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A Practical Analytic Model for the Radiosity of Translucent Scenes

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Leaf

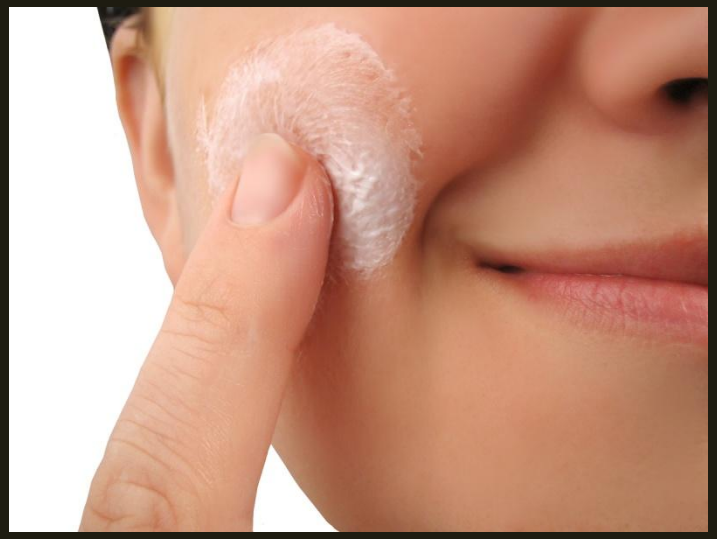
twisia.com

Wax

sweet-station.com

Jade

From Smithsonian National museum of natural history



Skin

salonnordic.com

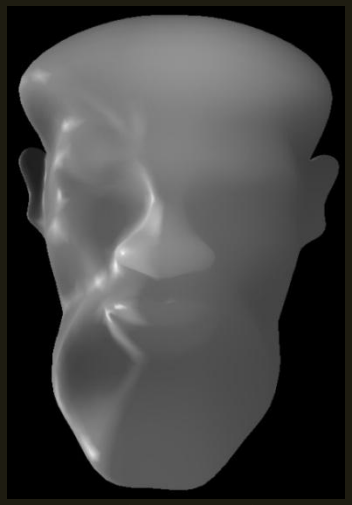
Rendering Translucent Objects

Monte-Carlo

[Jensen et al. 1999; Pharr and Hanrahan 2000]

Analytic model

[Jensen et al. 2001; Donner and Jensen 2007]



