Filtering Color Mapped Textures and Surfaces

I3D 2013

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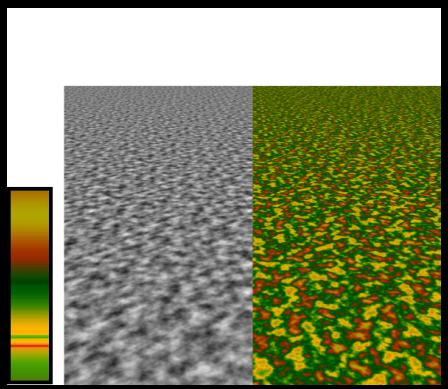
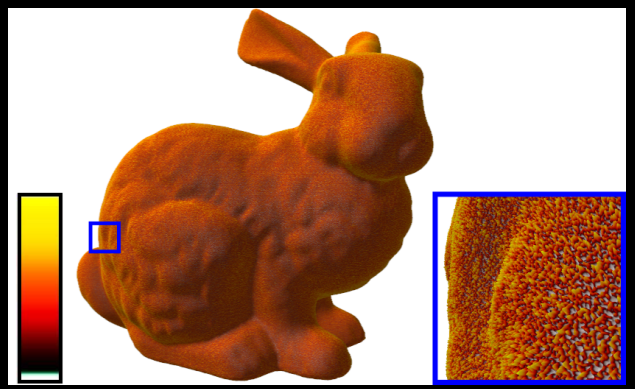
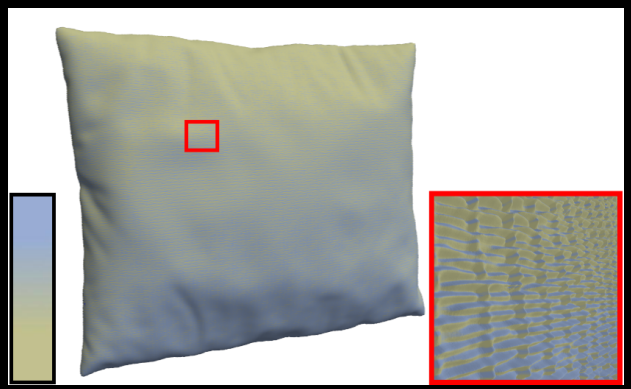


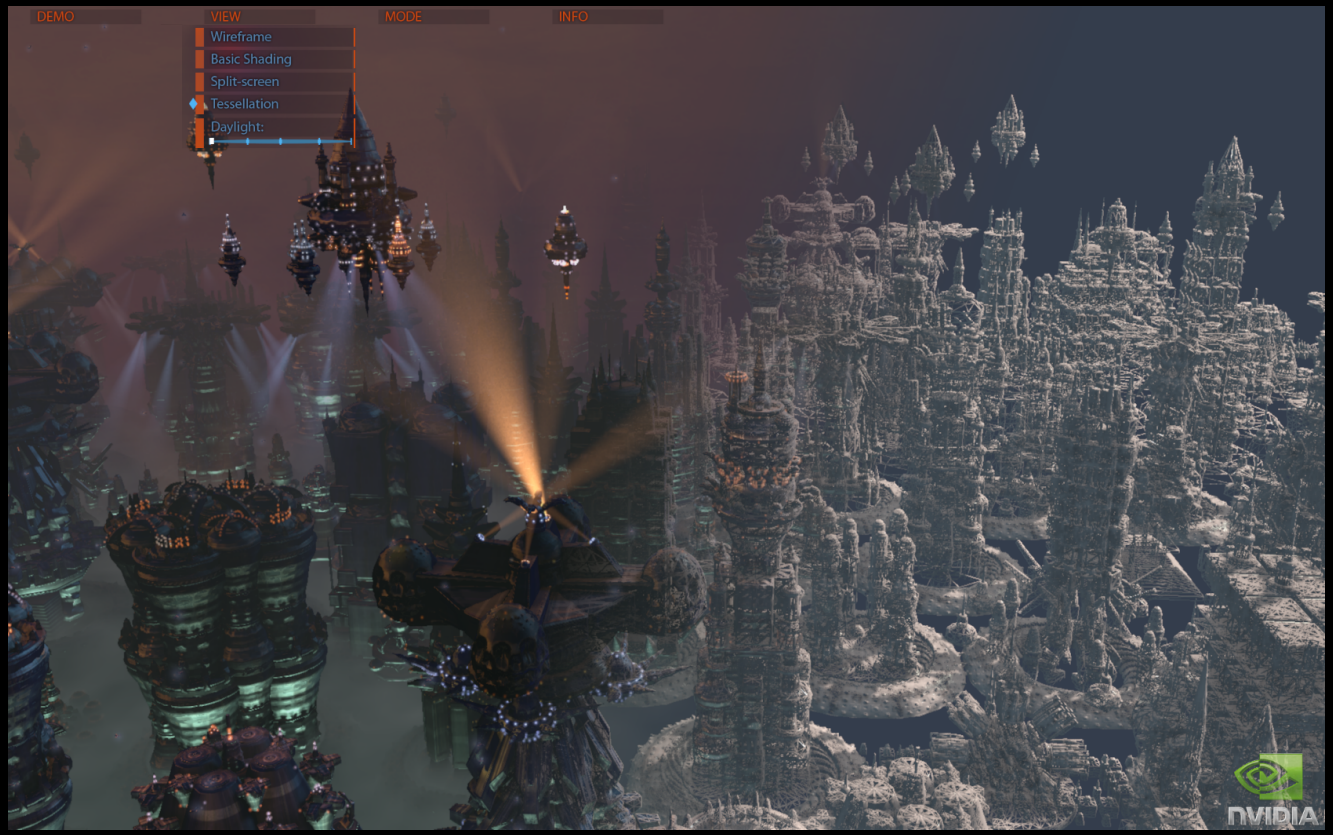




Introduction

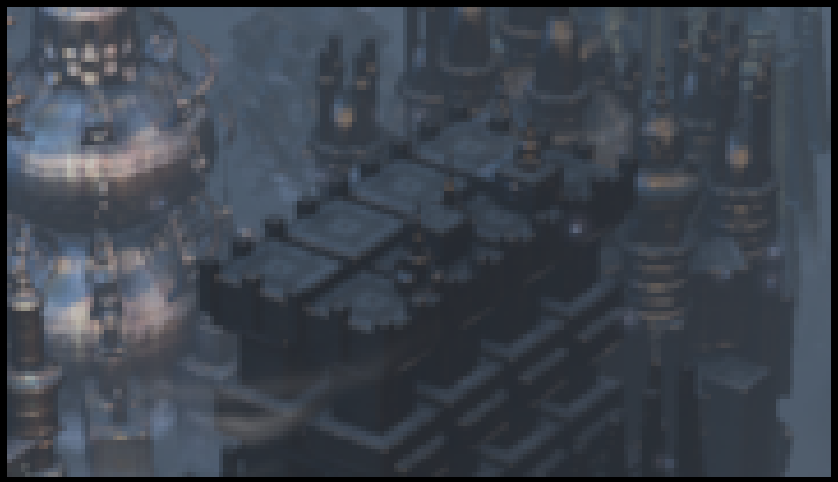
NVidia's Endless City Demo

- real-time
- amazing content and details



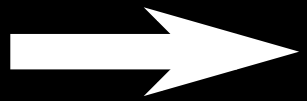
Introduction

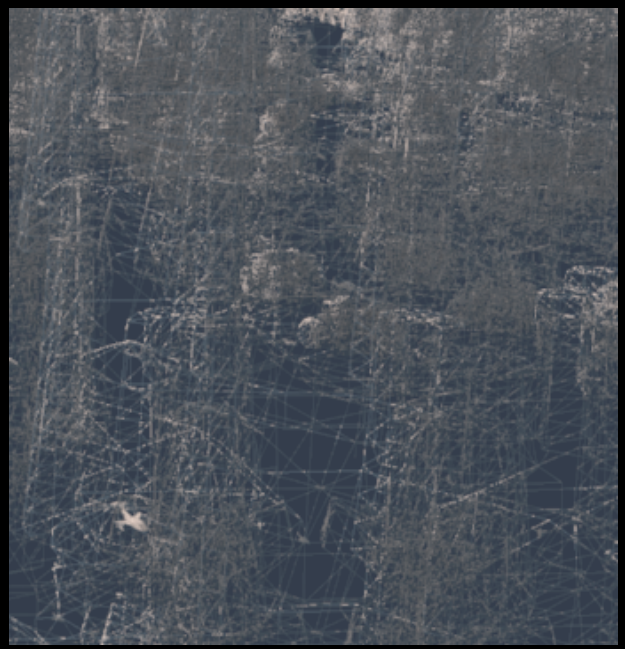
Level of detail transition



Introduction

Managing geometry level of detail is important... but is not enough

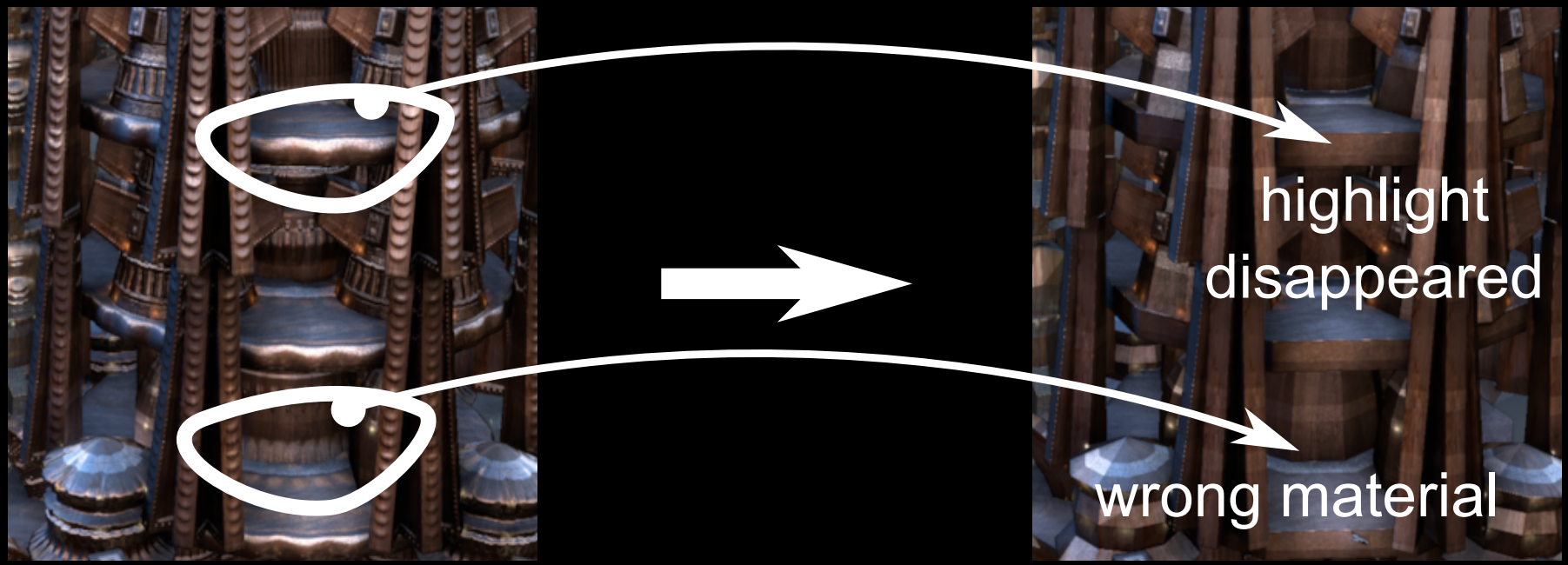




Introduction

Level of detail should also preserve appearance

- material
- BRDF
- normals
- visibility

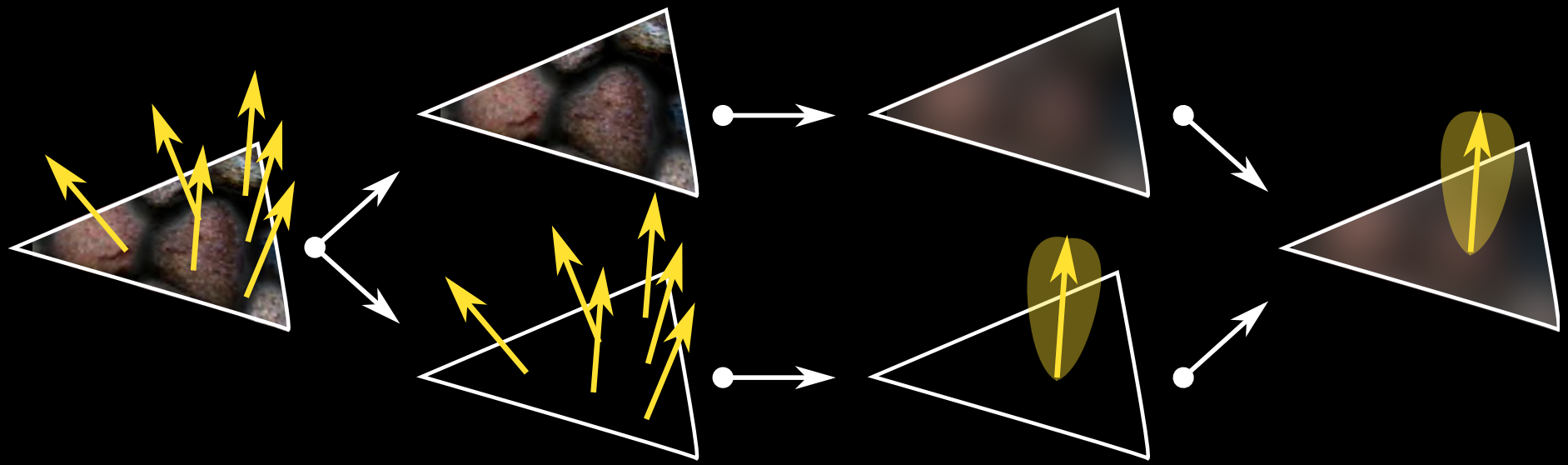


Introduction

Current CG model: coarse geometry + textures

$\rightarrow$ visibility, curvature and orientation are constant within triangles

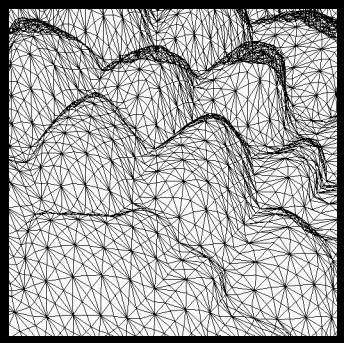
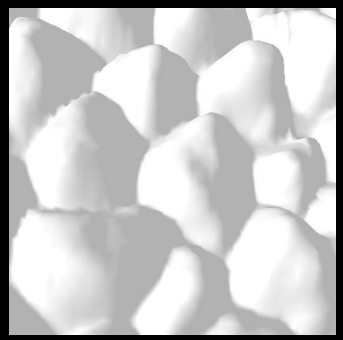
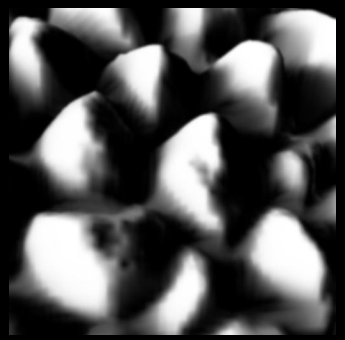
$\rightarrow$ textures can be filtered separately



separate colors and normals filtering

Introduction

What if geometry matches up texture resolution?

color		geometry		shading		visibility
	x		x		x	
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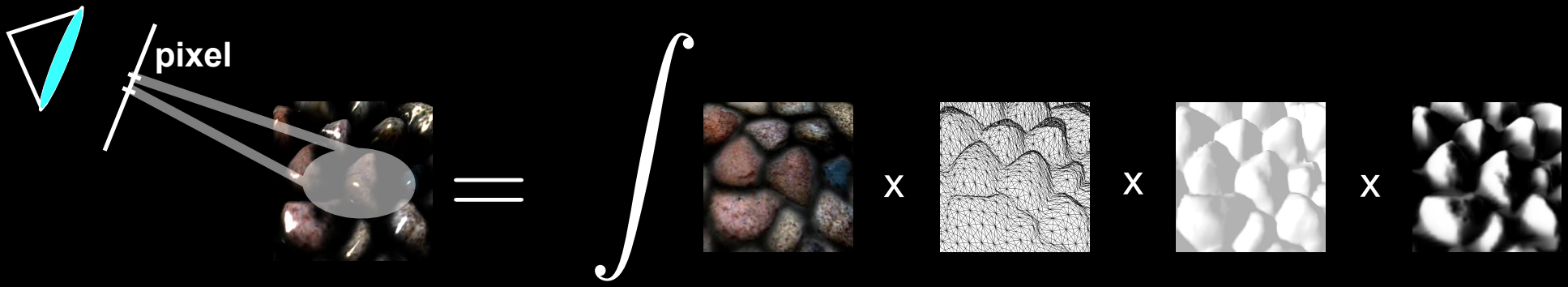
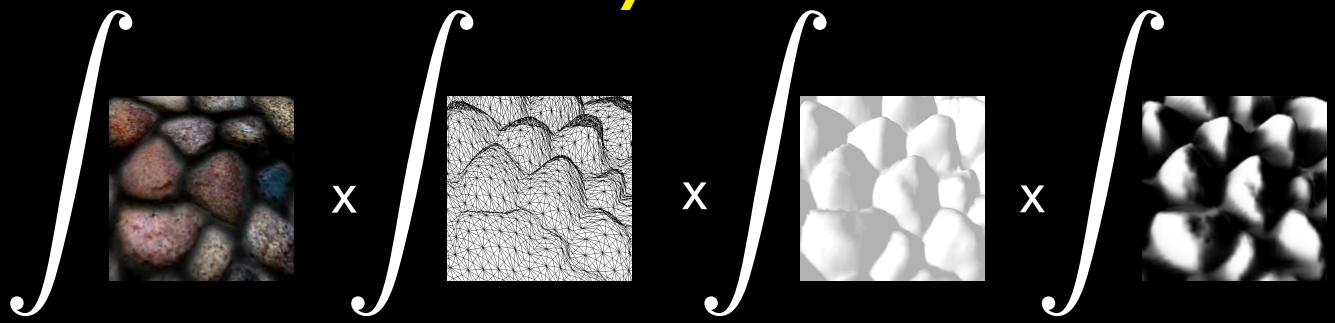
Introduction

physically correct



$\neq$



physically wrong

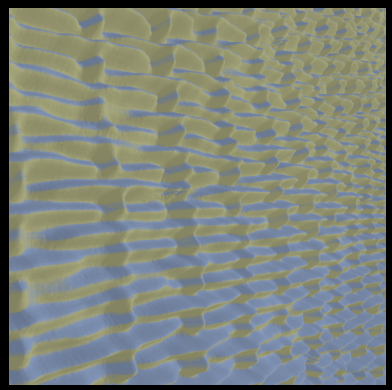
energy conservation violated

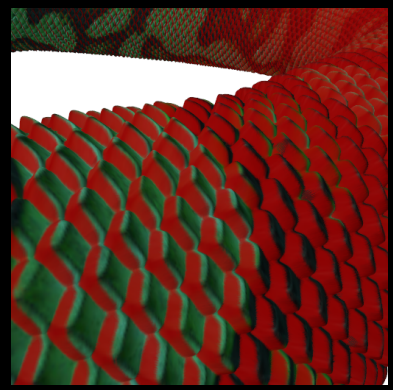
popping, aliasing, and inconsistent appearance

