

Visual Chatter in the Real World

Shree K. Nayar

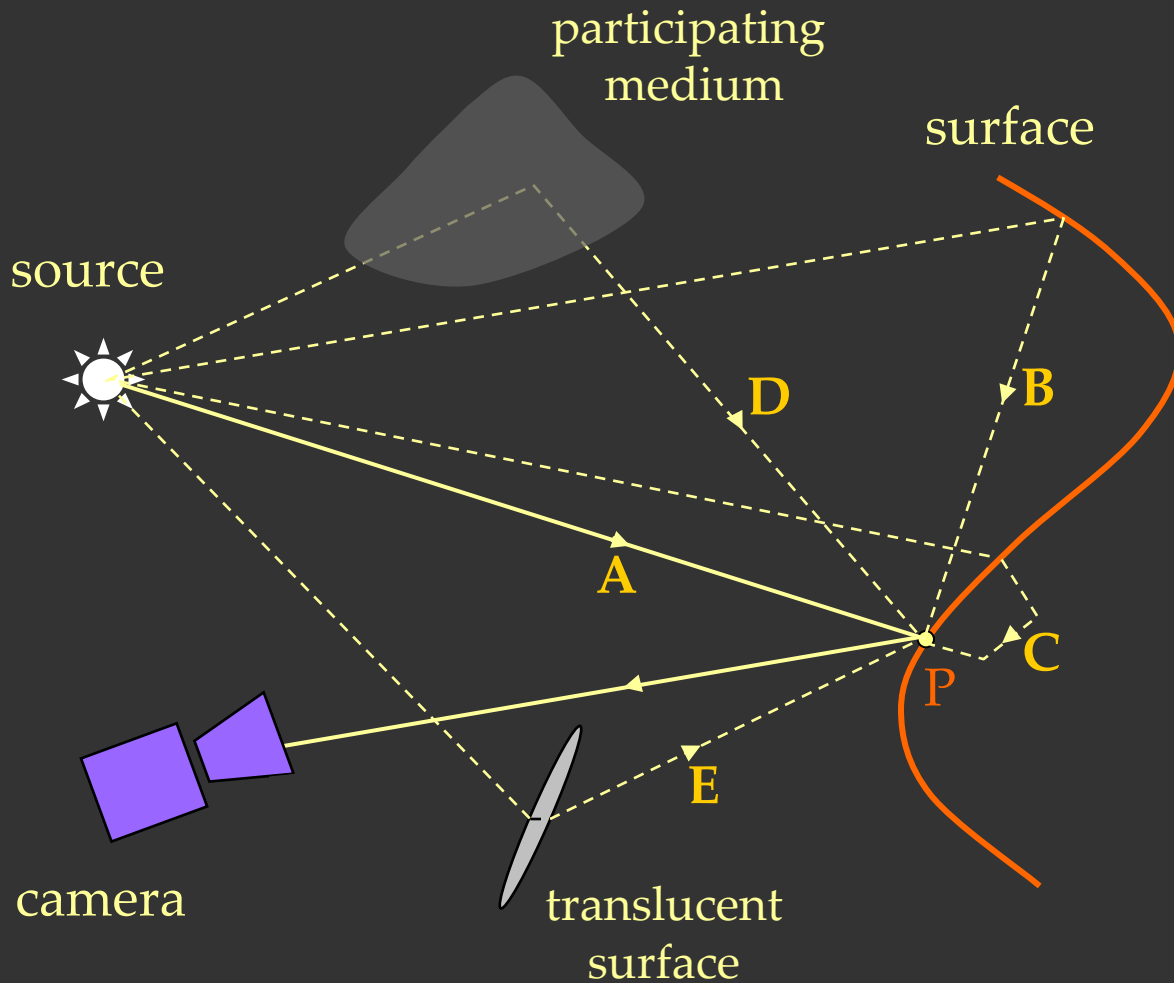
Computer Science
Columbia University

With: Guru Krishnan, Michael Grossberg, Ramesh Raskar

Eurographics Rendering Symposium
June 2006, Nicosia, Cyprus

Support: ONR

Direct and Global Illumination

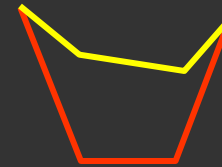
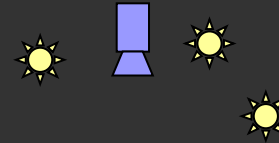


- A : Direct
- B : Interreflection
- C : Subsurface
- D : Volumetric
- E : Diffusion

Related Work

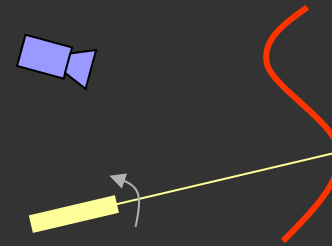
- Shape from Interreflections

(Nayar et. al., ICCV 90)



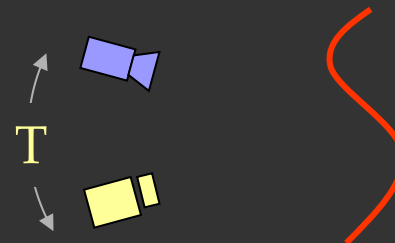
- Inverse Light Transport

(Seitz et. al., ICCV 05)



- Dual Photography


(Sen et. al., Siggraph 05)



Fast Separation of Direct and Global Images

- Create Novel Images of the Scene
- Enhance Brightness Based Vision Methods
- New Insights into Material Properties