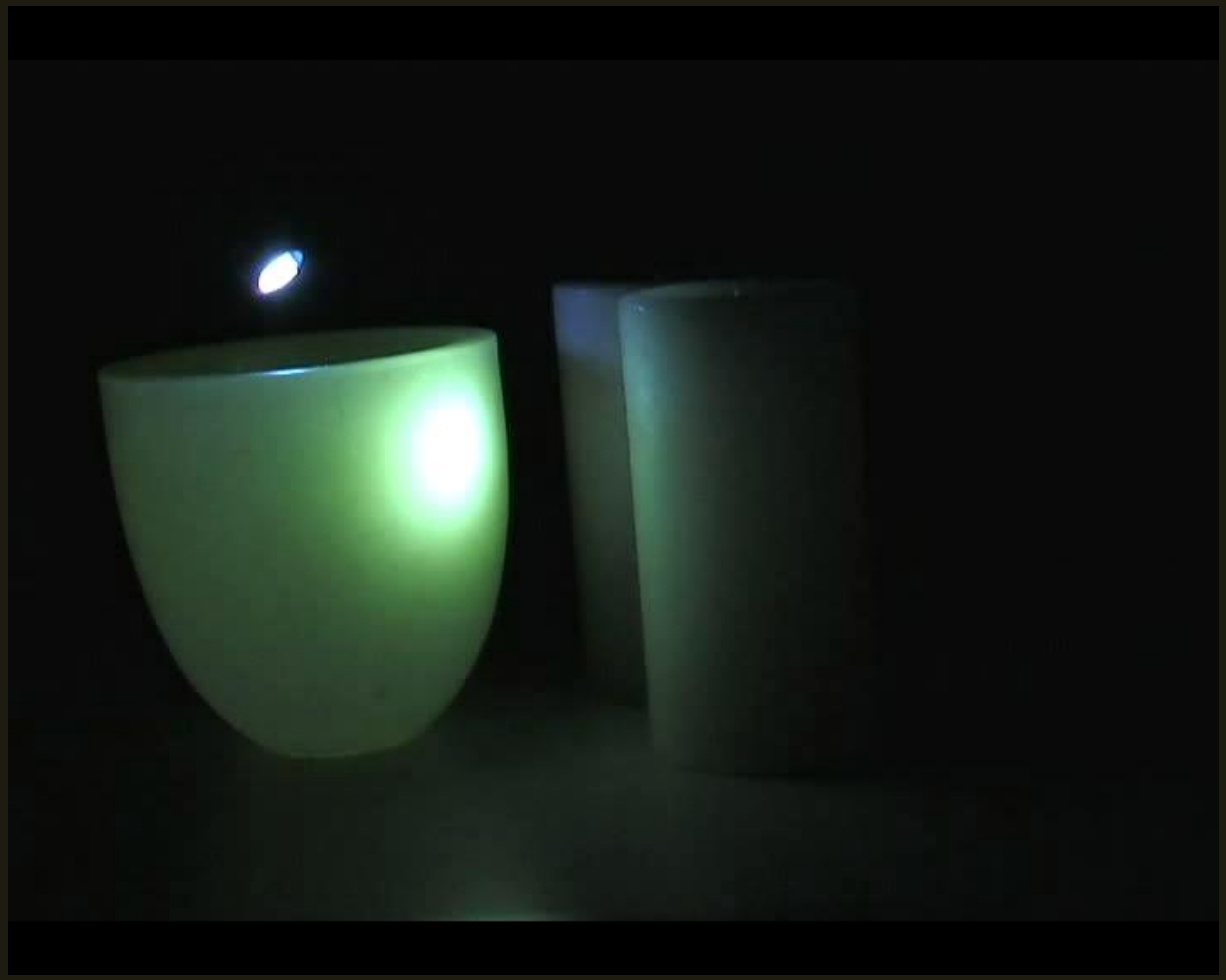
Radiosity based method

[Lensch et al. 2002; Carr et al. 2003]