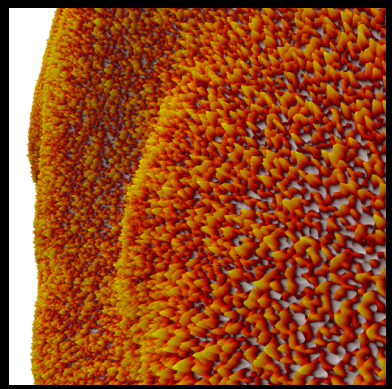
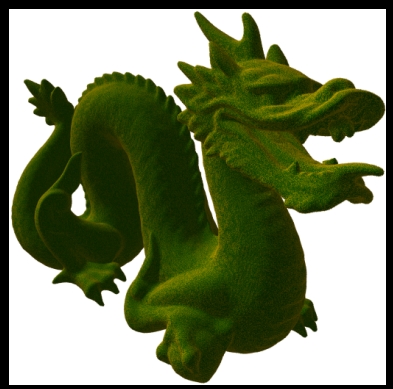
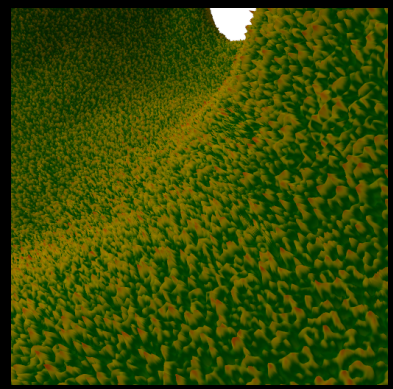
Introduction

We investigate how to

- filter correctly procedural surfaces
- with small-scale geometry, colors, and visibility

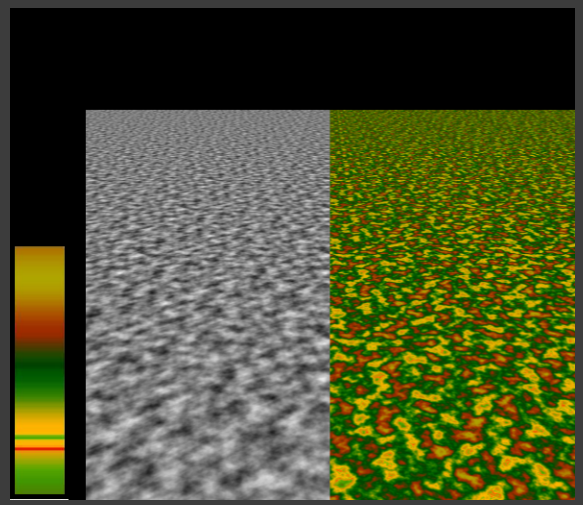





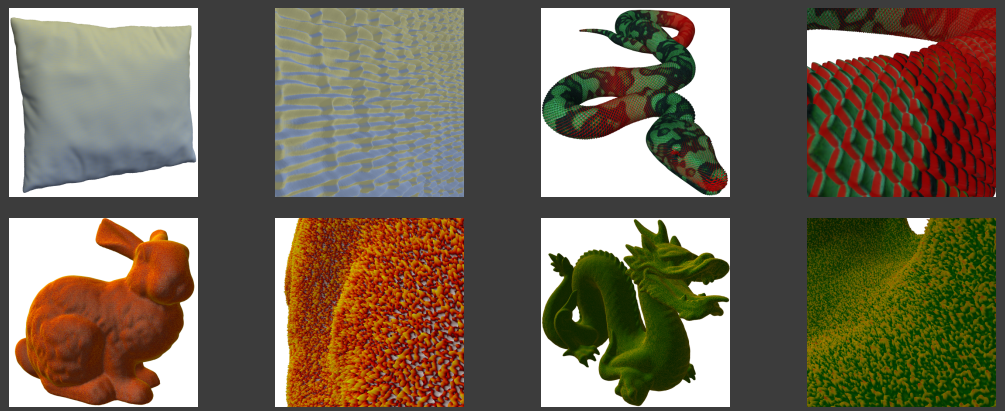




Plan

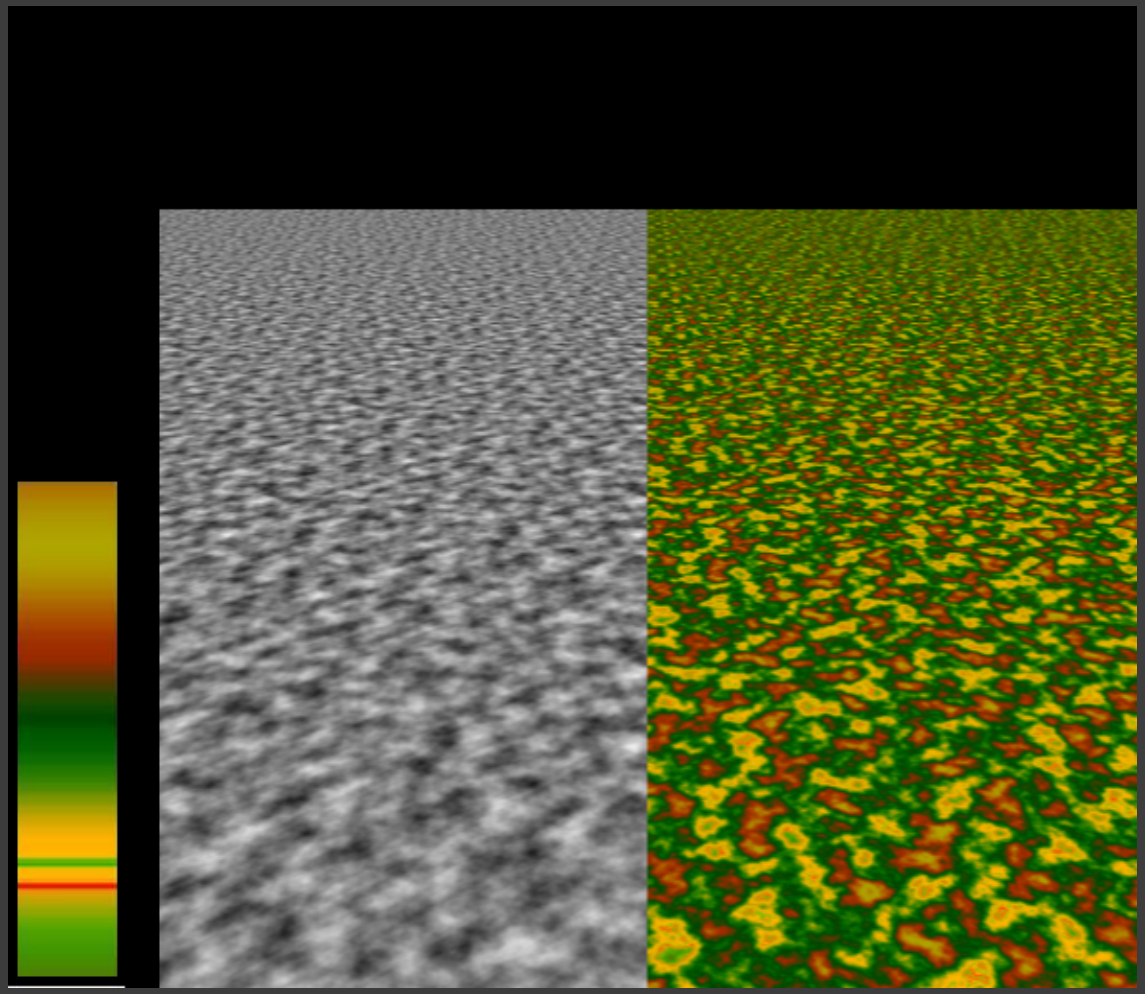
I. Filtering Procedural Textures (only colors)



II. Filtering Procedural Surfaces (colors and geometry)



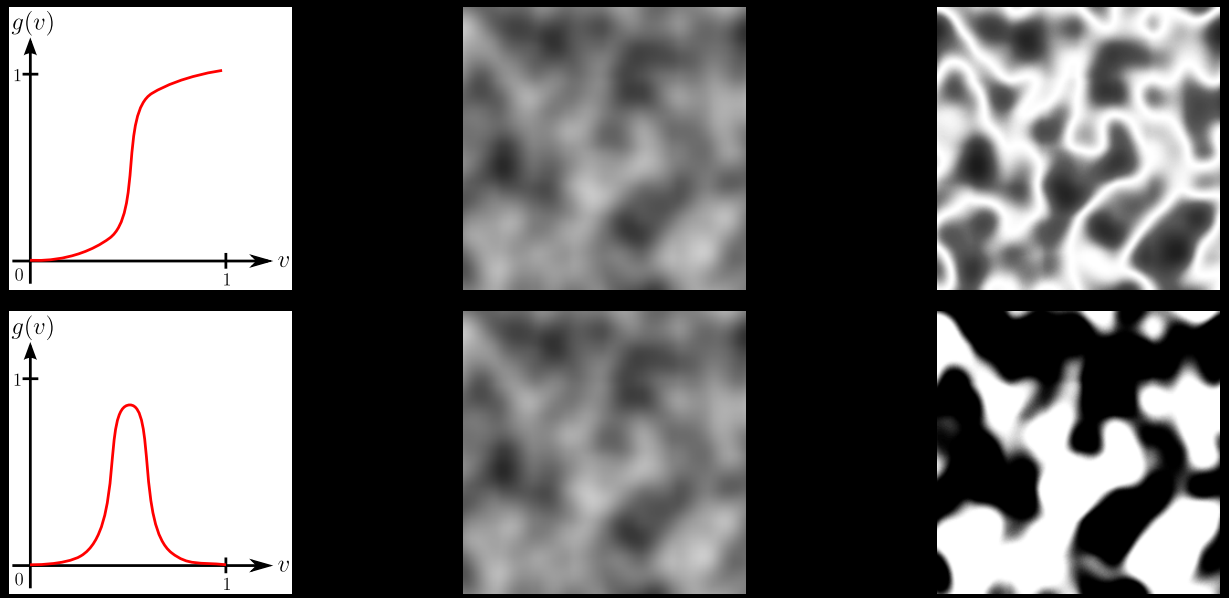
I. Filtering Procedural Textures



I.1 Definition

$$\text{texture}(x) = g(f(x))$$

$g \quad \circ \quad f \quad = \quad g(f)$



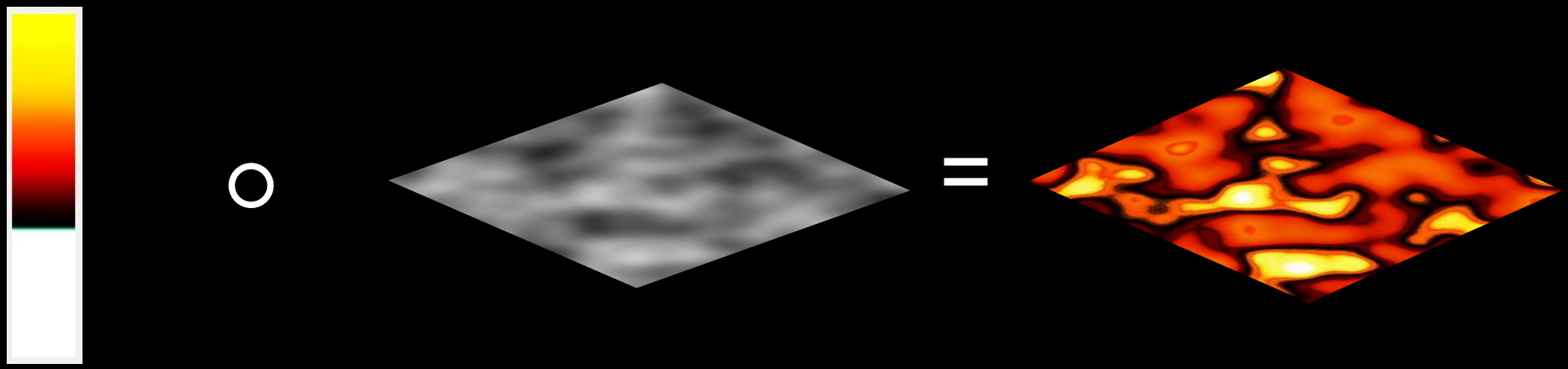
$f =$ **noise [Perlin83, Worley96, LLDD09]**

$g =$ **nonlinear transfer function**

I.1 Definition

Nonlinear operations summarized in color maps

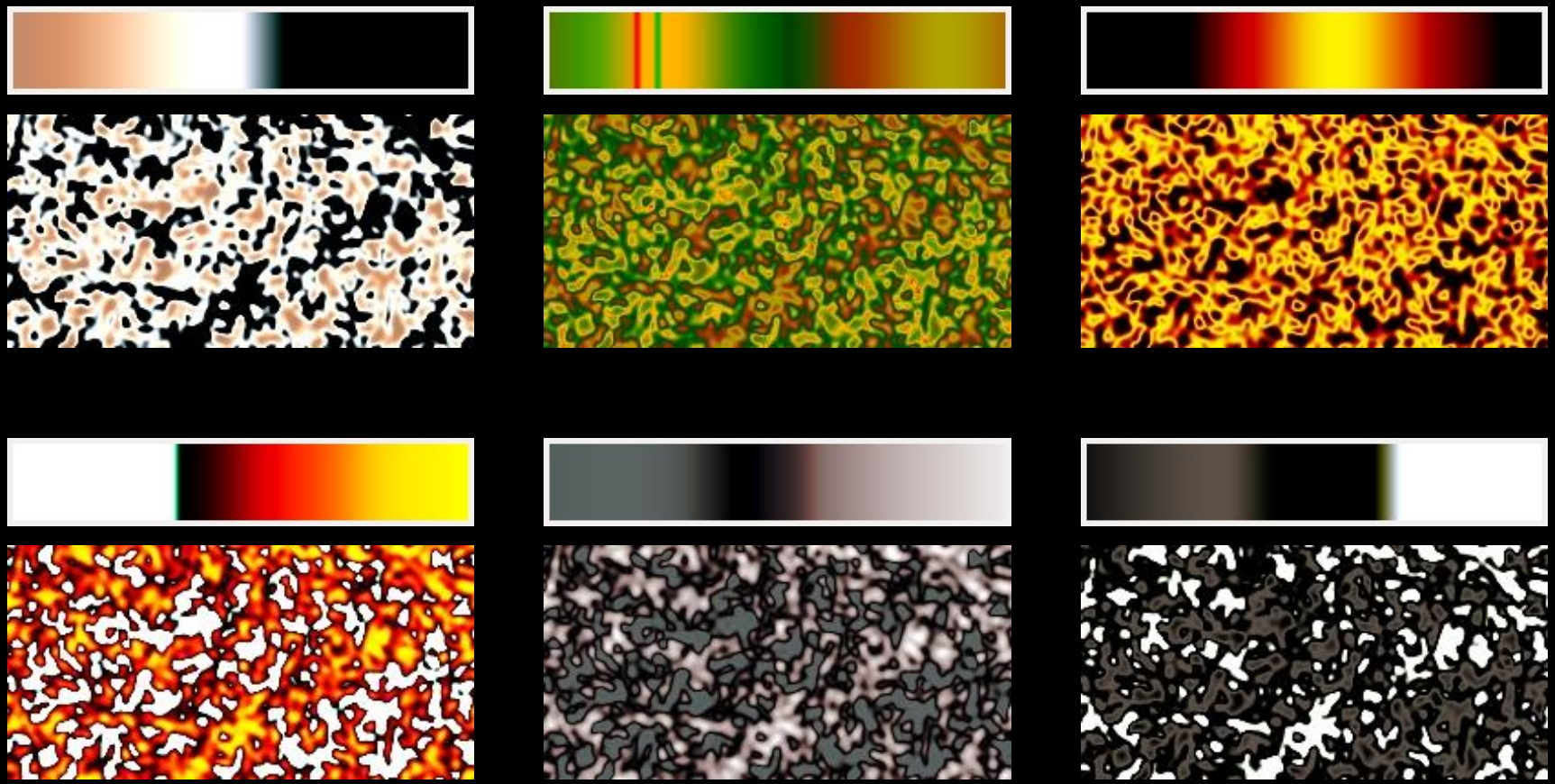
C_0 $\quad$ f $\quad$ $C_0 \circ f$



Color map $\quad$ **Grayscale function**

I.1 Definition

Nonlinear operations summarized in color maps



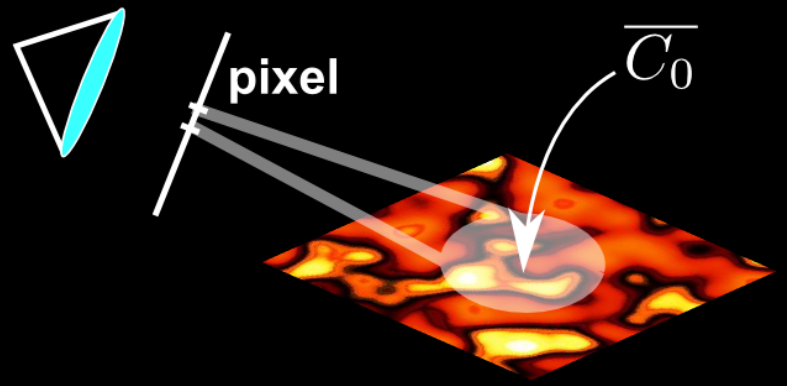
I.2 Problem

Important properties of procedural textures

- efficient on-the-fly evaluation
- intuitive control parameters

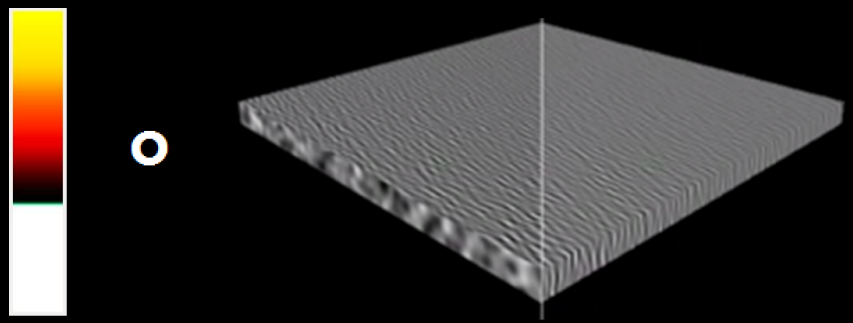
Filtering does not work

correct $\int C_0(f) \quad =$



$\neq$

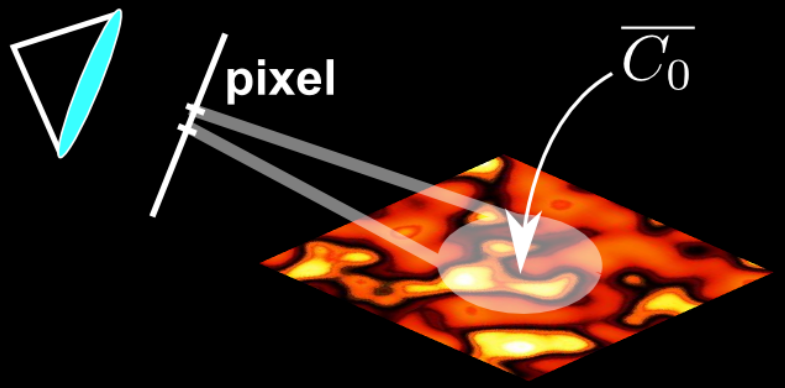
wrong $C_0(\int f) \quad =$



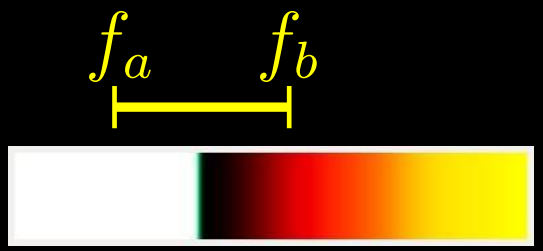
I.3 Previous Work

[RTBS92, HCKT99, LLDD09]

$$\bar{C}_0 = \int C_0(f(x))\, dx \quad \approx \quad \int_{f_a}^{f_b} C_0(f)\, df$$