Compute Direct and Global Images
of a Scene from Two Captured Images

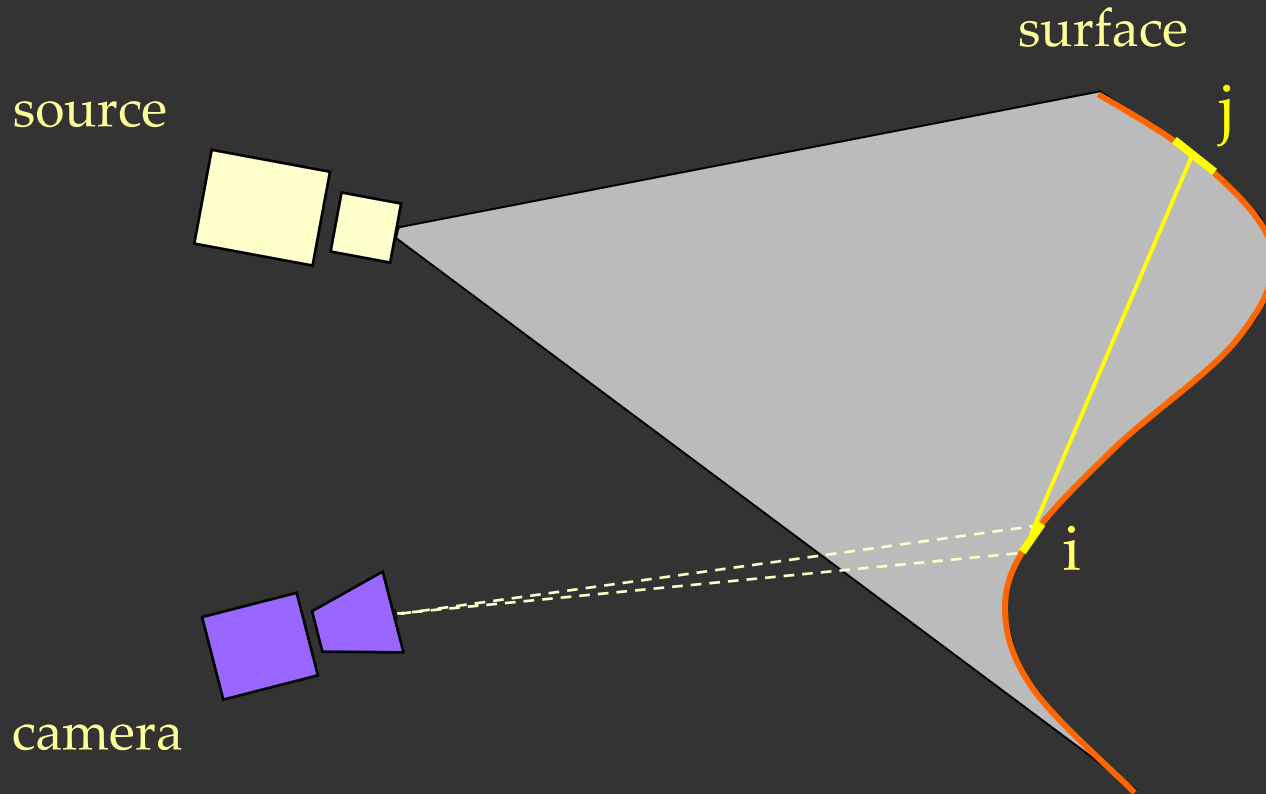


Create Novel Images of the Scene

Enhance Brightness Based Vision Methods

New Insights into Material Properties

Direct and Global Components: Interreflections



$$L[c, i] = L_d[c, i] + L_g[c, i]$$

radiance

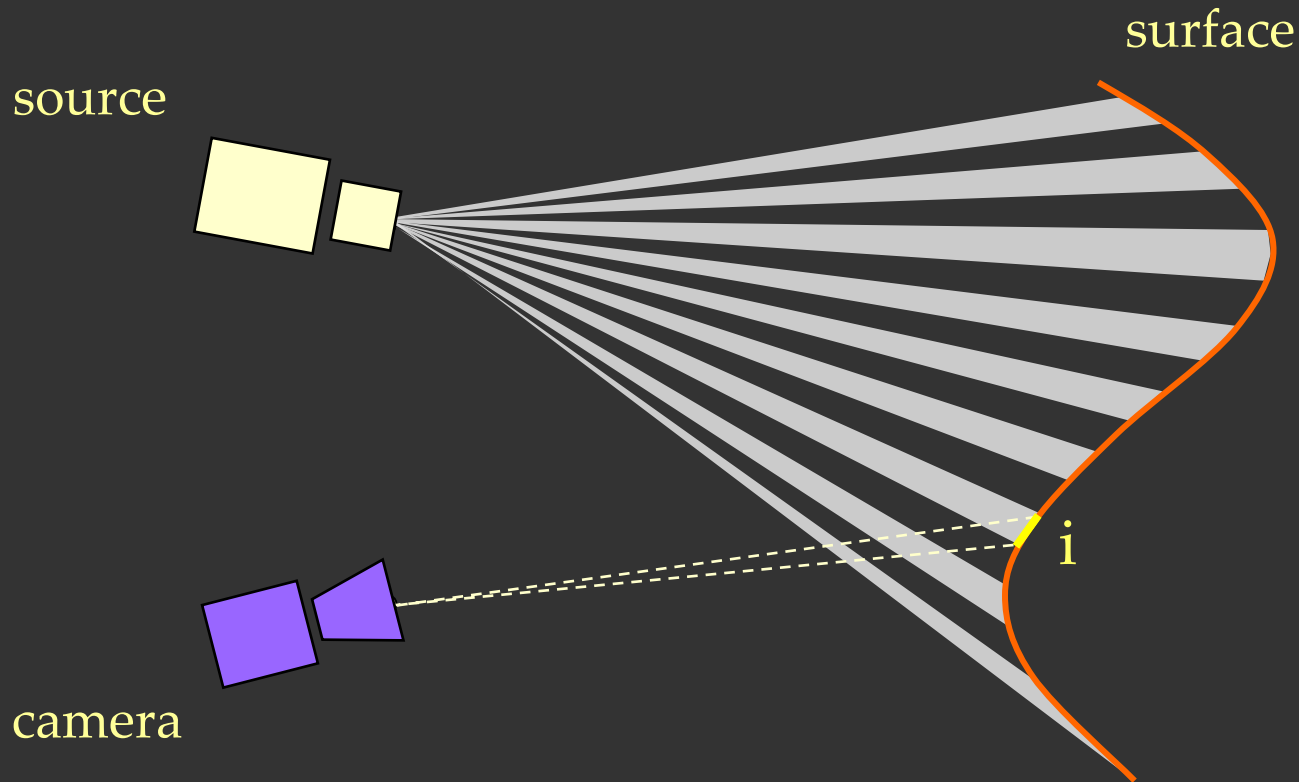
direct

global

$$L_g[c, i] = \sum_P A[i, j] L[i, j]$$

BRDF and geometry

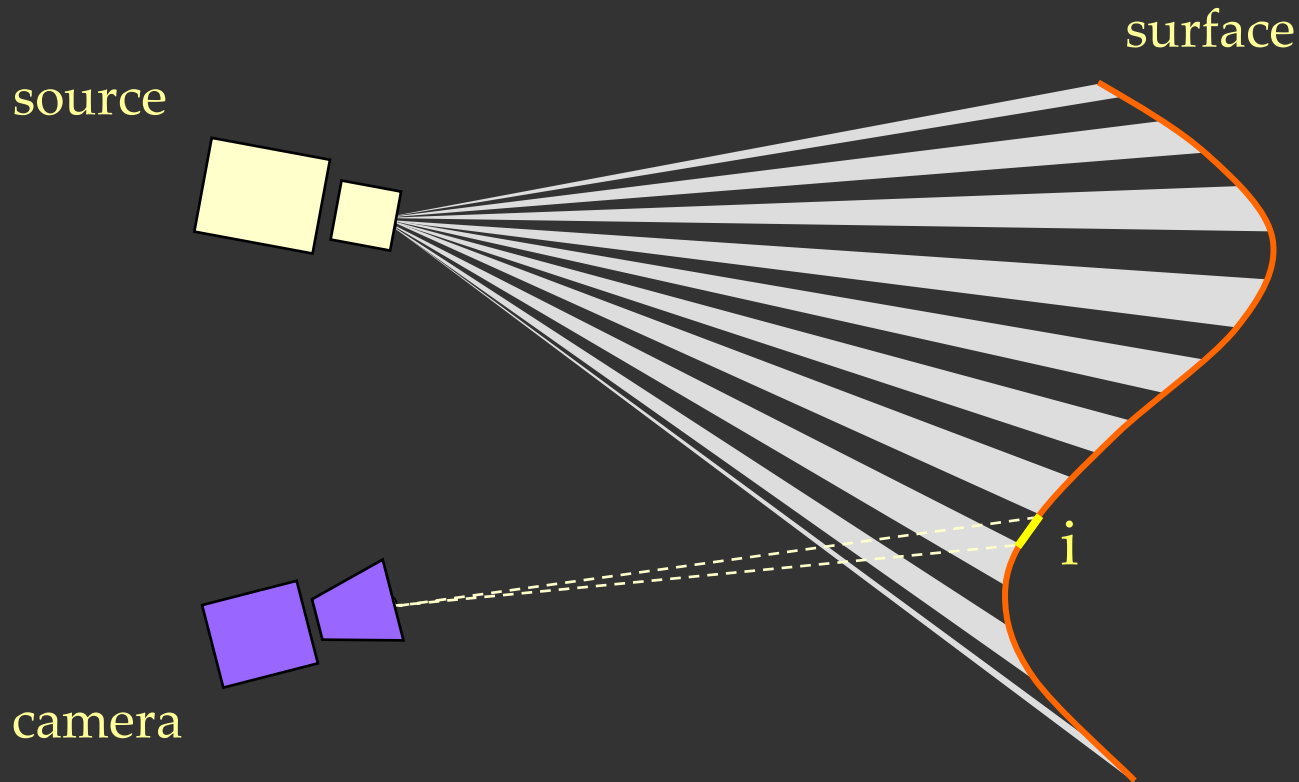
High Frequency Illumination Pattern



$$L^+[c, i] = L_d[c, i] + \alpha L_g[c, i]$$

fraction of activated source elements

High Frequency Illumination Pattern



$$L^+[c, i] = L_d[c, i] + \alpha L_g[c, i]$$

$$L^-[c, i] = (1 - \alpha) L_g[c, i]$$

fraction of activated source elements