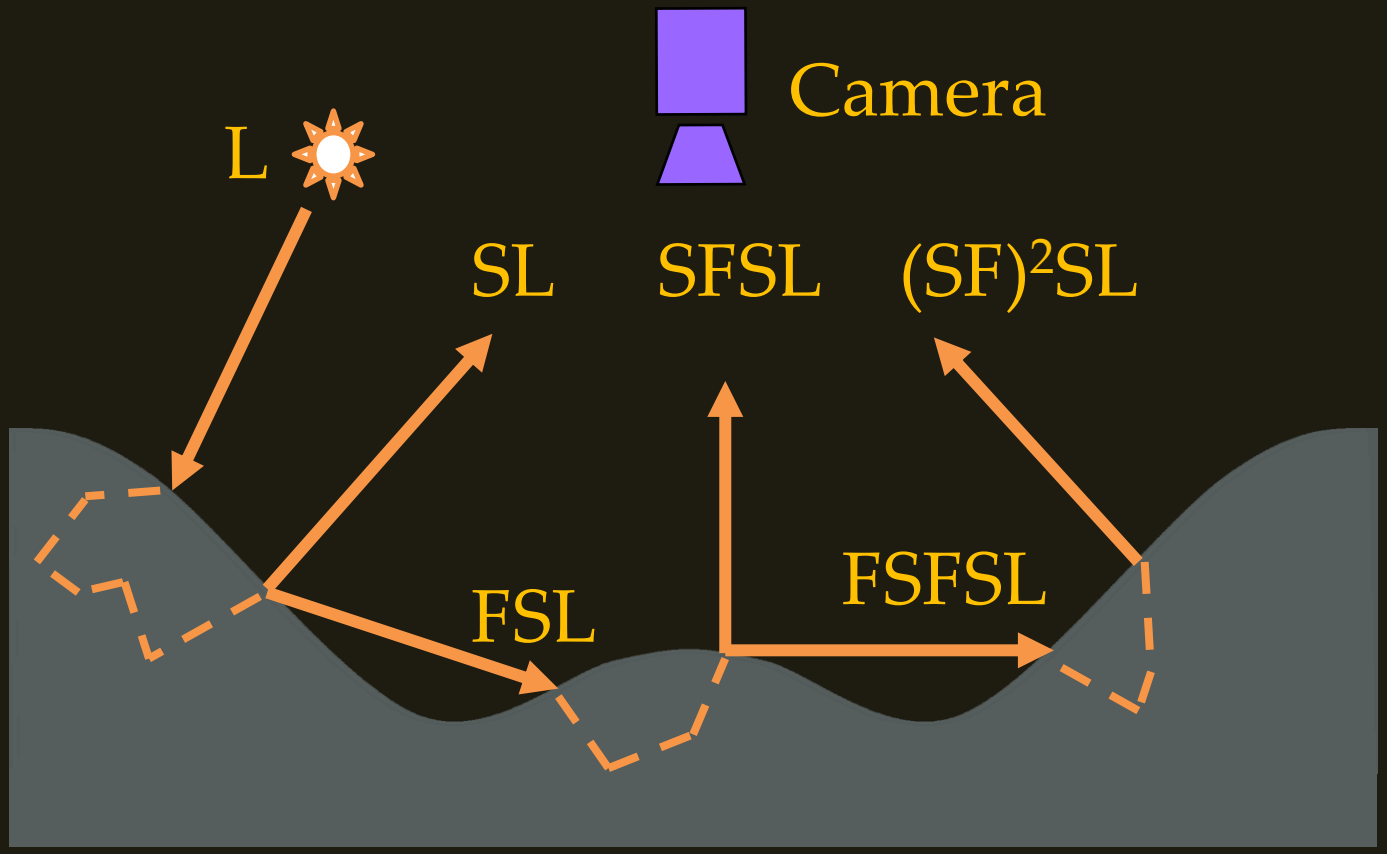
Precomputed Radiance Transfer

[Wang et al. 2005; Wang et al. 2008]

Optical Interactions between Translucent Objects



Light Transport Pathways



Subsurface scattering: S

Inter-reflection: F

Analytic Model

First bounce:

$$\underbrace{\begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nn} \end{bmatrix}}_{S} \underbrace{\begin{bmatrix} L_1 \\ \vdots \\ L_n \end{bmatrix}}_{L}$$

Second bounce:

$$\underbrace{\begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nn} \end{bmatrix}}_{S} \underbrace{\begin{bmatrix} F_{11} & \cdots & F_{1n} \\ \vdots & \ddots & \vdots \\ F_{n1} & \cdots & F_{nn} \end{bmatrix}}_{F} \underbrace{\begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nn} \end{bmatrix}}_{S} \underbrace{\begin{bmatrix} L_1 \\ \vdots \\ L_n \end{bmatrix}}_{L}$$

N-th bounce: $(SF)^{N-1}SL$

All bounces: $B = \sum_{N=1}^{\infty} (SF)^{N-1}SL = (I - SF)^{-1}SL$

Comparing with Traditional Radiosity

Radiosity: $B = (I - F)^{-1}L$

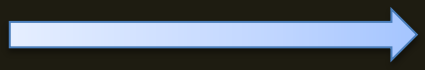
$S = I$  S

Analytic model: $B = (I - SF)^{-1}SL$

Pros:

- Realtime changing viewpoints
- Fast relighting and changing materials

Cons:

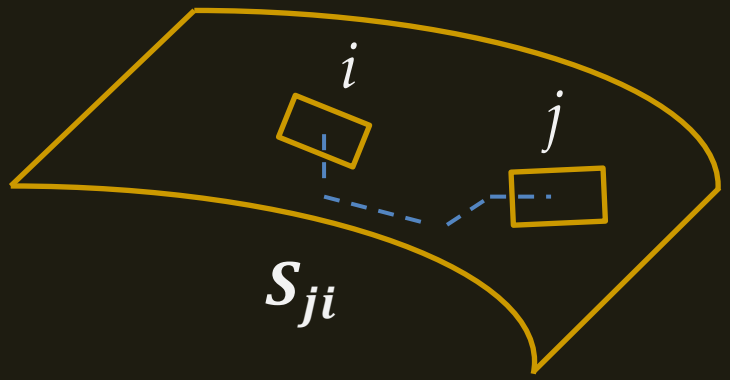
- Precomputating S and F: 10+ minutes
- Memory consumption: 1.5 GB  100MB