$\approx$



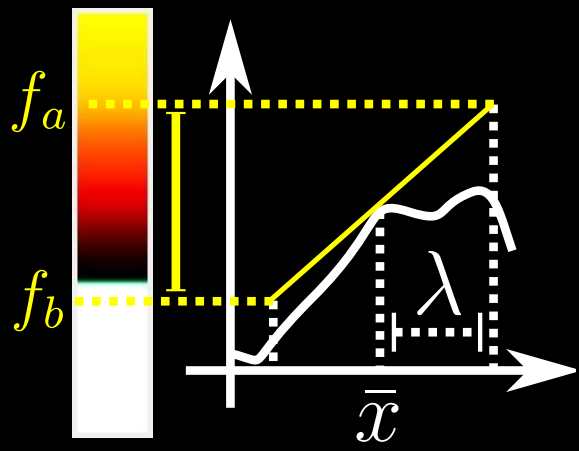
texture filtering $\approx$ **color map**

I.3 Previous Work

Box Filtering

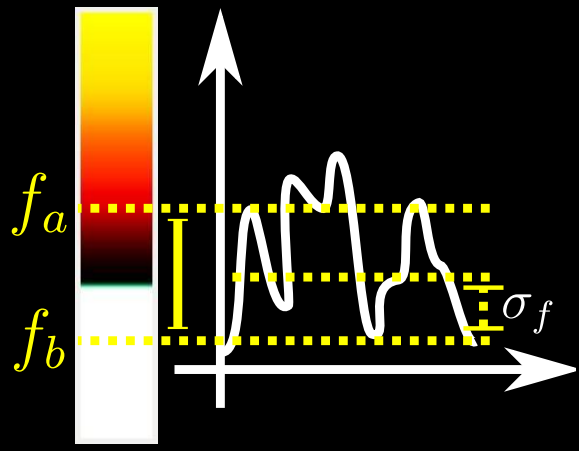
[Hart99]

- works only locally (first-order expansion)
- gradient ill-defined

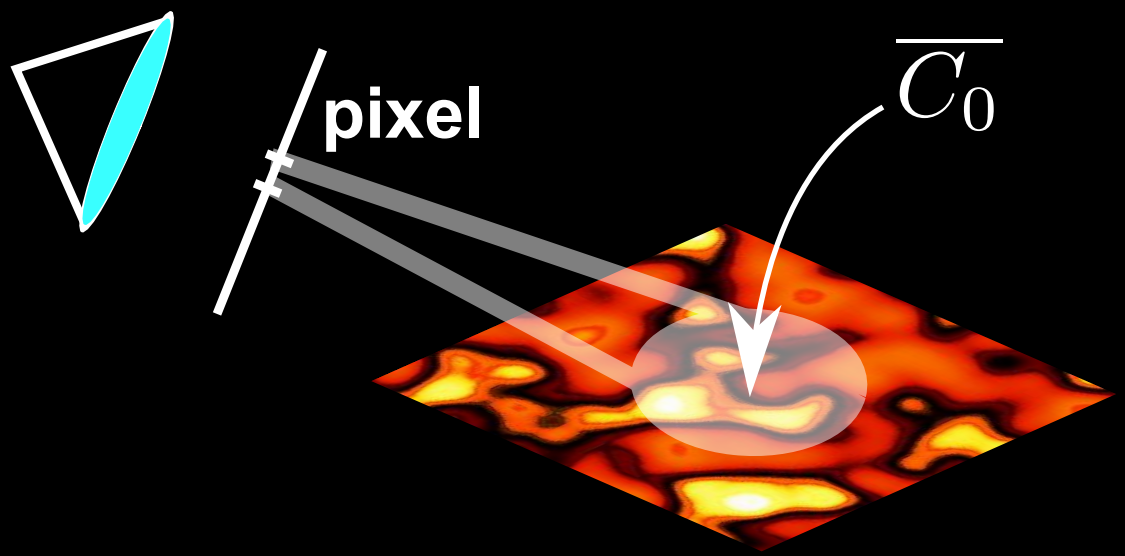


[Lagae09]

- better but Box Filter is still not ideal



I.4 Our Method



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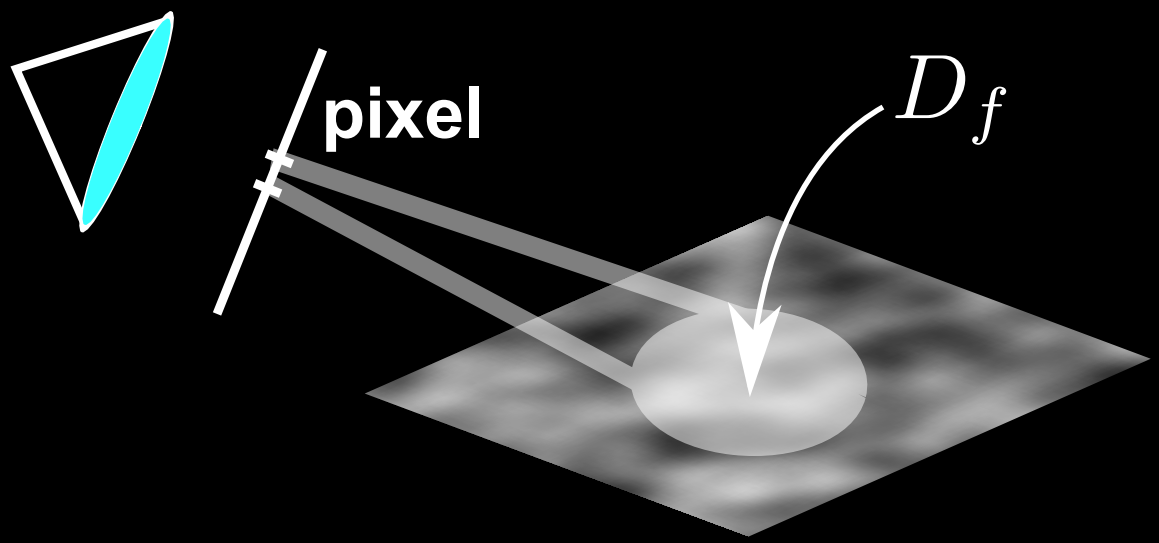
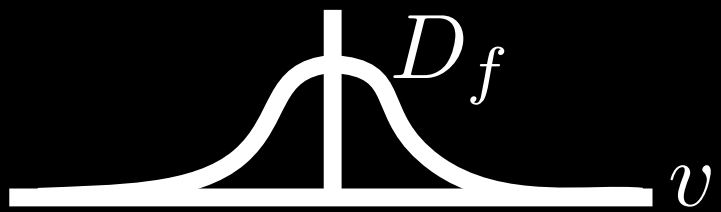
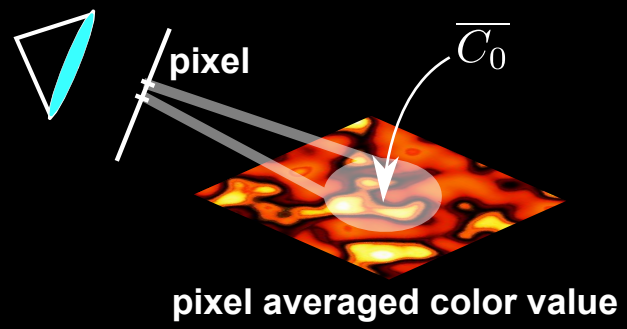


grayscale value distribution within pixel footprint



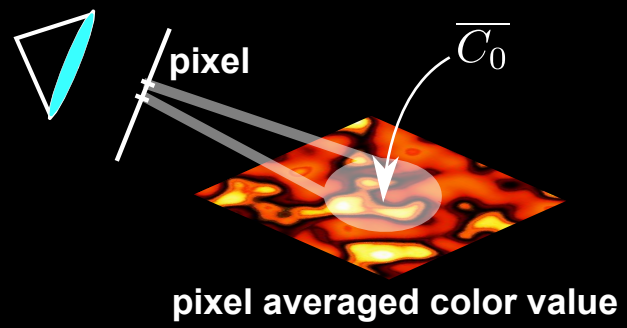
I.4 Our Method



is exactly the inner product

$$\overline{C_0} = \; < \; v \; D_f \; , \; \; >$$

I.4 Our Method



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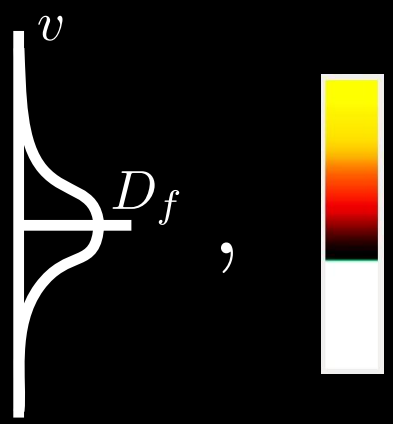
$$\overline{C_0} = \; < \; D_f \; , \; \; >$$



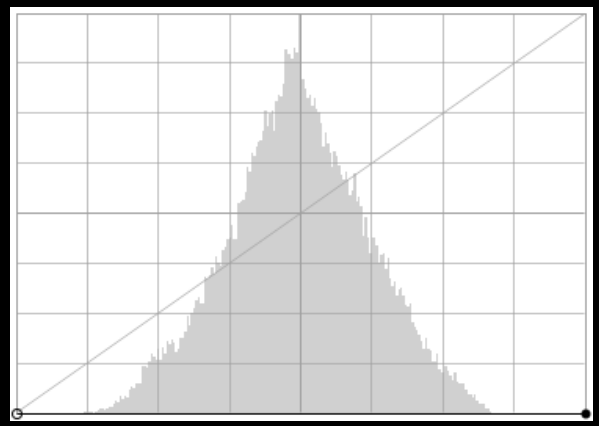
1. **How to represent grayscale distributions?**
2. **How to compute the inner product?**

I.4 Our Method

We choose Gaussian distributions

- noise = Gaussian process
- lightweight, analytical

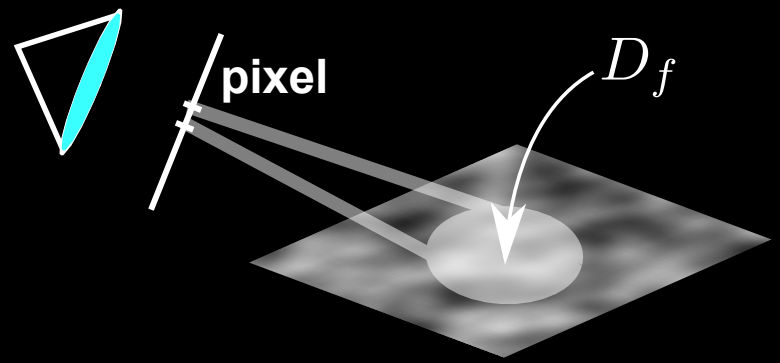
noise



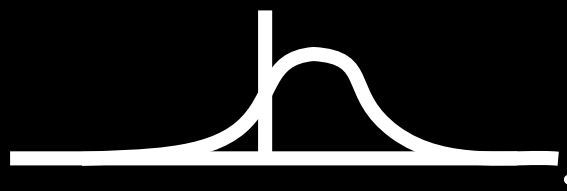
noise histogram

I.4 Our Method

1. fetch / compute
noise Gaussian distribution



$$D_f = \mathcal{N}(\overline{f}, \sigma_f^2)$$



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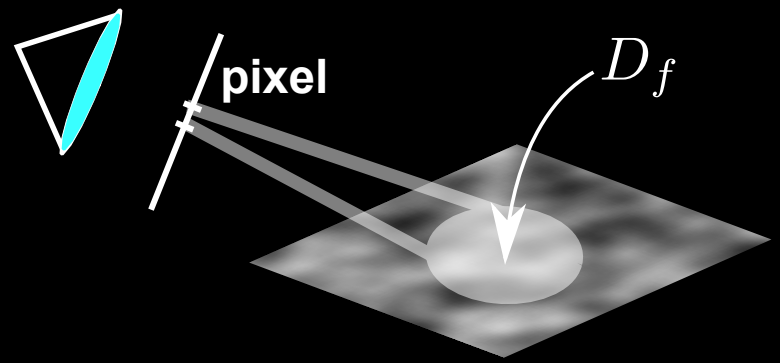
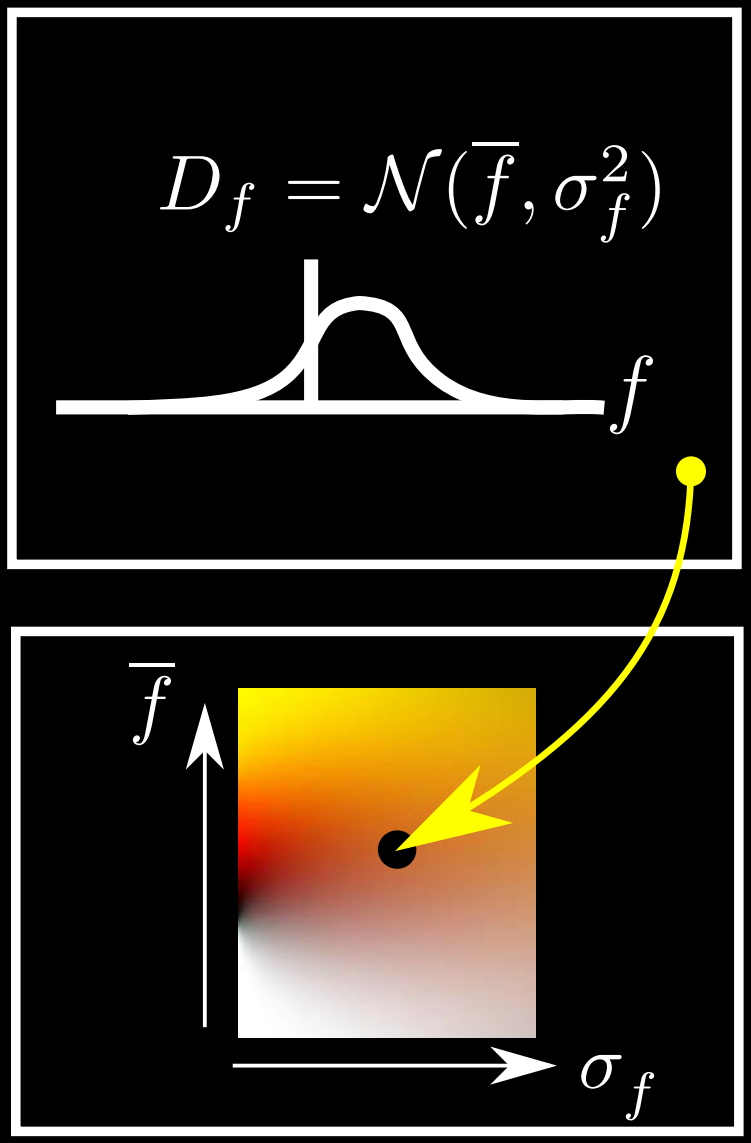
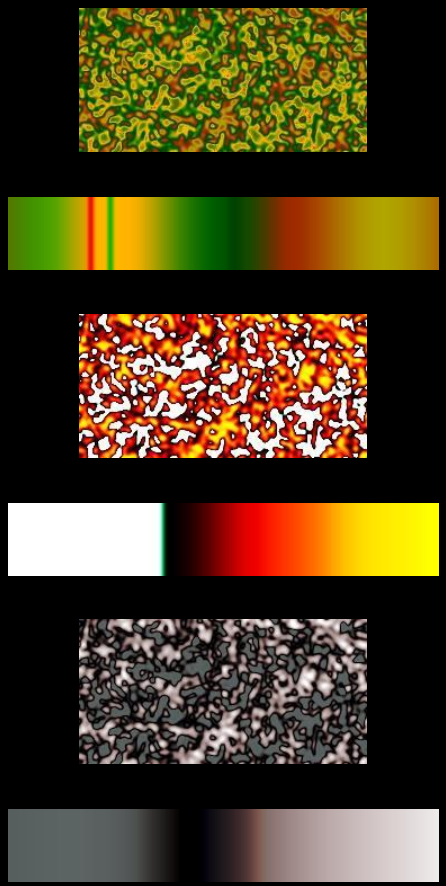


