

# Visual Chatter in the Real World

Shree K. Nayar

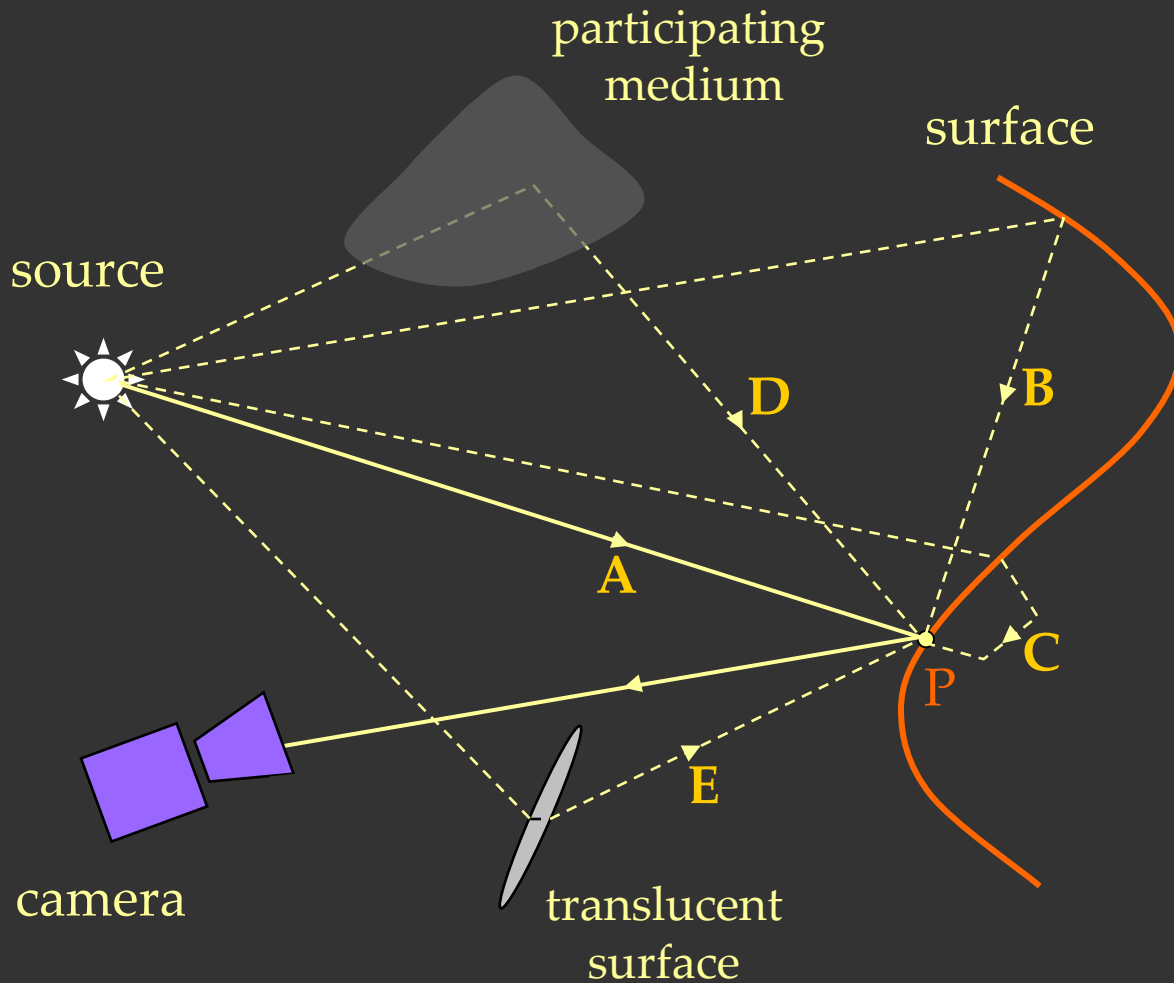
Computer Science  
Columbia University

With: Guru Krishnan, Michael Grossberg, Ramesh Raskar

Eurographics Rendering Symposium  
June 2006, Nicosia, Cyprus

Support: ONR

# Direct and Global Illumination



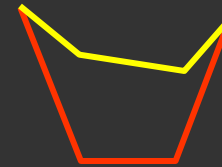
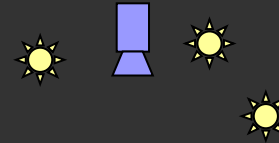
- A : Direct
- B : Interreflection
- C : Subsurface
- D : Volumetric
- E : Diffusion

# Related Work

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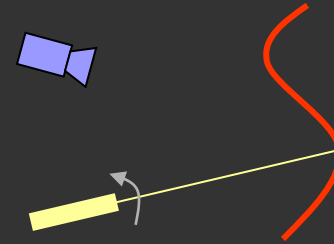
- Shape from Interreflections

(Nayar et. al., ICCV 90)



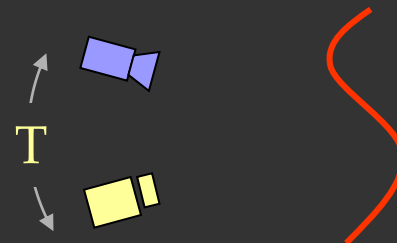
- Inverse Light Transport

(Seitz et. al., ICCV 05)



- Dual Photography

(Sen et. al., Siggraph 05)