[Willmott et al. 1999]

Subsurface Scattering Matrix

Subsurface scattering matrix:

$$S = \begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nn} \end{bmatrix}$$



Subsurface scattering factor: [Carr et al. 2003]

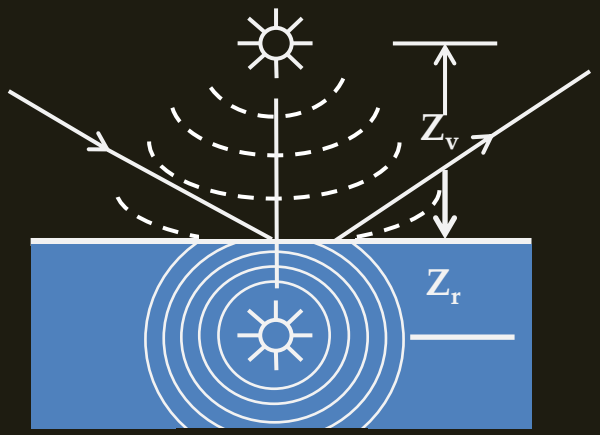
$$S_{ji} = \frac{1}{A_i} \int_{A_i} \int_{A_j} s(i,j)\, dA_j dA_i$$

BSSRDF $s(i, \vec{\omega}_i; j, \vec{\omega}_j)$

Homogeneous Materials

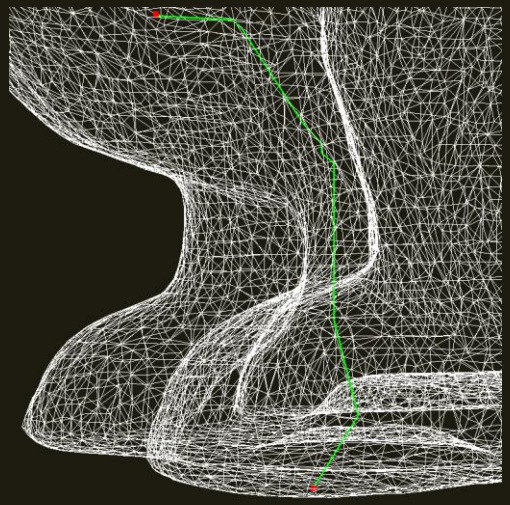
Subsurface scattering factor:

$$S_{ji} = \frac{1}{A_i} \int_{A_i} \int_{A_j} s(r)\, dA_j\, dA_i$$

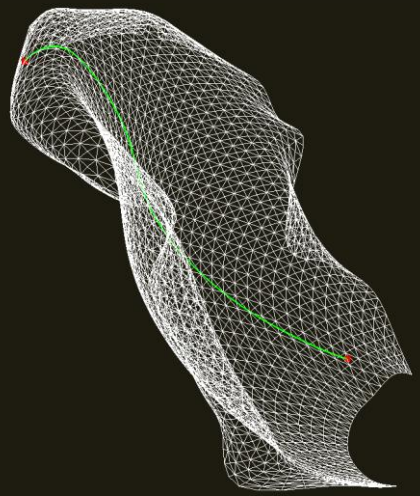


Dipole diffusion

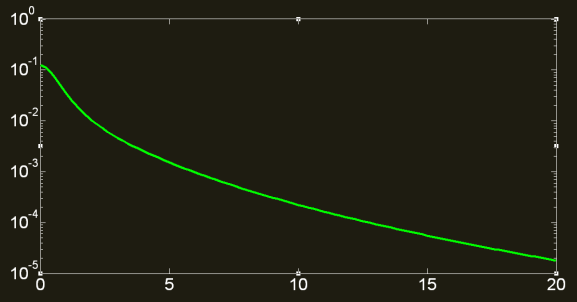
Computing distance r:



Volume



Shell

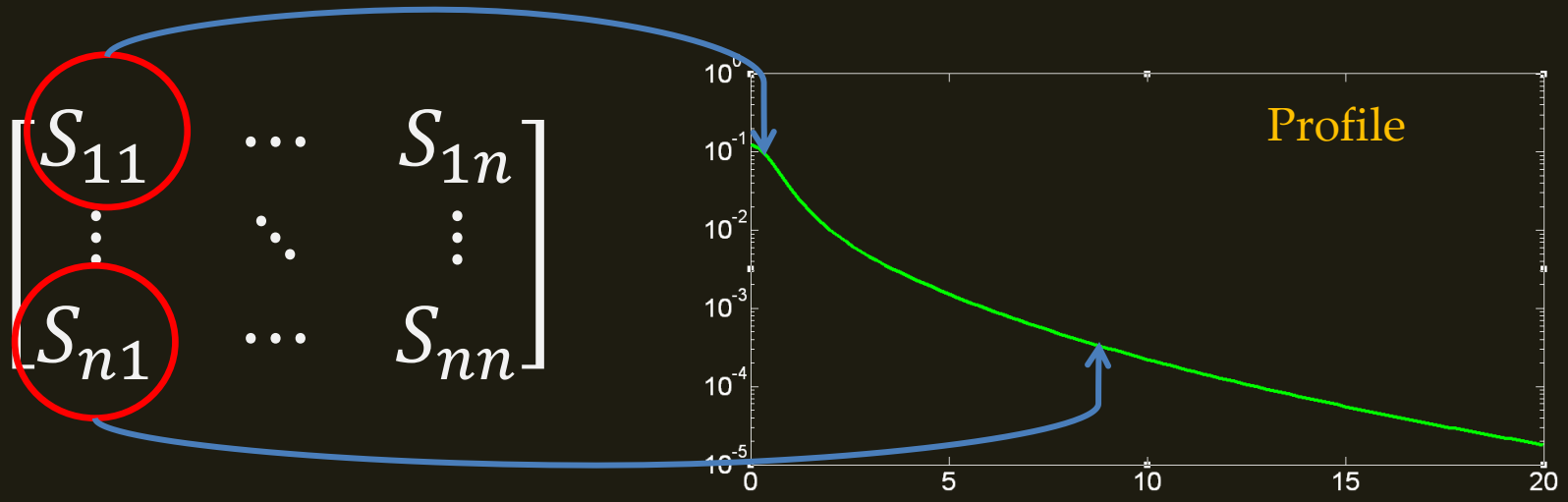


Profile

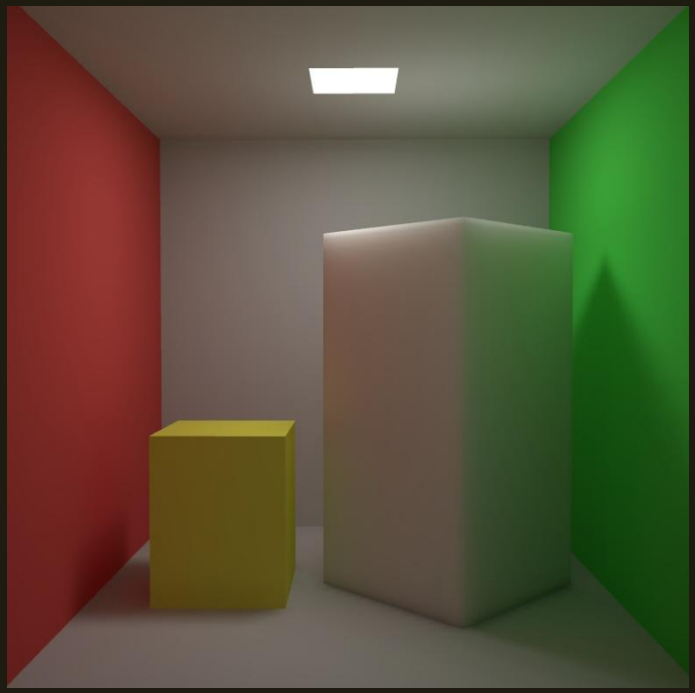
Changing Translucencies

Subsurface scattering factor:

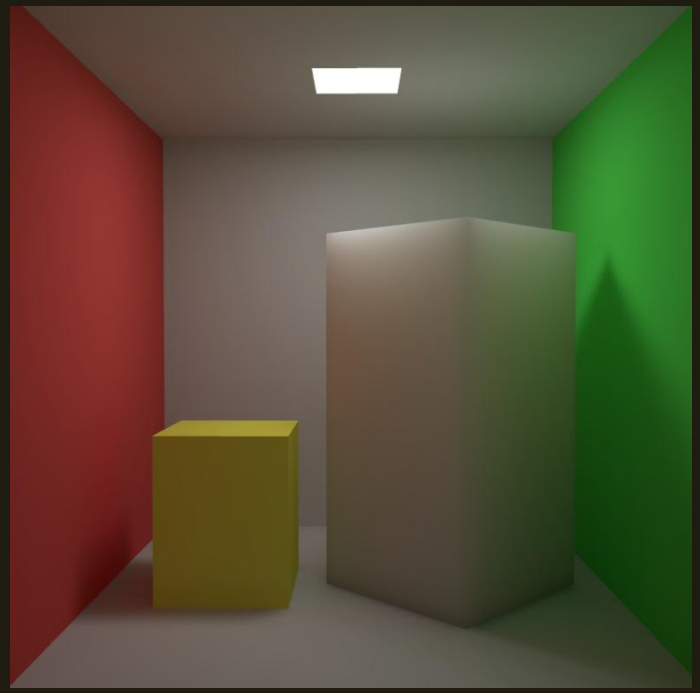
$$S_{ji} = \frac{1}{A_i}\int_{A_i}\int_{A_j} s(r)\, dA_j dA_i \approx \frac{1}{A_i}\sum_{\Delta A_i}\sum_{\Delta A_j} s(r)\Delta A_j \Delta A_i$$



Changing Translucencies



Less translucent



More translucent

Performance: 2fps

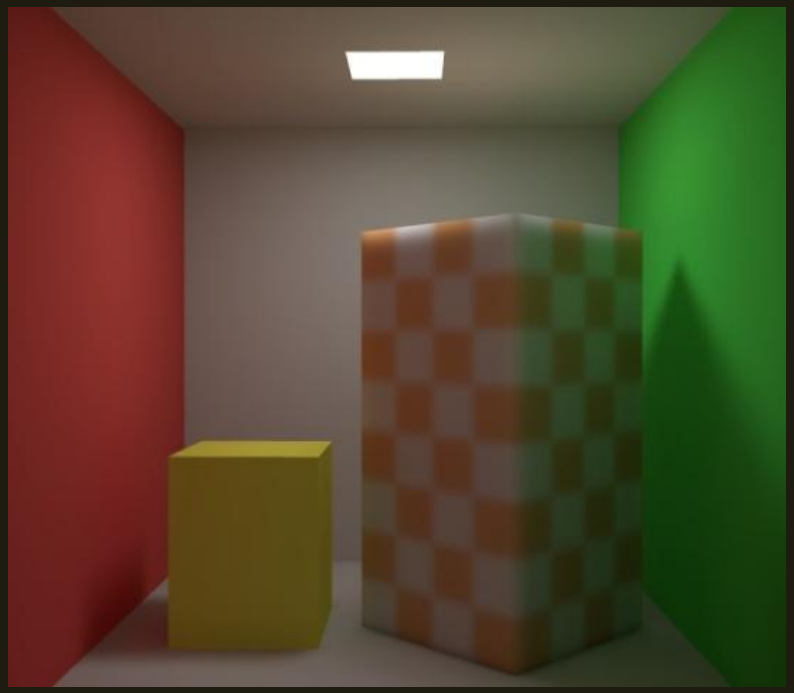
Heterogeneous materials

Subsurface scattering factor:

$$S_{ji} = \frac{1}{A_i} \int_{A_i} \int_{A_j} s(i,j)\, dA_j dA_i$$

4D BSSRDF Function:

- Measurement: DISCO [Goesele et al. 2004]
- Simulation: [wang et al. 2008], [Arbree et al. 2011]