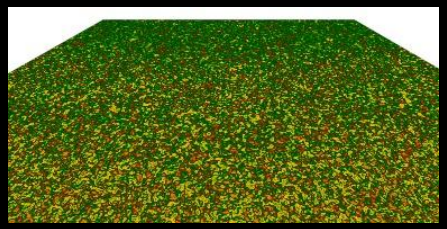
2. fetch pre-convoluted
color map



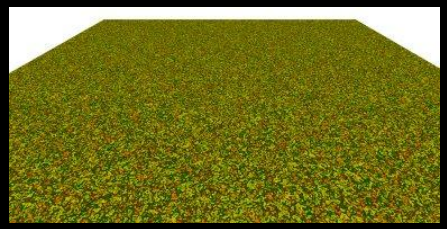
I.5 Results



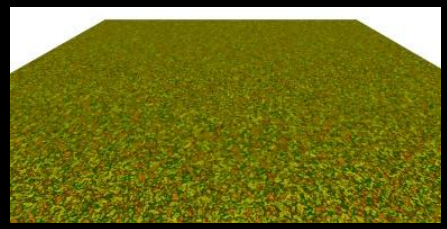
Color map & close view



Naïve filtering

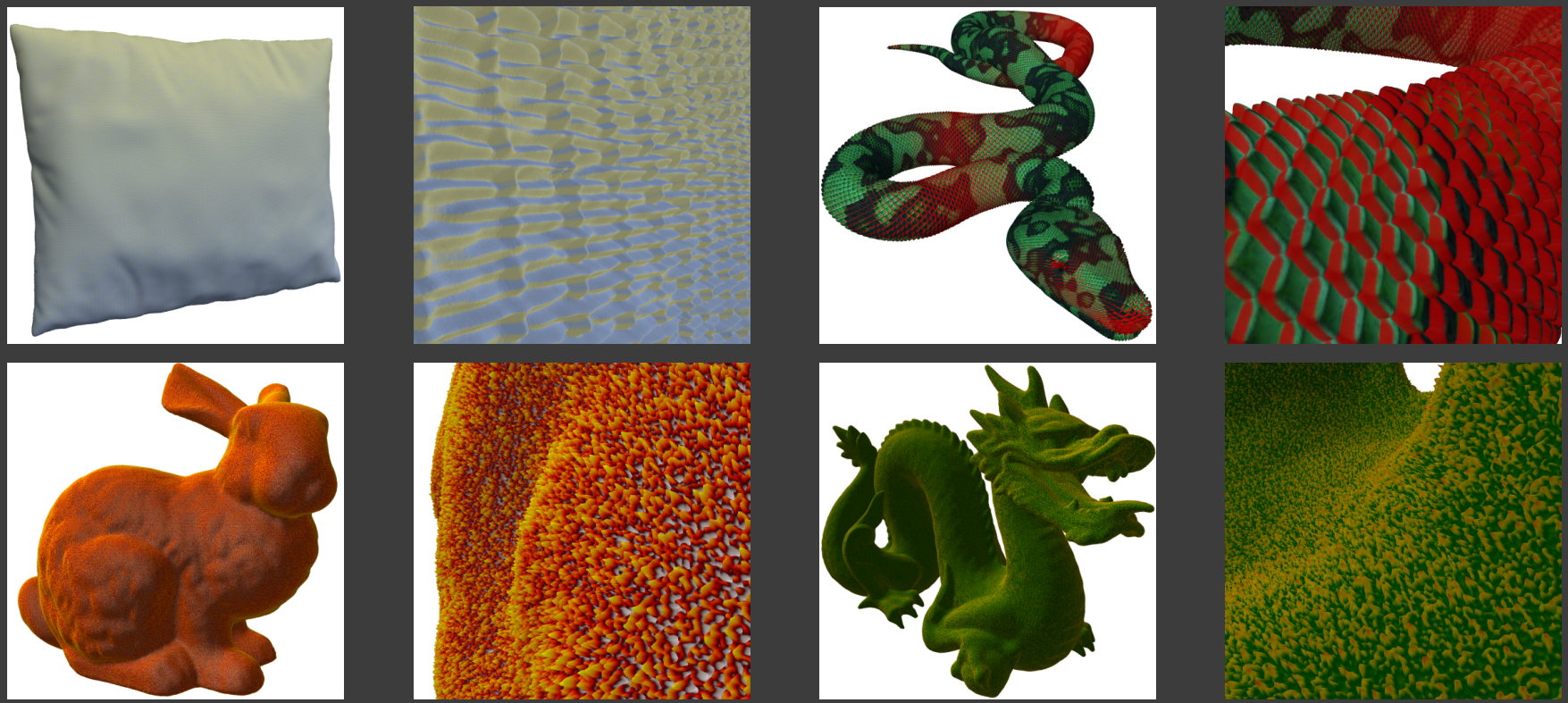


Ground Truth



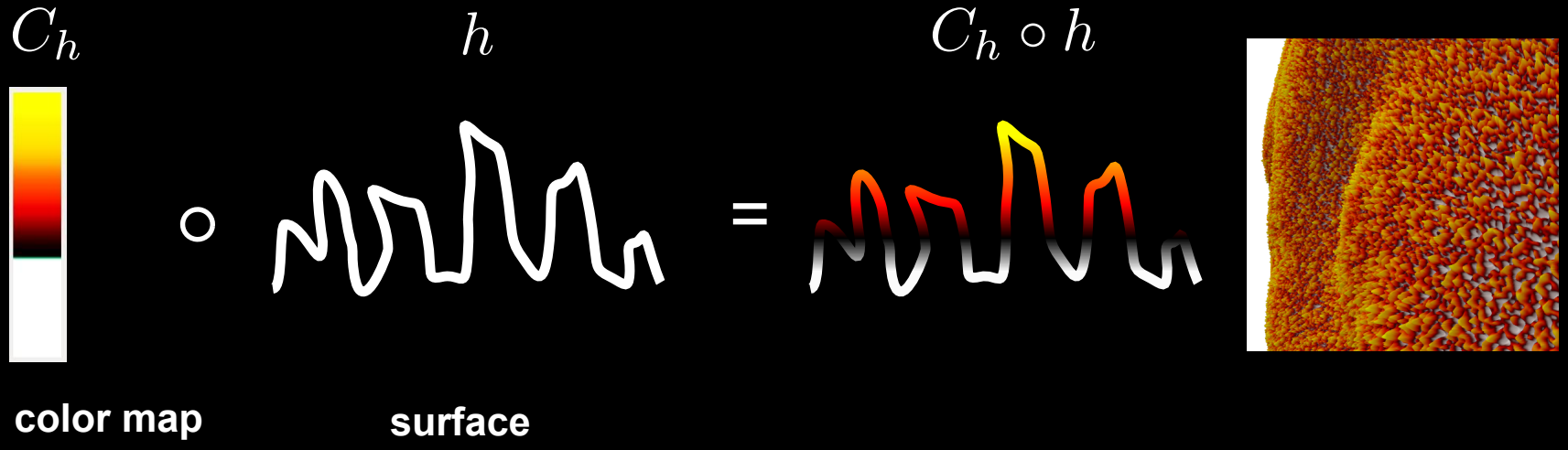
Our model

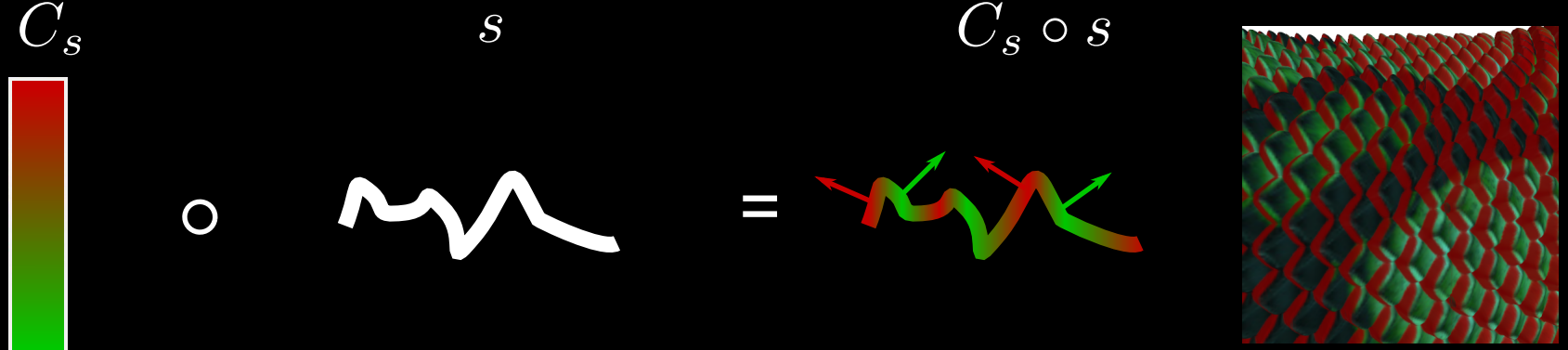
II. Filtering Procedural Surfaces



II.1 Color Mapping Surfaces

Correlations with height and slope





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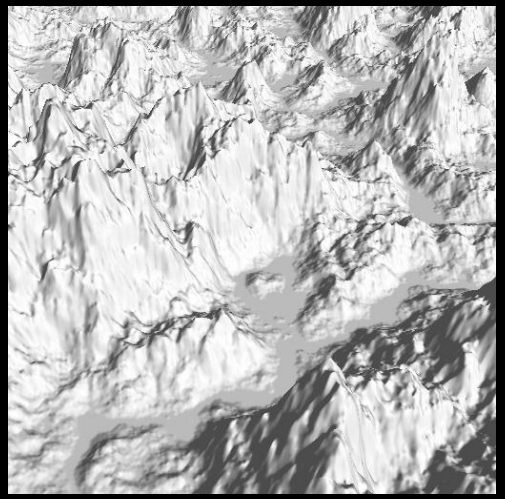
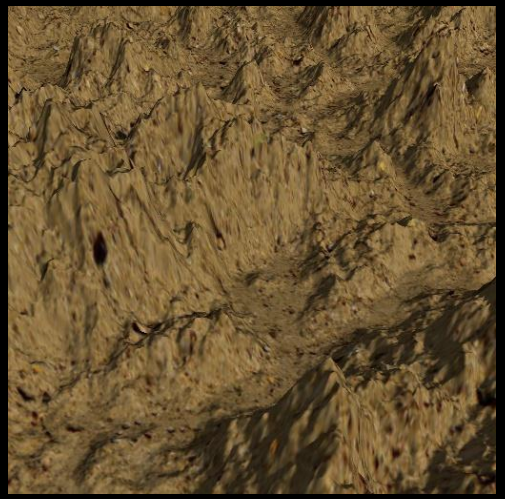


II.1 Color Mapping Surfaces

ground textures



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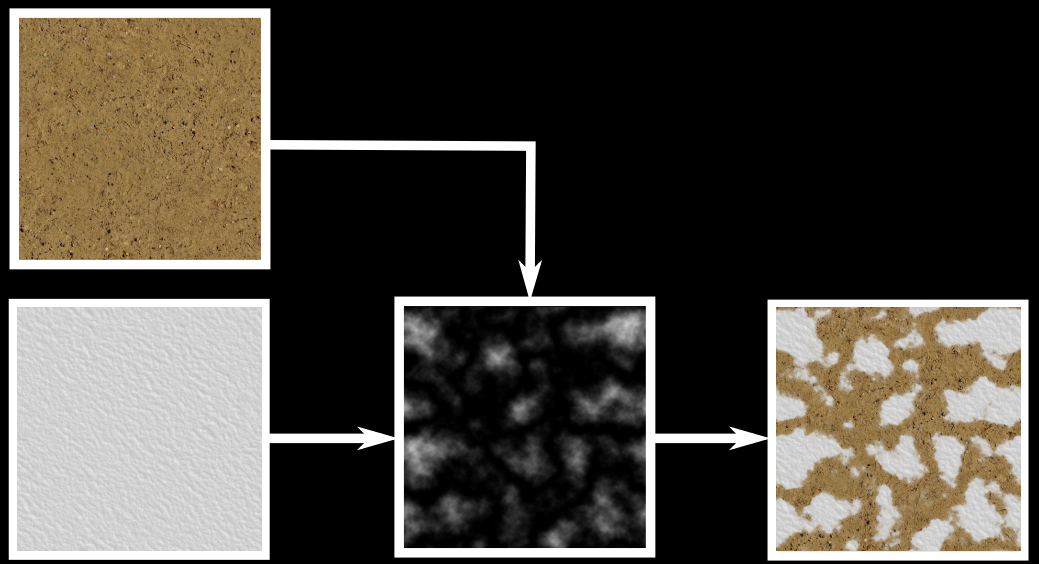
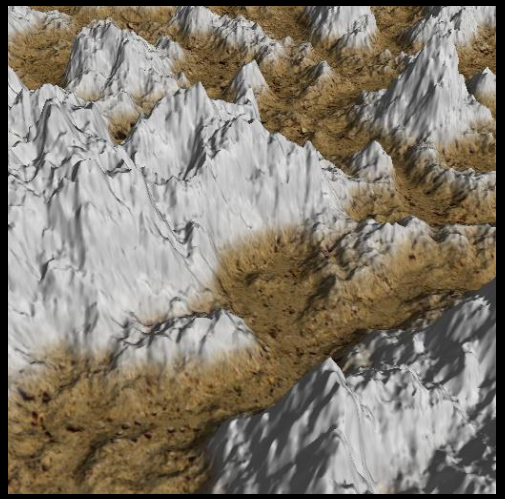


height
composition



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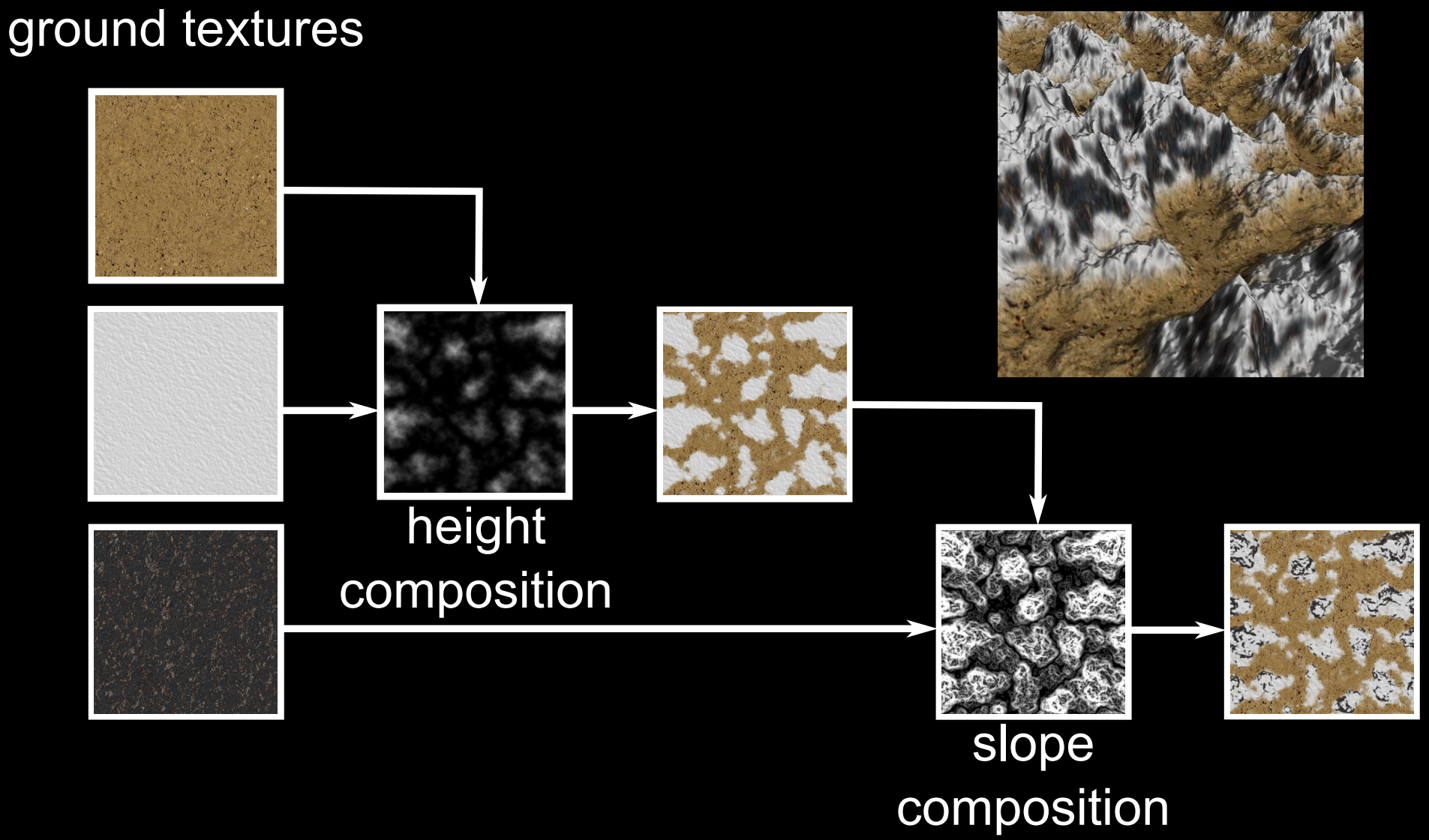
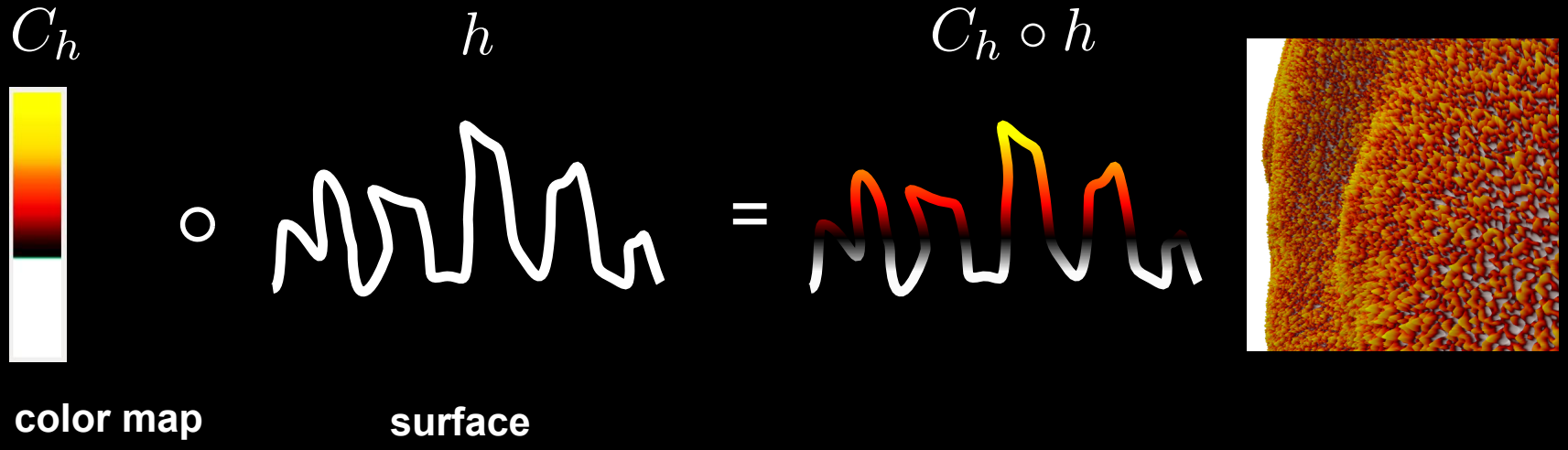
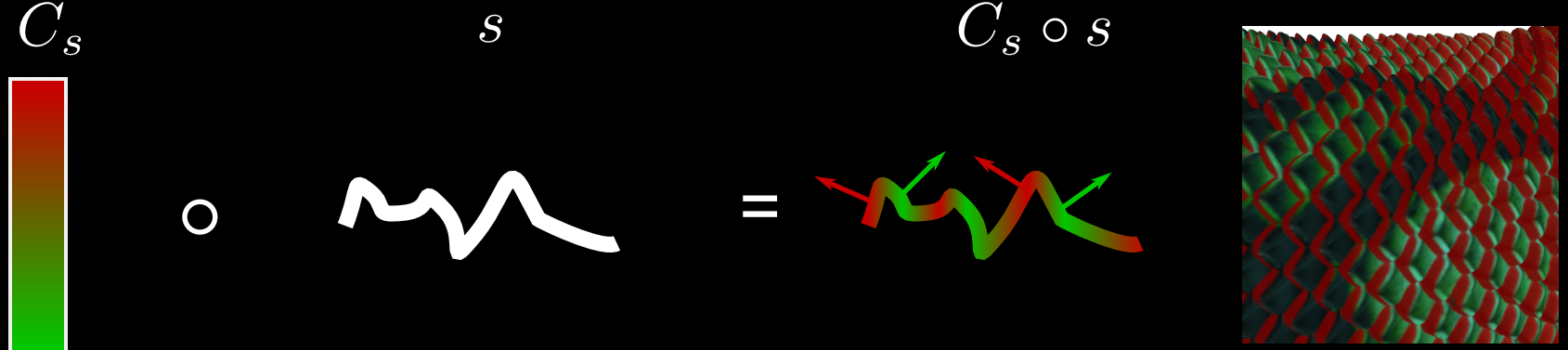