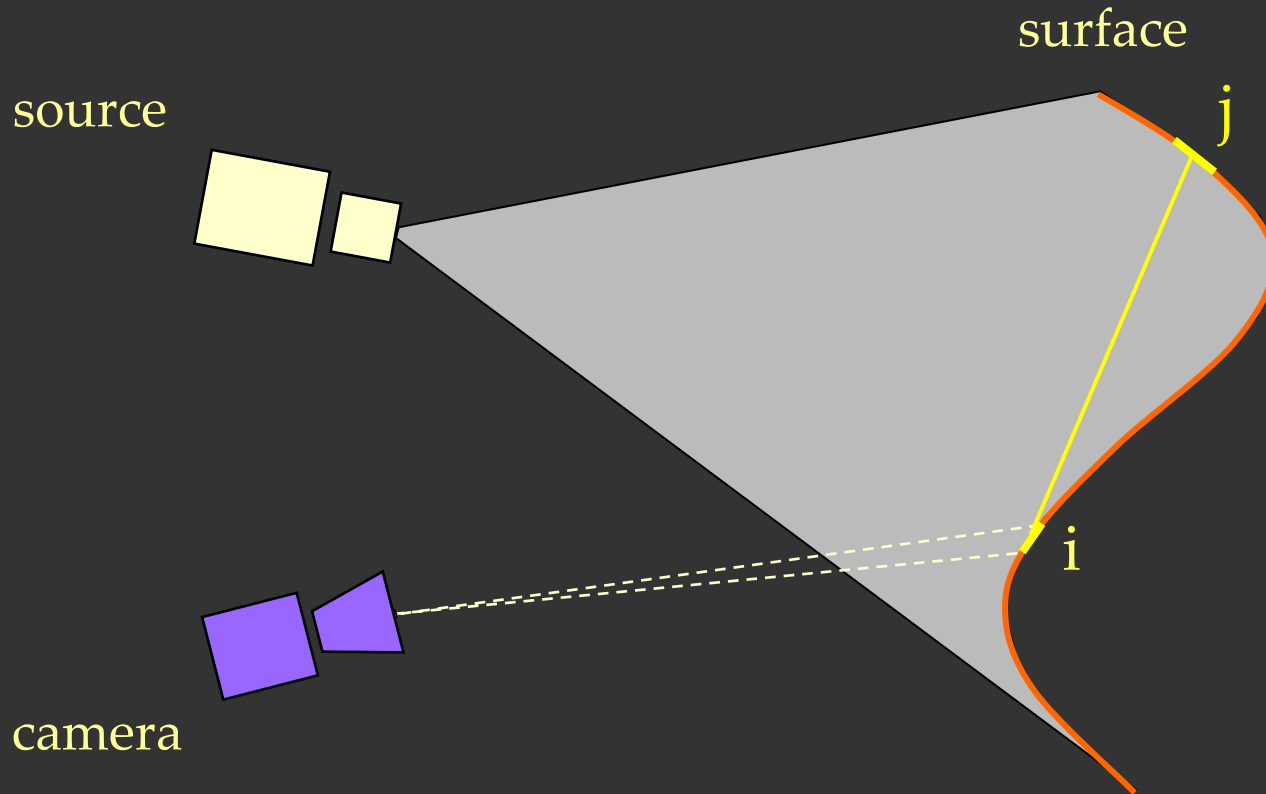


# Fast Separation of Direct and Global Images

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

# Direct and Global Components: Interreflections



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

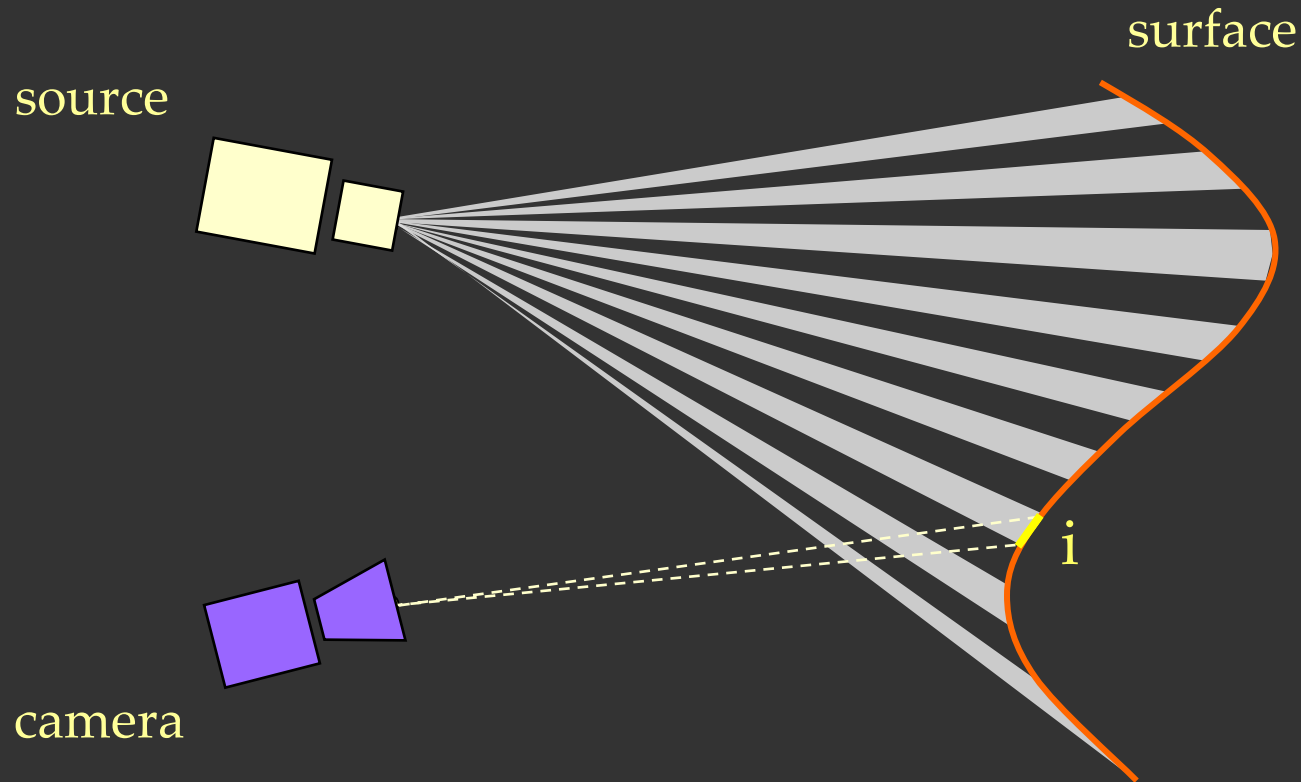
radiance      direct      global

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

BRDF and geometry

# High Frequency Illumination Pattern

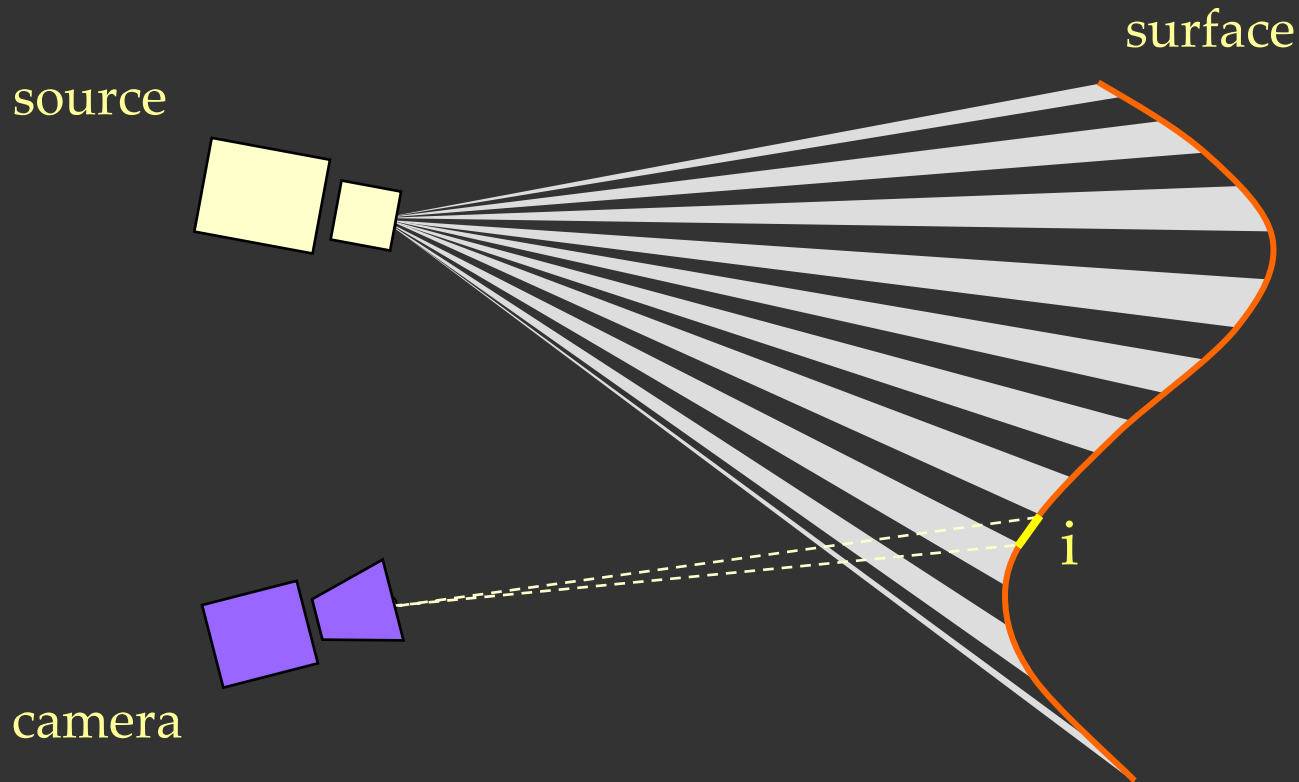
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$$L^+[c, i] = L_d[c, i] + \alpha L_g[c, i]$$

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

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

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

direct

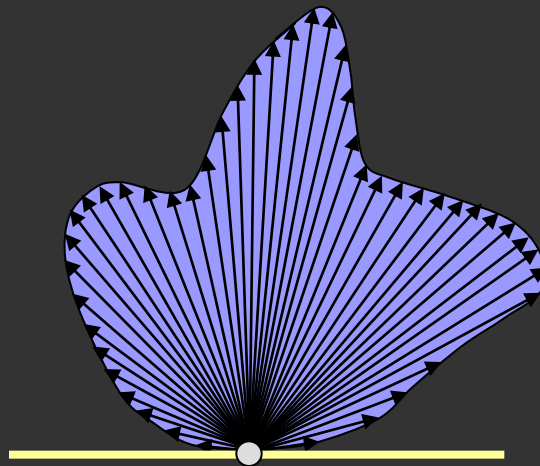
global



# Minimum Illumination Frequency

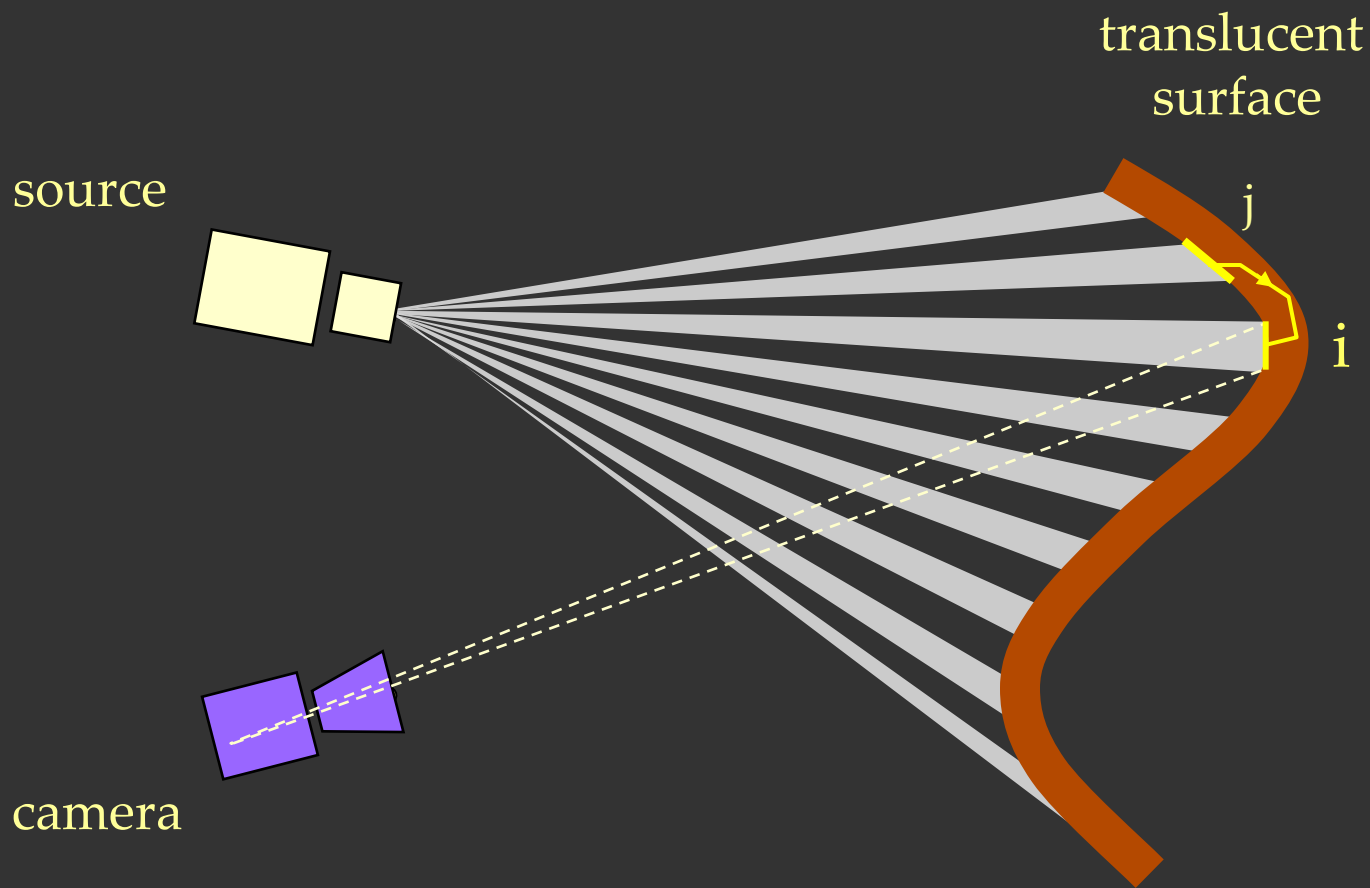
$$\alpha L_g = \int A(y) L(y) dy$$

$$(\omega_A + \omega_L)$$



# Other Global Effects: Subsurface Scattering

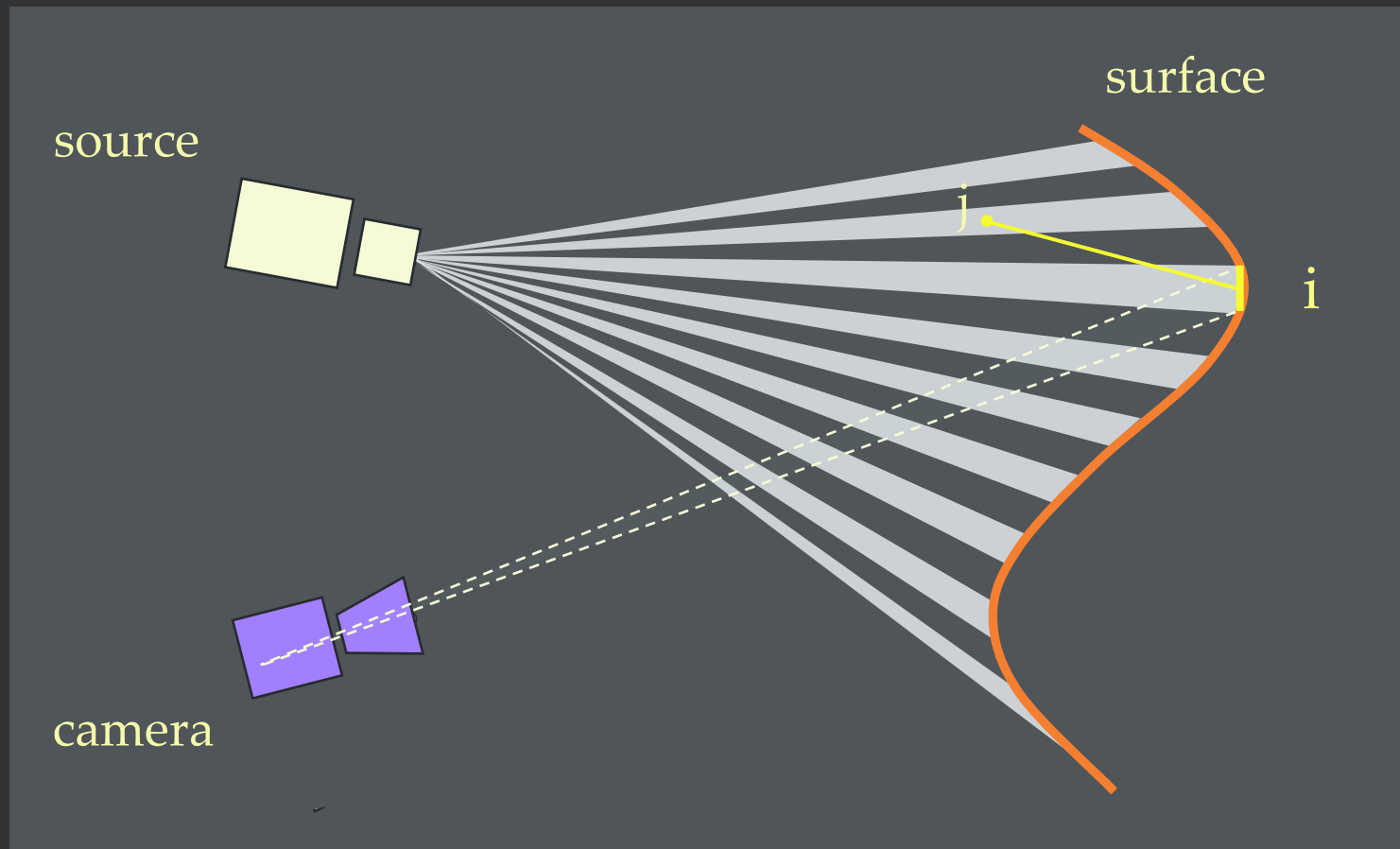
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# Other Global Effects: Volumetric Scattering

