Matting and Transparency

15-463: Computational Photography
Alexei Efros, CMU, Fall 2008

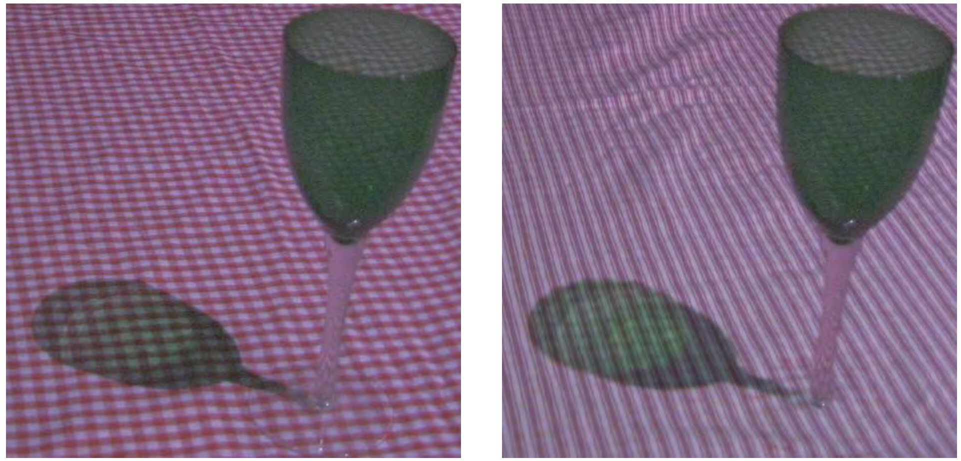
How does Superman fly?

Super-human powers?

OR

Image Matting?

Physics of Alpha Matting



Semi-transparent objects

Pixels too large

alpha channel

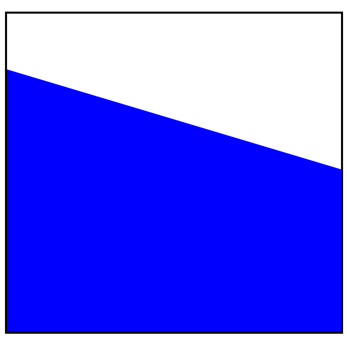
Add one more channel:

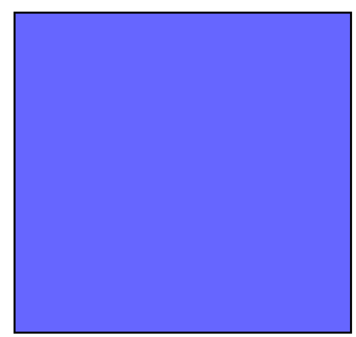
- Image(R,G,B,alpha) ← *Sprite!*

Encodes transparency (or pixel coverage):

- Alpha = 1: opaque object (complete coverage)
- Alpha = 0: transparent object (no coverage)
- 0<Alpha<1: semi-transparent (partial coverage)

Example: alpha = 0.7





Partial coverage or semi-transparency

Multiple Alpha Blending

So far we assumed that one image (background) is opaque.

If blending semi-transparent sprites (the “A over B” operation):

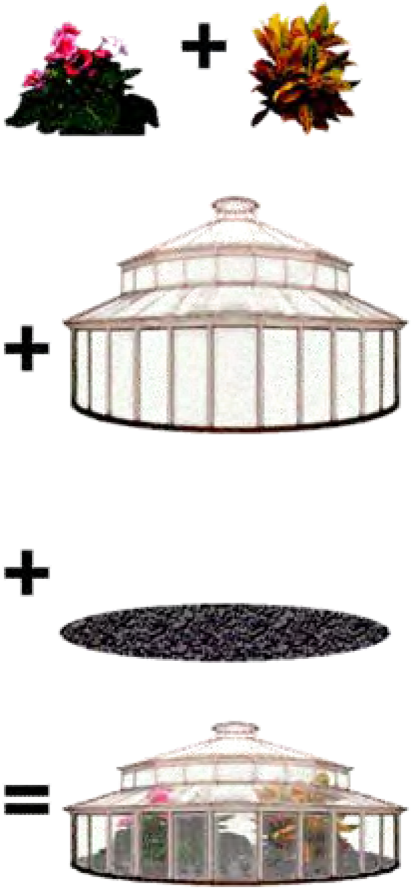
$$I_{comp} = \alpha_a I_a + (1-\alpha_a)\alpha_b I_b$$

$$\alpha_{comp} = \alpha_a + (1-\alpha_a)\alpha_b$$

Note: sometimes alpha is premultiplied: im(αR,αG,αB,α):

$$I_{comp} = I_a + (1-\alpha_a)I_b$$

(same for alpha!)



"Pulling a Matte"

Problem Definition:

- The separation of an image C into
  - A foreground object image C_o,
  - a background image C_b,
  - and an alpha matte α
- C_o and α can then be used to composite the foreground object into a different image

Hard problem

- Even if alpha is binary, this is hard to do automatically (background subtraction problem)
- For movies/TV, manual segmentation of each frame is infeasible
- Need to make a simplifying assumption…

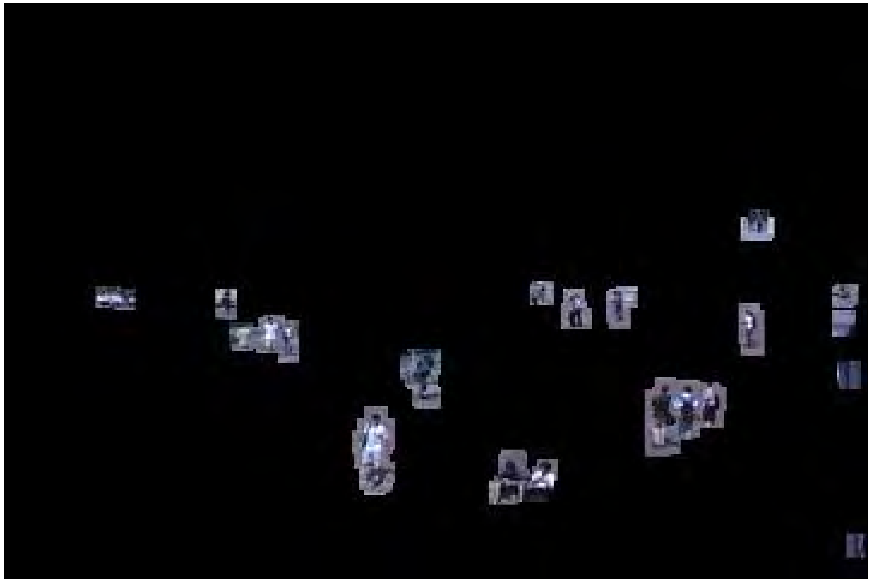
Average/Median Image

What can we do with this?

