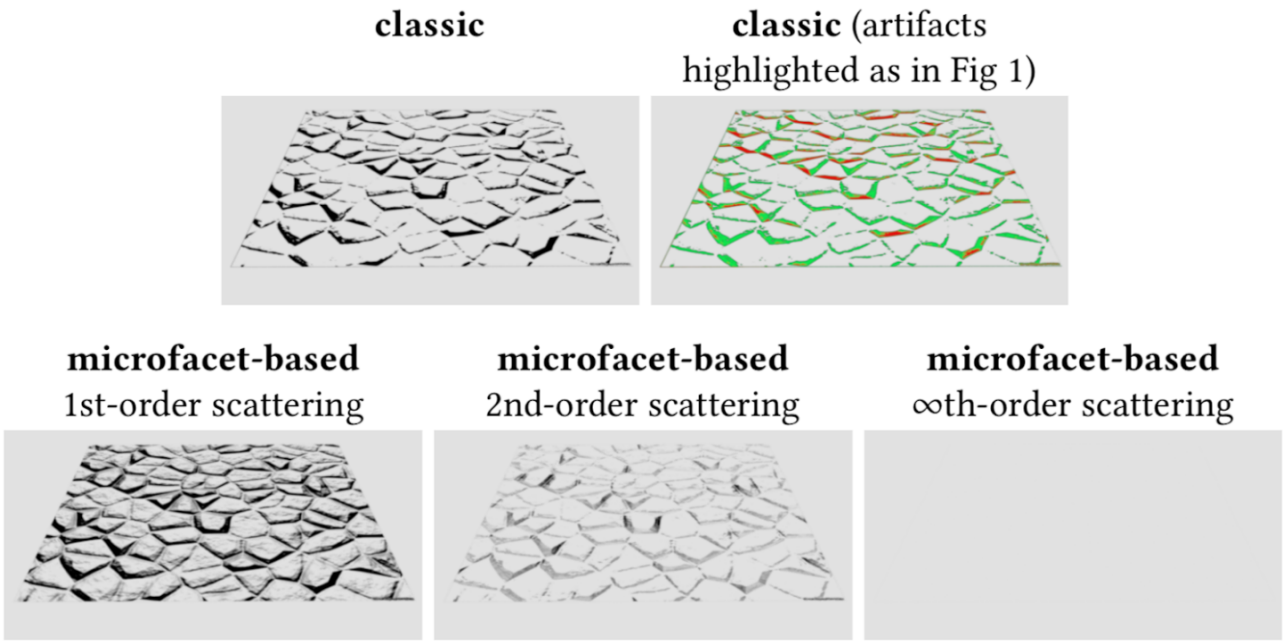


Related works

Microfacet-based Normal Mapping

Result *by SCHÜSSLER et al. [2017]*

1. Resolved violation of energy conservation problem(white furnace test)

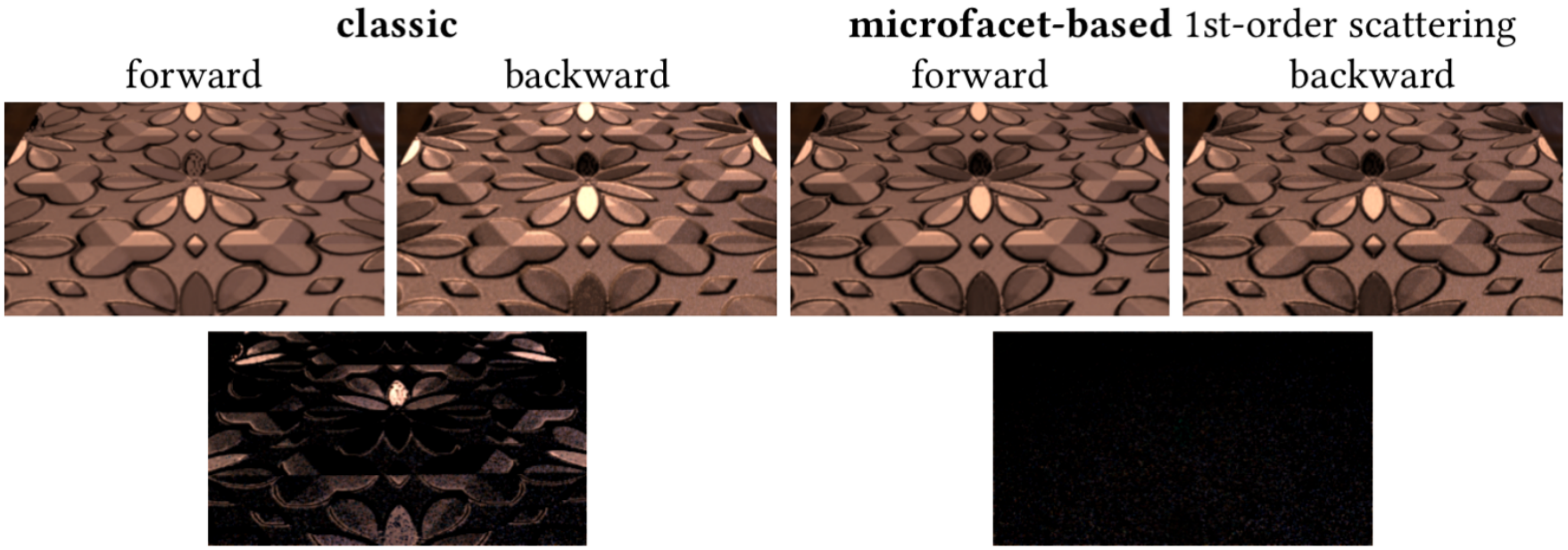


Related works

Microfacet-based Normal Mapping

Result *by SCHÜSSLER et al. [2017]*

2. Resolved violation of symmetry of light transport problem



Problem statement

Remaining problem of microfacet-based normal mapping

by SCHÜSSLER et al.:

1. Speed
2. Artifacts with interpolated vertex normals

Problem statement

Remaining problem of microfacet-based normal mapping

by SCHÜSSLER et al.:

1. Speed : Up to 70% more costly than classic normal mapping

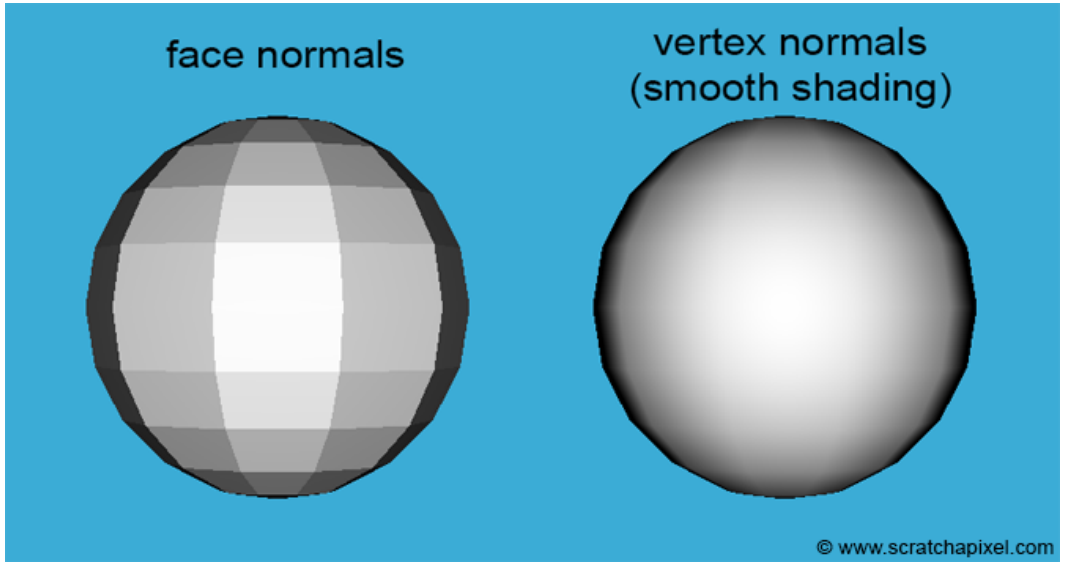
classic			**microfacet-based**			
classic	switch (3.4)	flip (3.4)	same material tangent facet (6.1)		specular tangent facet (6.2)	
29s	30s	30s	2nd-order 45s	∞th-order 49s	2nd-order 44s using Algo. 2 39s using Eq. (23)	∞th-order 47s