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participating medium



Diffuse  
Interreflections



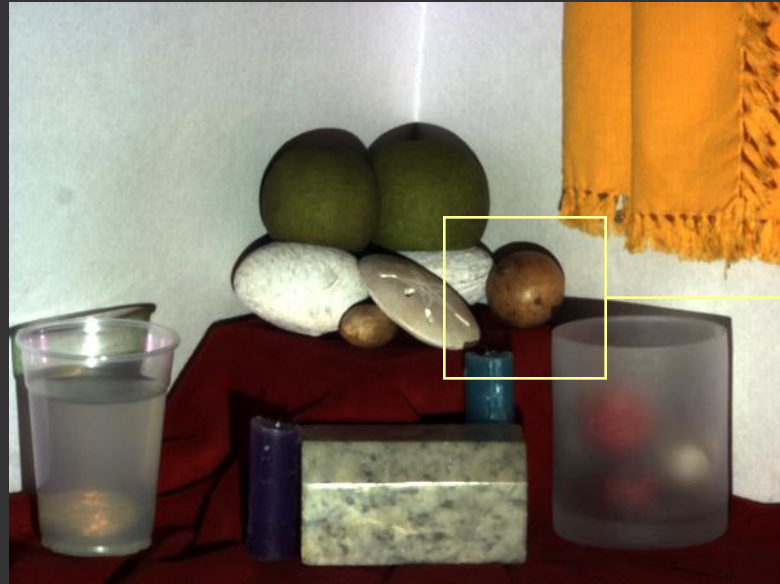
Diffusion

Subsurface  
Scattering

Specular  
Interreflections

Volumetric  
Scattering

Scene



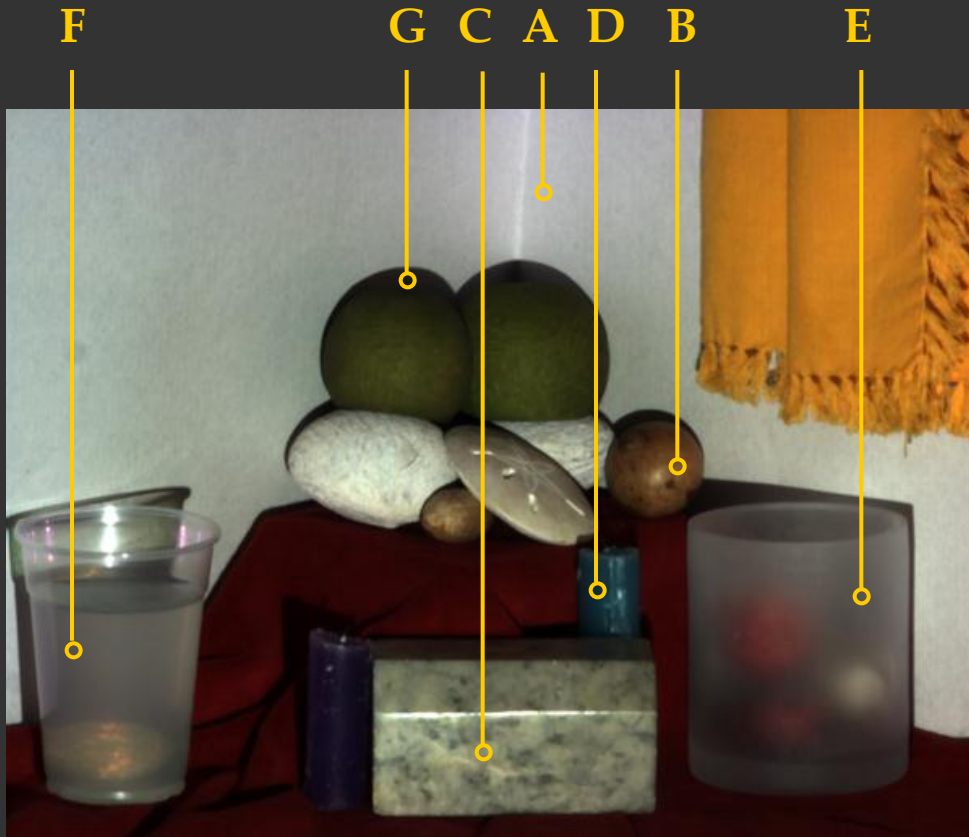
Direct



Global

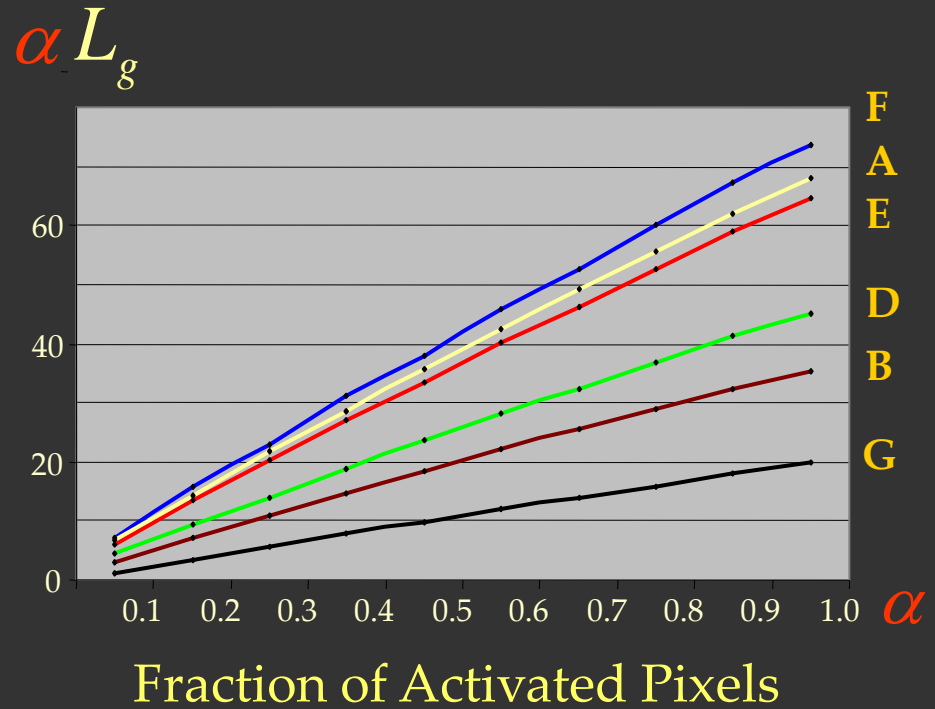
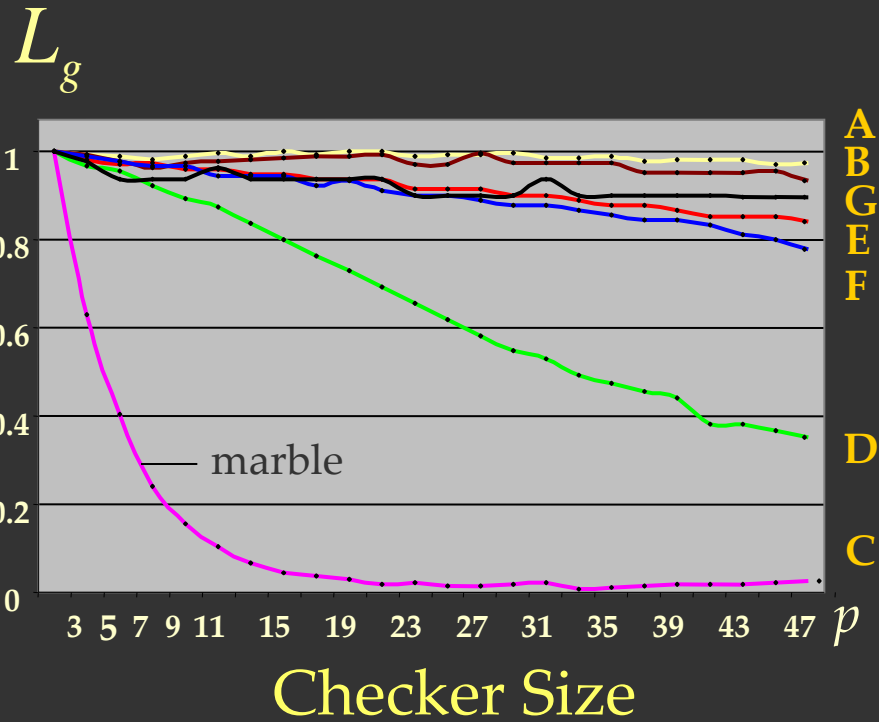
# Verification

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- 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