Background Subtraction

-

=

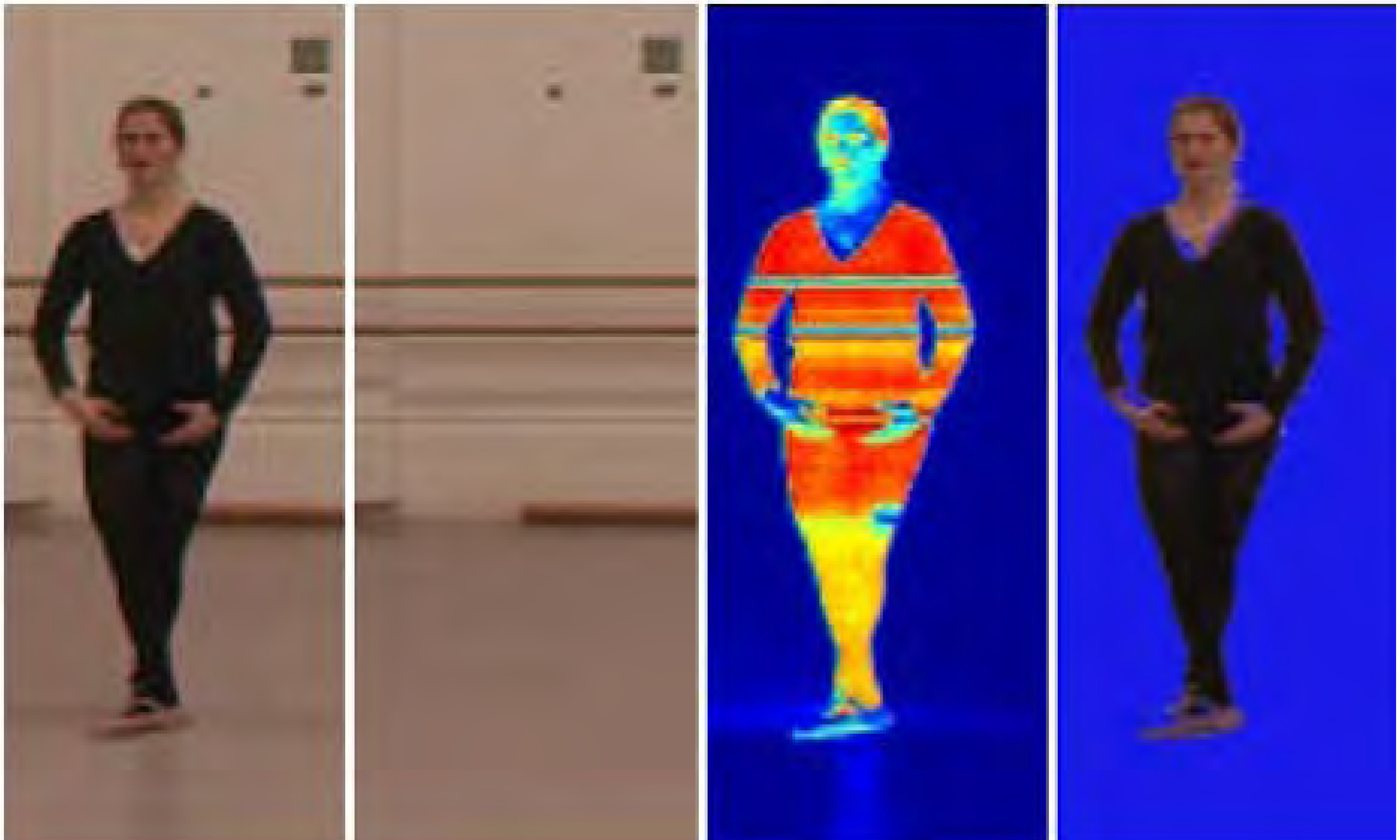


Crowd Synthesis (with Pooja Nath)

1. Do background subtraction in each frame
2. Find and record "blobs"
3. For synthesis, randomly sample the blobs, taking care not to overlap them

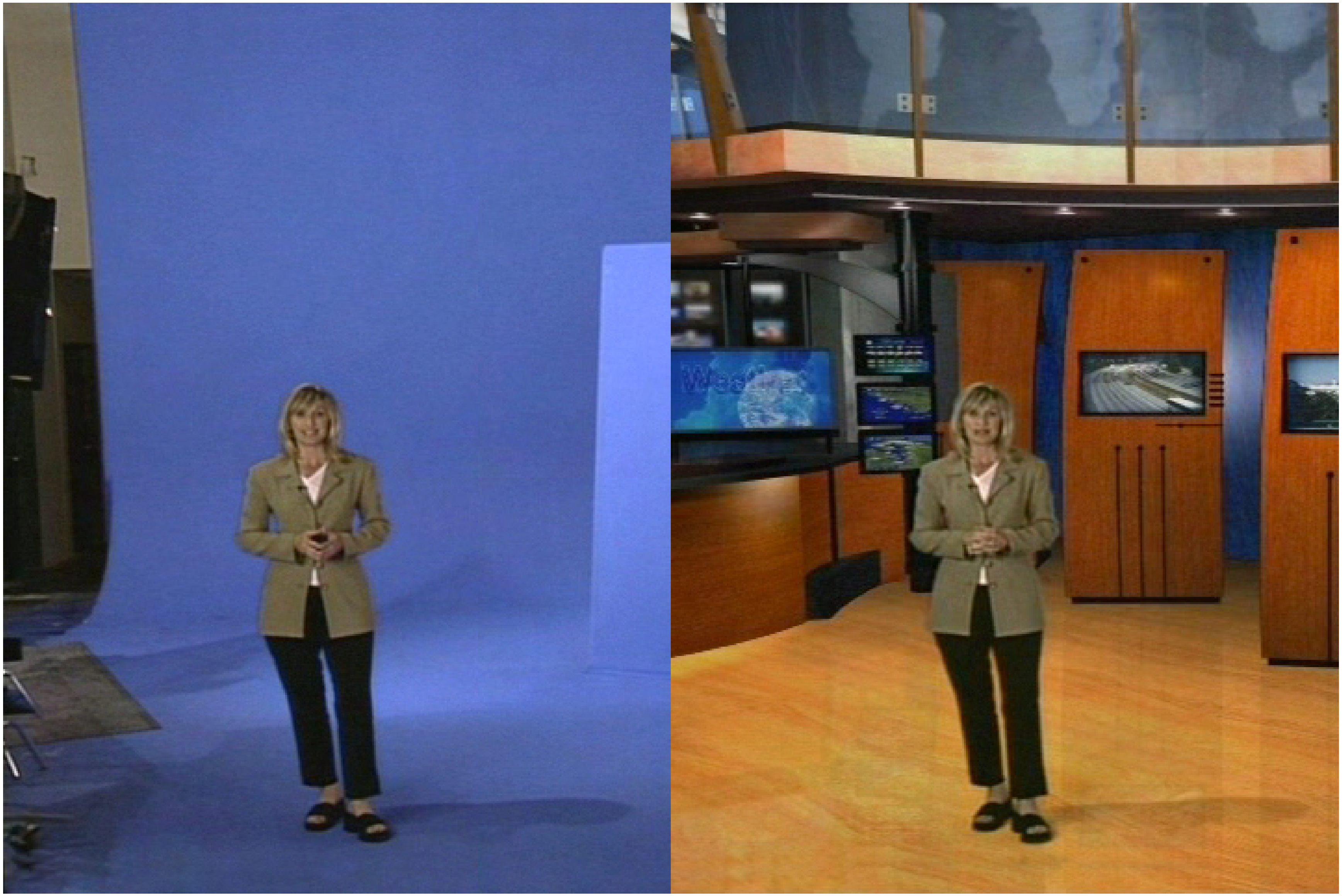
Background Subtraction

A largely unsolved problem…



One video frame | Estimated background | Difference Image | Thresholded Foreground on blue

Blue Screen



Blue Screen matting

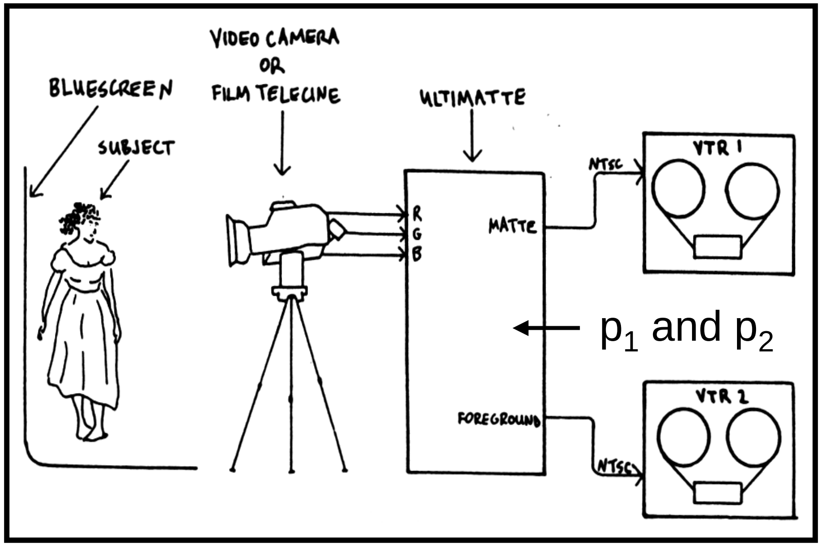
Most common form of matting in TV studios & movies

Petros Vlahos invented blue screen matting in the 50s. His Ultimatte® is still the most popular equipment. He won an Oscar for lifetime achievement.