Separation from Two Images

$$\alpha = \frac{1}{2}:$$

$$L_d = L_{\max} - L_{\min}, \quad L_g = 2L_{\min}$$

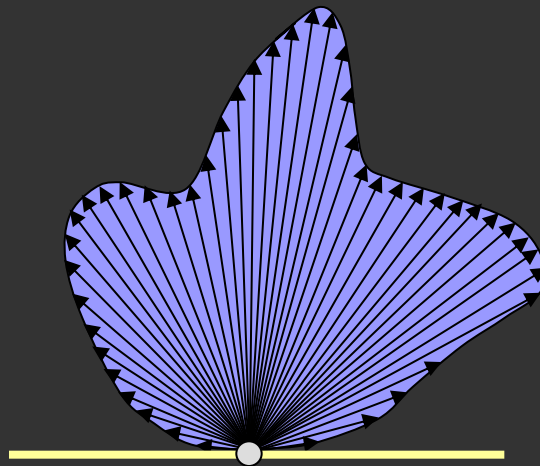
direct

global

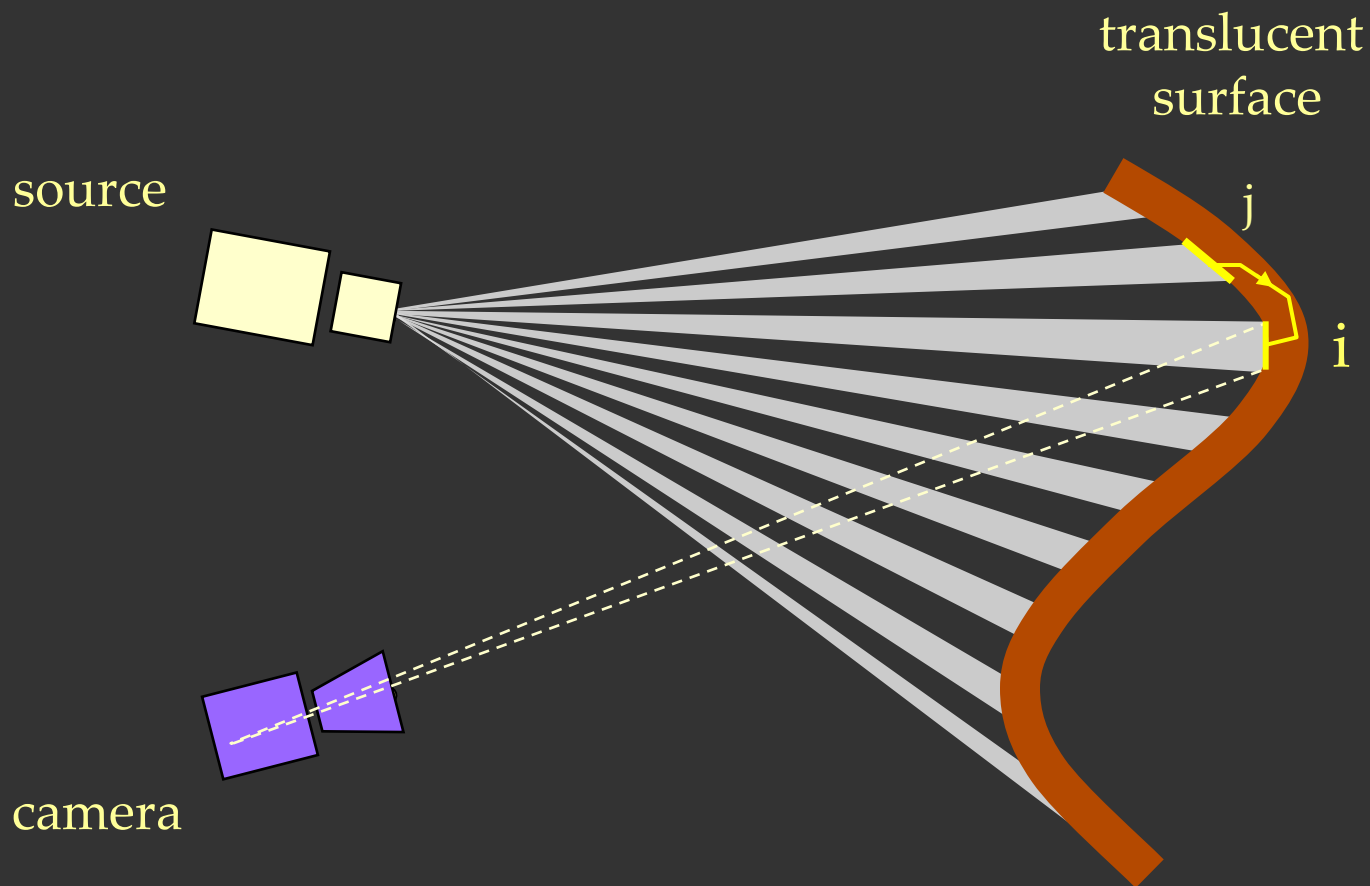
Minimum Illumination Frequency

$$\alpha L_g = \int A(y) L(y) dy$$

$$(\omega_A + \omega_L)$$

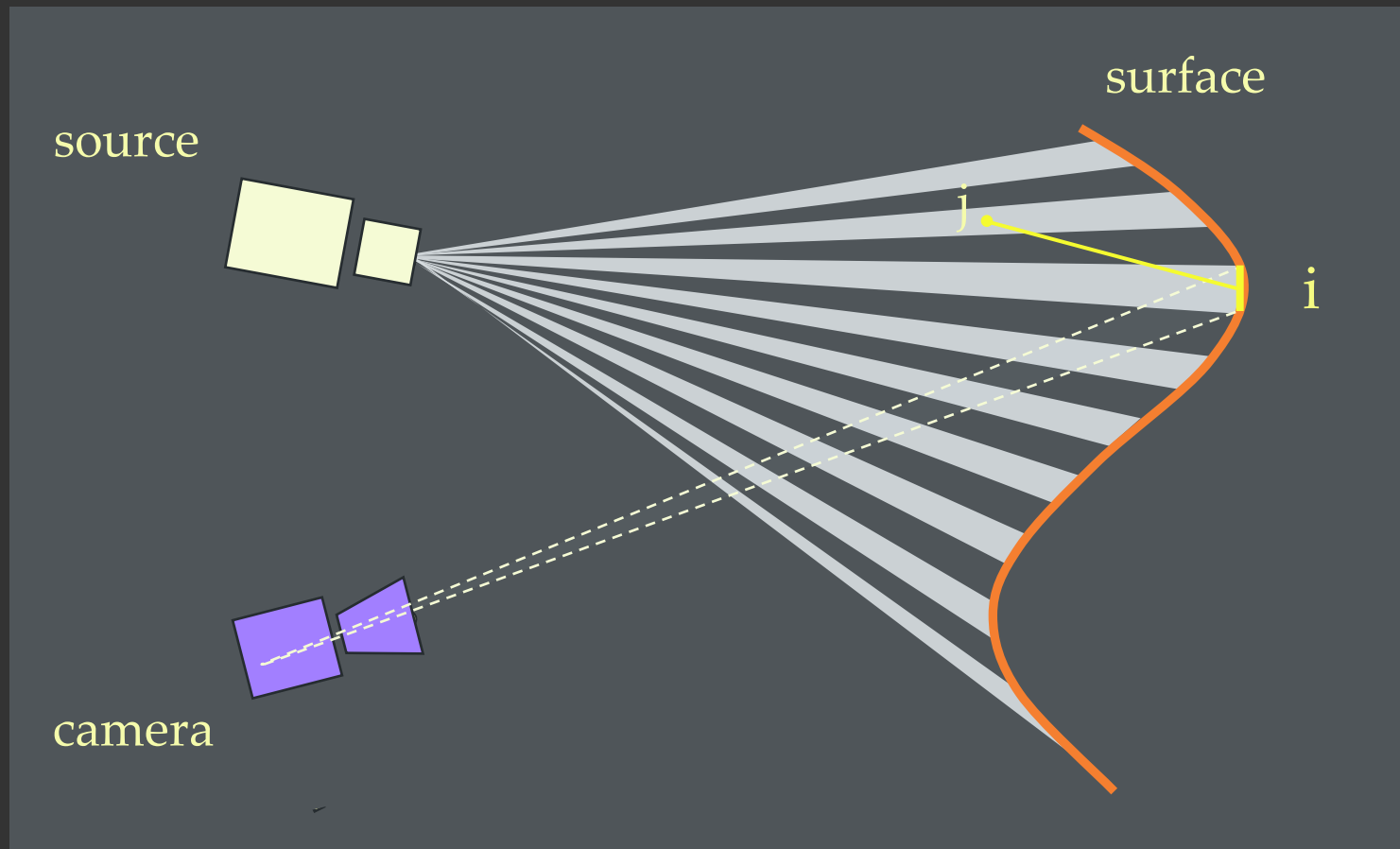


Other Global Effects: Subsurface Scattering



Other Global Effects: Volumetric Scattering

participating medium



Diffuse
Interreflections

Specular
Interreflections

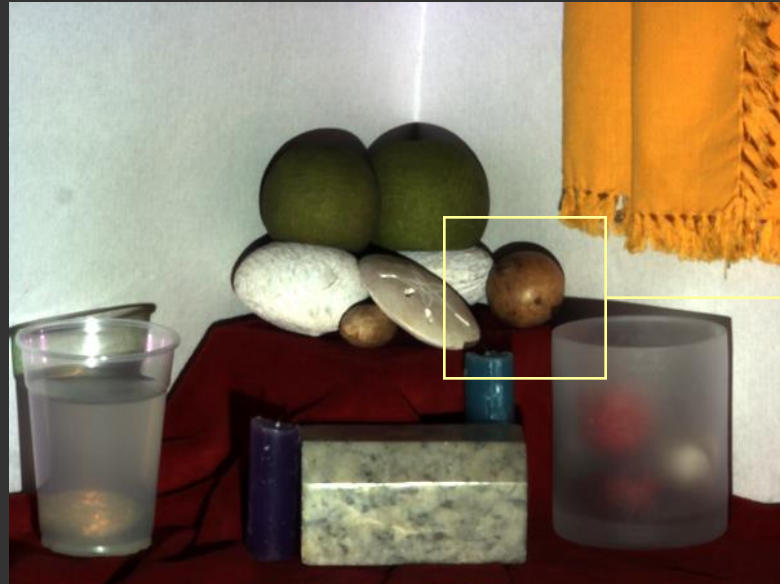
Diffusion

Volumetric
Scattering

Subsurface
Scattering



Scene

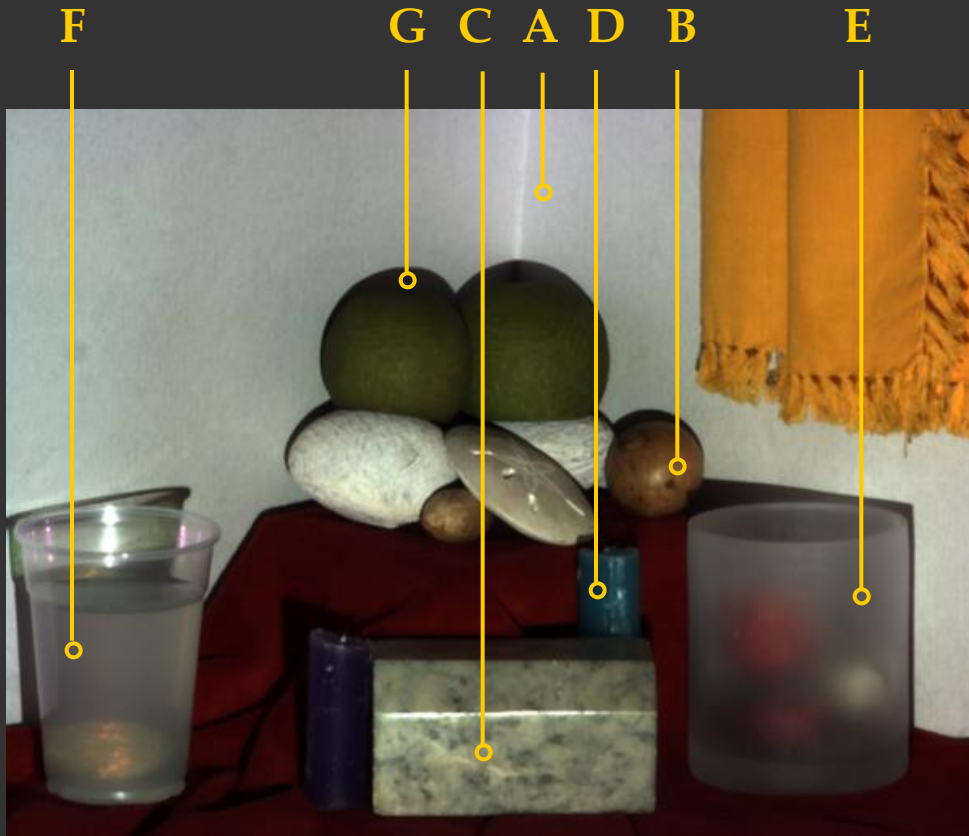


Direct



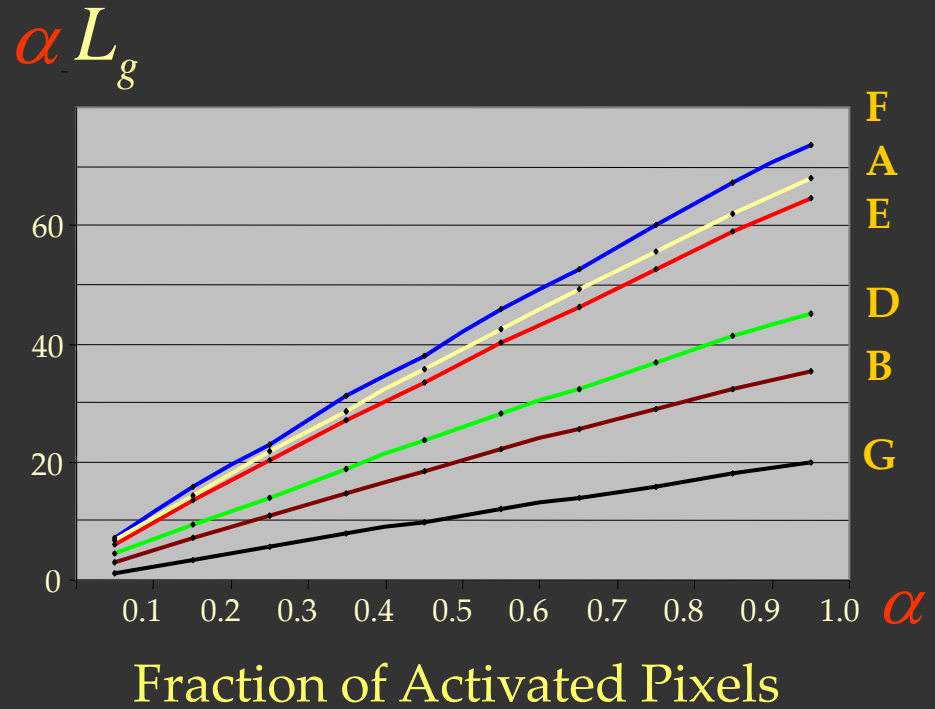
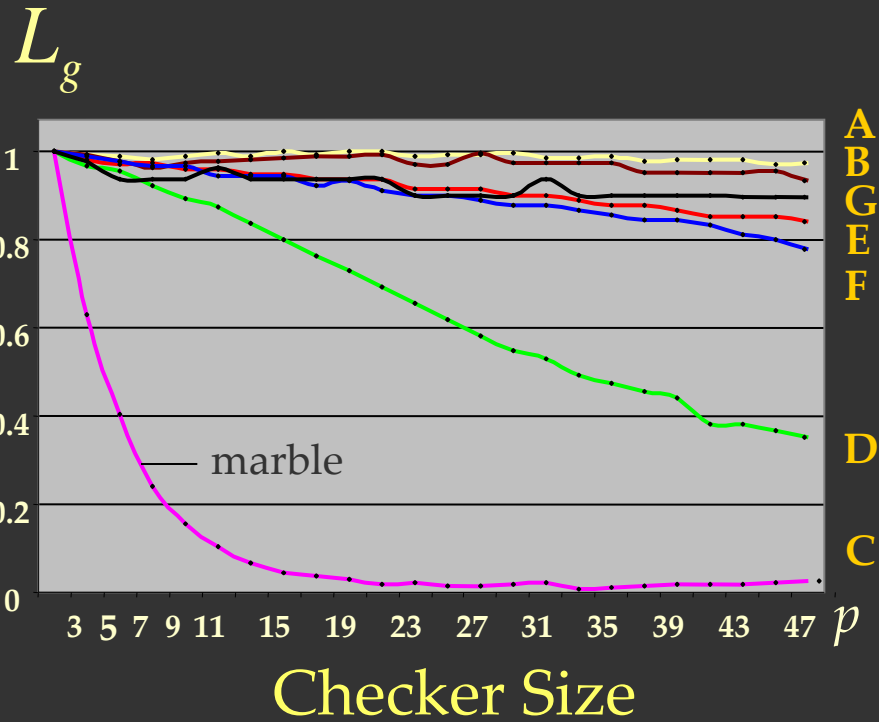
Global