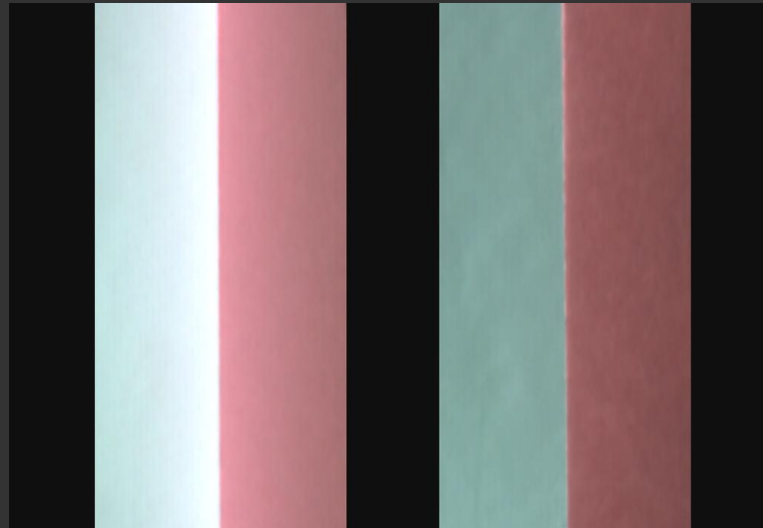




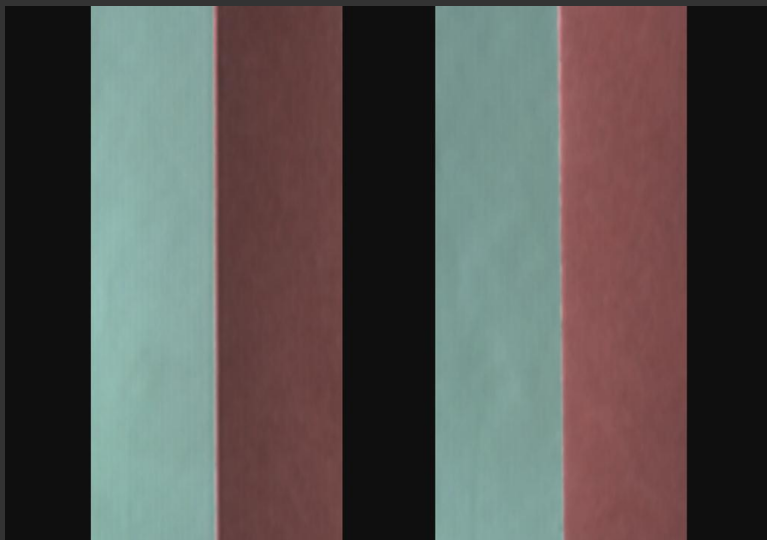
# V-Grooves: Diffuse Interreflections

concave

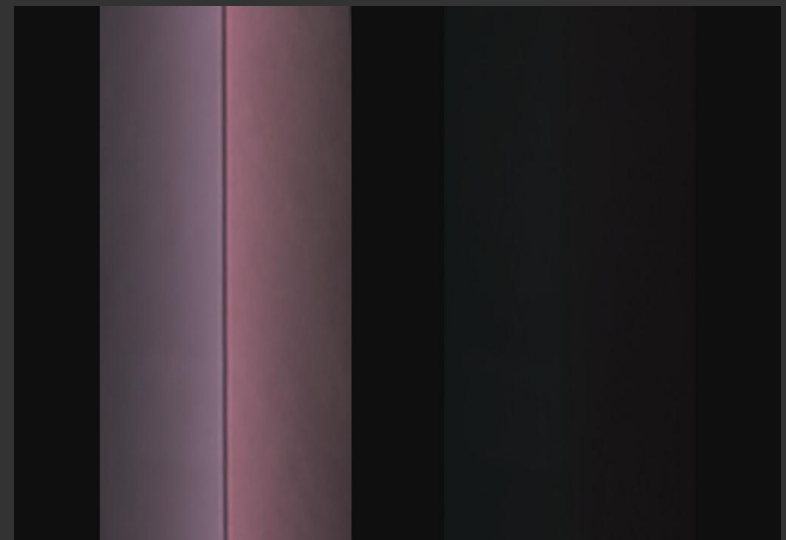
convex



Psychophysics:  
Gilchrist 79, Bloj et al. 04

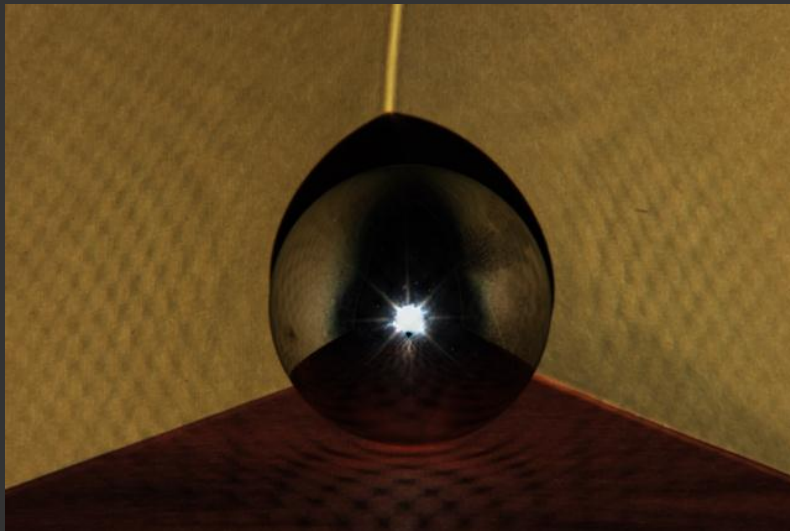
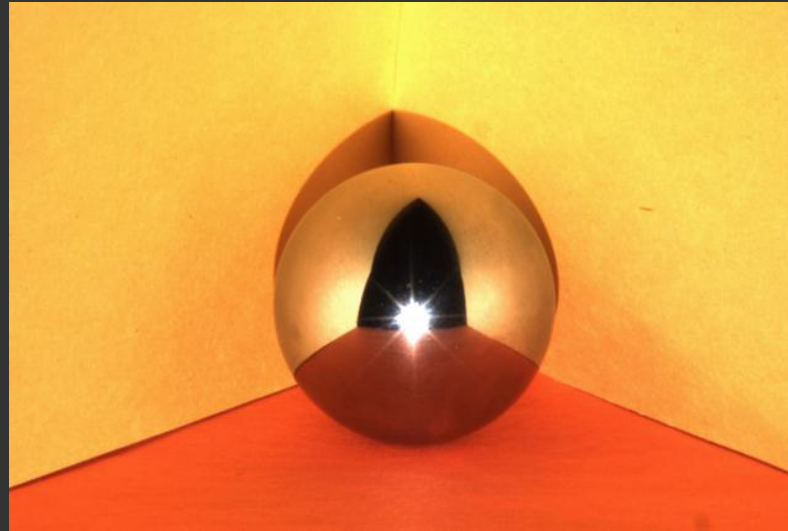


Direct

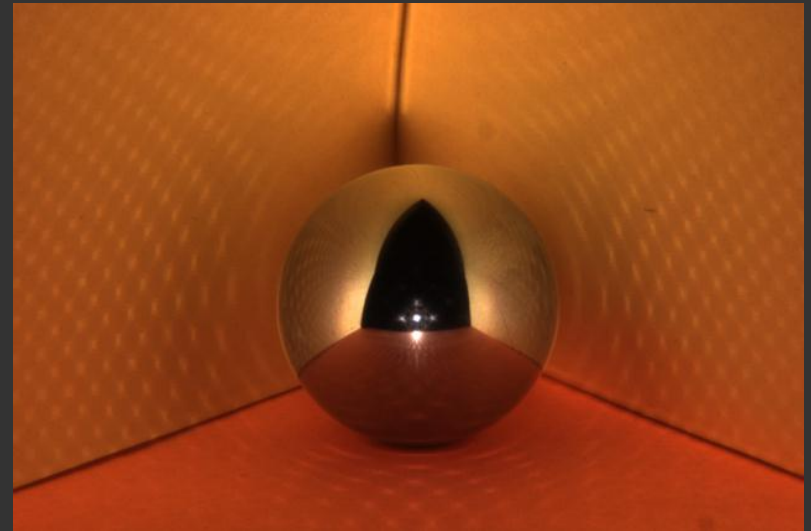


Global

# Mirror Ball: Failure Case



Direct



Global

Real World Examples:

Can You Guess the Images?