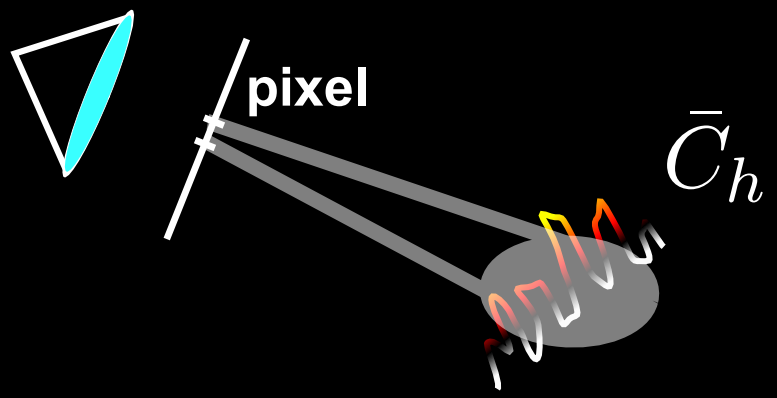
II.1 Color Mapping Surfaces

Correlations with height and slope



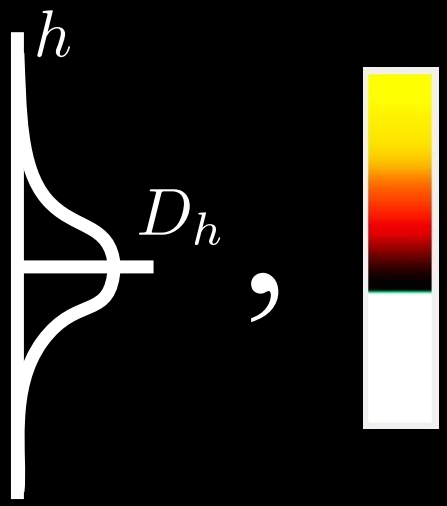


II.2 Problem

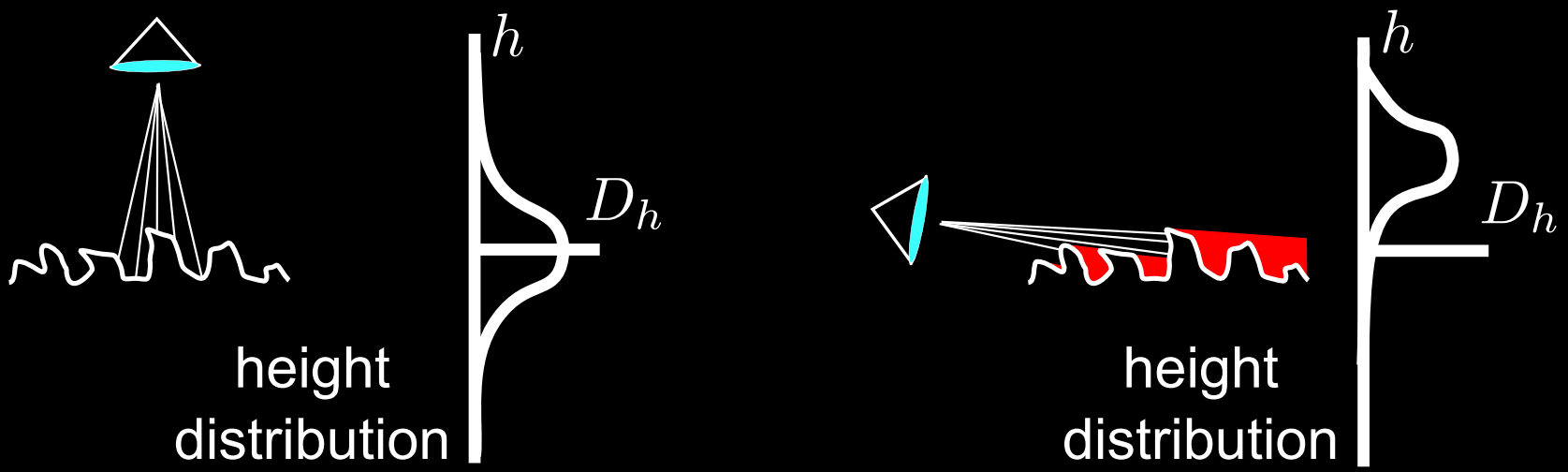


is exactly the inner product

$$\bar{C}_h = < D_h \; , \; >$$

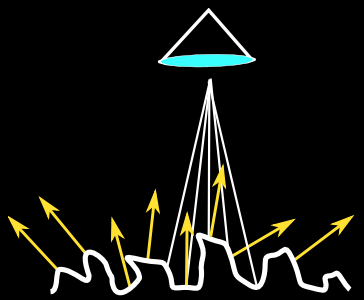


II.2 Problem

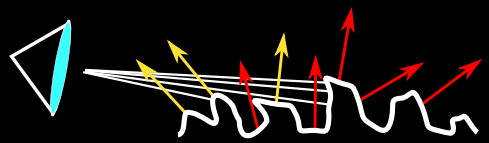


Height distribution D_h is view- and light-dependent because of masking and shadowing

II.2 Problem



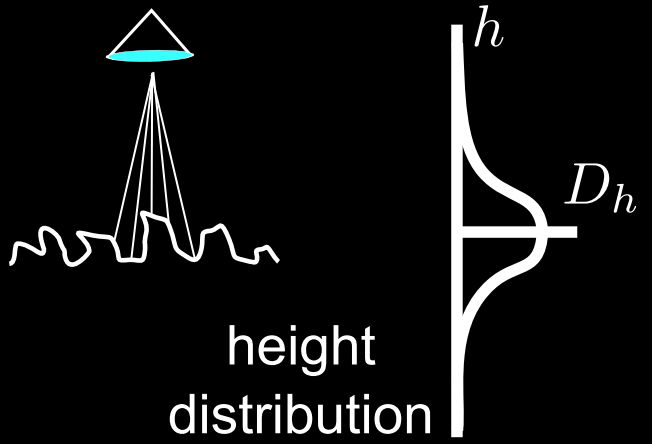
slope (normal)
distribution



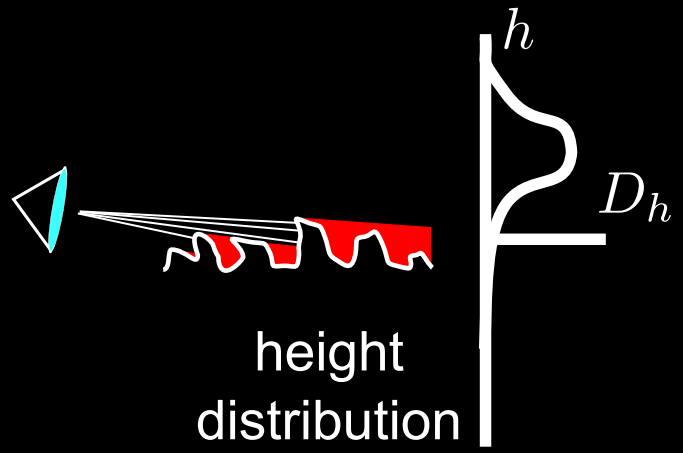
slope (normal)
distribution

Slope distribution D_s is view-dependent because of back-face culling and area weighting

II.2 Problem

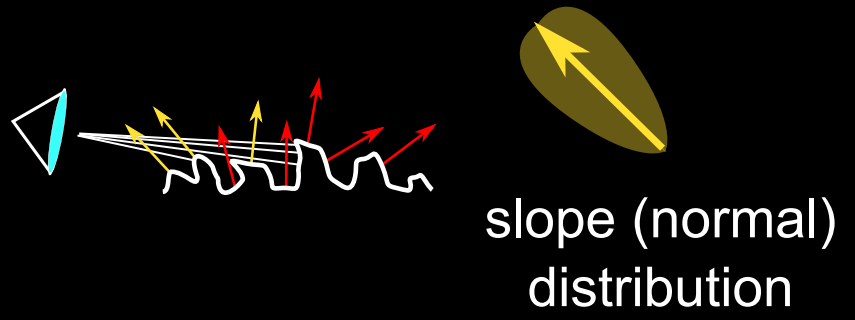


height distribution



height distribution

slope (normal) distribution



slope (normal) distribution

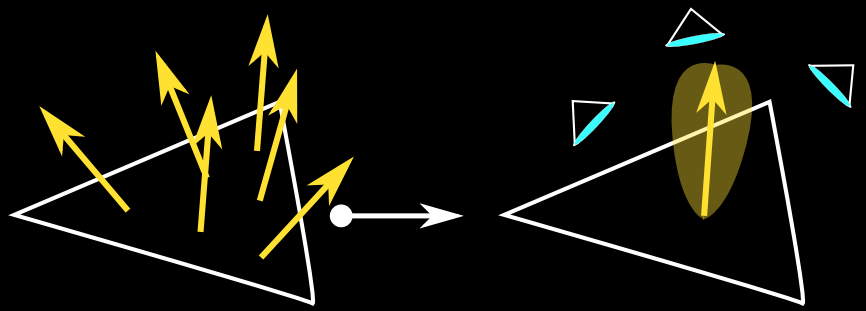
These schemes are qualitative.
How to model quantitatively view-dependency?

II.2 Problem

View-dependency is usually NOT taken in account

e.g.

- **[Smooth Transitions between Bump Rendering Algorithms], SIGGRAPH 93**
- **[Multiresolution Reflectance Filtering], EGSR05**
- **[Frequency Domain Normal Map Filtering], SIGGRAPH 07**
- **[LEAN Mapping], I3D 10**



normal filtering on flat surface

II.2 Problem

View-dependency is usually NOT taken in account

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- **[Smooth Transitions between Bump Rendering Algorithms], SIGGRAPH 93**
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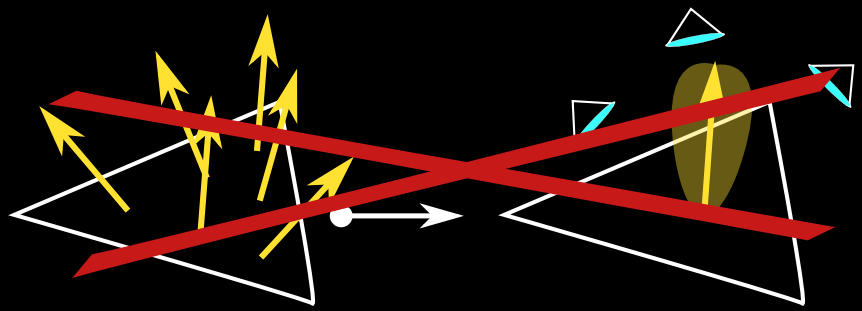
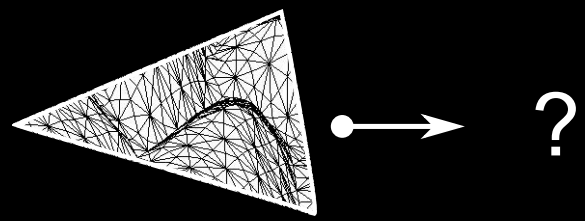


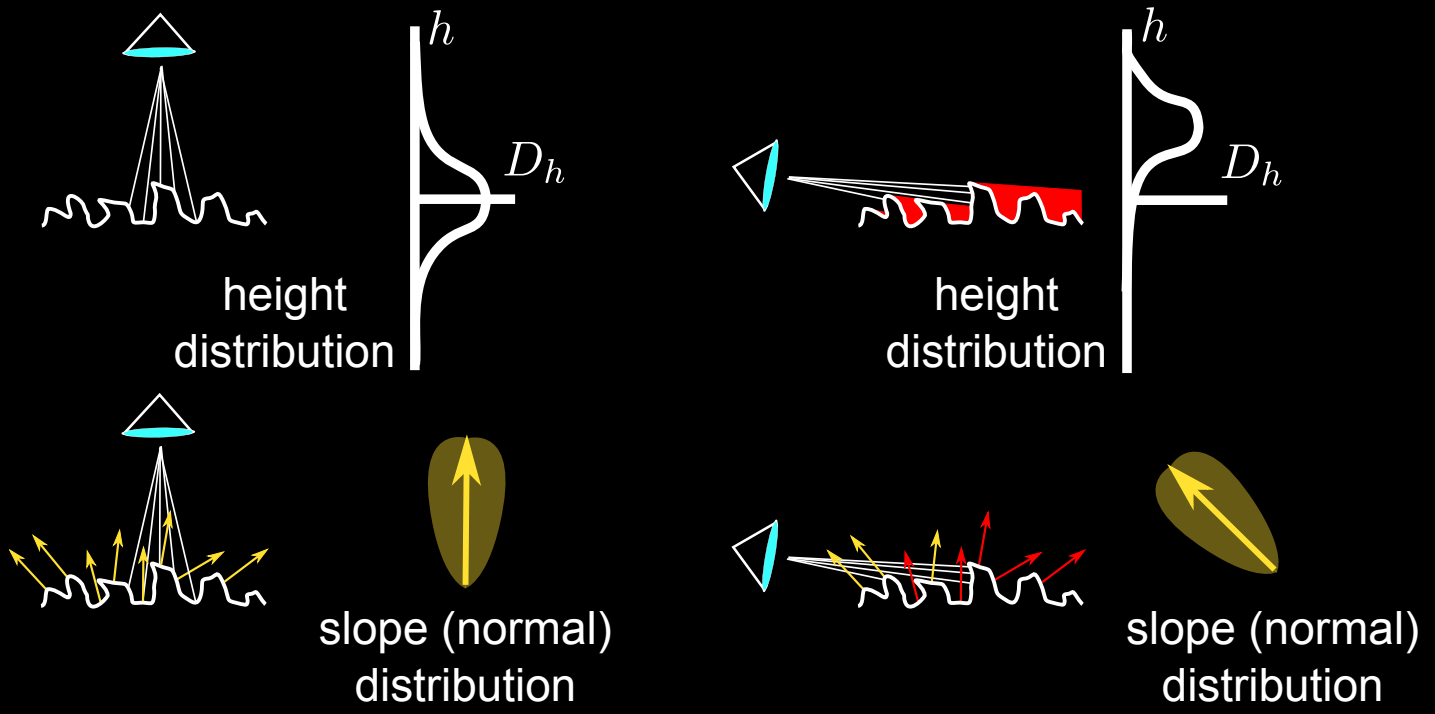
normal filtering on flat surface



normal filtering on detailed surface

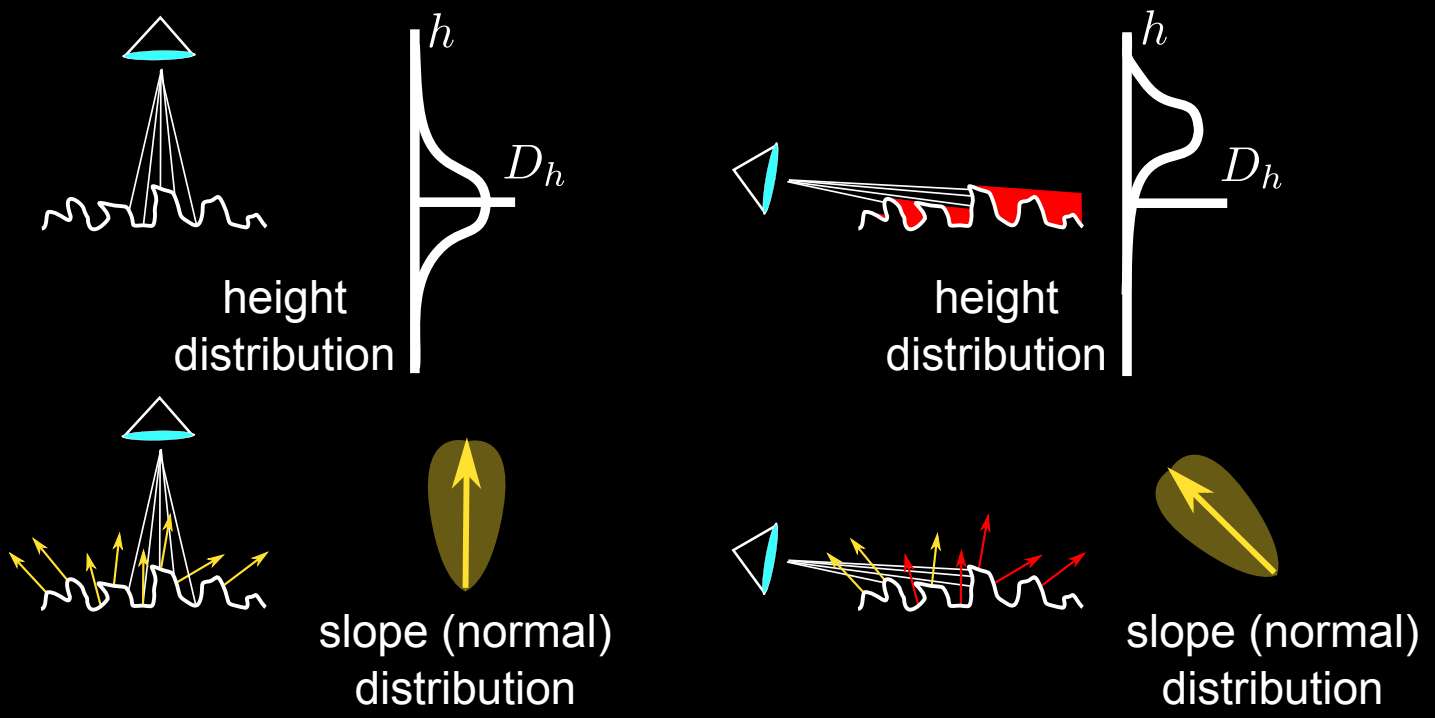
II.3 Our Method

How to model and compute view-dependency?