Verification



- A:** Diffuse Interreflection (Board)
- B:** Specular Interreflection (Nut)
- C:** Subsurface Scattering (Marble)
- D:** Subsurface Scattering (Wax)
- E:** Translucency (Frosted Glass)
- F:** Volumetric Scattering (Dilute Milk)
- G:** Shadow (Fruit on Board)

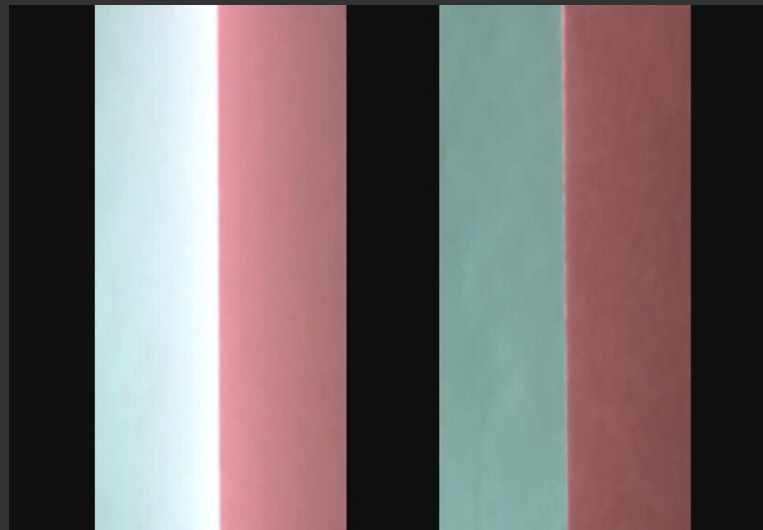
Verification Results



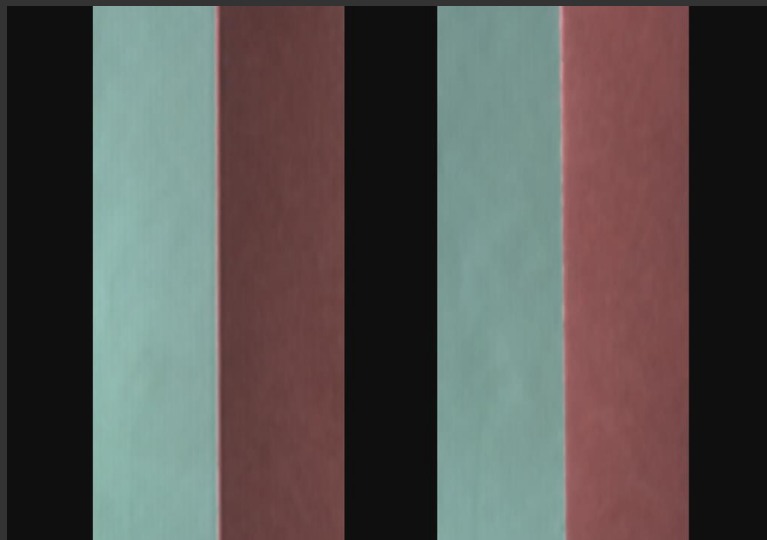
V-Grooves: Diffuse Interreflections

concave

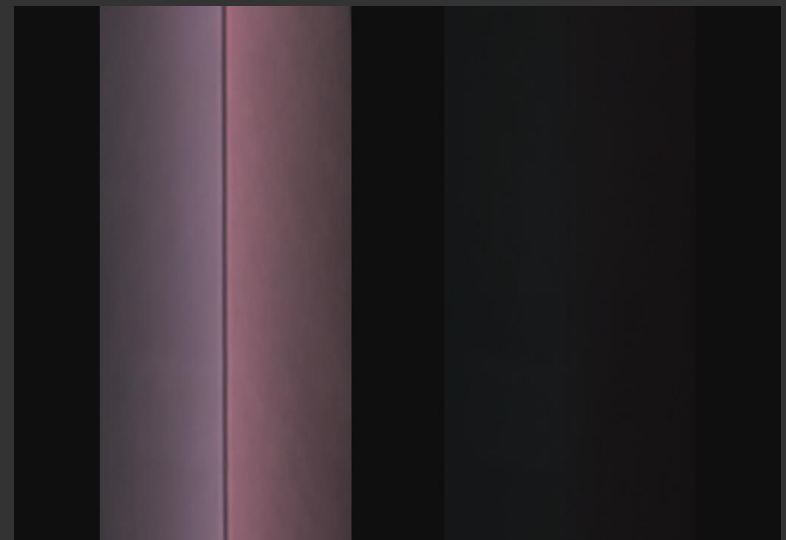
convex



Psychophysics:
Gilchrist 79, Bloj et al. 04

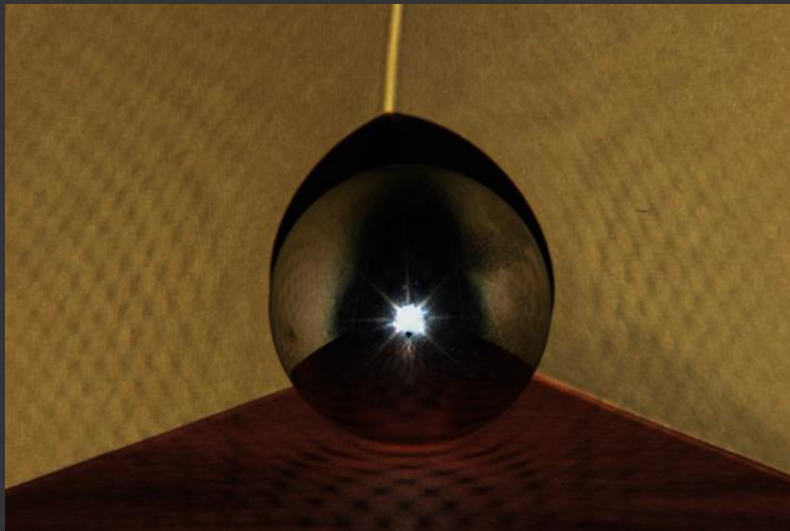
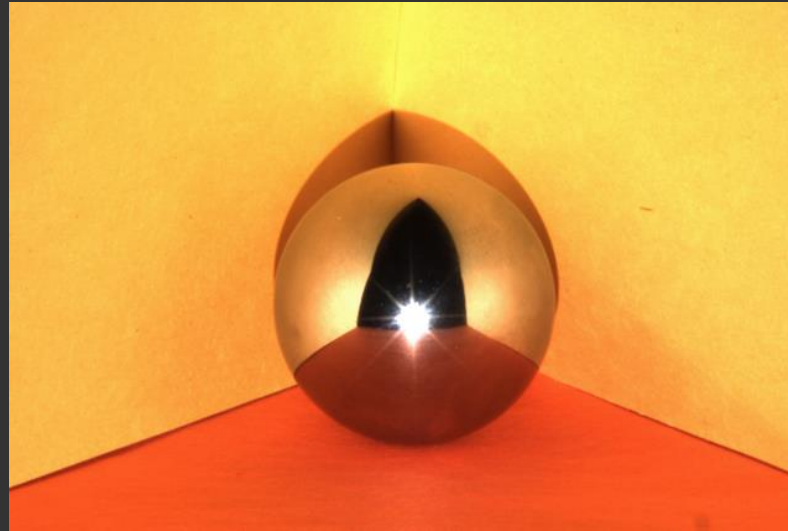


Direct

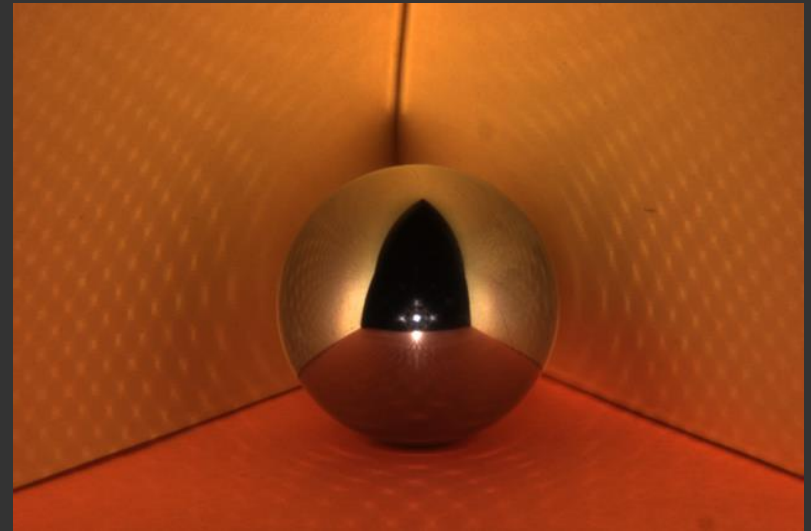


Global

Mirror Ball: Failure Case



Direct



Global

Real World Examples:

Can You Guess the Images?