Problem statement

Remaining problem of microfacet-based normal mapping

by SCHÜSSLER et al.:

2. Artifact with interpolated vertex normals



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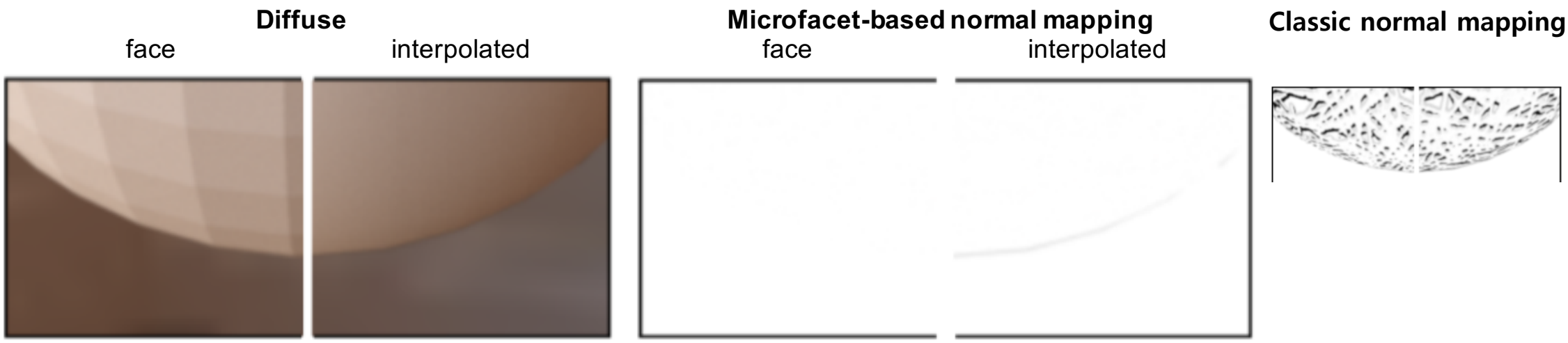


Suggestion

Remaining problem of microfacet-based normal mapping

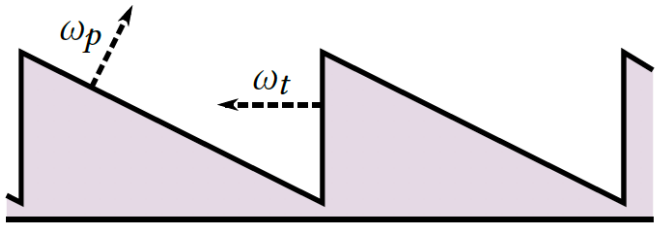
by SCHÜSSLER et al.:

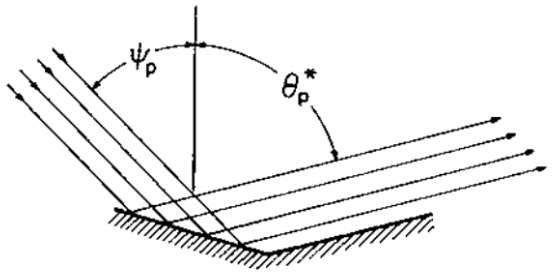
1. Speed
2. Artifacts with interpolated vertex normals

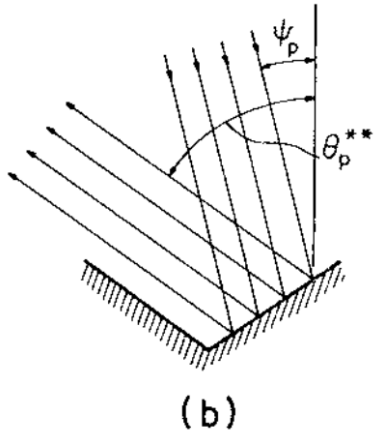
Modify Microgeometry?