A form of background subtraction:

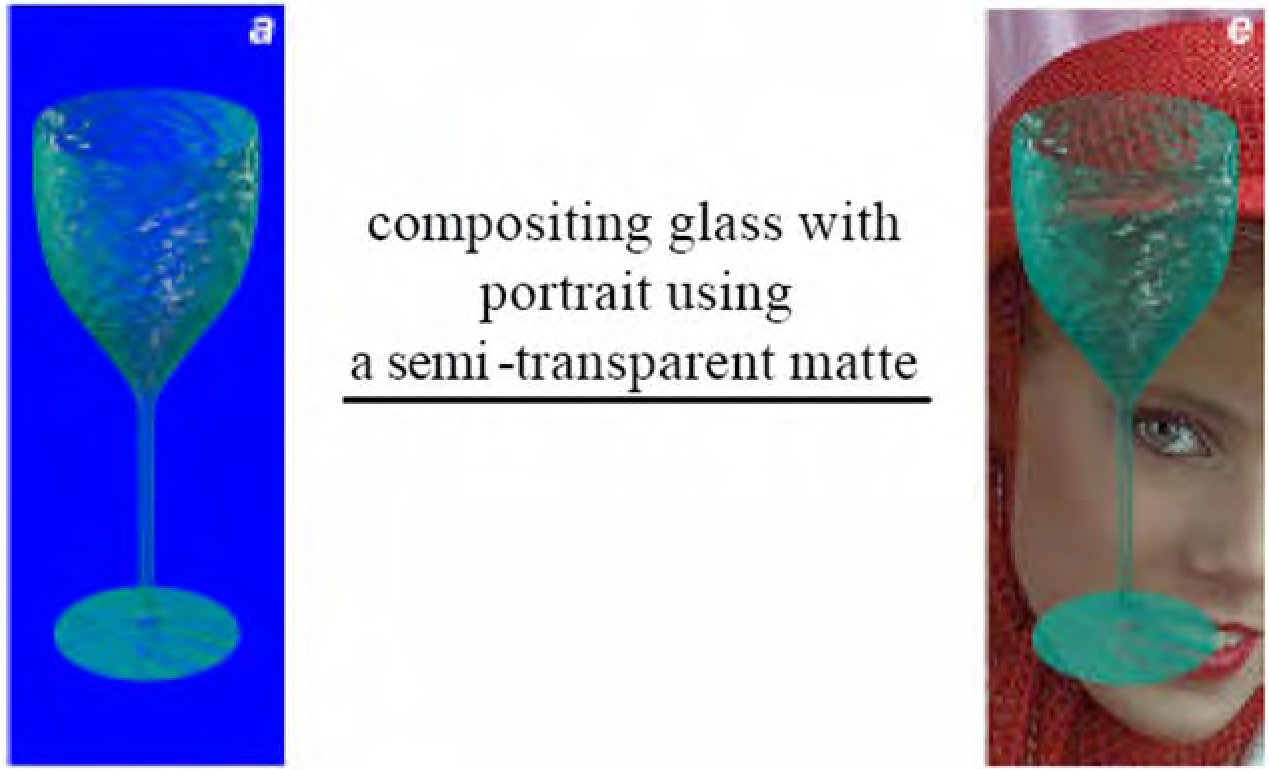
- Need a known background
- Compute alpha as SSD(C,Cb) > threshold
  - Or use Vlahos' formula: $\alpha = 1 - p_1(B - p_2 G)$
- Hope that foreground object doesn't look like background
  - no blue ties!
- Why blue?
- Why uniform?

The Ultimatte



Blue screen for superman?

Semi-transparent mattes



What we really want is to obtain a true alpha matte, which involves semi-transparency

- Alpha between 0 and 1

Matting Problem: Mathematical Definition

For every pixel in the composite image,

<u>given</u>

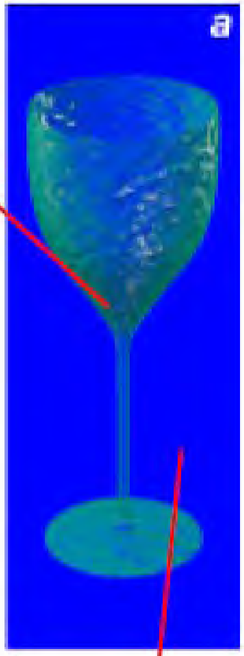
- backing color $C_k = [R_k \;\; G_k \;\; B_k]$, and
- composite pixel color $C = [R \;\; G \;\; B]$

<u>compute</u>

- foreground pixel color
  $C_o = [R_o \;\; G_o \;\; B_o \;\; \alpha_o]$ ($= [\alpha_o R_o \; \alpha_o G_o \; \alpha_o B_o]$)
  such that

The matting equation

$$C = C_o + (1 - \alpha_o) C_k$$



Why is general matting hard?

Matting Equation:

$$C = C_o + (1 - \alpha_o) C_k$$

Solution #1: No Blue!

Matting Equation:

$$C = C_o + (1 - \alpha_o)\, C_k$$

- If we know that the foreground contains no blue, we have $B_o = 0$
- This leaves us with 3 equations and 3 unknowns, which has exactly one solution

$$R = \alpha_o R_o + (1 - \alpha_o)\, R_k \quad \leftarrow \text{3. Solve for } R_o$$
$$G = \alpha_o G_o + (1 - \alpha_o)\, G_k \quad \leftarrow \text{2. Solve for } G_o$$
$$B = B_k - \alpha_o B_k \quad \leftarrow \text{1. Solve for } \alpha_o$$

Main difficulty:

Solution #2: Gray or Flesh

Matting Equation:

$$C = C_o + (1 - \alpha_o)\, C_k$$

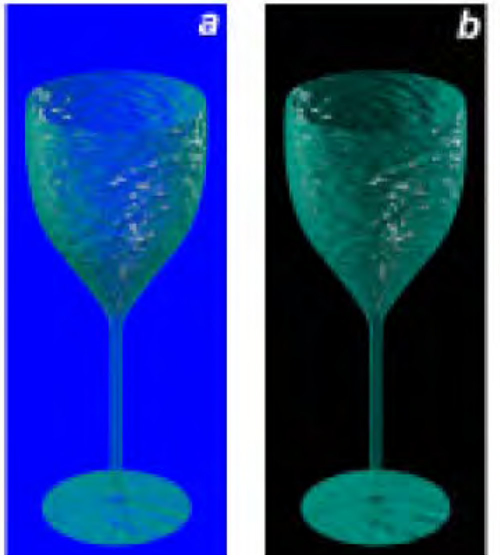
- If we know that the foreground contains gray, that means that $R_o = B_o = G_o$
- This leaves us with 3 equations and 2 unknowns

Triangulation Matting (Smith & Blinn)

Matting Equation:

$$C = C_o + (1 - \alpha_o) C_k$$

- Instead of reducing the number of unknowns, we could attempt to increase the number of equations
- One way to do this is to photograph an object of interest in front of two known but distinct backgrounds



How many equations?

How many unknowns?

Does the background need to be constant color?

The Algorithm

For every pixel p in the composite image,

given

- backing color $C_{k1} = [R_{k1} \;\; G_{k1} \;\; B_{k1}]$ at p,
- backing color $C_{k2} = [R_{k2} \;\; G_{k2} \;\; B_{k2}]$ at p,
- composite pixel color $C_1 = [R_1 \;\; G_1 \;\; B_1]$ at p, and
- composite pixel color $C_2 = [R_2 \;\; G_2 \;\; B_2]$ at p,

solve the system of 6 equations

$$
\begin{aligned}
R_1 &= \alpha_o R_o + (1 - \alpha_o) R_{k1} & R_2 &= \alpha_o R_o + (1 - \alpha_o) R_{k2} \\
G_1 &= \alpha_o G_o + (1 - \alpha_o) G_{k1} & G_2 &= \alpha_o G_o + (1 - \alpha_o) G_{k2} \\
B_1 &= \alpha_o B_o + (1 - \alpha_o) B_{k1} & B_2 &= \alpha_o B_o + (1 - \alpha_o) B_{k2}
\end{aligned}
$$

for unknowns R_o, G_o, B_o, α_o

Triangulation Matting Examples

From Smith & Blinn's
SIGGRAPH'96 paper

More Examples

More examples

Problems with Matting

Images do not look realistic

Lack of Refracted Light

Lack of Reflected Light

Solution:

Modify the Matting Equation

Environment Matting and Compositing

slides by Jay Hetler

Douglas E. Zongker ~ Dawn M. Werner ~ Brian Curless ~ David H. Salsin

Environment Matting Equation

$$C = F + (1 - \alpha)B + \Phi$$

C ~ Color

F ~ Foreground color

B ~ Background color

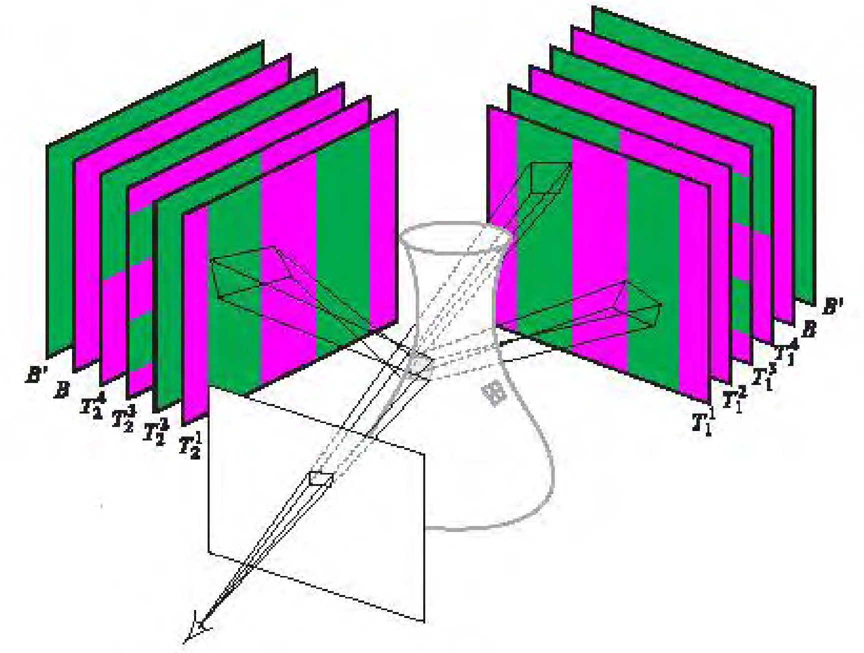
α ~ Amount of light that passes through the foreground

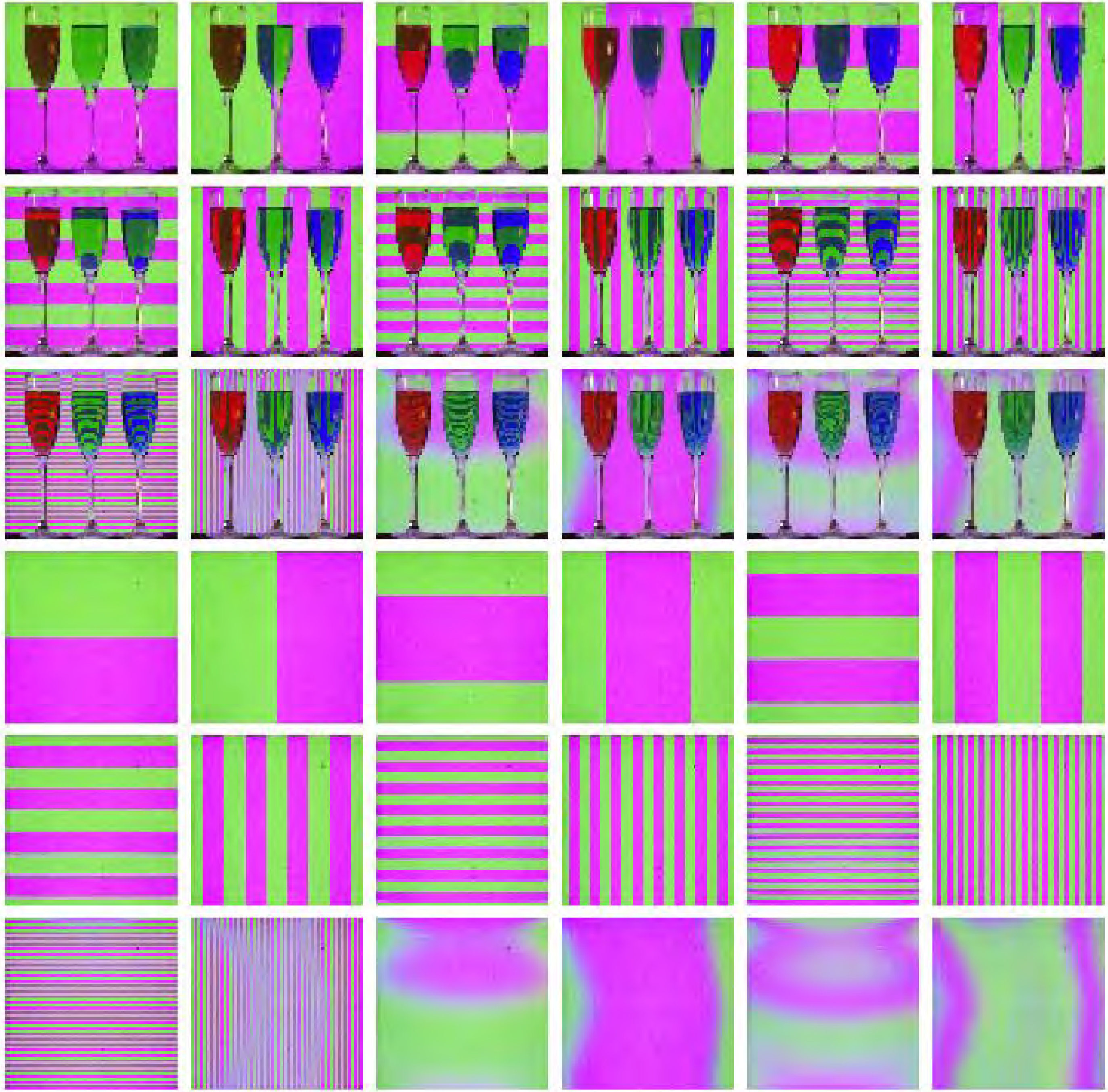
Φ ~ Contribution of light from Environment that travels through the object

Explanation of Φ

$$\Phi = \sum_{i=1}^{m} \int R_i(\boldsymbol{x})\, T_i(\boldsymbol{x})\, d\boldsymbol{x}$$

R – reflectance image
T – Texture image





Environment Mattes

Performance

Calibration

Matting: 10-20 minutes extraction time for each texture map (Pentium II 400Mhz)

Compositing: 4-40 frames per second

Real-Time?

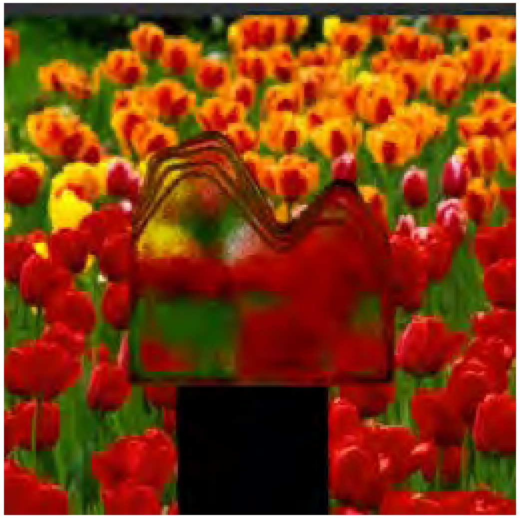
How much better is Environment Matting?

Alpha Matte **Environment Matte** **Photograph**

How much better is Environment Matting?

Alpha Matte **Environment Matte** **Photograph**

Movies!



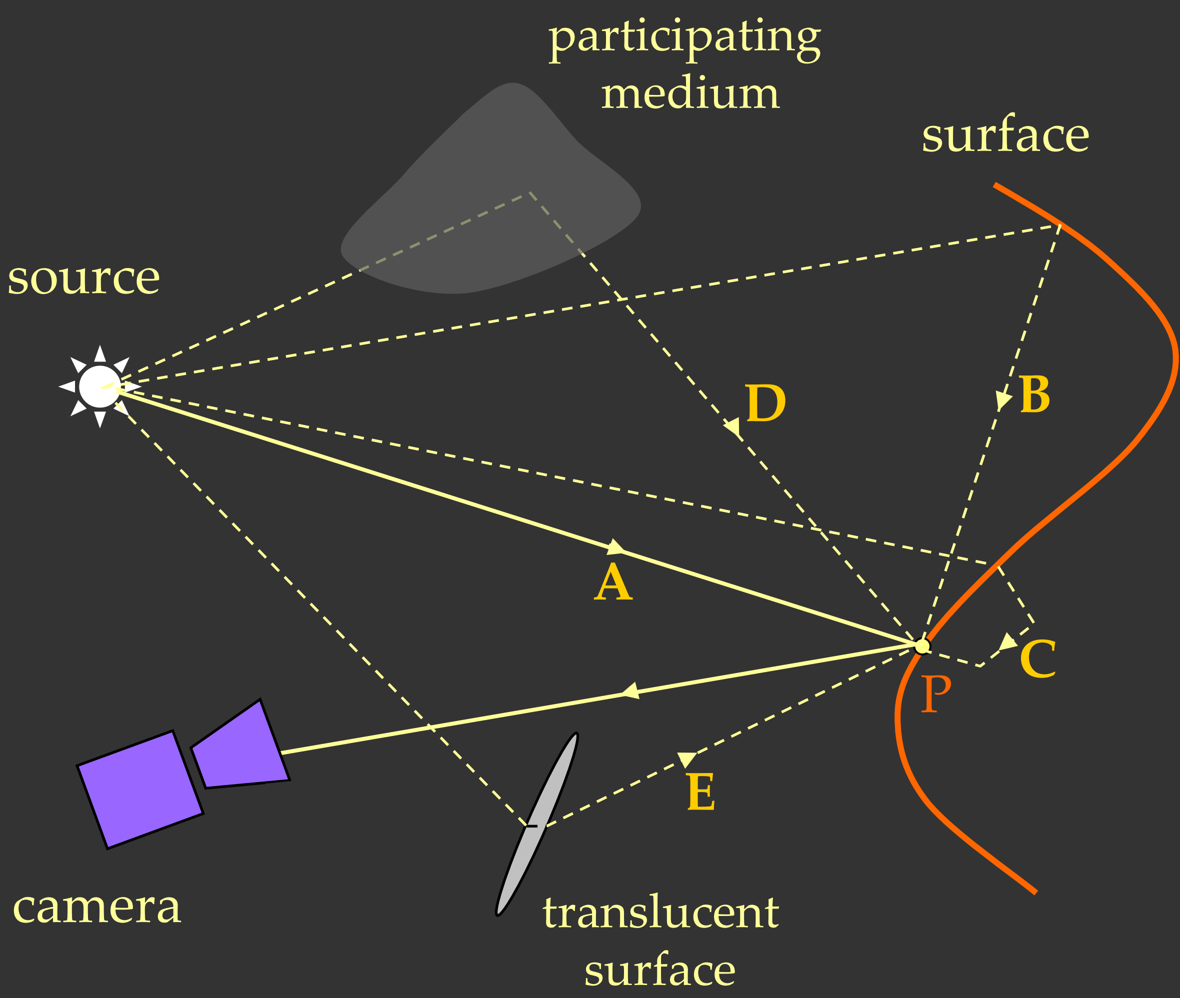
Fast Separation of Direct and Global Images Using High Frequency Illumination