Eggs: Diffuse Interreflections

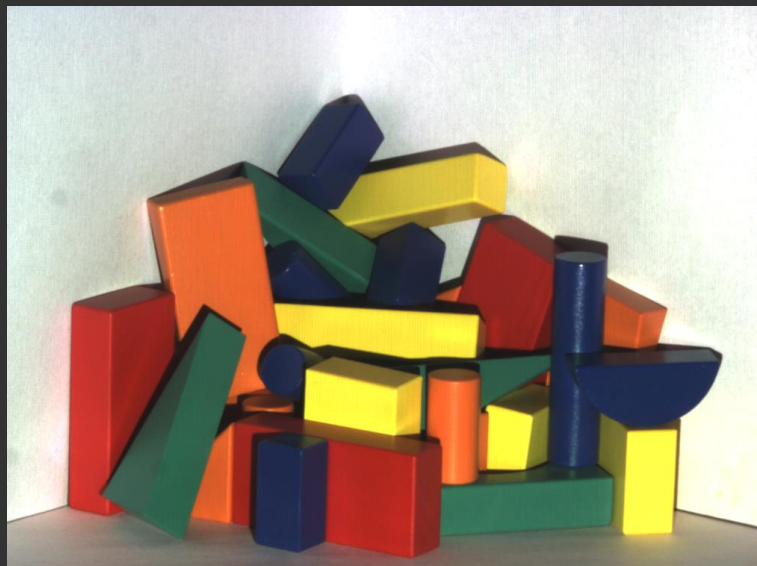


Direct

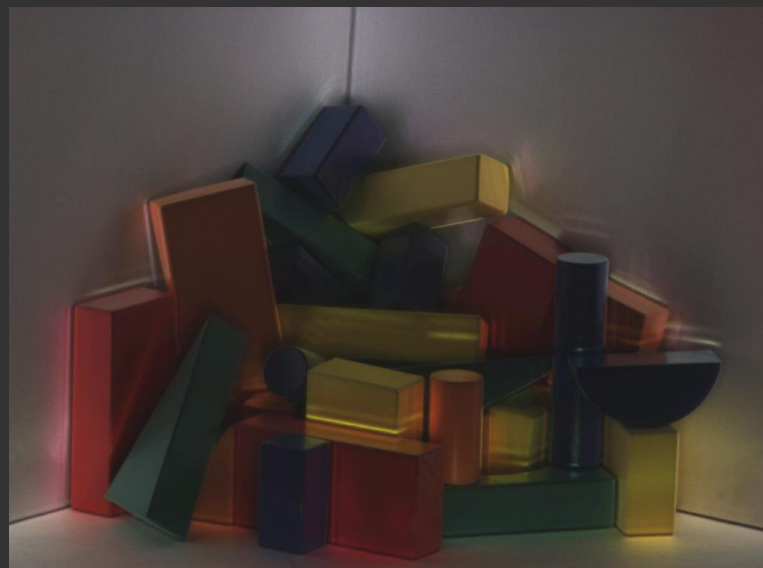


Global

Wooden Blocks: Specular Interreflections

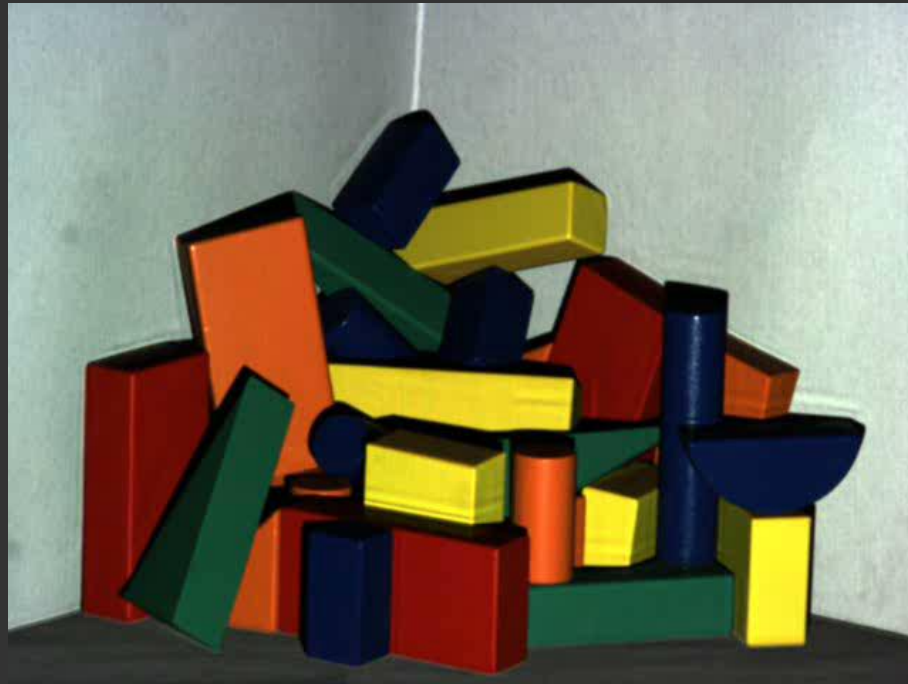


Direct



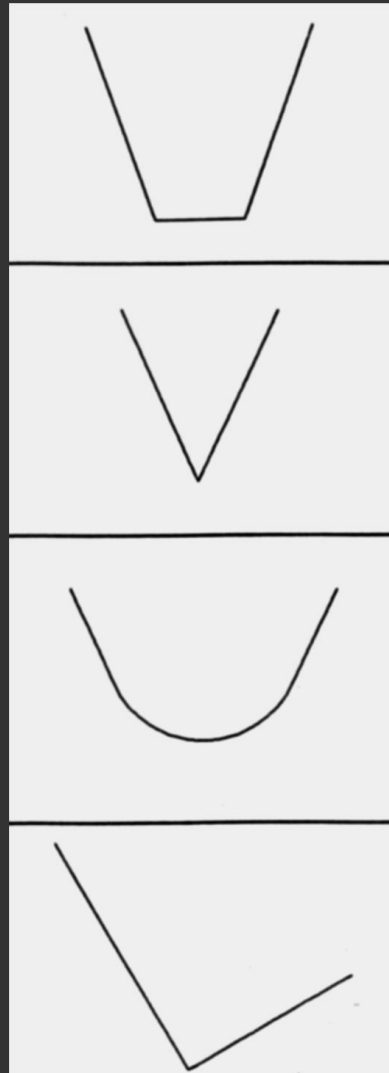
Global

Novel Images

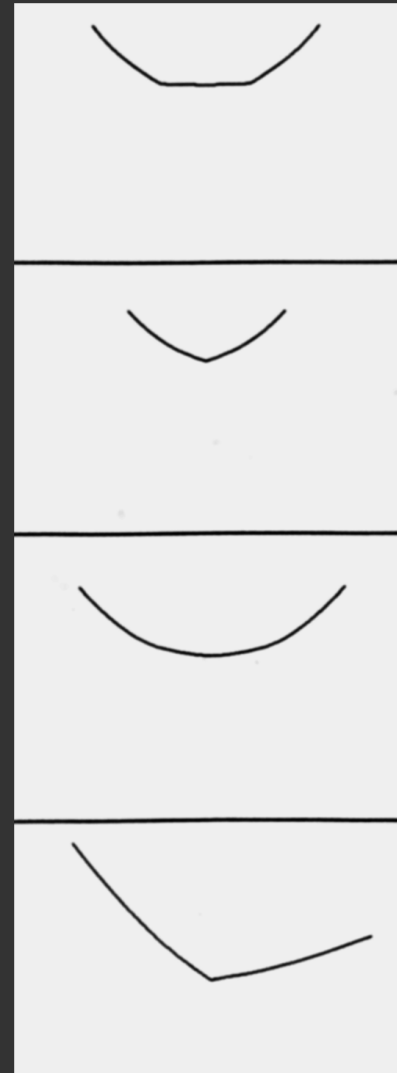


Photometric Stereo: The Pseudo Shape

Actual Shape
($\rho=0.95$)