II.3 Our Method

How to model and compute view-dependency?

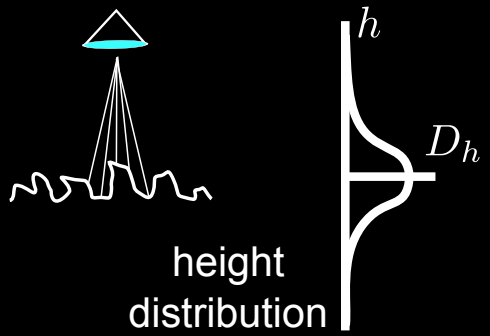


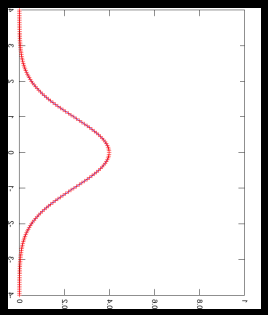
→ micro-facet theory is the appropriate paradigm

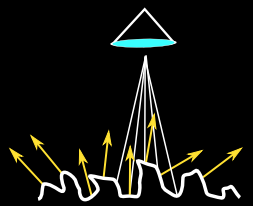
- physically sound formulation
- accurate analytical approximations

II.3 Our Method

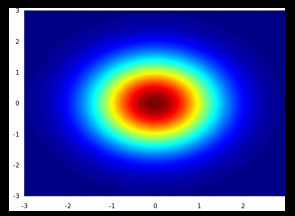
We derive accurate analytical approximations

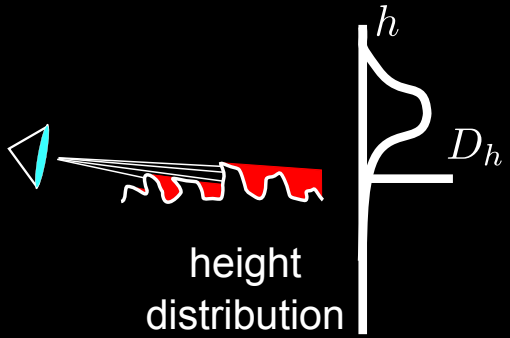


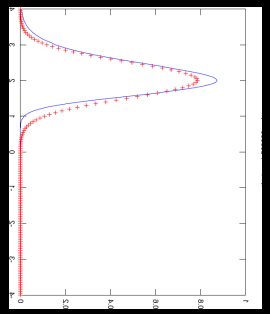


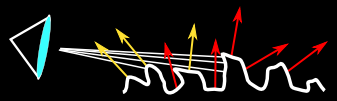


slope (normal)
distribution

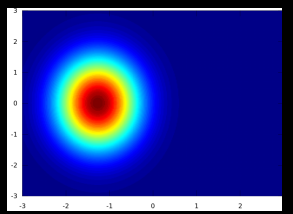






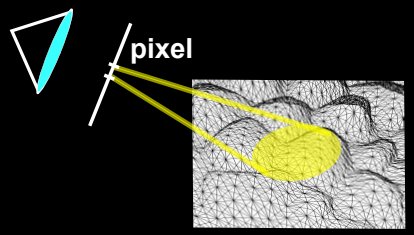


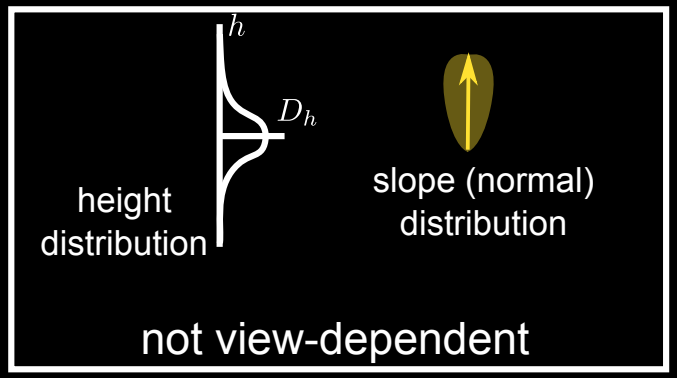
slope (normal)
distribution



II.3 Our Method

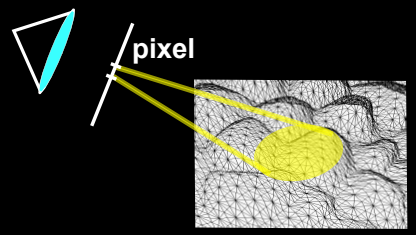
1. fetch / compute surface parameters



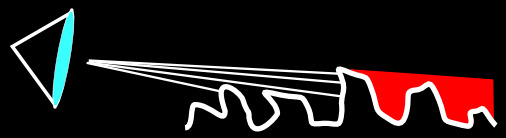


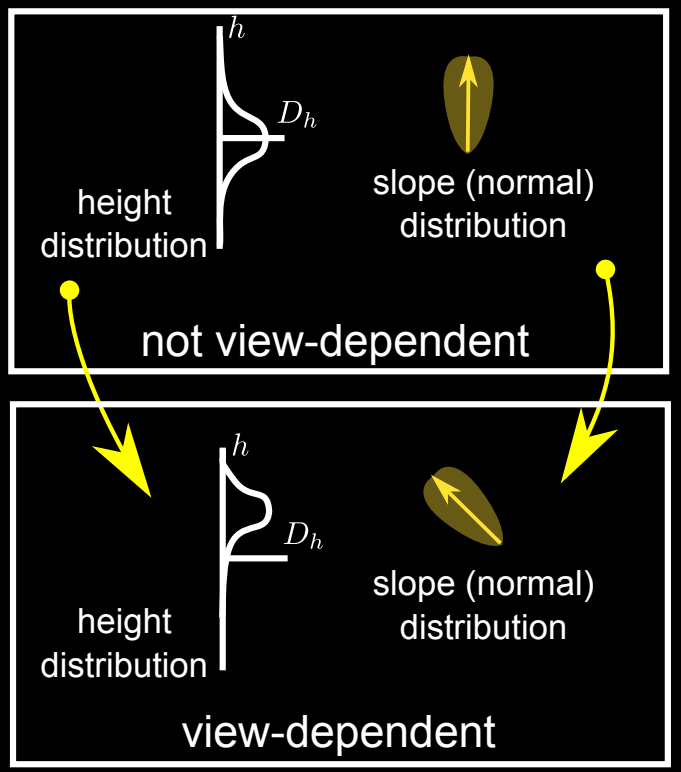
II.3 Our Method

1. fetch / compute surface parameters



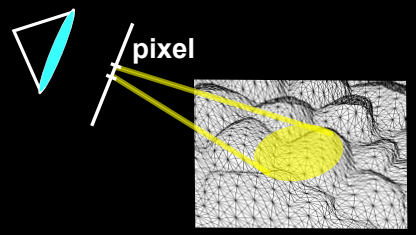
2. compute view-dependent surface parameters



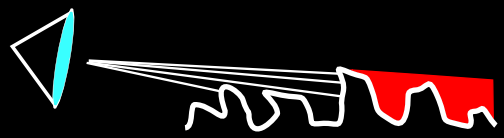


II.3 Our Method

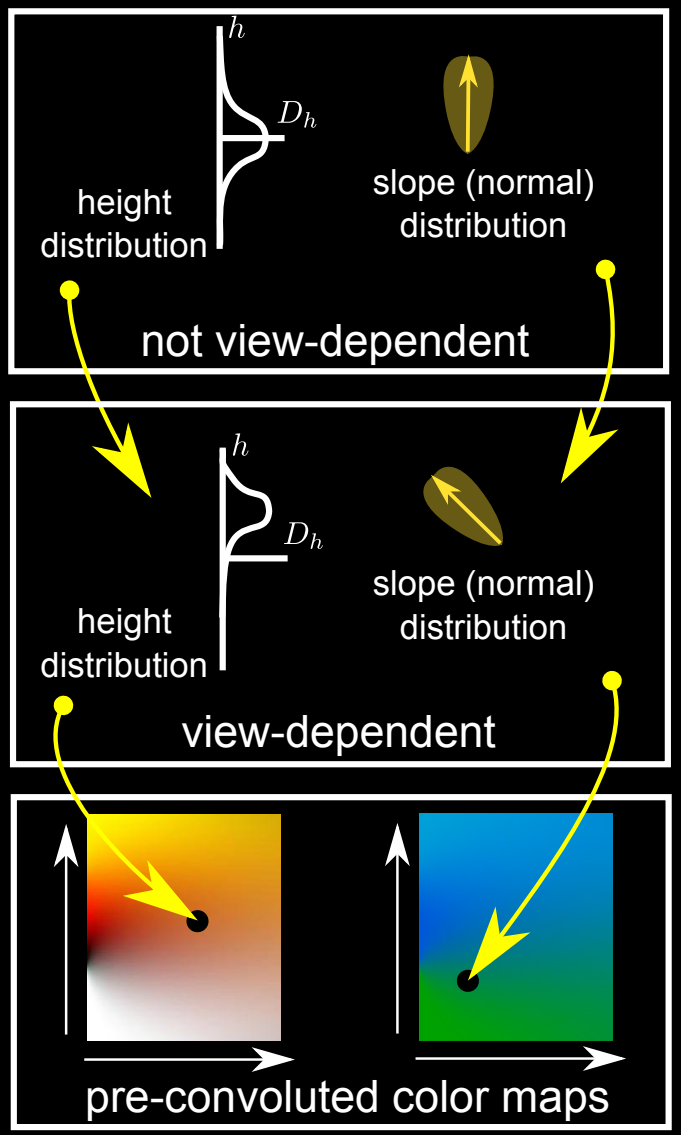
1. fetch / compute surface parameters



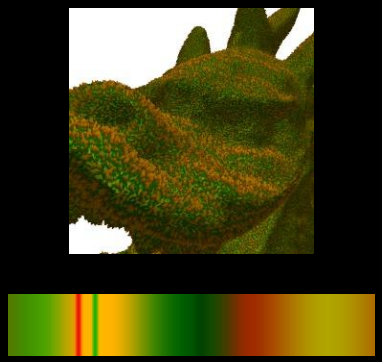
2. compute view-dependent surface parameters

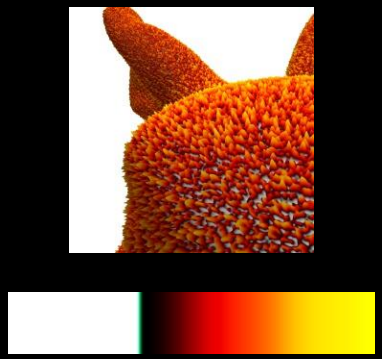


3. fetch pre-convoluted color maps



II.4 Results



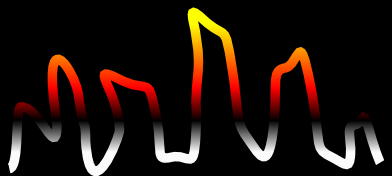


Color map & close view

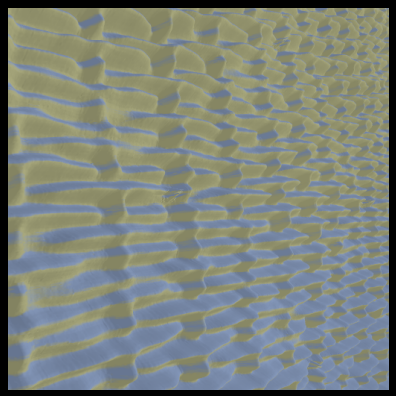
Texture filtering

Ground Truth

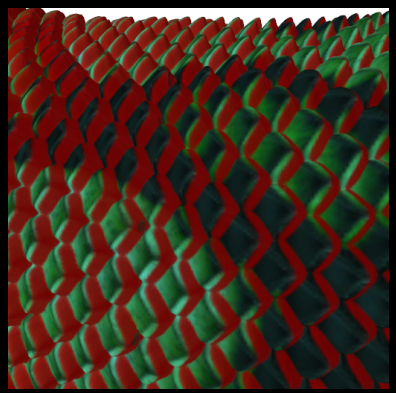
Surface filtering



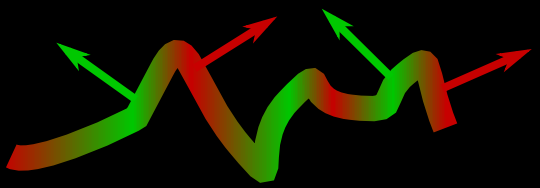
II.4 Results








Close view | Texture filtering | Ground Truth | Surface filtering

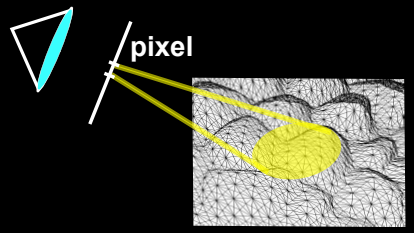


II.4 Results

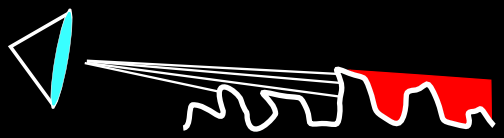
	 Texture filtering	 Ground Truth	 Surface Filtering
Tessellation ON	130Hz	$<$1Hz 256 samples/pixel	130Hz
Tessellation OFF	869Hz	3Hz 256 samples/pixel	800Hz

II.5 Implementation

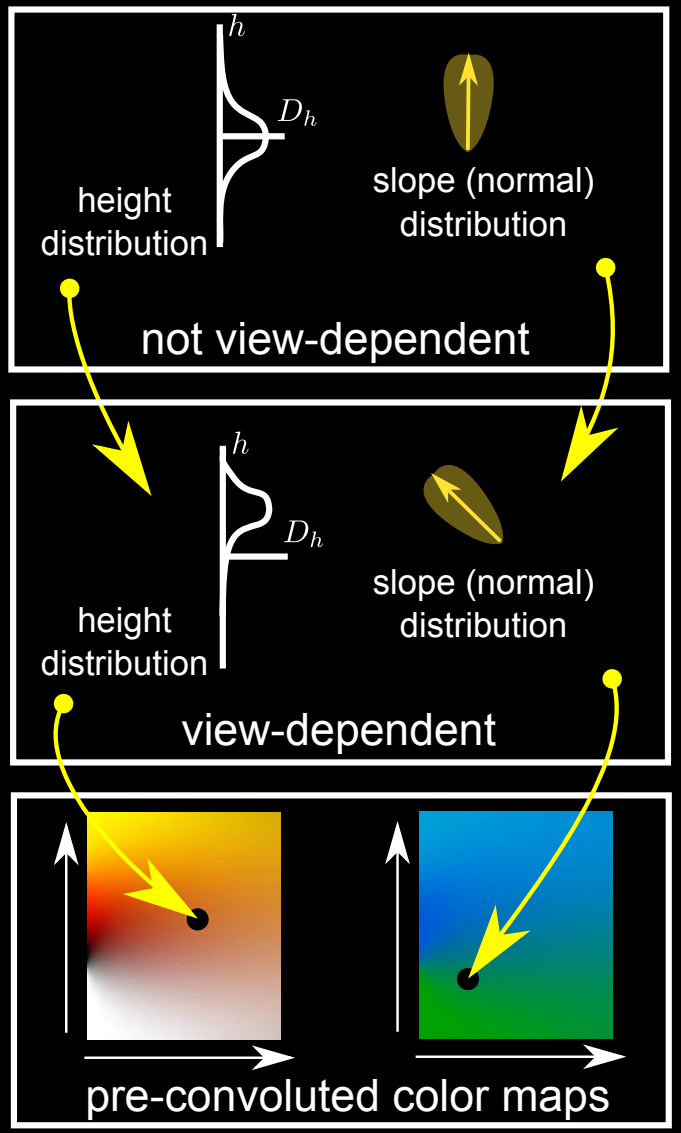
1. fetch / compute surface parameters



2. compute view-dependent surface parameters



3. fetch pre-convoluted color maps



II.5 Implementation

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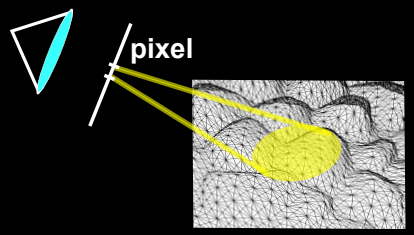
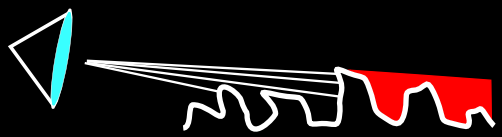
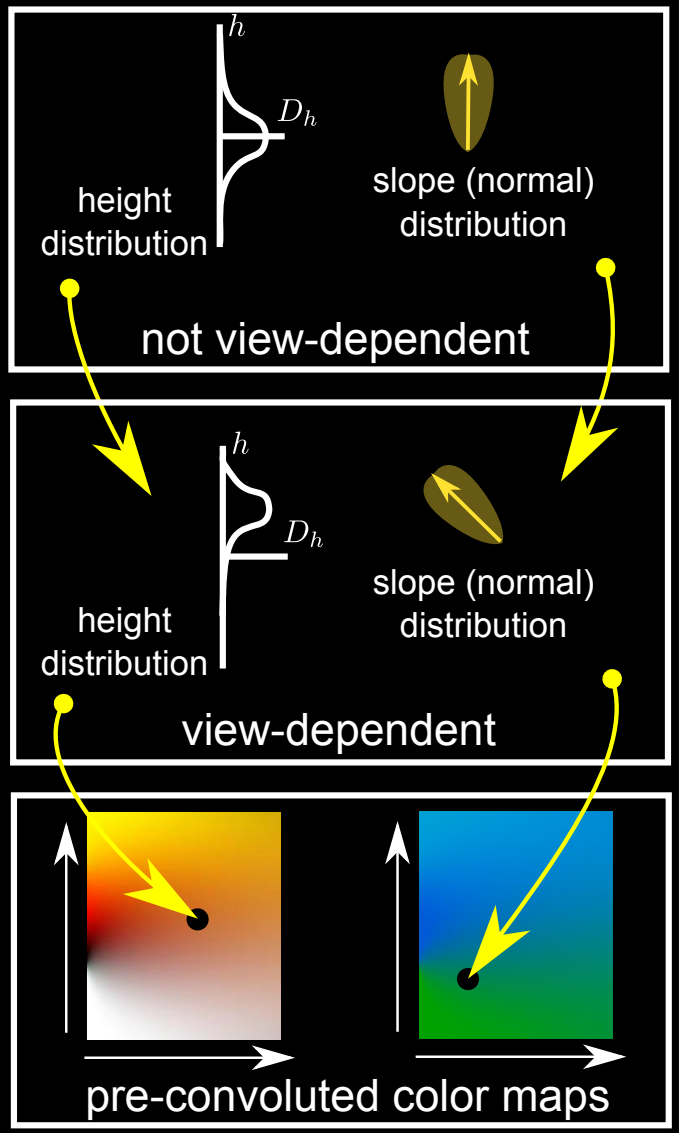