Suggestion

Modification of geometry







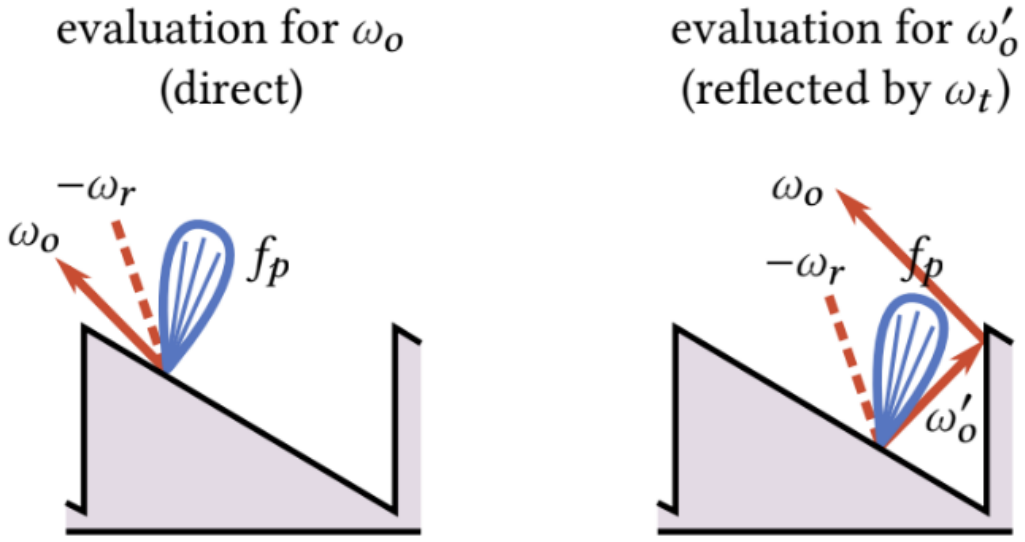
Current model:

Developed by Torrance-Sparrow.

Suggestion

Modification of geometry

Random walk algorithm to evaluate the BRDF function, and for path tracing.



Difficulties

Constraints to consider

- Geometry constraint
- We may have to adapt the random walk algorithm that give the path of the ray and the BRDF function.

Progression

- We build Mitsuba(render) plugging the paper's extension ***`normalmap_microfacet`***
- We are trying to get familiar with the Mitsuba framework and read through how they implemented their idea.

Progression

- We reproduced the performance comparison on our own environment.

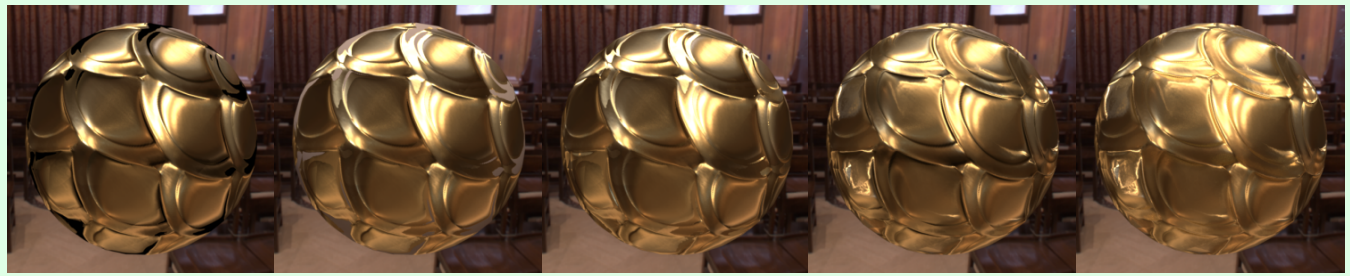
Result from the paper

classic			microfacet-based	
classic	switch (3.4)	flip (3.4)	specular tangent facet (6.2)	
29s	30s	30s	2nd-order 44s using Algo. 2 39s using Eq. (23)	∞th-order 47s