Pseudo Shape



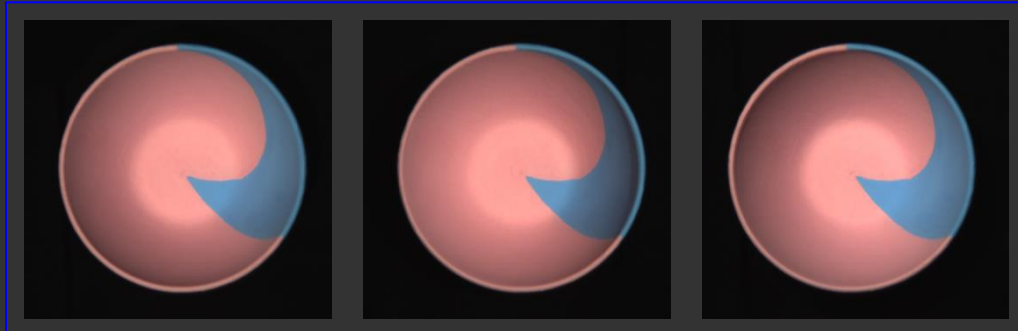
Photometric Stereo using Direct Images

Source 1

Source 2

Source 3

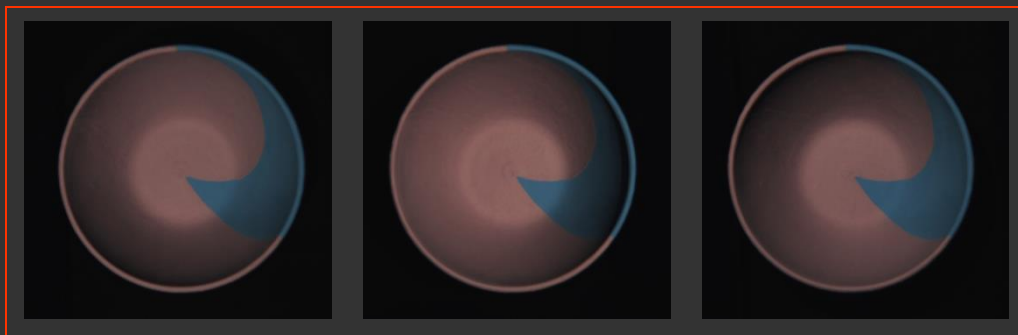
Bowl



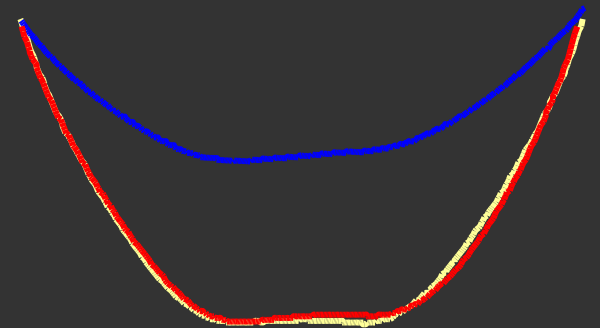
Global



Direct

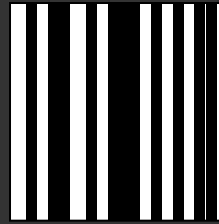


Shape



Variants of Separation Method

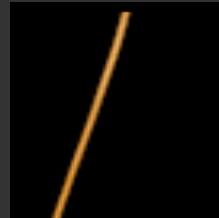
- Coded Structured Light



- Shifted Sinusoids



- Shadow of Line Occluder



- Shadow of Mesh Occluders



Building Corner



Stick



Shadow

3D from Shadows:
Bouguet and Perona 99

$$L_d = L_{\max} - L_{\min}, \quad L_g = L_{\min}$$

direct

global

Building Corner



Direct



Global

Shower Curtain: Diffuser



Mesh



Shadow

$$L_d = L_{\max} - \beta L_{\min}, \quad L_g = \beta L_{\min}$$

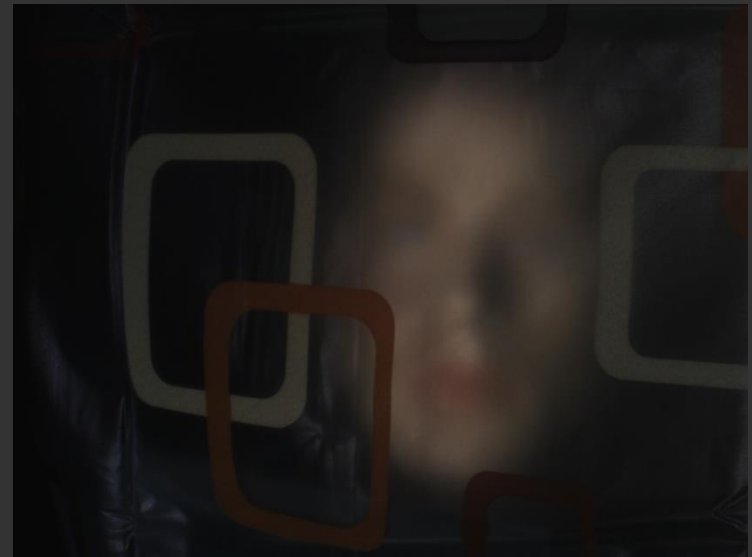
direct

global

Shower Curtain: Diffuser

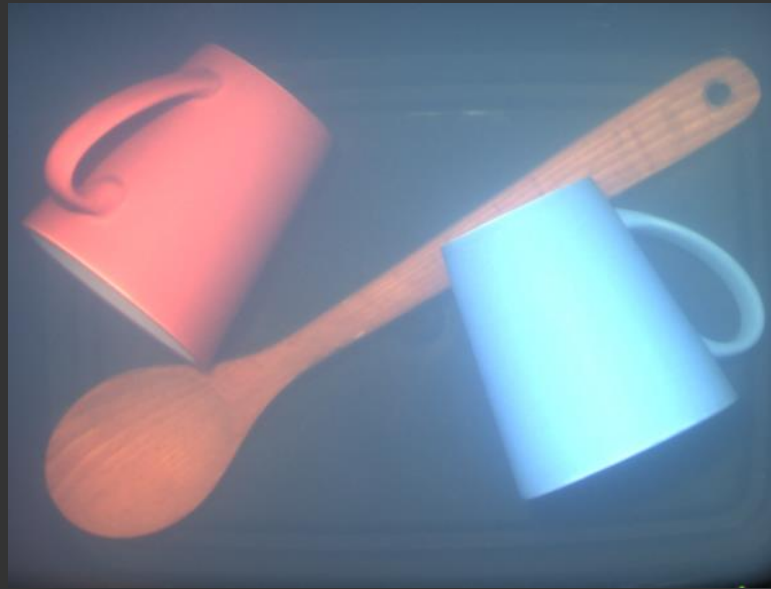


Direct



Global

Kitchen Sink: Volumetric Scattering



Volumetric Scattering:
Chandrasekar 50, Ishimaru 78

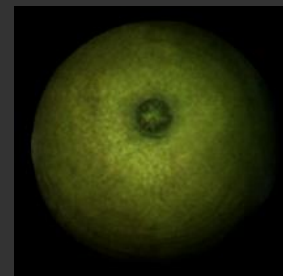


Direct



Global

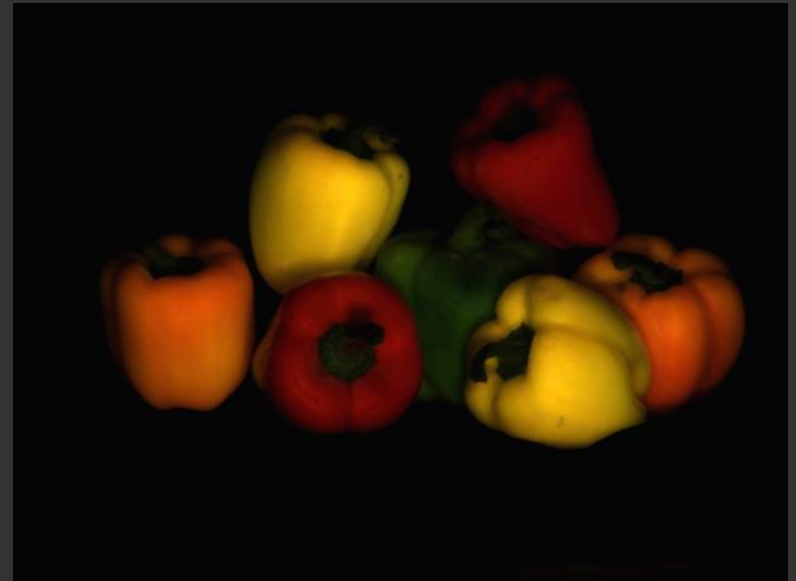
Novel Image



Peppers: Subsurface Scattering



Direct

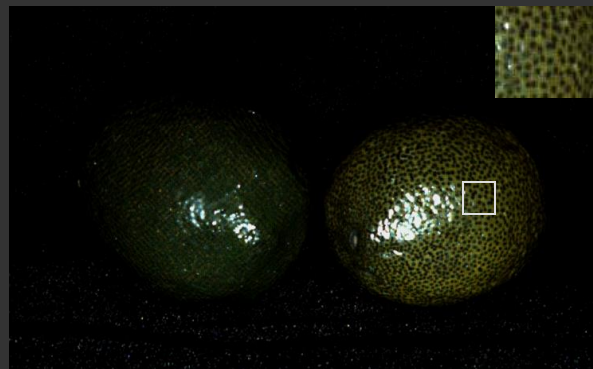
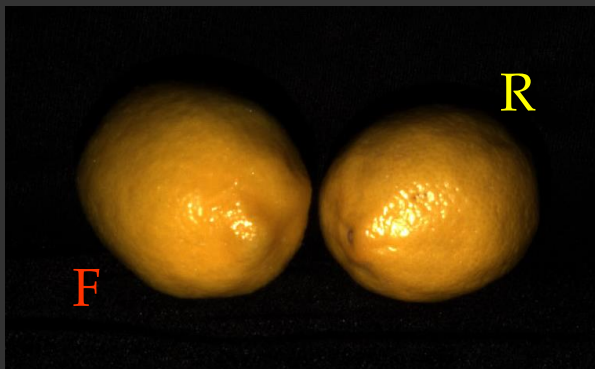
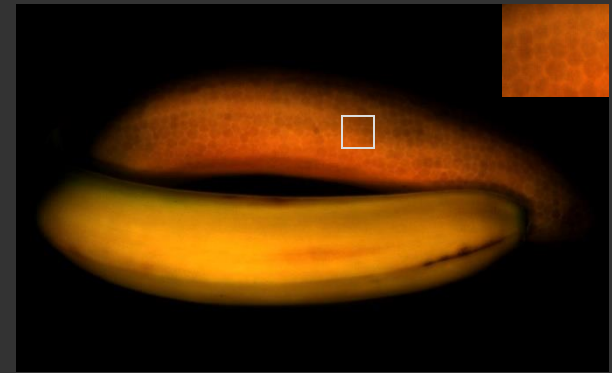
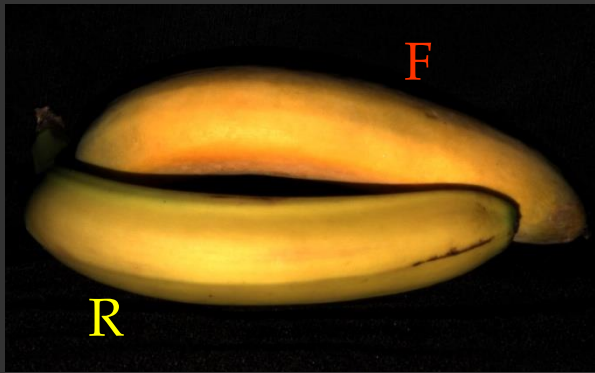


Global

Novel Images



Real or Fake ?



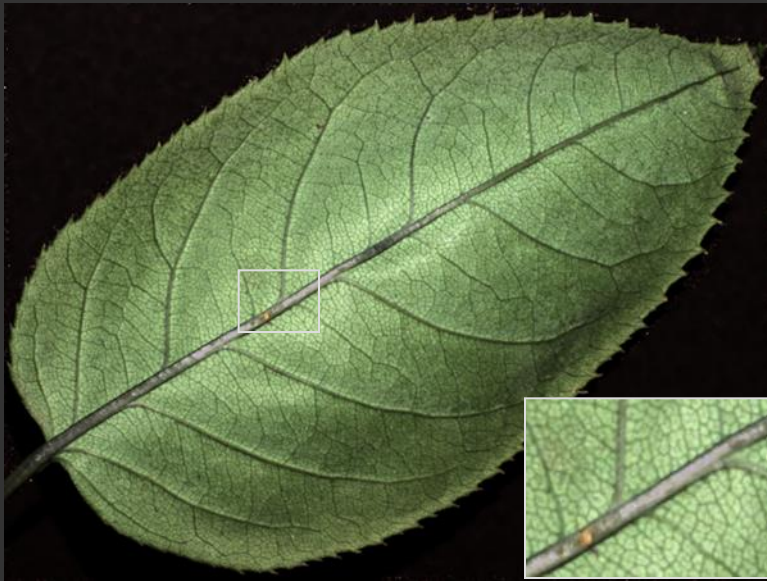
Direct

Global

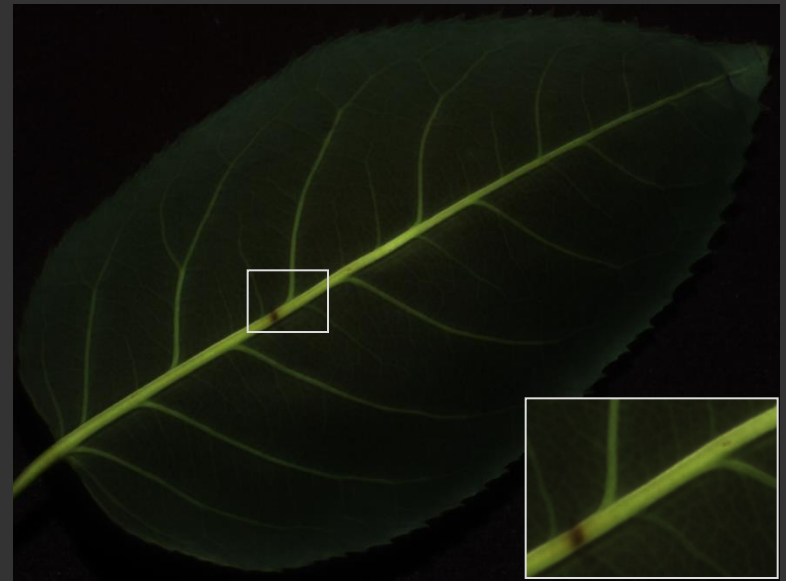
Tea Rose Leaf



Leaf Anatomy: Purves et al. 03



Direct



Global

Translucent Rubber Balls



Direct



Global

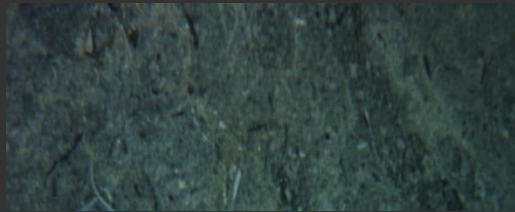
Marble: When BSSRDF becomes BRDF

Scene

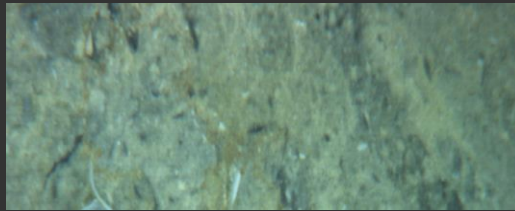
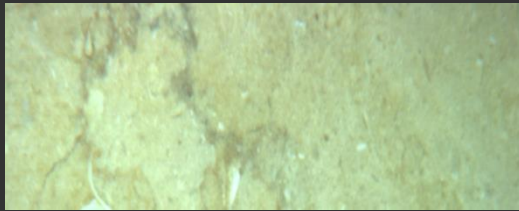
Direct