2. compute view-dependent surface parameters



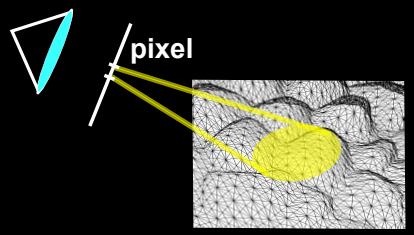
3. fetch pre-convoluted color maps



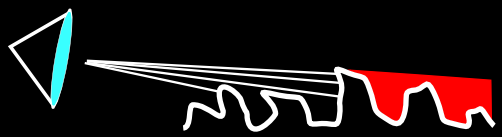
$\bar{h}$ average height (used for tessellation)

II.5 Implementation

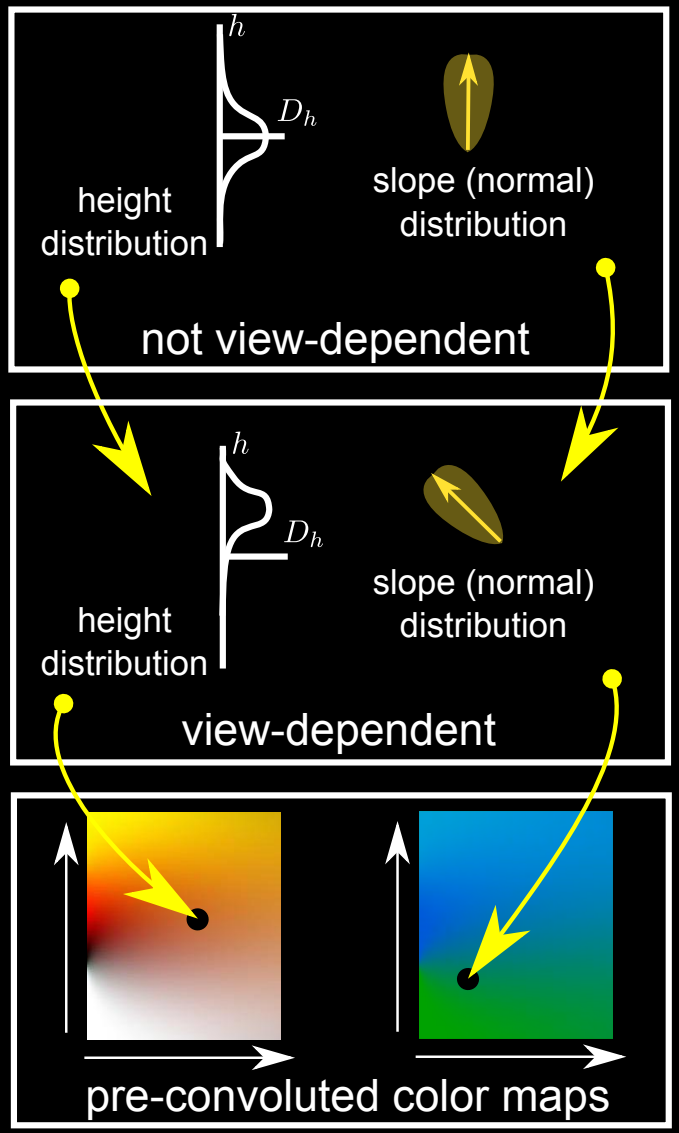
1. fetch / compute surface parameters



2. compute view-dependent surface parameters



3. fetch pre-convoluted color maps

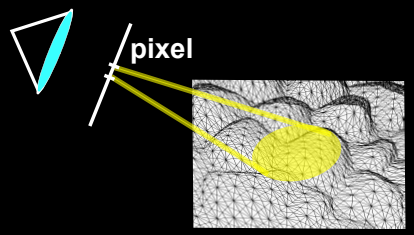


$\bar{h}$ average height (used for tessellation)

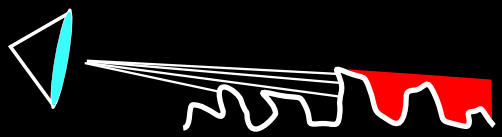
$\bar{h}^2$ height second momentum

II.5 Implementation

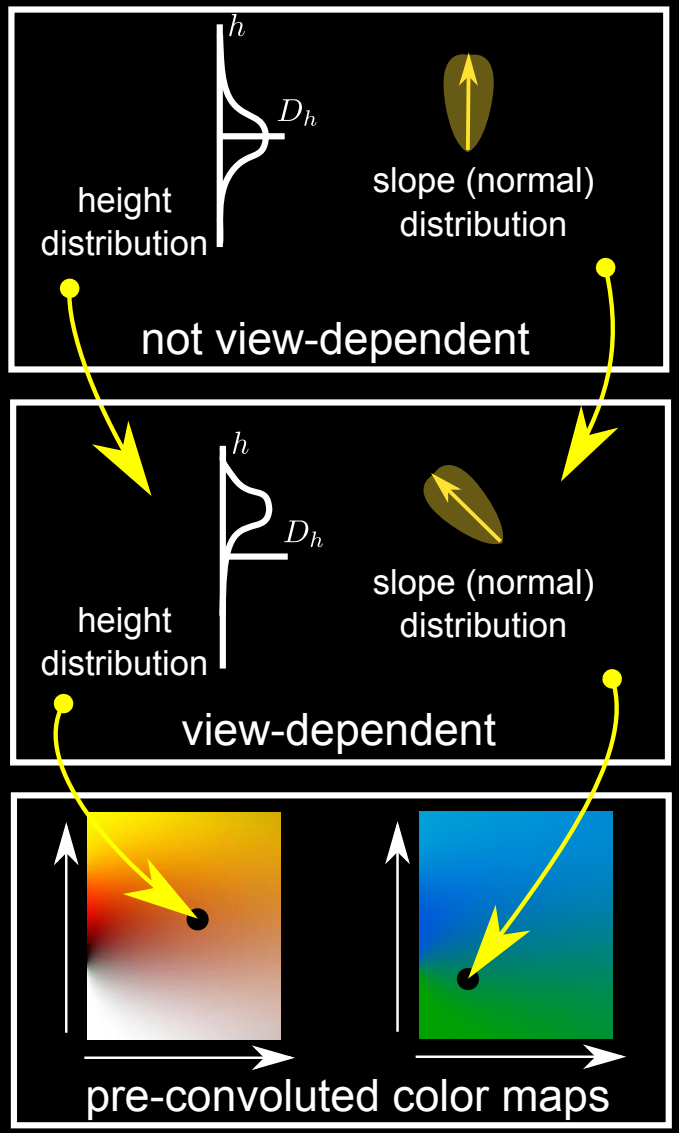
1. fetch / compute surface parameters



2. compute view-dependent surface parameters



3. fetch pre-convoluted color maps



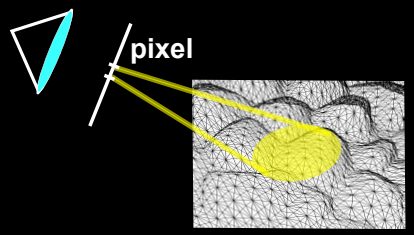
$\bar{h}$ average height (used for tessellation)

$\bar{h}^2$ height second momentum

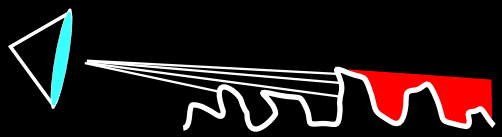
$\bar{s}_x$ $\bar{s}_y$ average slope/normal (used for shading)

II.5 Implementation

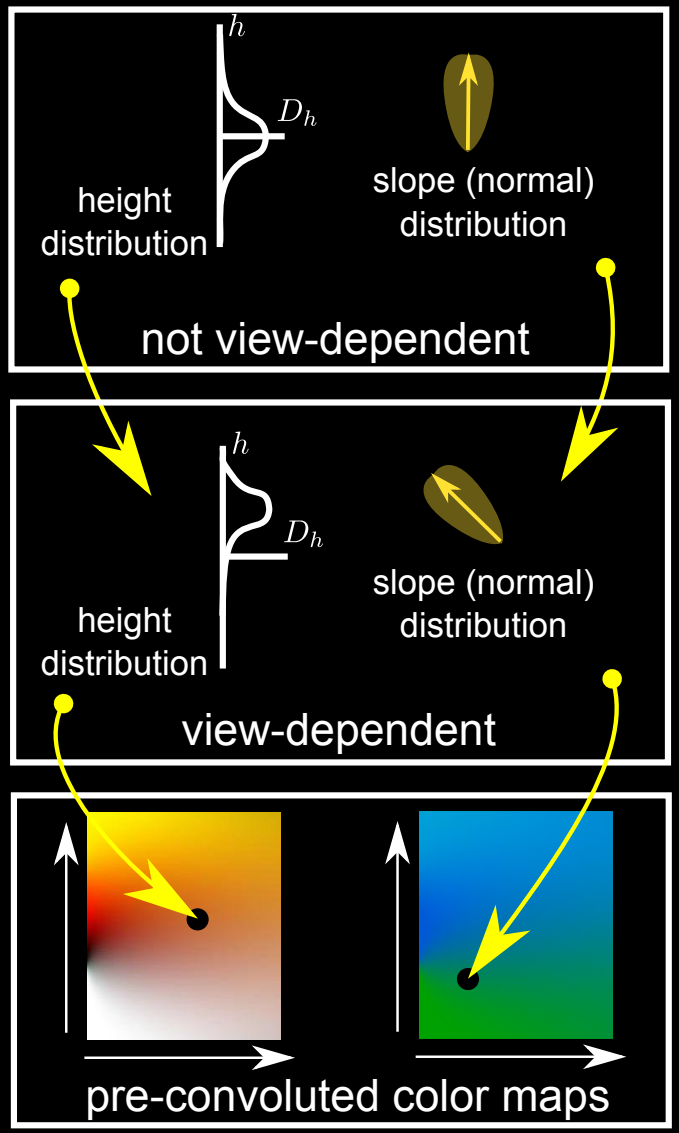
1. fetch / compute surface parameters



2. compute view-dependent surface parameters



3. fetch pre-convoluted color maps



$\bar{h}$ average height (used for tessellation)

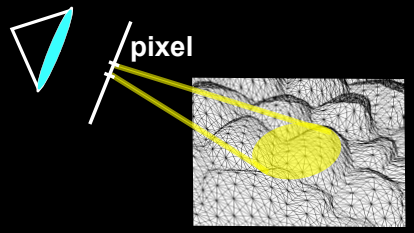
$\bar{h}^2$ height second momentum

$\bar{s}_x$ $\bar{s}_y$ average slope/normal (used for shading)

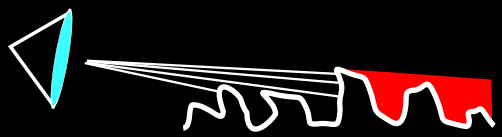
$\begin{bmatrix} \sigma_{s_x}^2 & c_{xy} \\ c_{xy} & \sigma_{s_y}^2 \end{bmatrix}$ slope covariance matrix (used in LEAN Mapping)

II.5 Implementation

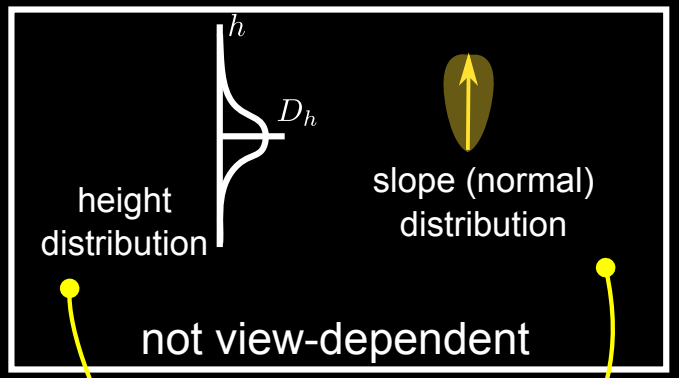
1. fetch / compute surface parameters

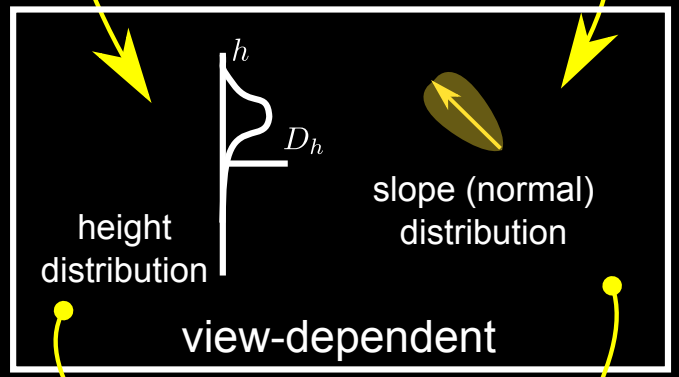


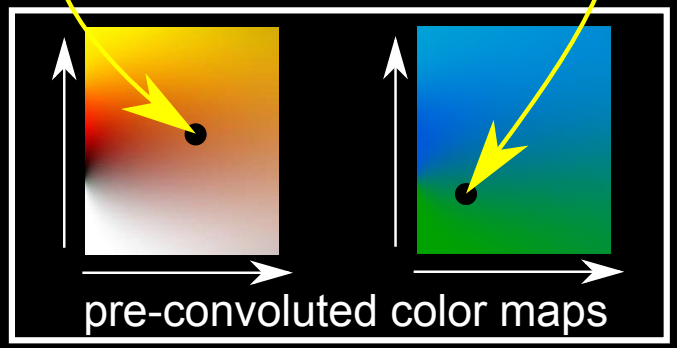
2. compute view-dependent surface parameters



3. fetch pre-convoluted color maps







$\bar{h}$ average height (used for tessellation)

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$\begin{bmatrix} \sigma^2_{s_x} & c_{xy} \\ c_{xy} & \sigma^2_{s_y} \end{bmatrix}$ slope covariance matrix (used in LEAN Mapping)

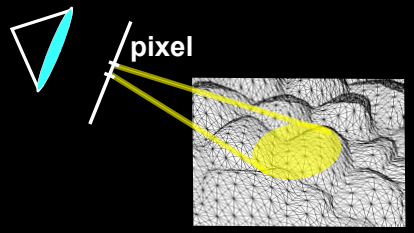
implement and call 2 functions

- function for height distribution

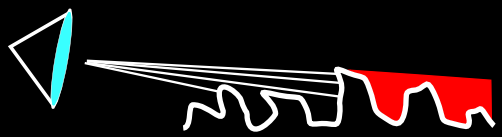
- function for slope distribution

II.5 Implementation

1. fetch / compute surface parameters



2. compute view-dependent surface parameters



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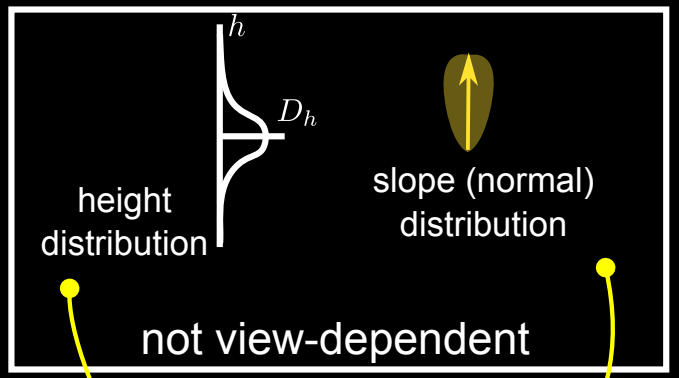

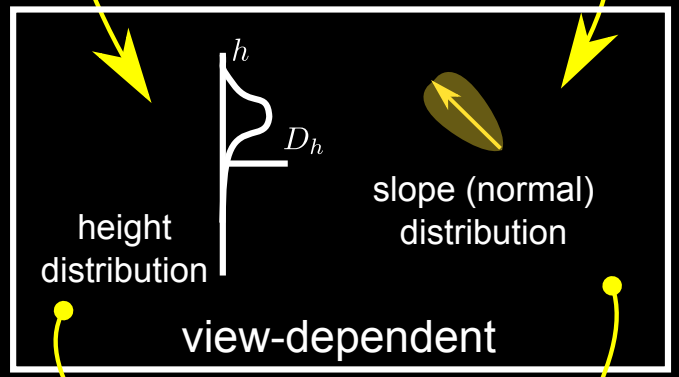

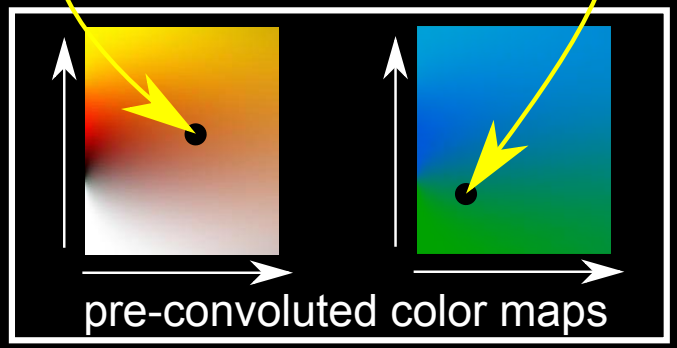

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2 lines of code

(formula in the paper)