Result that we reproduced

512x512
2048 samples
8 cores

192s **206s** **207s** **243s** **313s**



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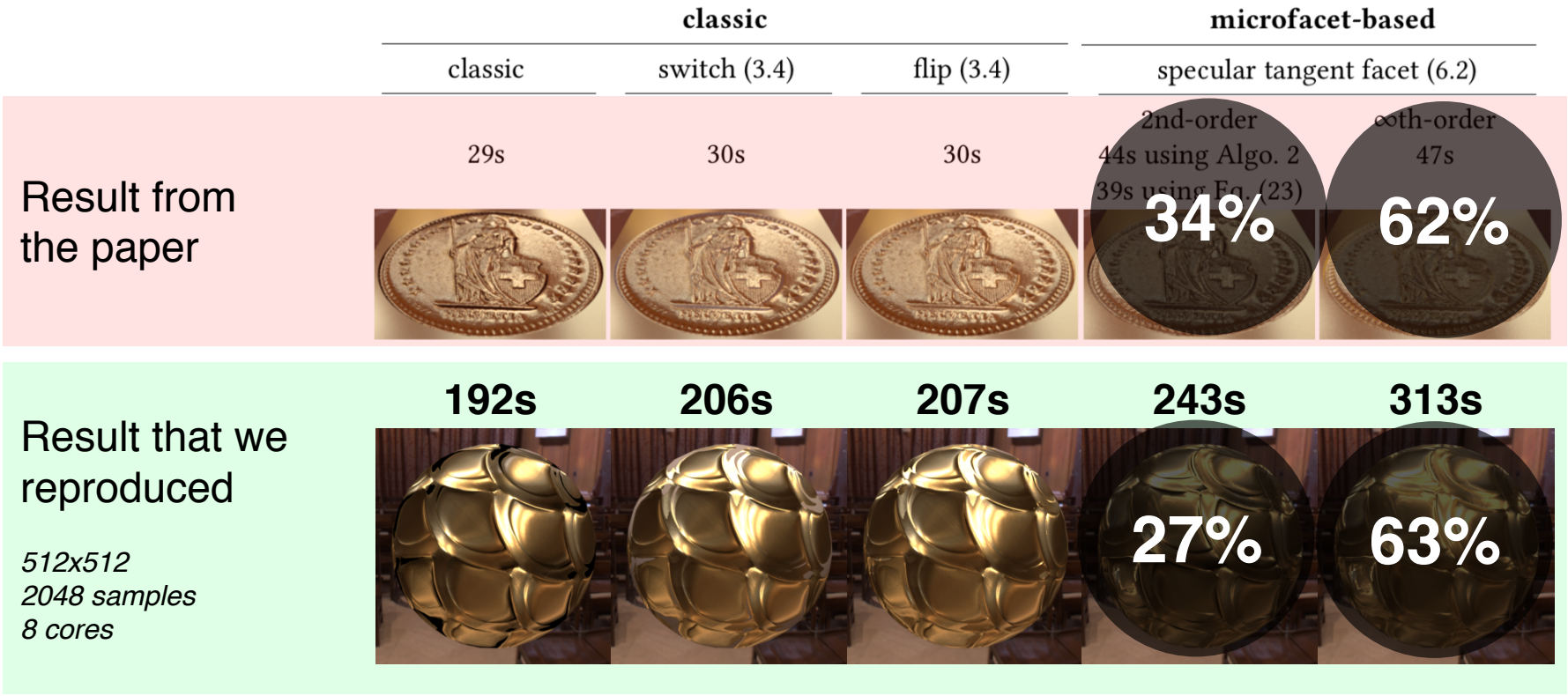


Schedule and Role

Schedule

- Run existing code
- Derivation of model with new geometry
- Change to code to make it work