Global

1



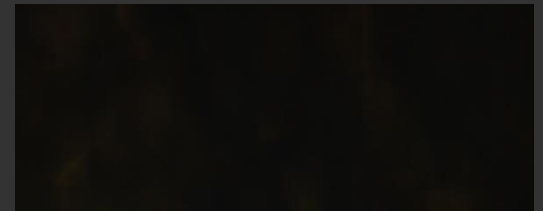
$\frac{1}{2}$



$\frac{1}{4}$



$\frac{1}{6}$



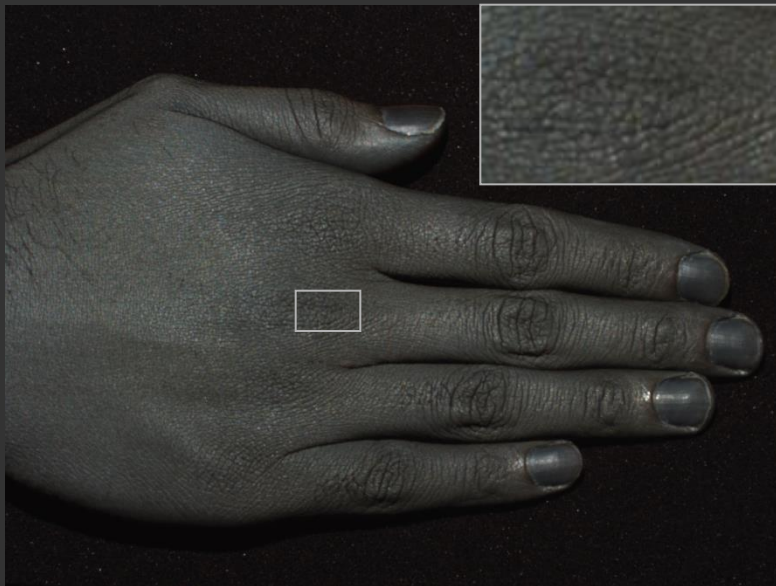
Resolution
↓

Subsurface Measurements:
Jensen et al. 01, Goesele et al. 04

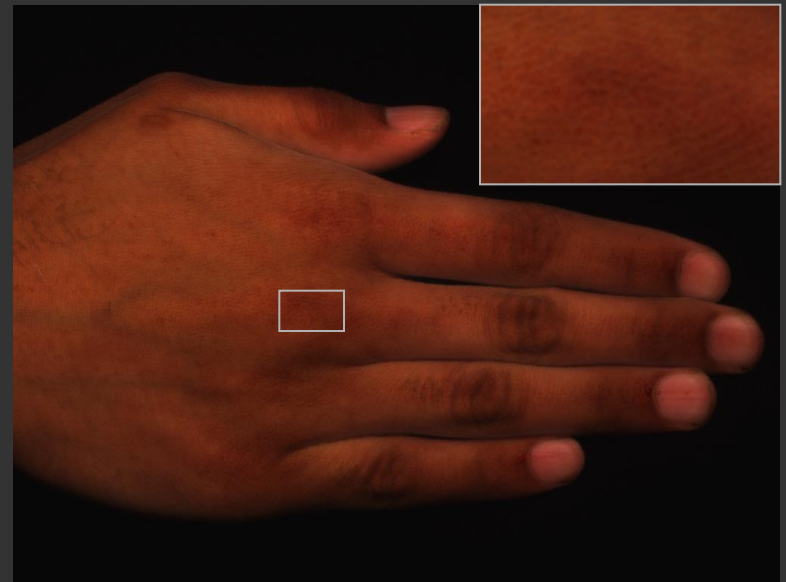
Hand



Skin: Hanrahan and Krueger 93,
Uchida 96, Haro 01, Jensen et al. 01,
Igarashi et al. 05, Weyrich et al. 05



Direct



Global

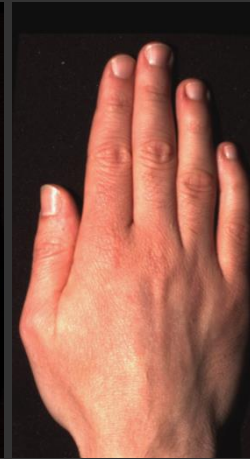
Hands



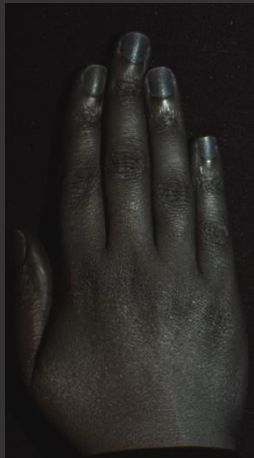
Afric. Amer.
Female



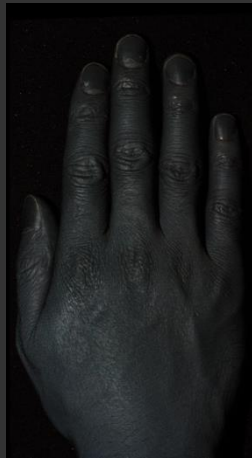
Chinese
Male



Spanish
Male



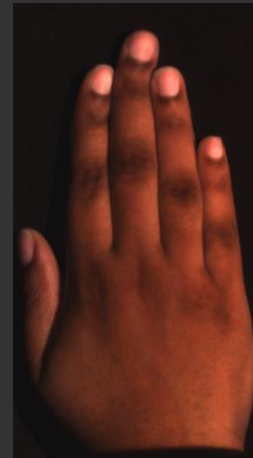
Afric. Amer.
Female



Chinese
Male



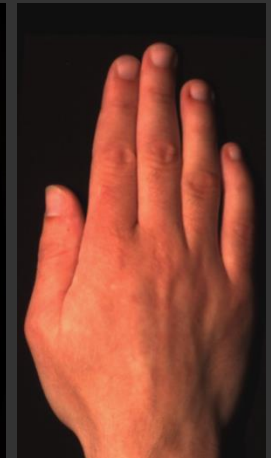
Spanish
Male



Afric. Amer.
Female



Chinese
Male

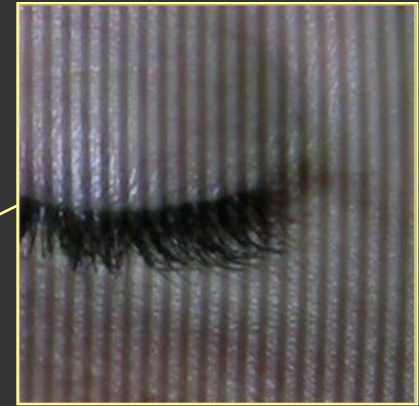
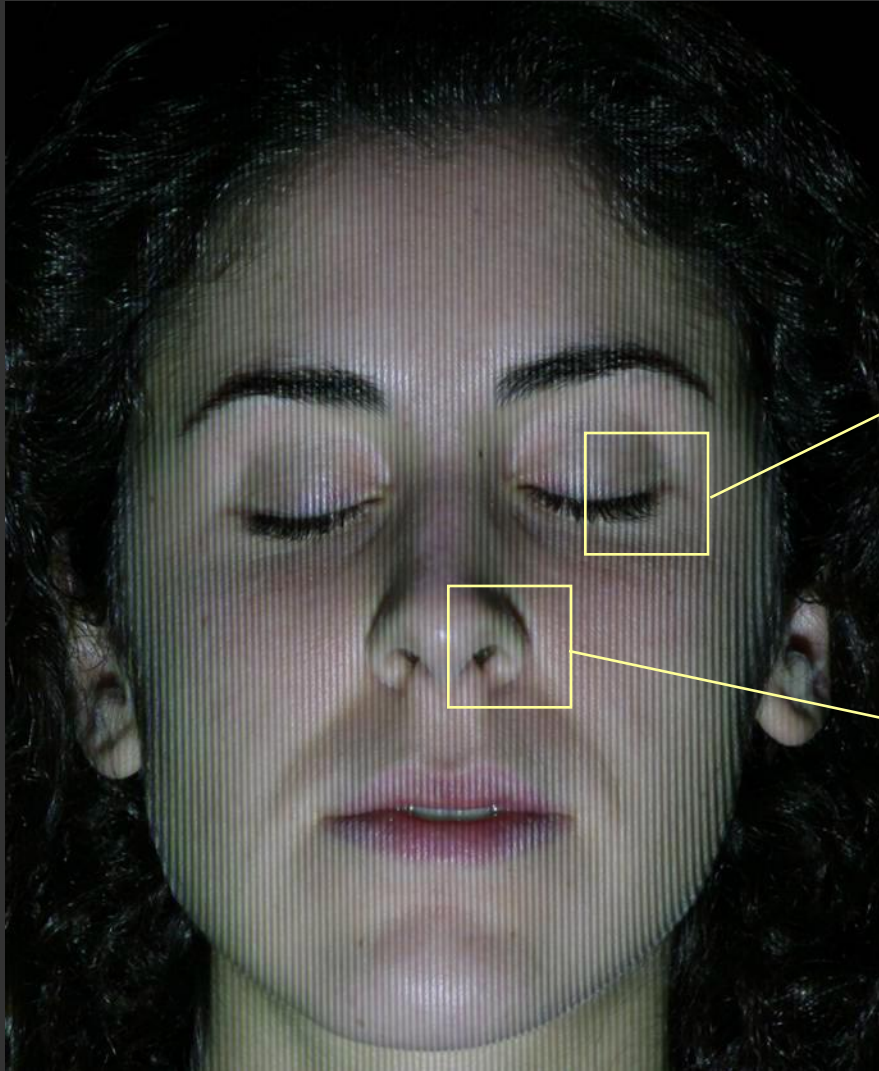


Spanish
Male

Direct

Global

Separation from a Single Image



Face



Direct



Global



Sum

Skin Tone Control



Skin Color and Lipids:
Tsumura et al. 03

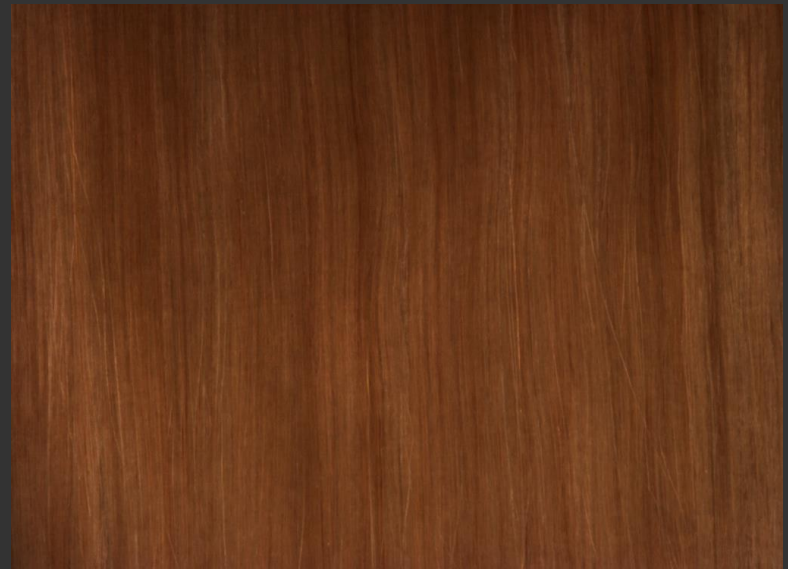
Blonde Hair



Hair Scattering: Stamm et al. 77,
Bustard and Smith 91, Lu et al. 00
Marschner et al. 03