# Eggs: Diffuse Interreflections

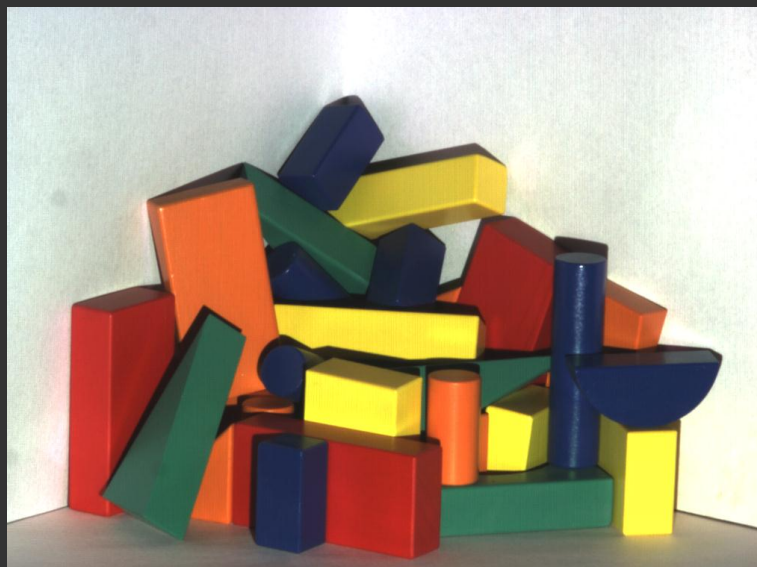


Direct

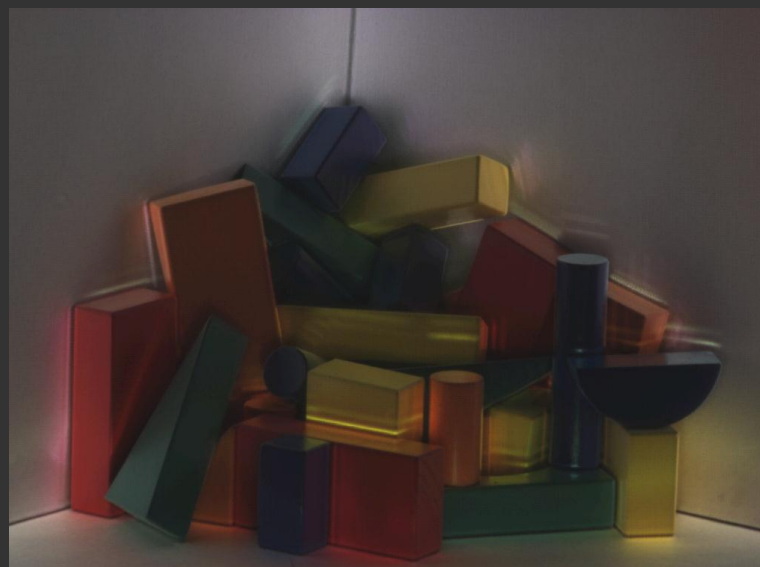


Global

# Wooden Blocks: Specular Interreflections

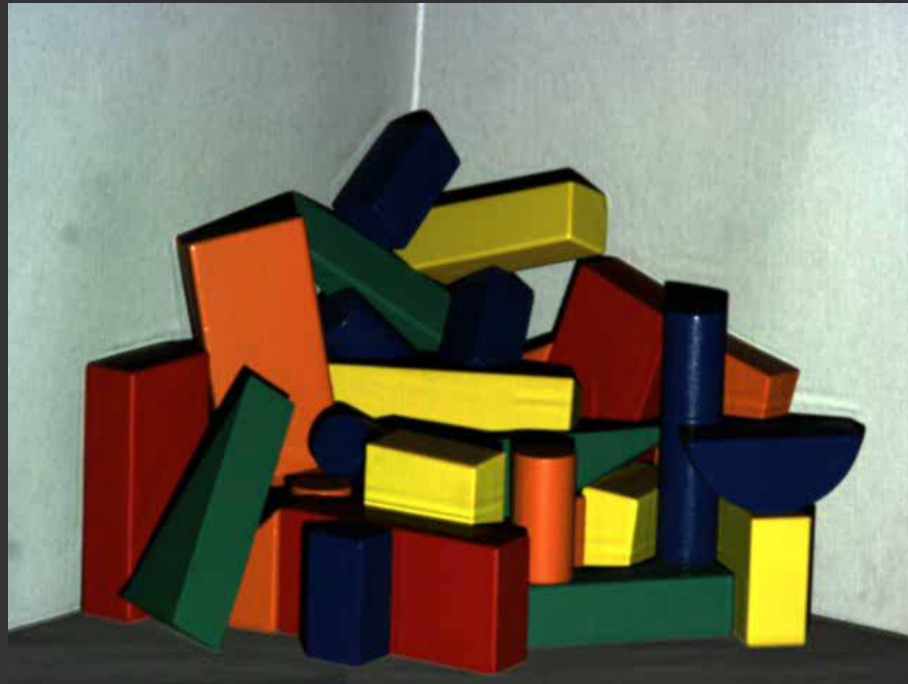


Direct



Global

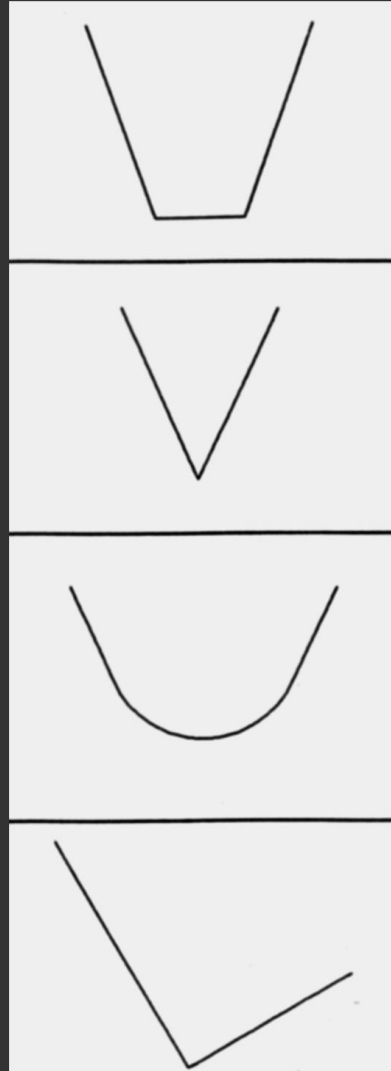
# Novel Images



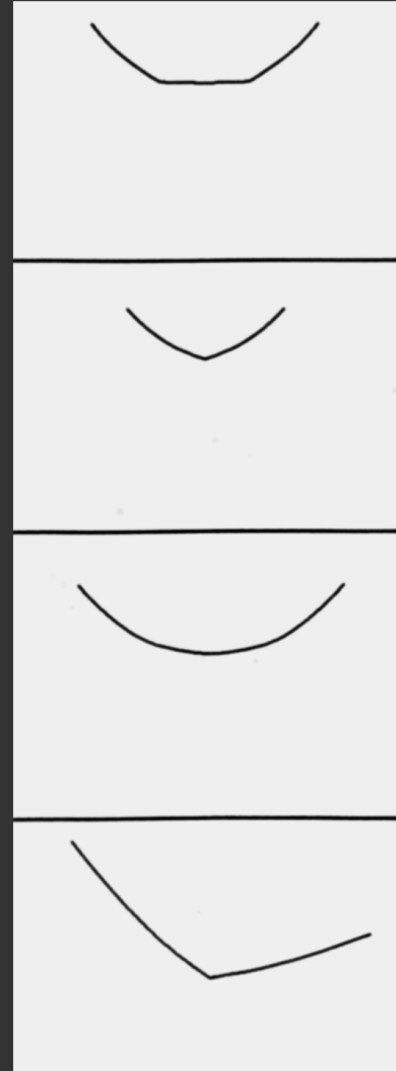


# Photometric Stereo: The Pseudo Shape

Actual Shape  
( $\rho=0.95$ )



Pseudo Shape





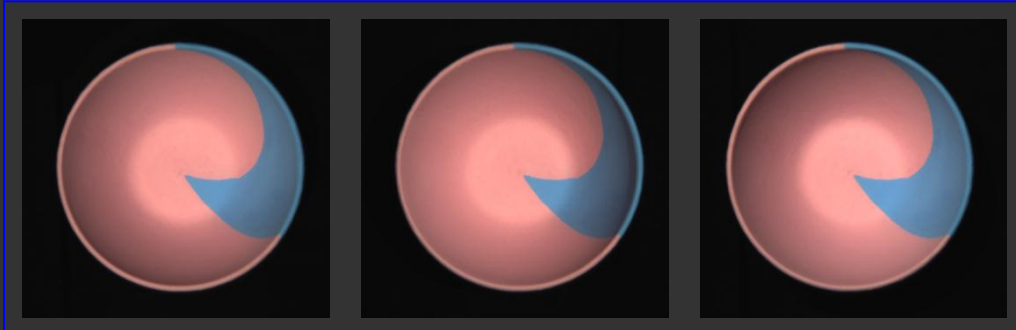
# Photometric Stereo using Direct Images

Source 1

Source 2

Source 3

Bowl



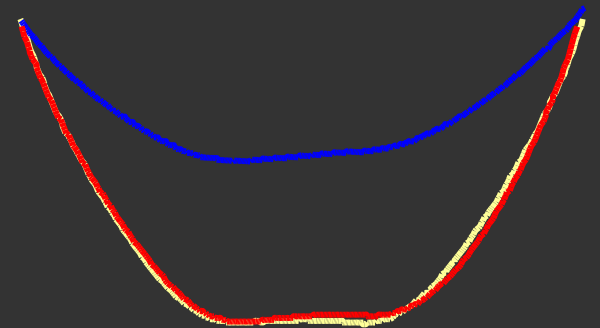
Global



Direct



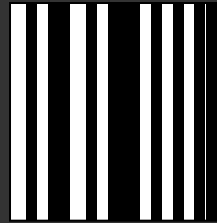
Shape



# Variants of Separation Method

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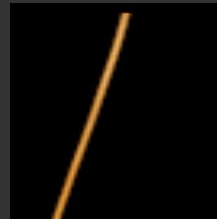
- Coded Structured Light