Shree K. Nayar
Gurunandan G. Krishnan
Columbia University
Michael D. Grossberg
City College of New York
Ramesh Raskar
MERL

SIGGRAPH Conference
Boston, July 2006

Support: ONR, NSF, MERL

Direct and Global Illumination



A : Direct

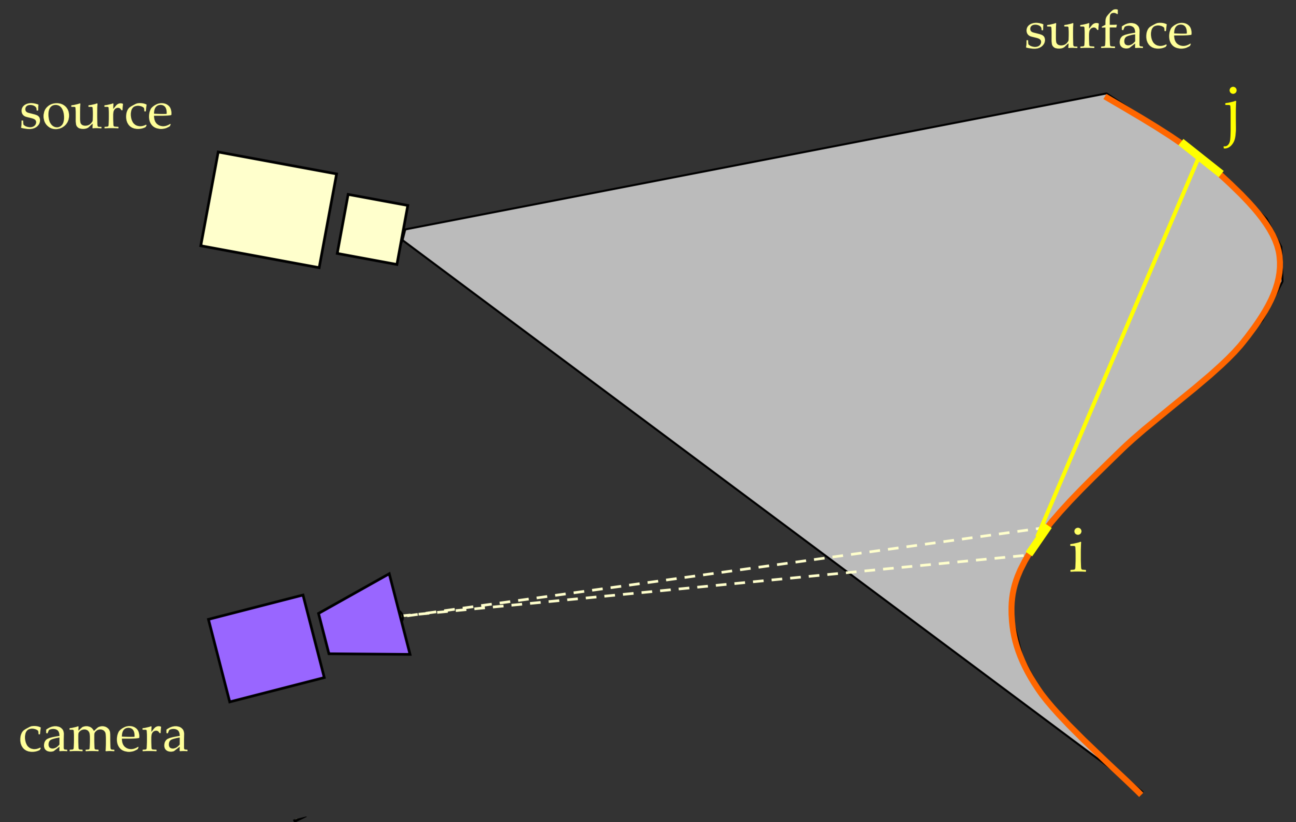
B : Interrelection

C : Subsurface

D : Volumetric

E : Diffusion

Direct and Global Components: Interreflections



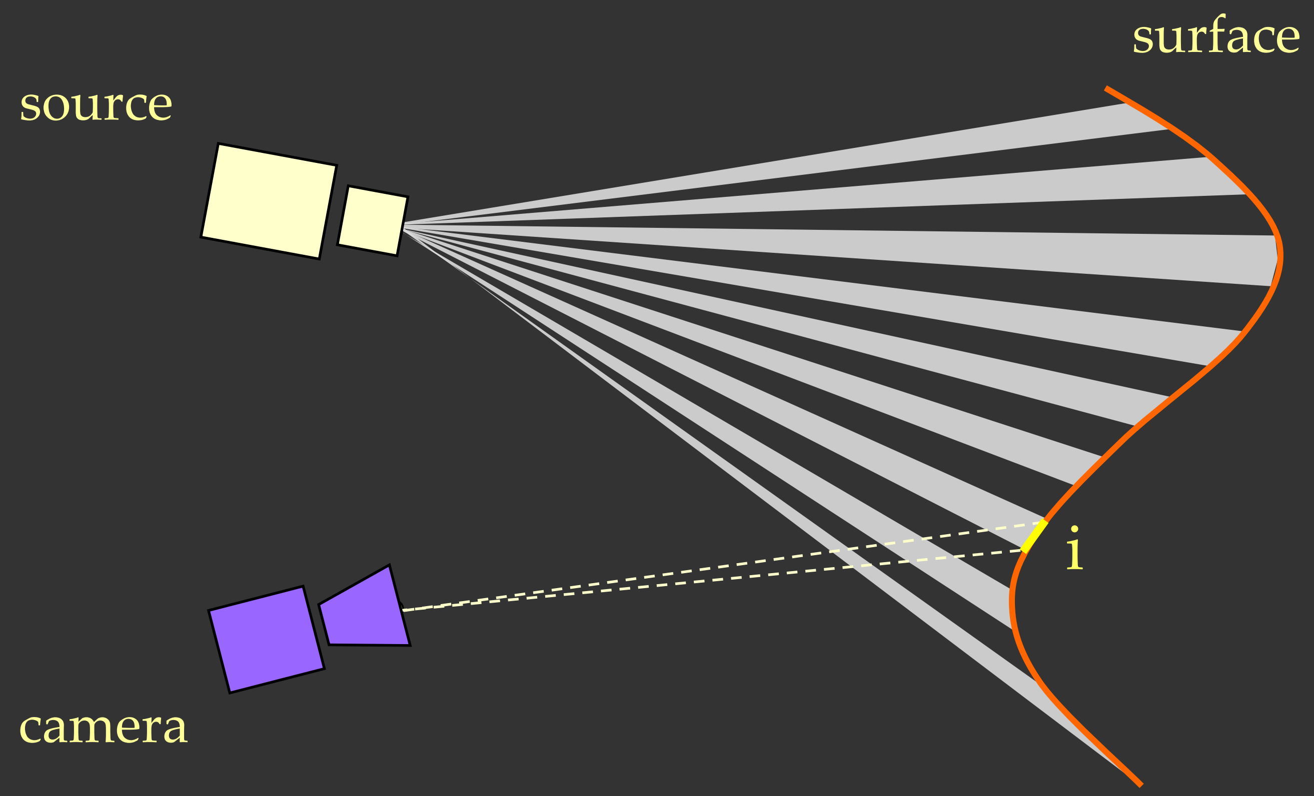
$$L[c,i] = L_d[c,i] + L_g[c,i]$$

radiance direct global

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

BRDF and geometry

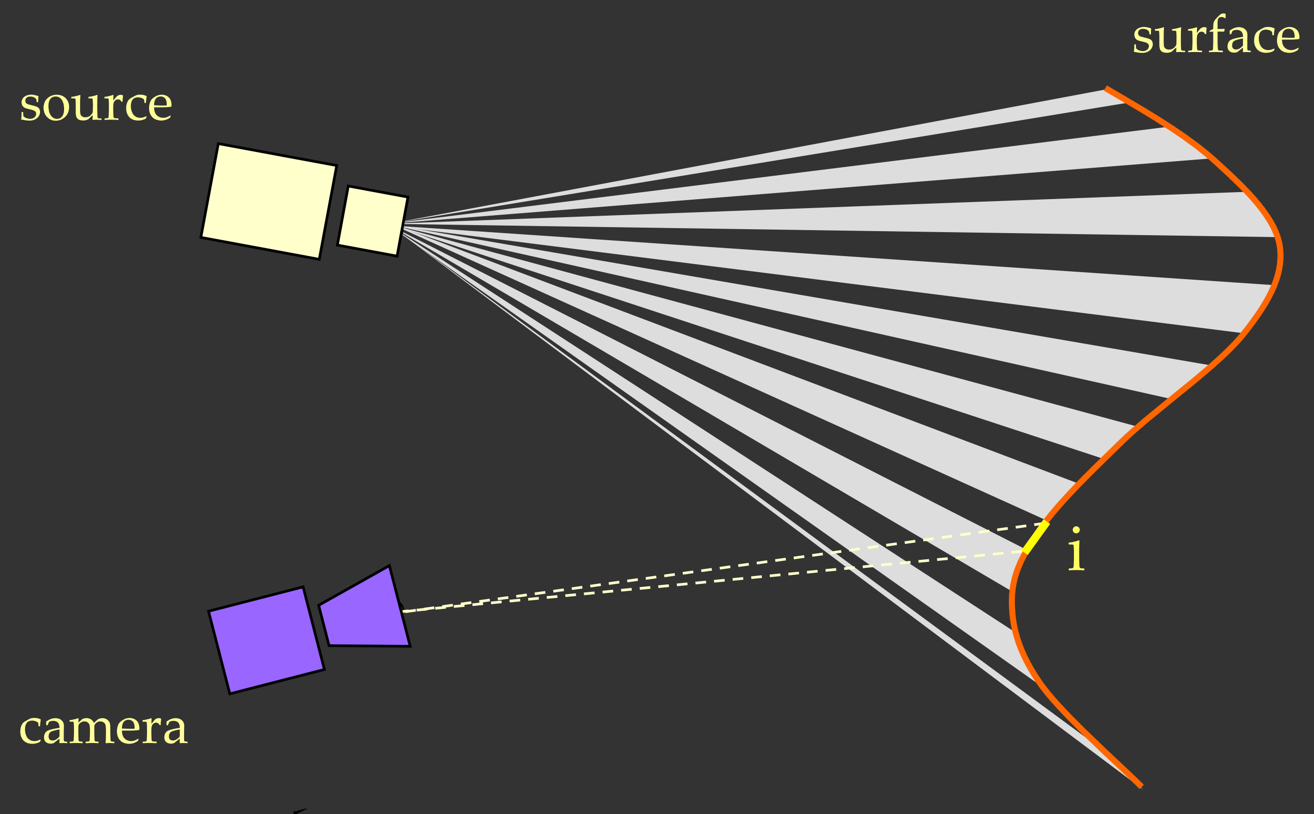
High Frequency Illumination Pattern