Role

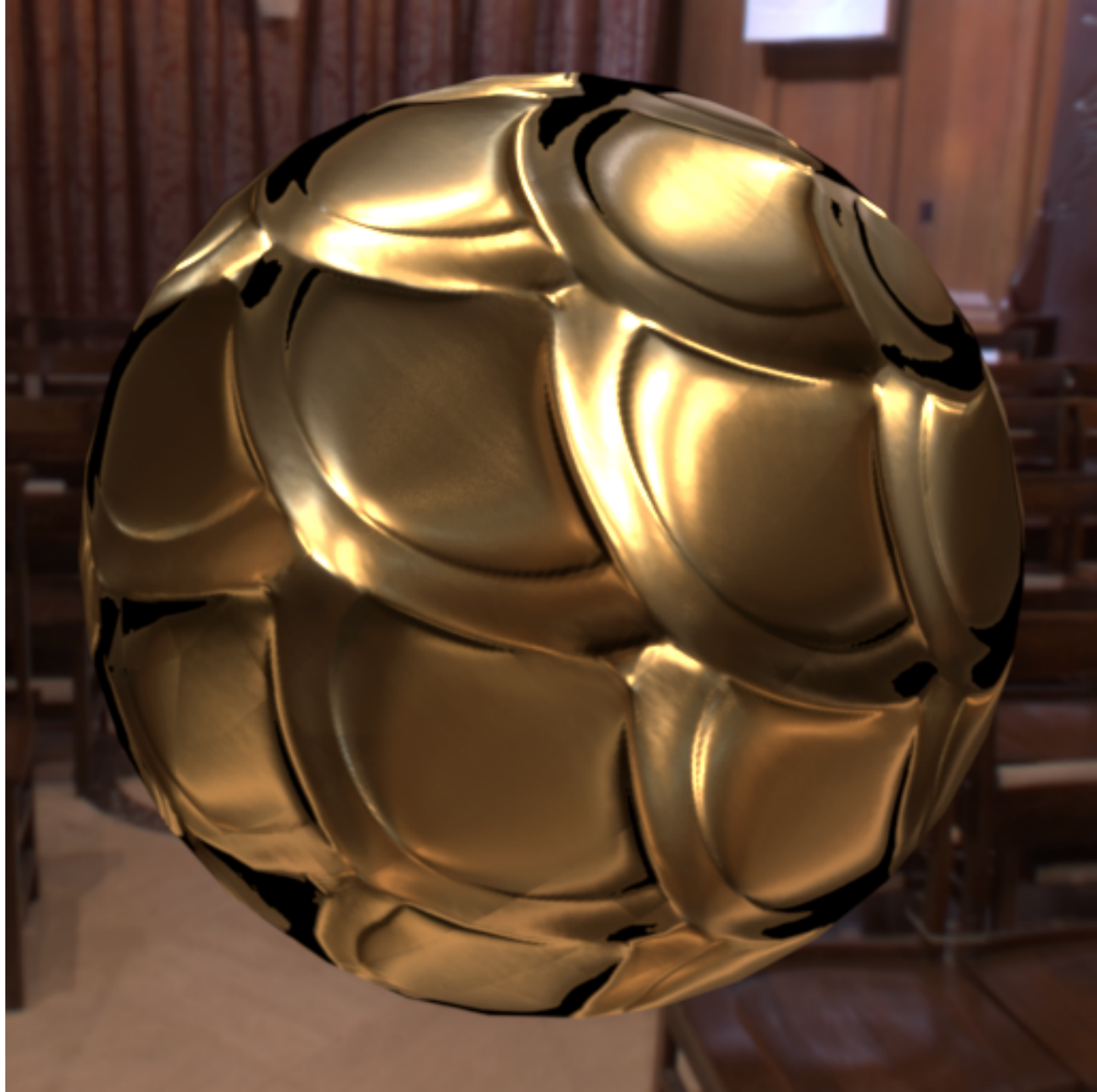
Work together overall

Responsible part each:

- **Gaspard**: Writing algorithm
- **Hakyeong**: Theoretical formulation of microfacet
- **Dahyun**: Implementation

Additional slides

Classic normal map



Classic normal map (switch)

Classic normal map (flip)

Microfacet-based normal map (w/ 2nd order)

Microfacet-based normal map (w/ inf. order)