- 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

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

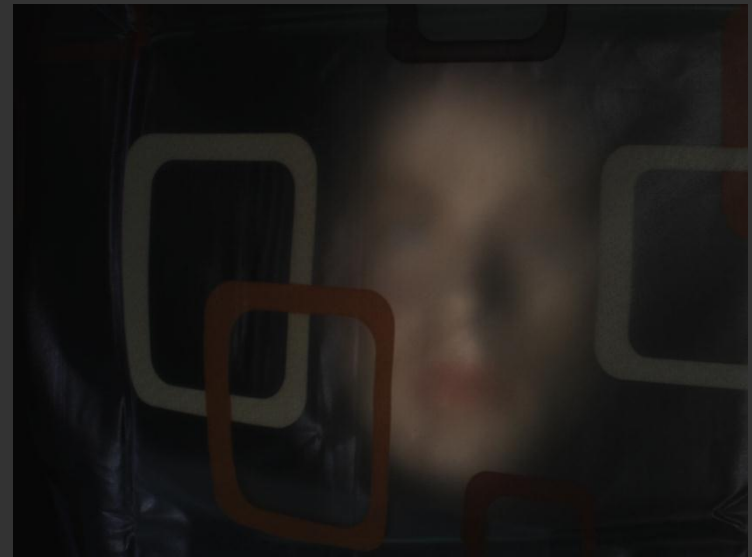
direct

global

# Shower Curtain: Diffuser



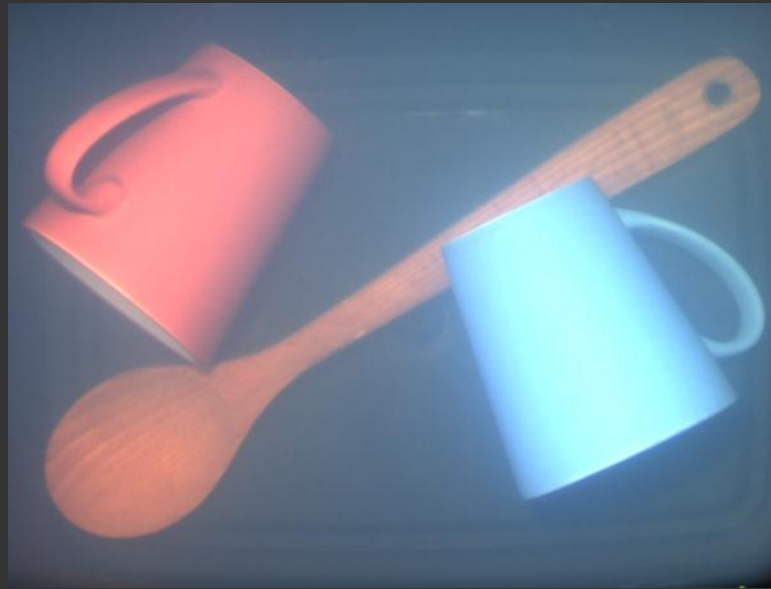
Direct



Global



# Kitchen Sink: Volumetric Scattering



Volumetric Scattering:  
Chandrasekar 50, Ishimaru 78



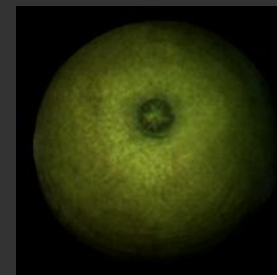
Direct



Global



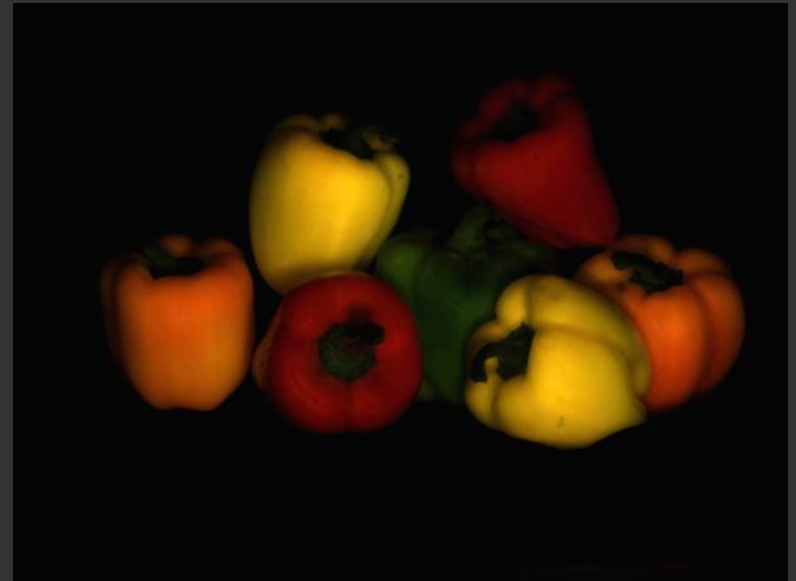
# Novel Image



# Peppers: Subsurface Scattering



Direct

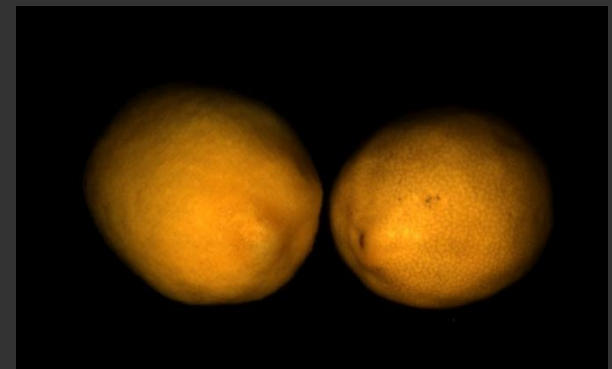
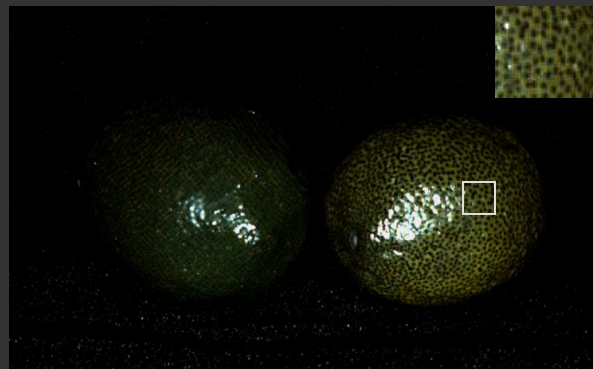
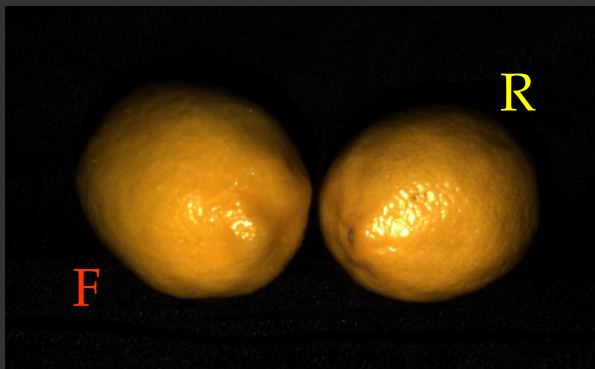
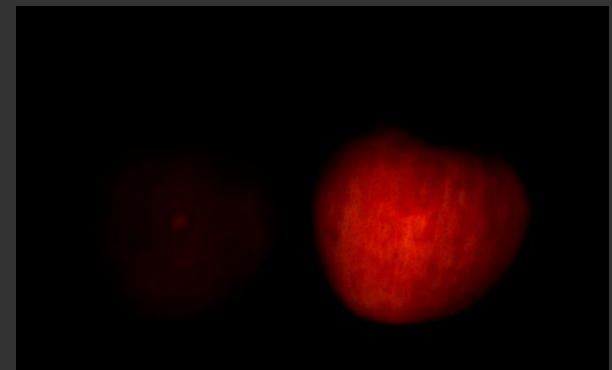
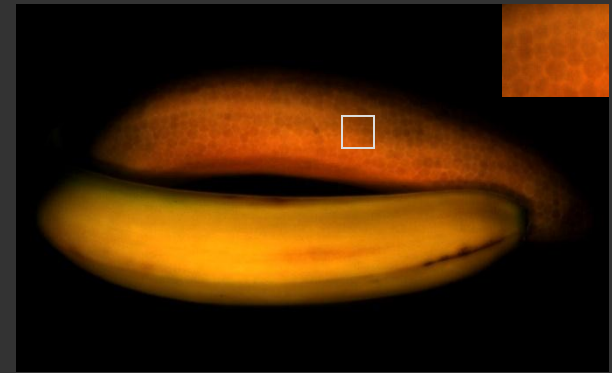
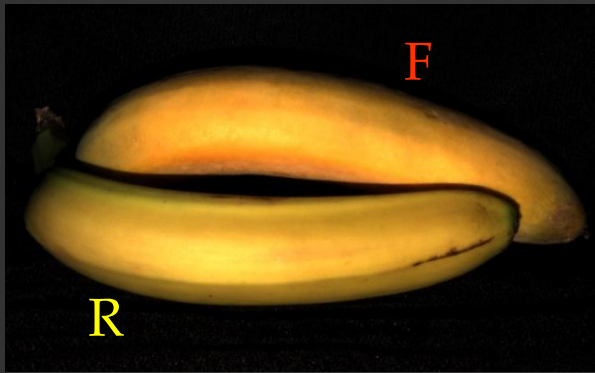


Global

# Novel Images



# Real or Fake ?



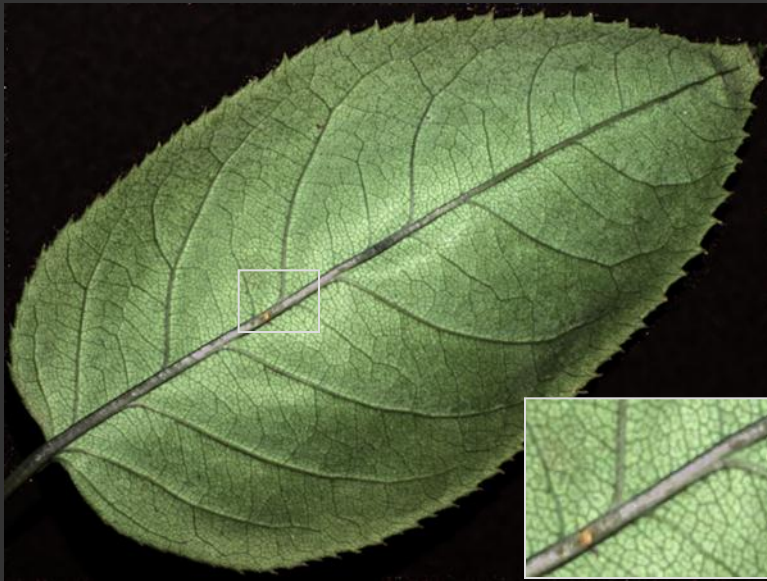
Direct

Global

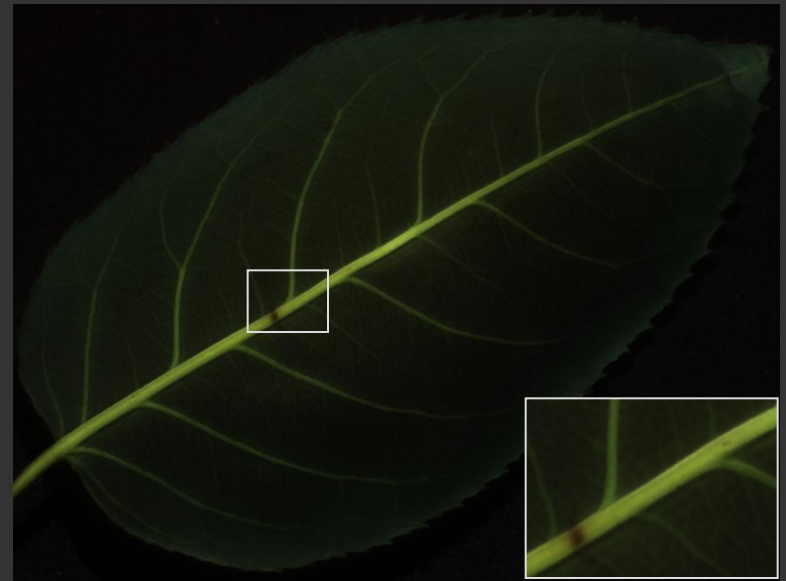
# Tea Rose Leaf



Leaf Anatomy: Purves et al. 03



Direct

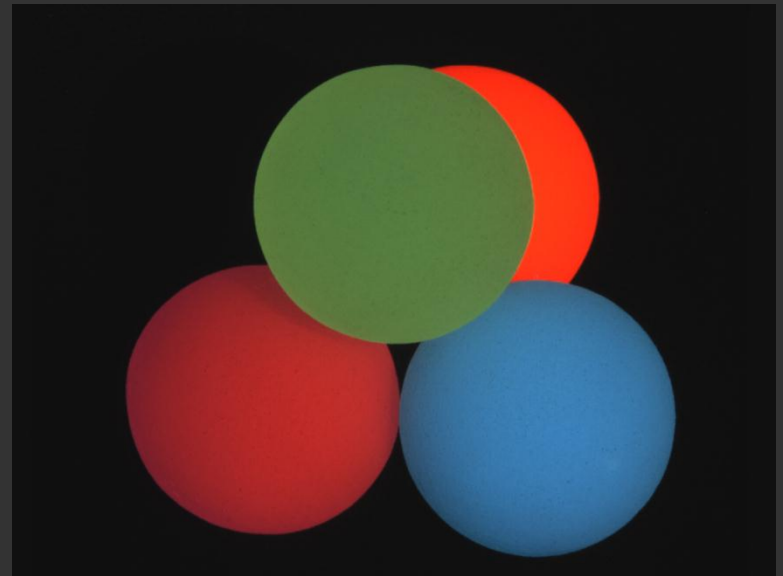


Global

# Translucent Rubber Balls



Direct



Global

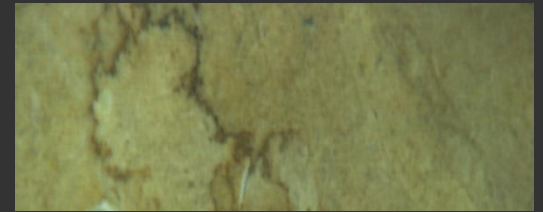
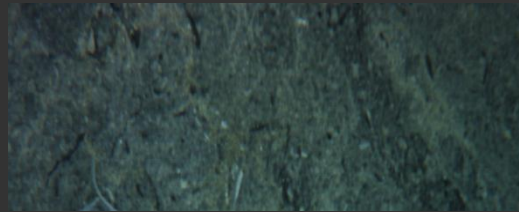
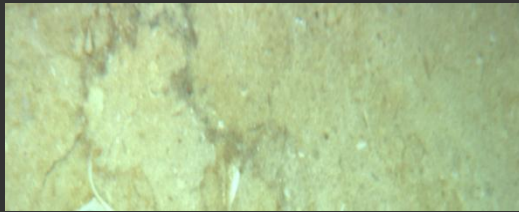
# Marble: When BSSRDF becomes BRDF

Scene

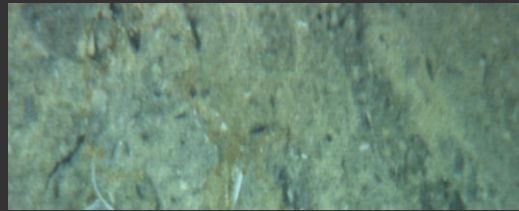
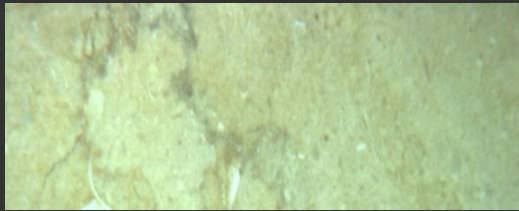
Direct