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

fraction of activated source elements

High Frequency Illumination Pattern



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

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

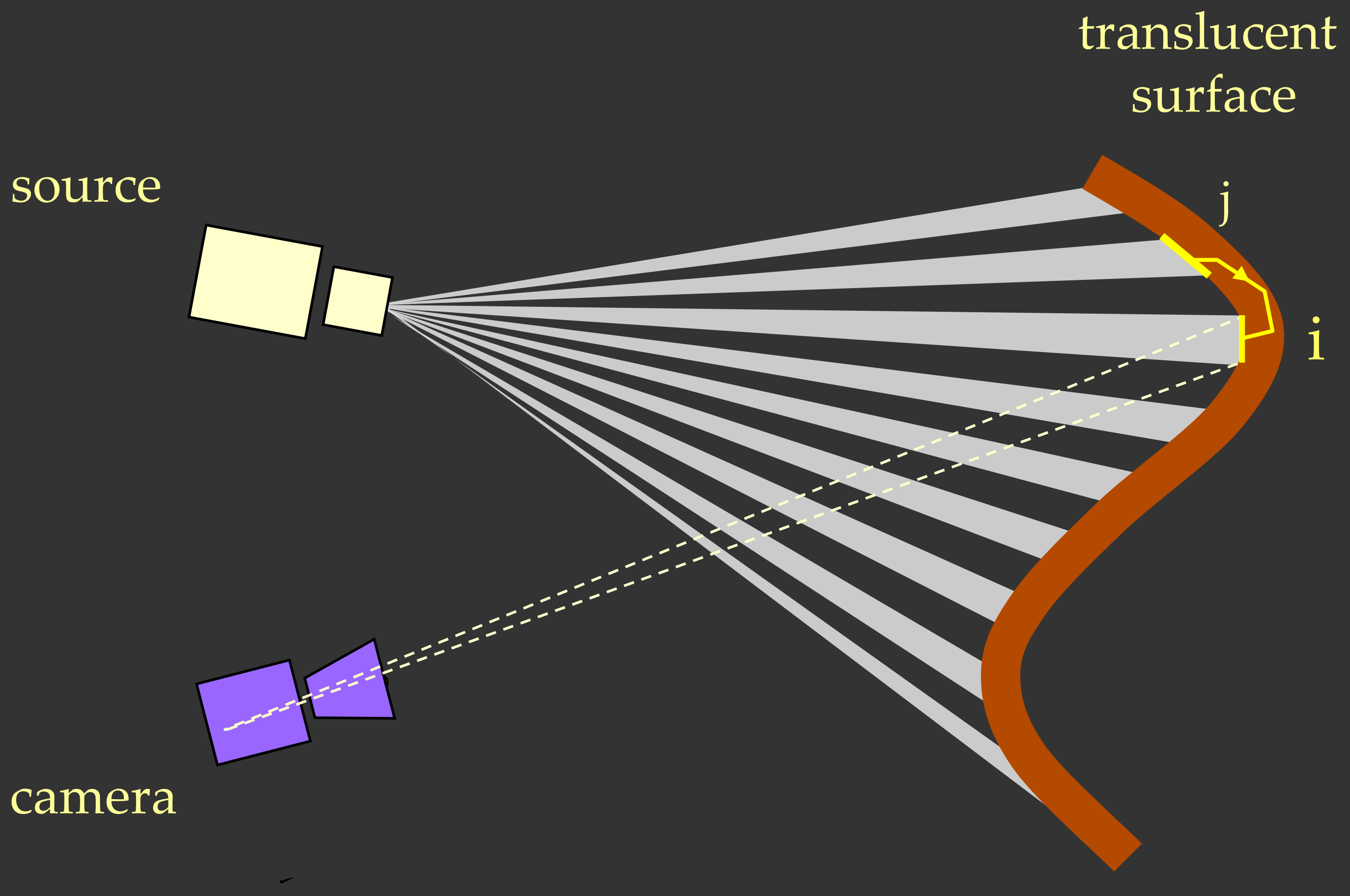
fraction of activated source elements

Separation from Two Images

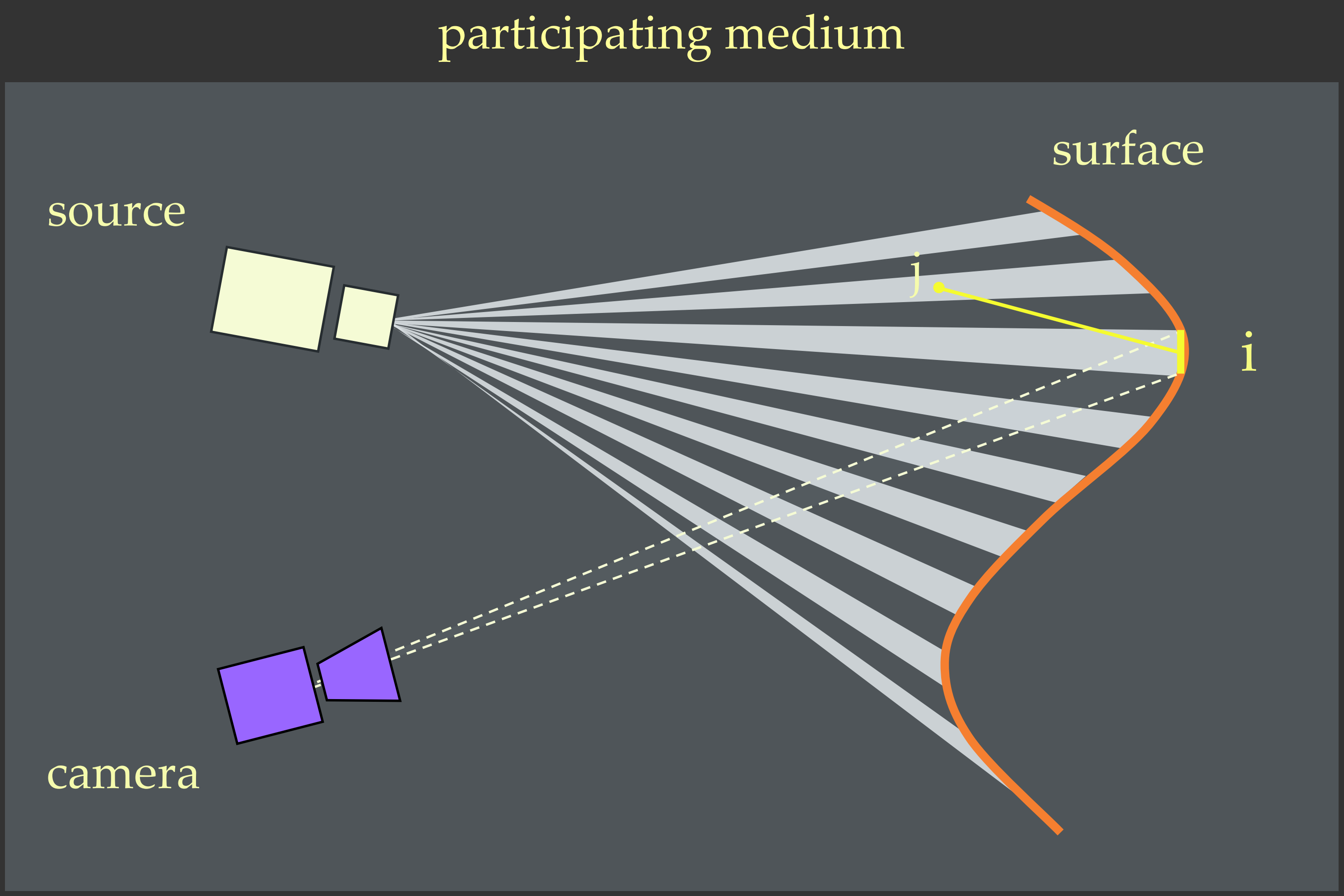
$$\alpha = \frac{1}{2}: \quad L_d = L_{max} - L_{min} \;, \quad L_g = 2L_{min}$$

direct global

Other Global Effects: Subsurface Scattering



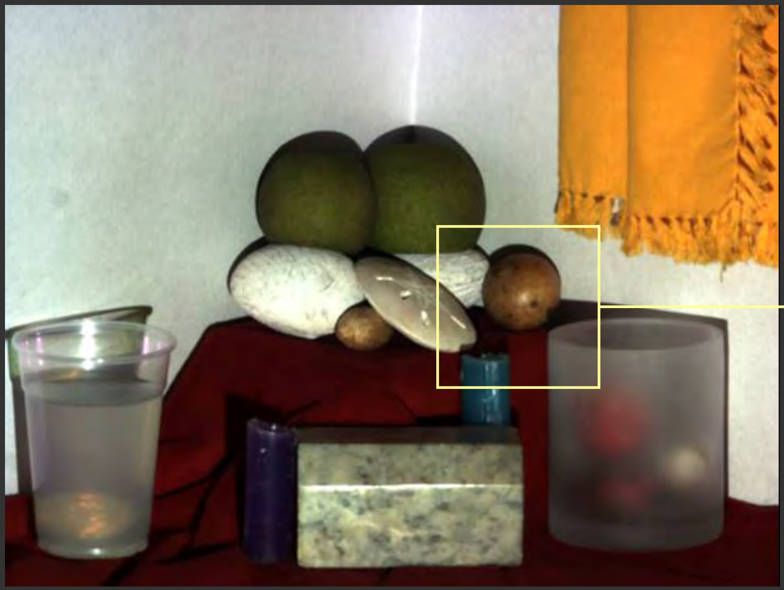
Other Global Effects: Volumetric Scattering




Diffuse Interreflections