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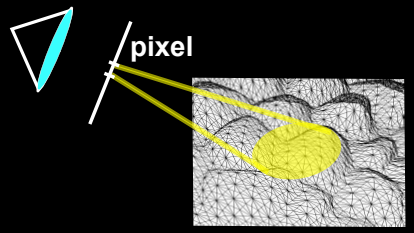

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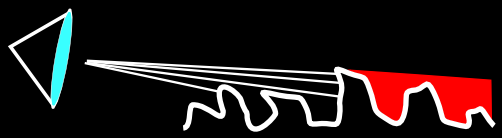

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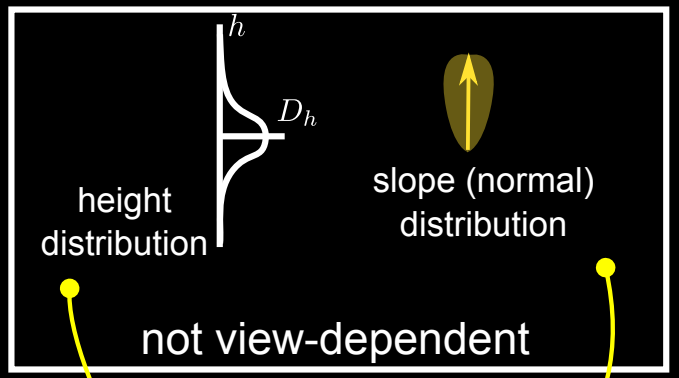

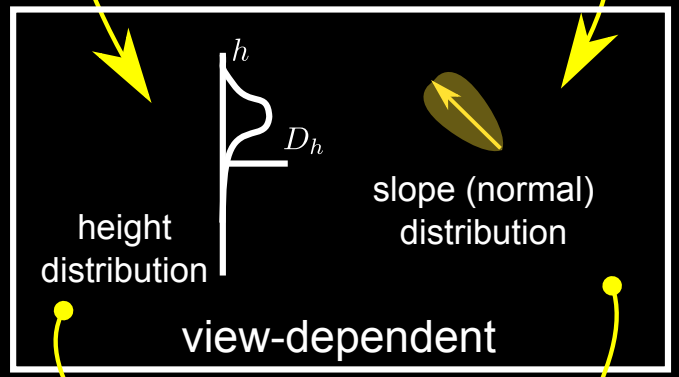

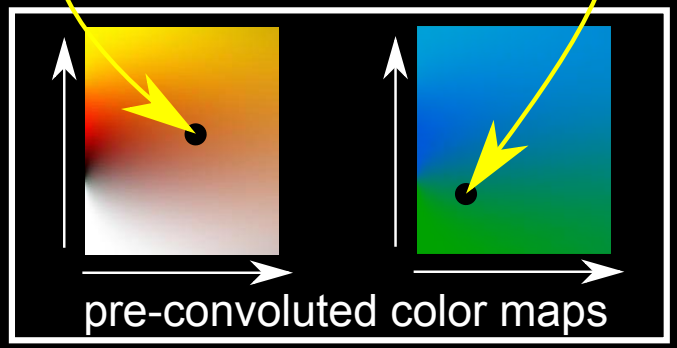

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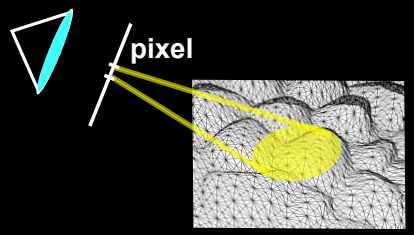

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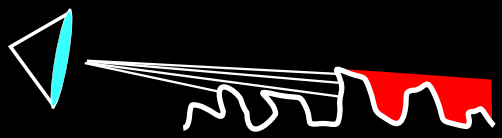

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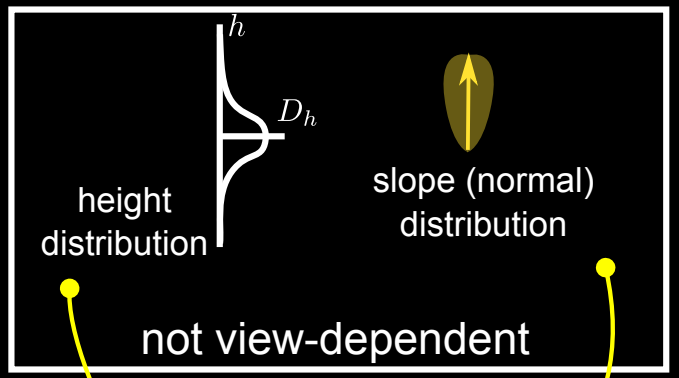

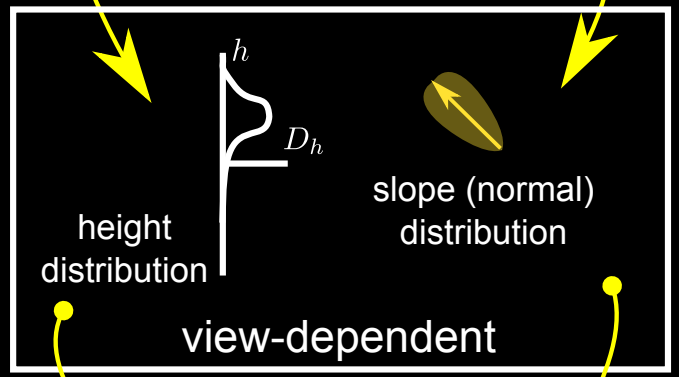

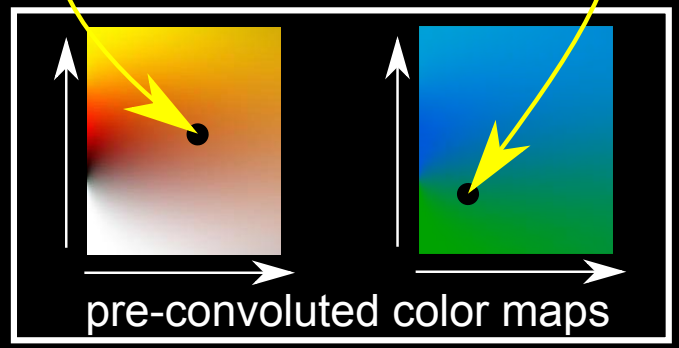

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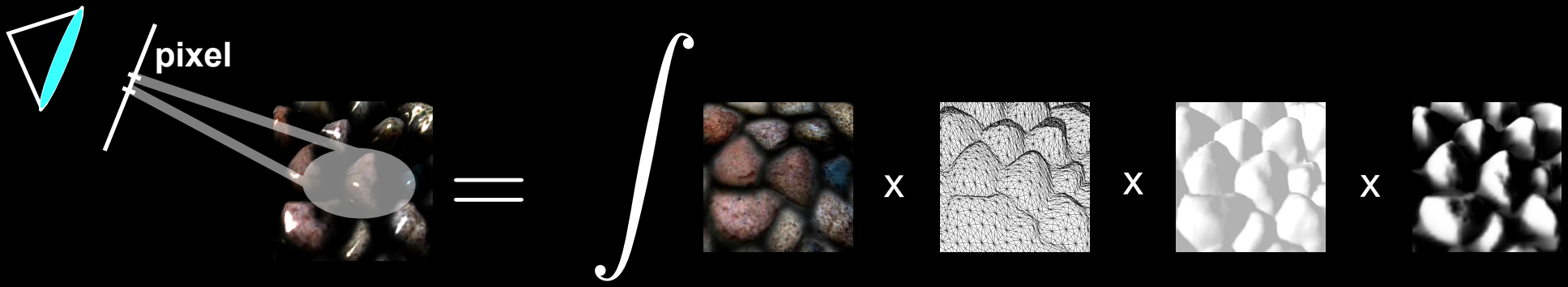
pre-convoluted color maps

in practice we use 256^2 textures with 4 color components
= 256KB per pre-convoluted

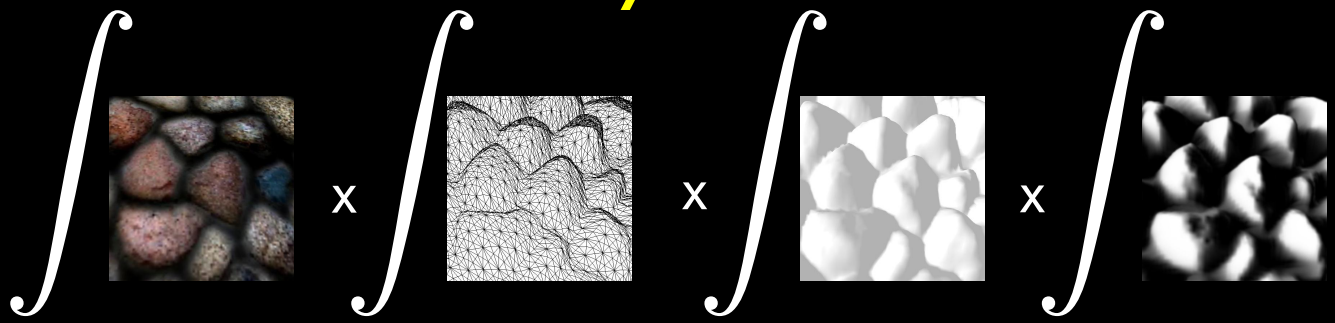
Conclusion and Future Work

Introduction

physically correct



$$\neq$$



physically wrong

energy conservation violated

popping, aliasing, and inconsistent appearance

Conclusion and Future Work

Our LoD framework

- colors/material
- smale-scale geometry
- visibility
- no BRDF

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Existing
physically-based rendering

- physically-based BRDFs
- physically incorrect LoD

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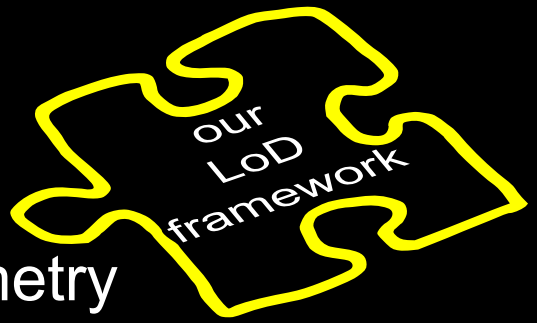

Existing
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- physically-based BRDFs
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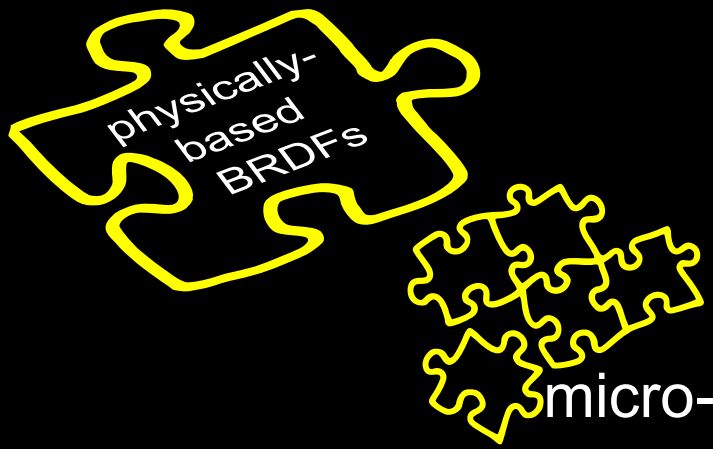

Conclusion and Future Work

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Existing
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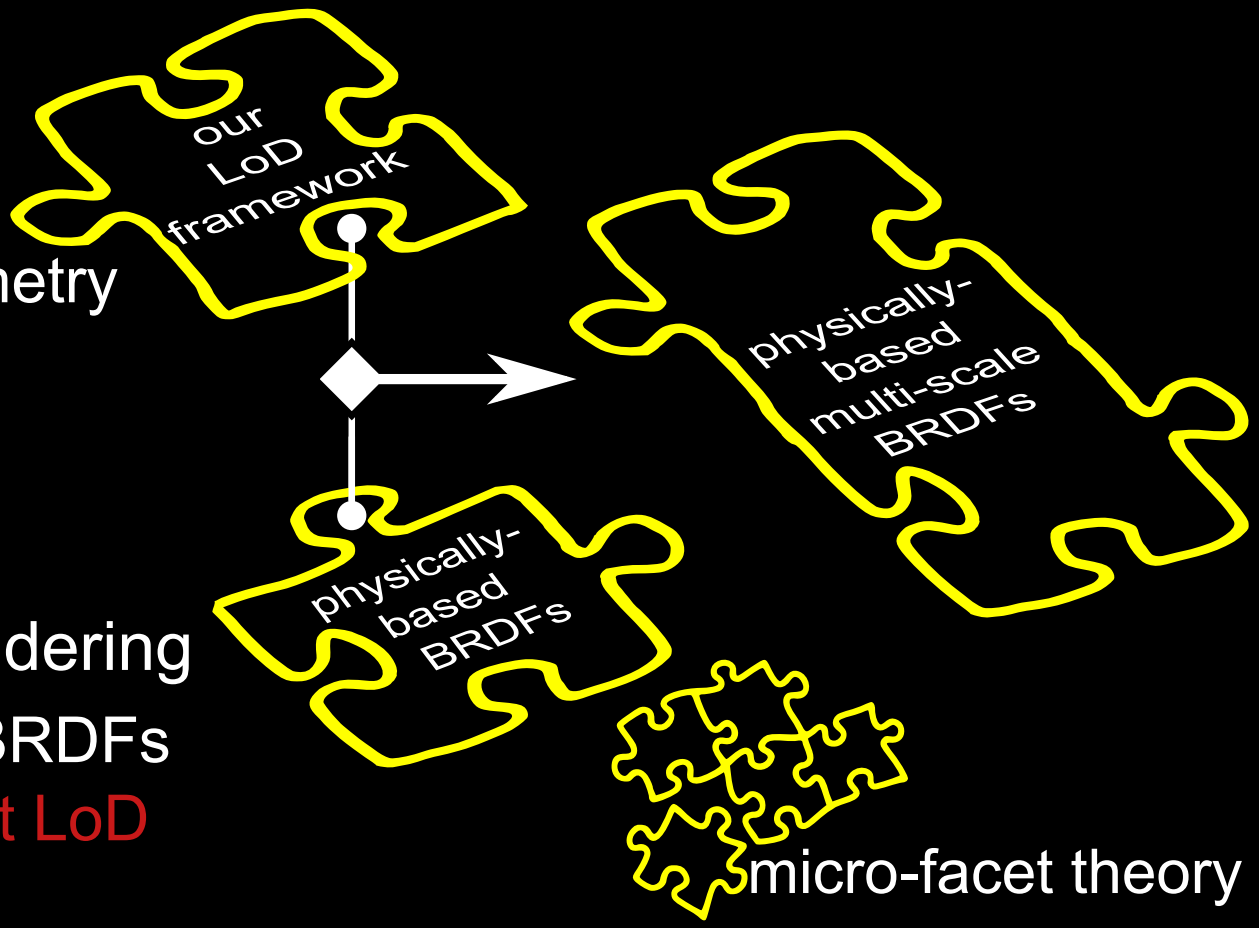
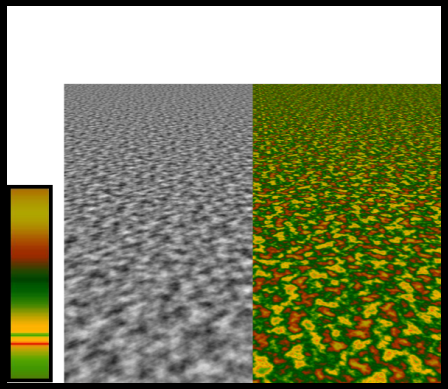
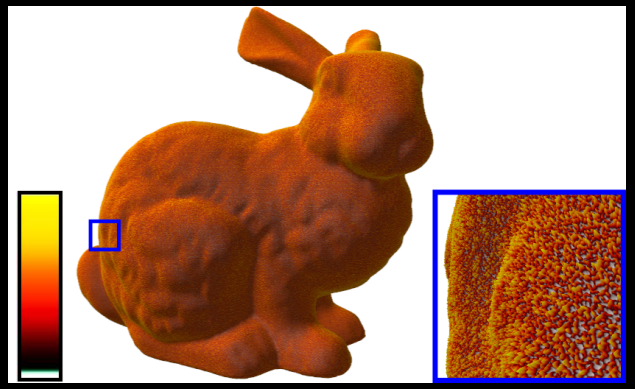
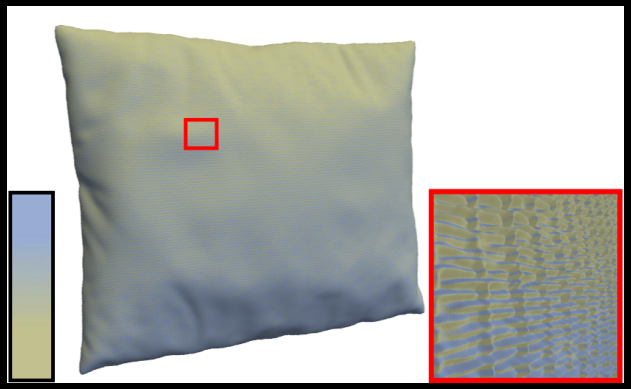
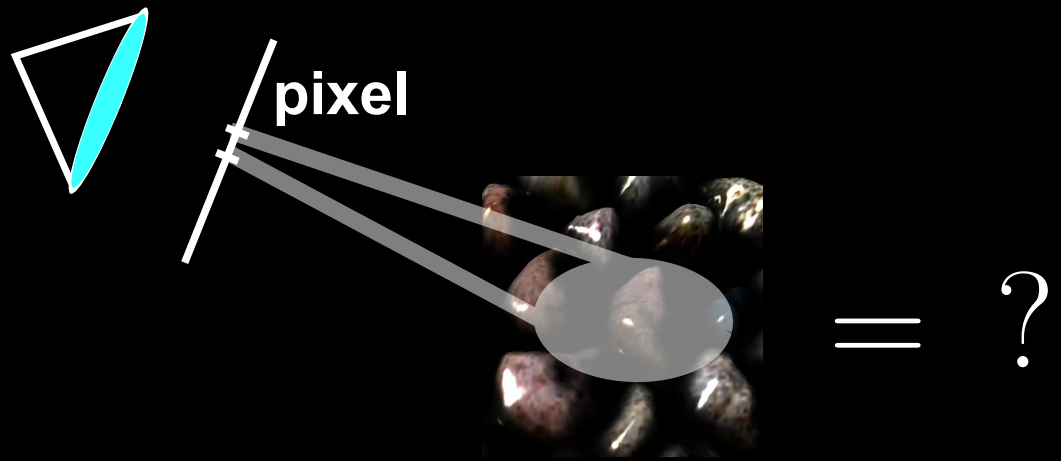








Thank you!



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