Global

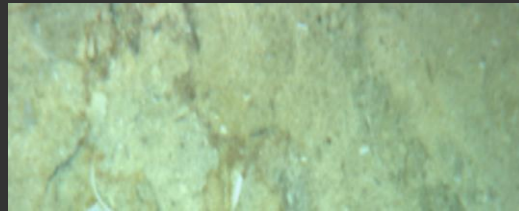
1



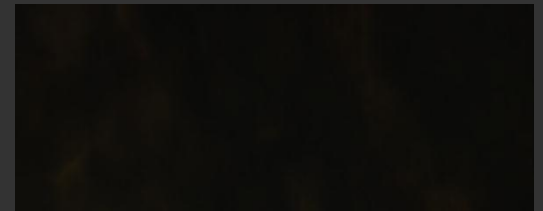
$\frac{1}{2}$



$\frac{1}{4}$



$\frac{1}{6}$



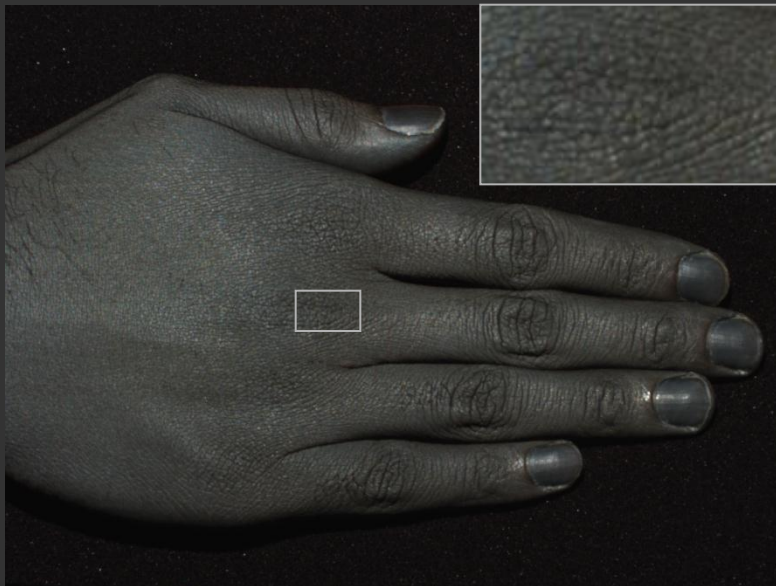
Resolution  
↓

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

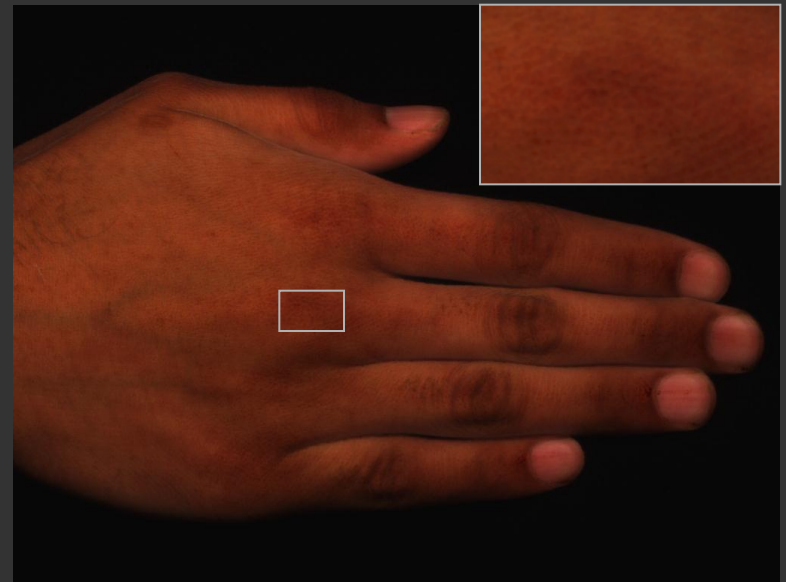
# Hand



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



Direct



Global



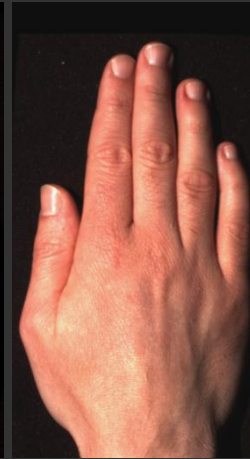
# Hands



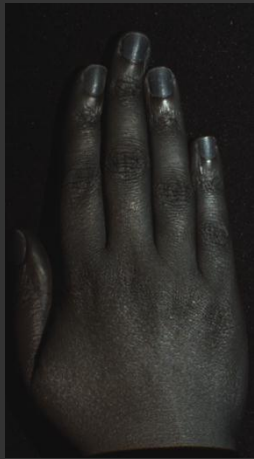
Afric. Amer.  
Female



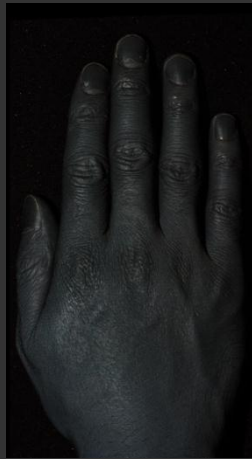
Chinese  
Male



Spanish  
Male



Afric. Amer.  
Female

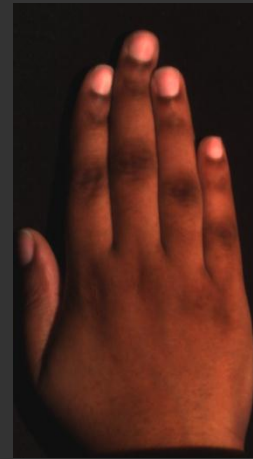


Chinese  
Male

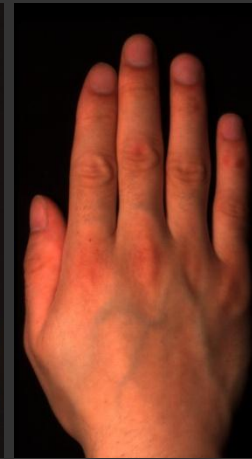


Spanish  
Male

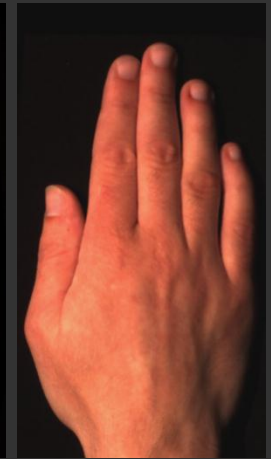
Direct



Afric. Amer.  
Female



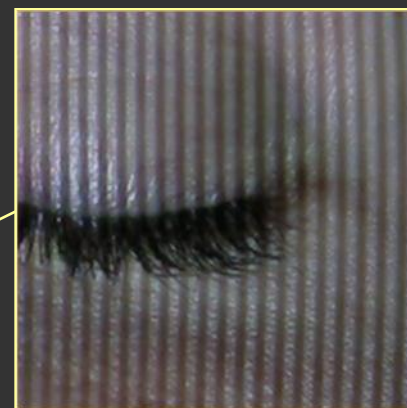
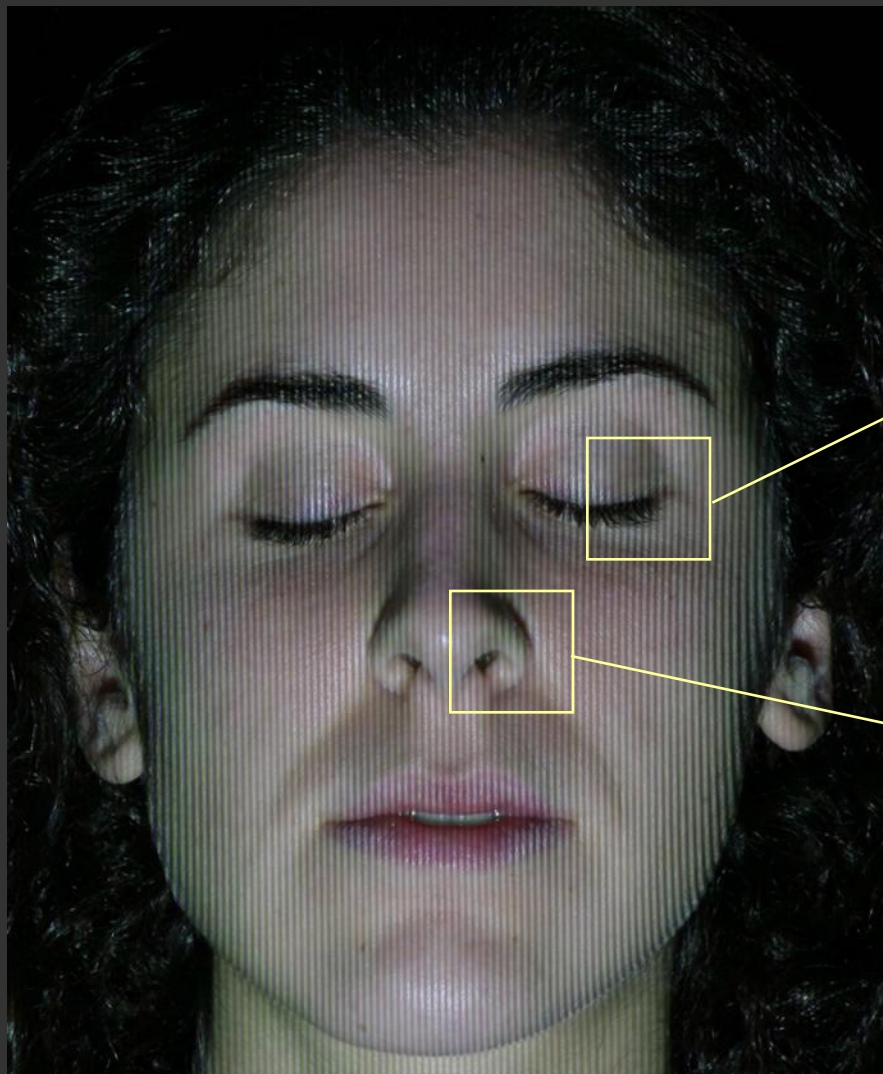
Chinese  
Male