Specular Interreflections
Diffusion
Volumetric Scattering
Subsurface Scattering

Scene

Scene



Direct

Global

Real World Examples:

Can You Guess the Images?

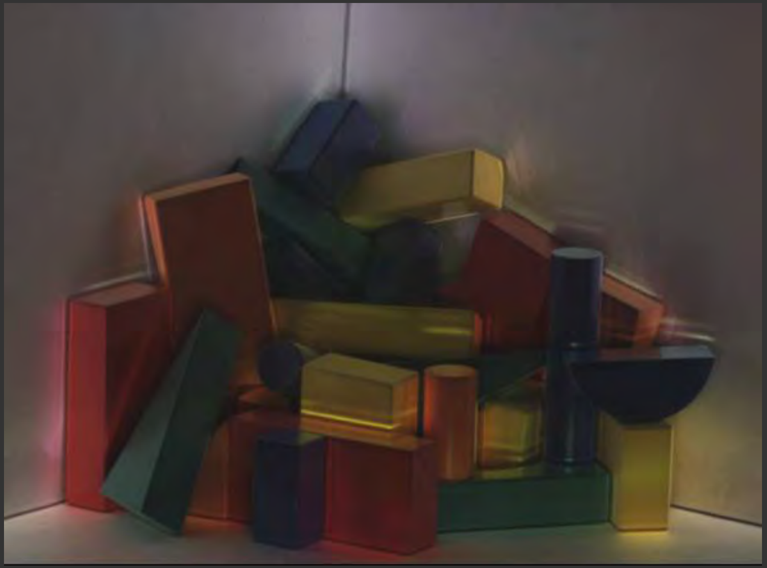
Eggs: Diffuse Interreflections

Direct

Global

Wooden Blocks: Specular Interreflections

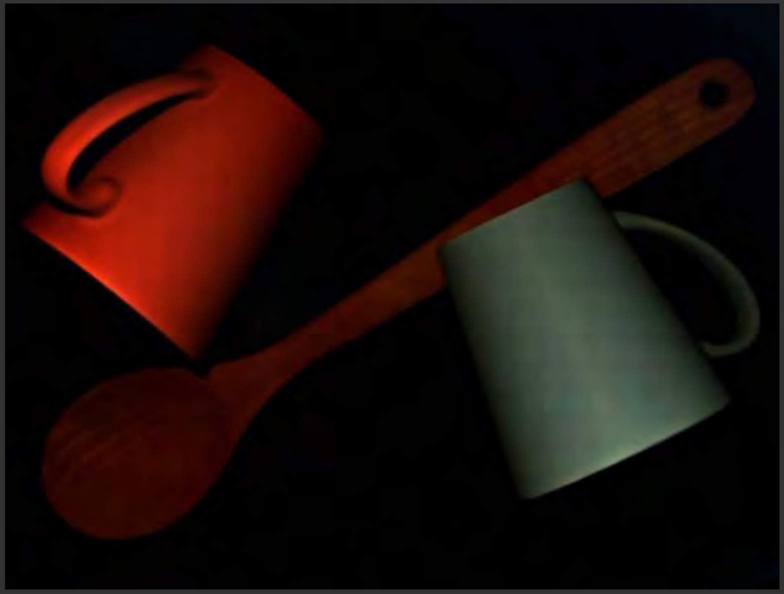
Direct



Global

Kitchen Sink: Volumetric Scattering

Volumetric Scattering:
Chandrasekar 50, Ishimaru 78



Direct

Global

Peppers: Subsurface Scattering

Direct

Global

Hand

Skin: Hanrahan and Krueger 93, Uchida 96, Haro 01, Jensen et al. 01, Cula and Dana 02, Igarashi et al. 05, Weyrich et al. 05