Direct



Global

Hair: Bidirectional Texture Function

Hair



Direct



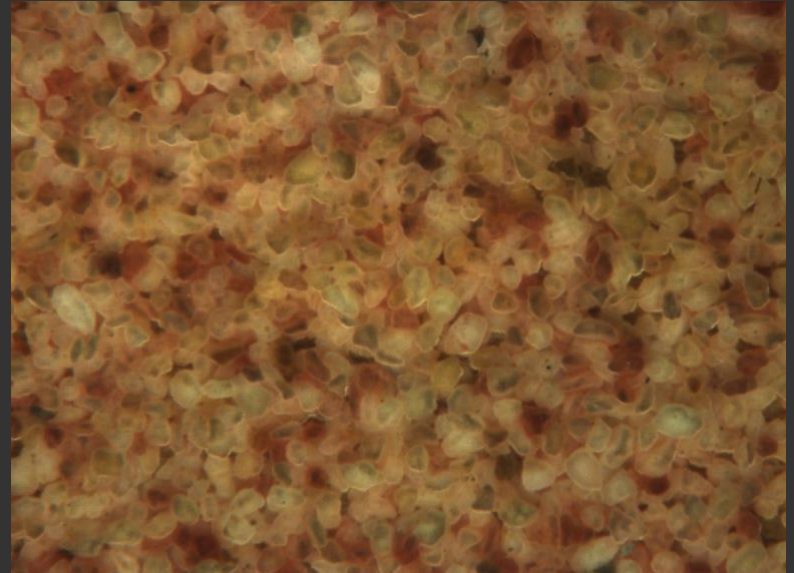
Global



Pebbles: 3D Texture



Direct



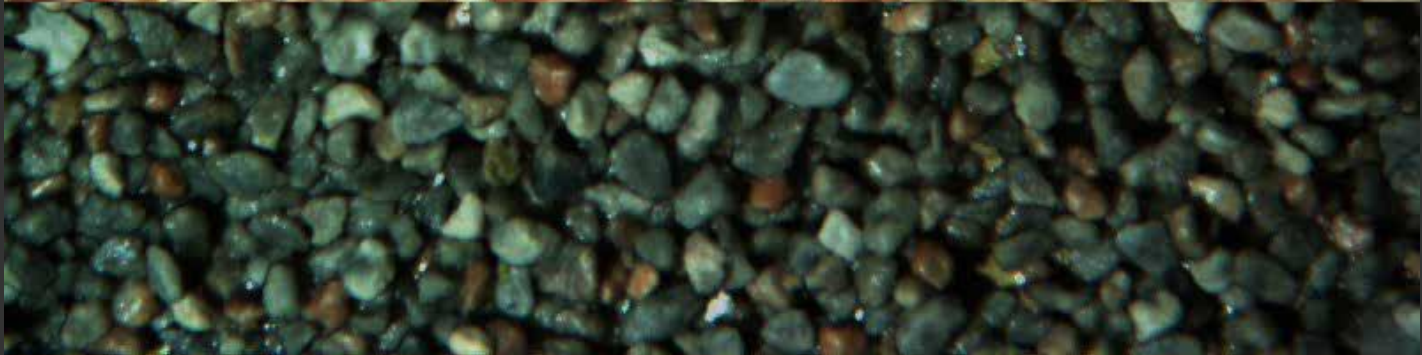
Global

Pebbles: Bidirectional Texture Function

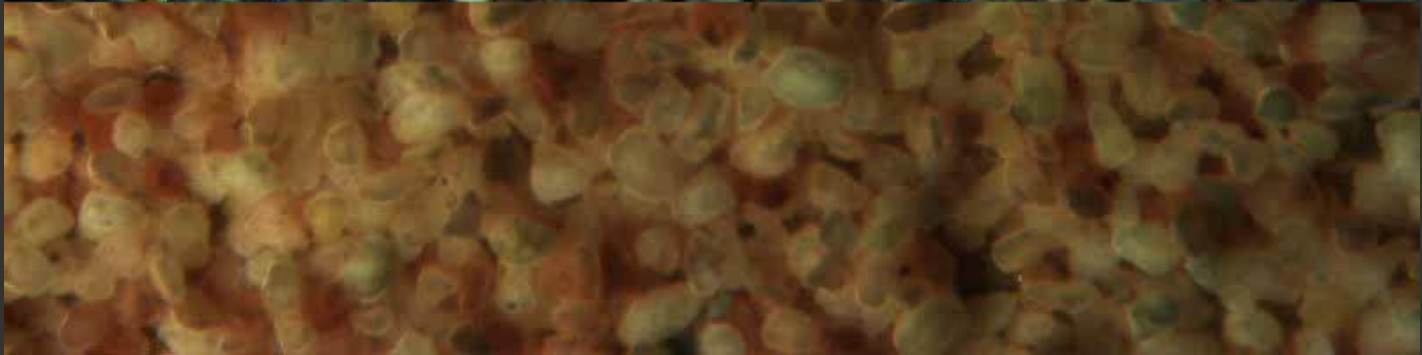
Pebbles



Direct



Global



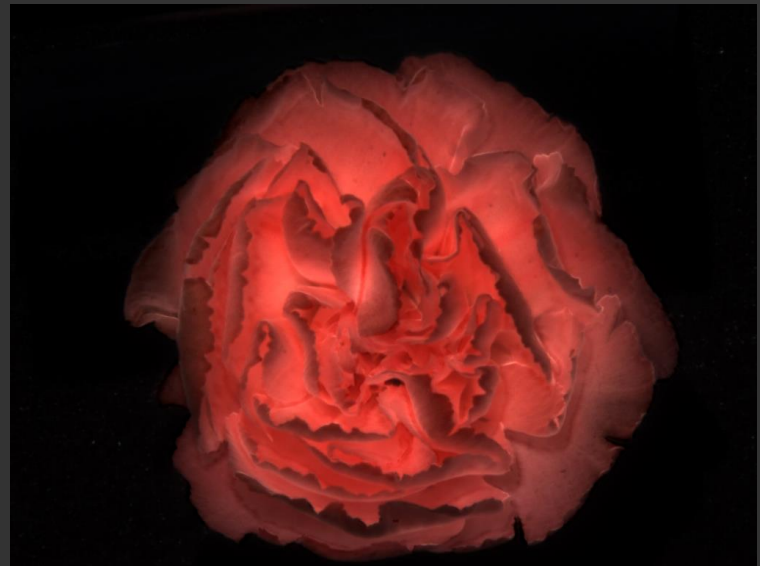
Pink Carnation



Spectral Bleeding: Funt et al. 91



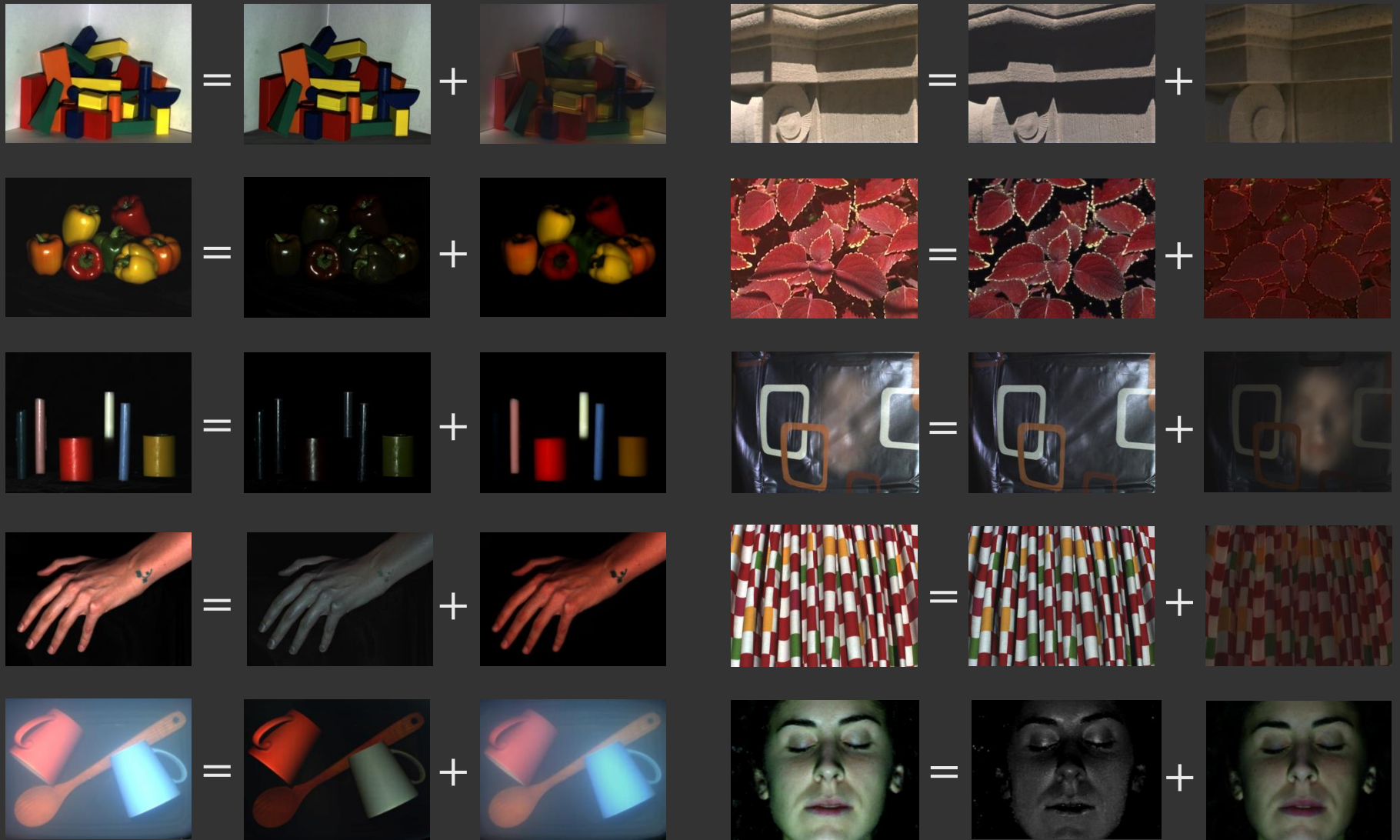
Direct



Global

Summary

- Fast and Simple Separation Method
- No Prior Knowledge of Material Properties
- Wide Variety of Global Effects
- Implications:
 - Generation of Novel Images
 - Enhance Computer Vision Methods
 - Insights into Properties of Materials



www.cs.columbia.edu/CAVE