Spanish  
Male

Global

# Separation from a Single Image



# Face



Direct

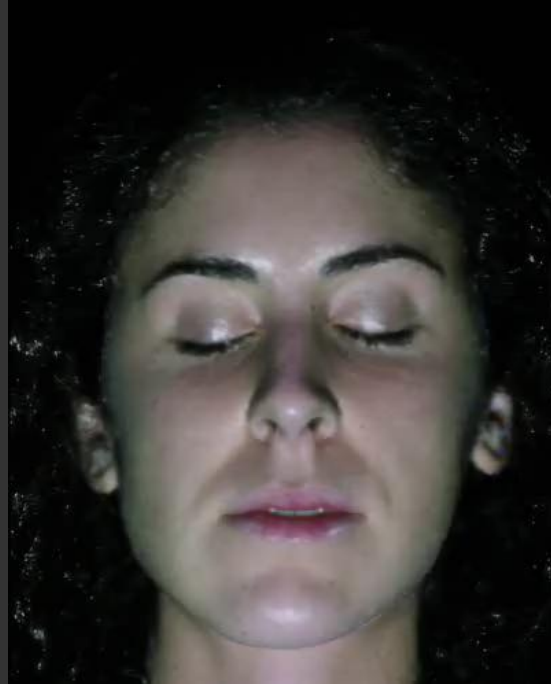


Global



Sum

# Skin Tone Control



**Skin Color and Lipids:**  
Tsumura et al. 03

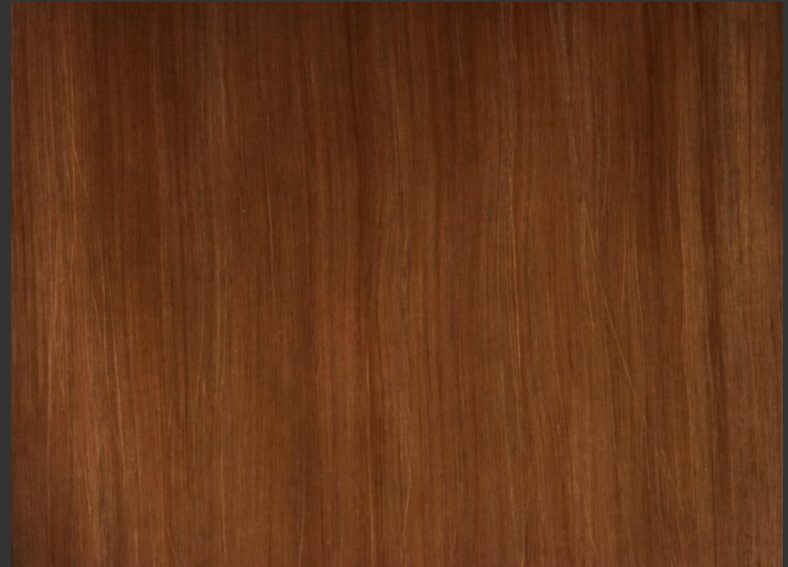
# Blonde Hair



**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



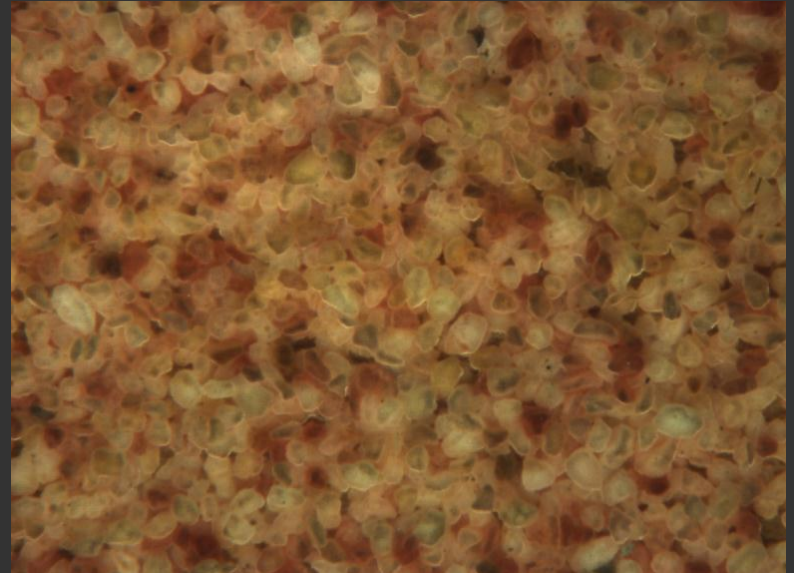
Global



# Pebbles: 3D Texture



Direct



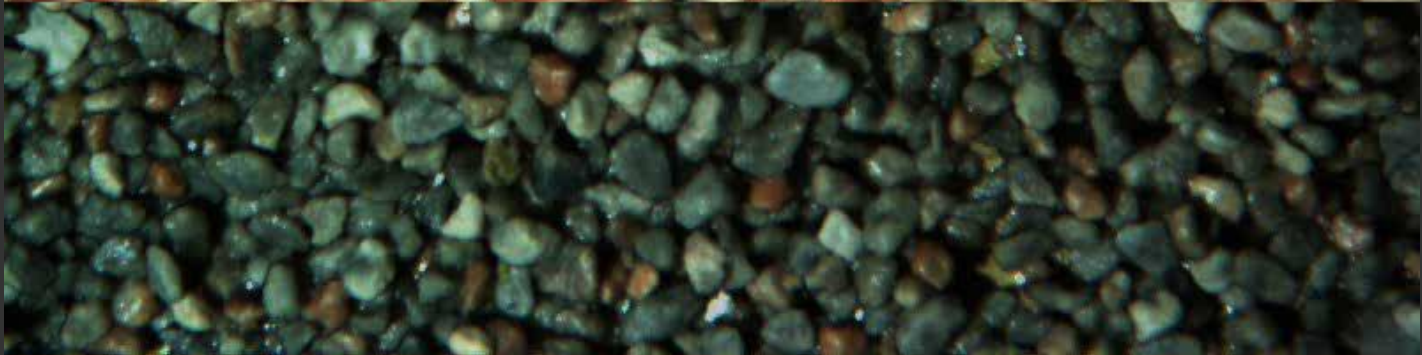
Global

# Pebbles: Bidirectional Texture Function

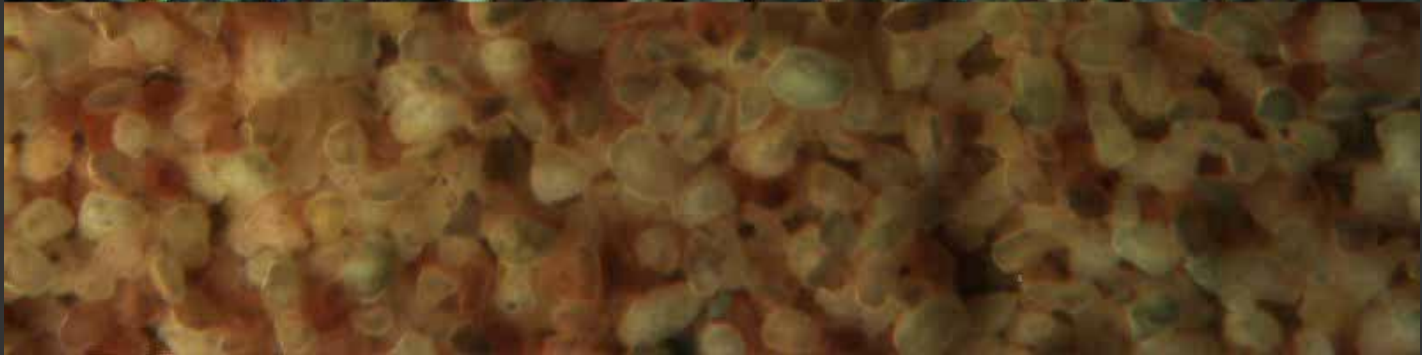
Pebbles



Direct



Global





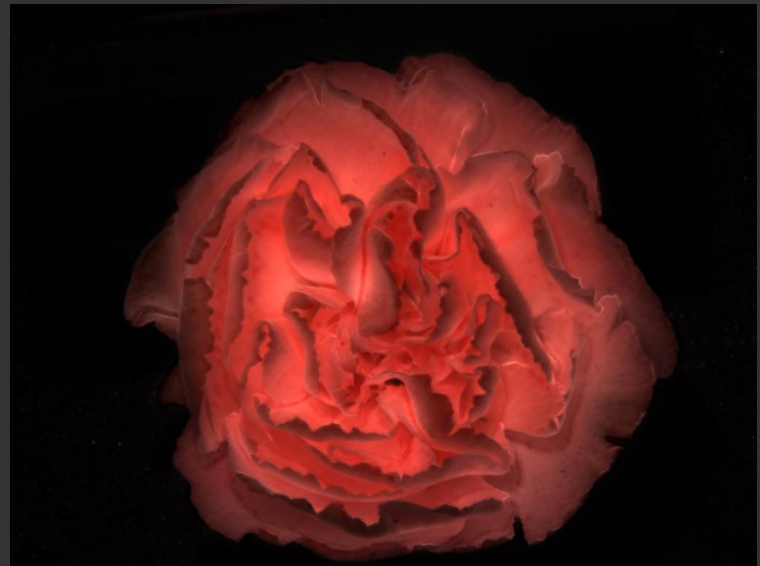
# Pink Carnation



Spectral Bleeding: Funt et al. 91



Direct



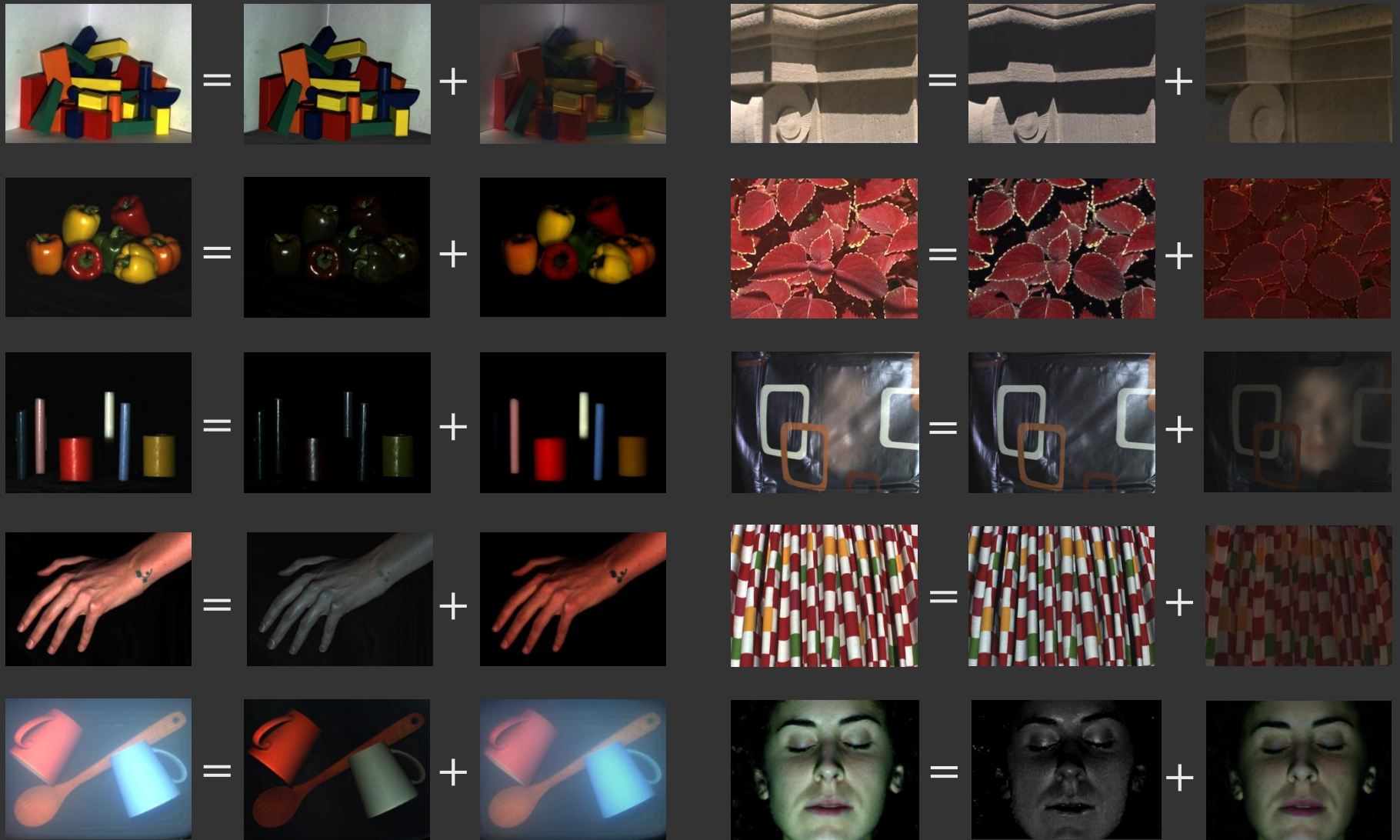
Global



# Summary

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- 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](http://www.cs.columbia.edu/CAVE)