Direct

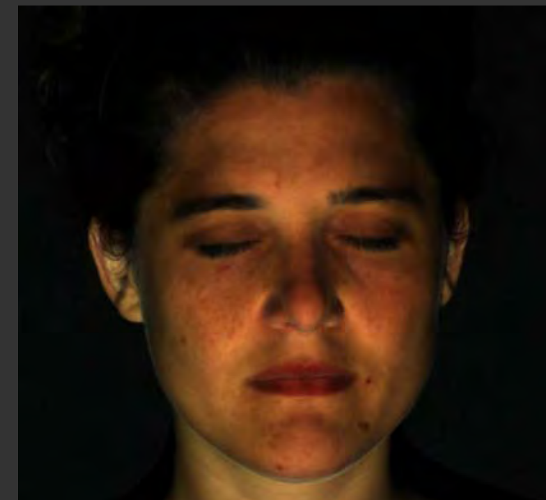
Global

Face: Without and With Makeup

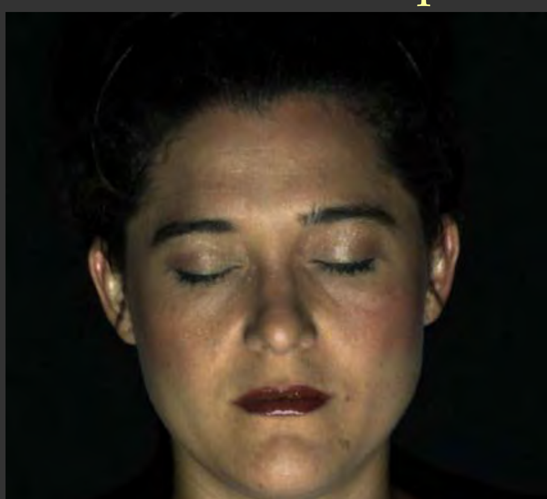
Without Makeup

Direct

Global

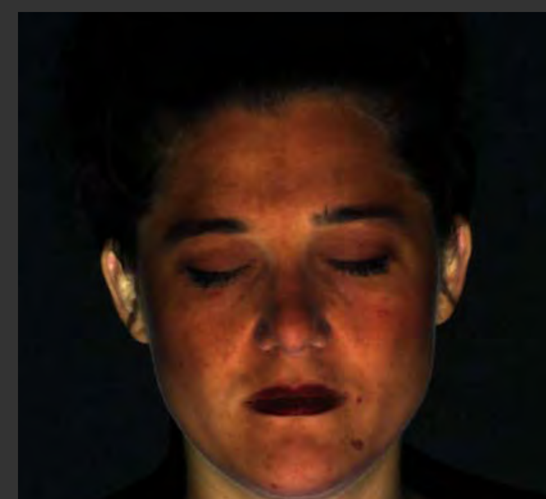


With Makeup



Direct

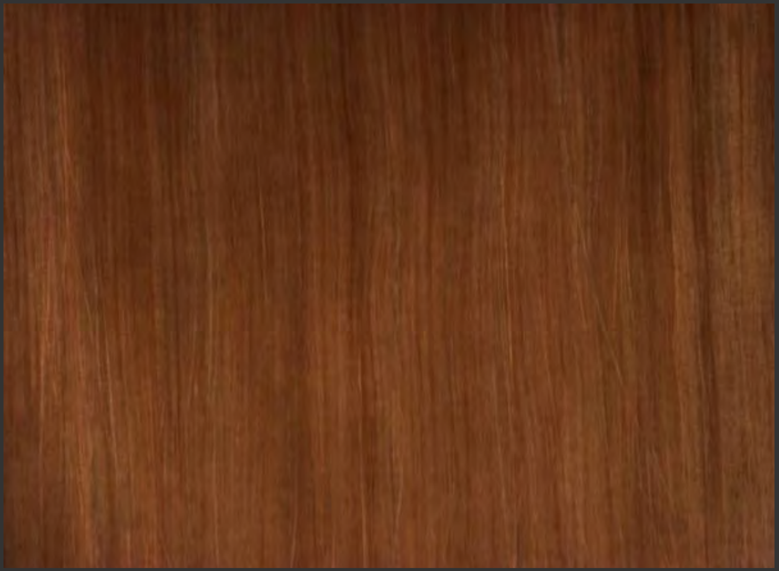
Global



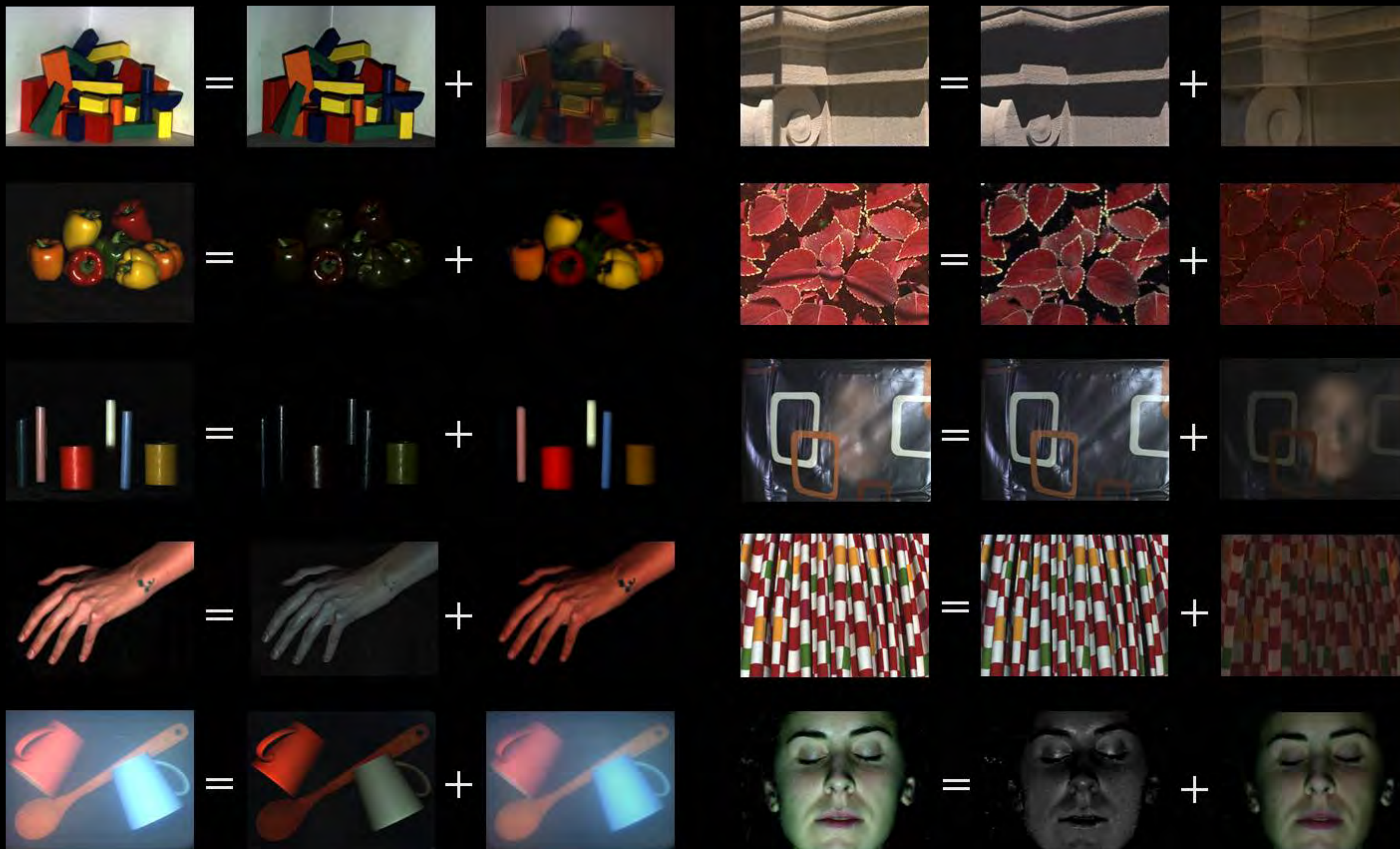
Blonde Hair

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

Direct



Global



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