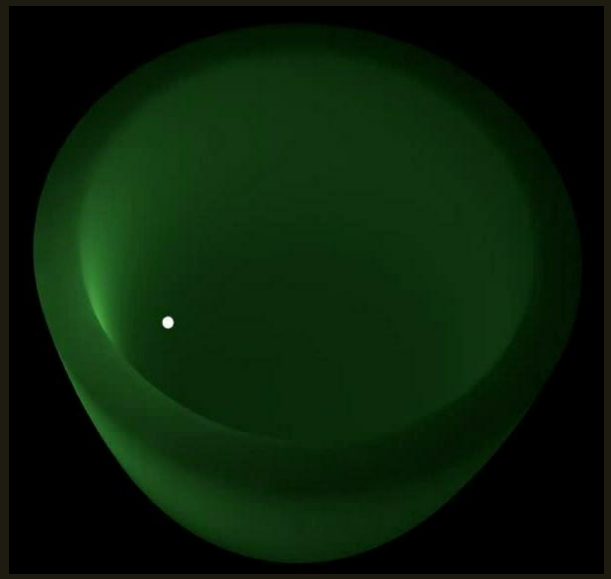
Relighting

Analytic model:

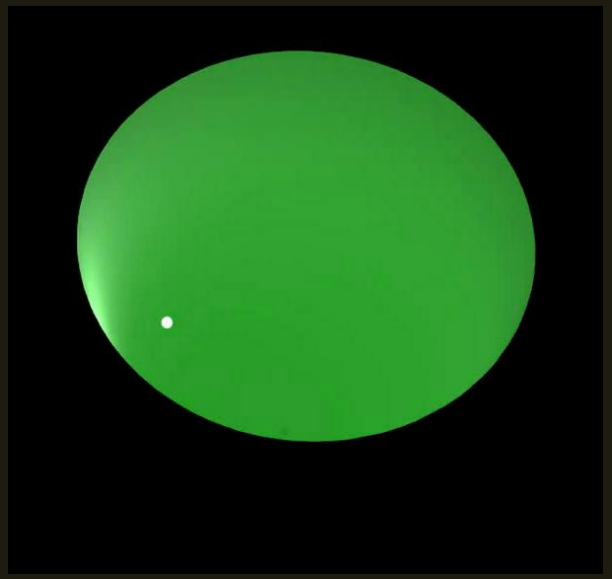
$$B = (I - SF)^{-1} SL = TL$$

Iterative solver: 5fps

Relighting only (>20 fps)



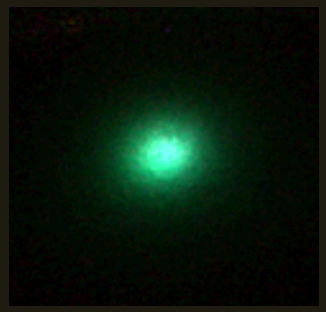
Translucent wax bowl



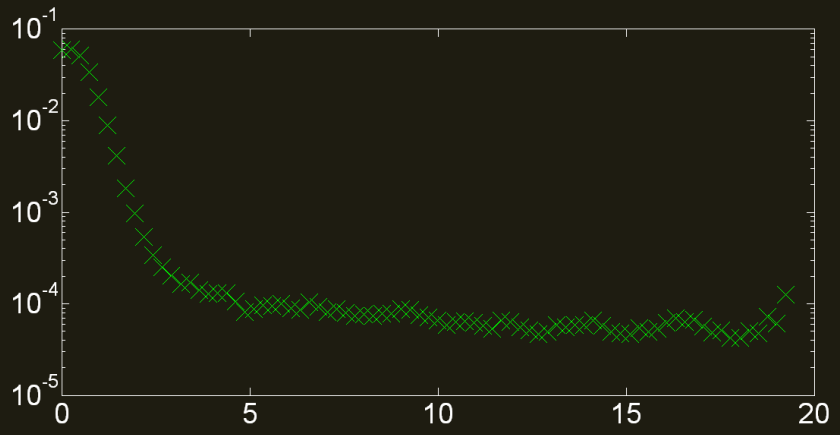
Diffuse bowl

Validation using Material Capture

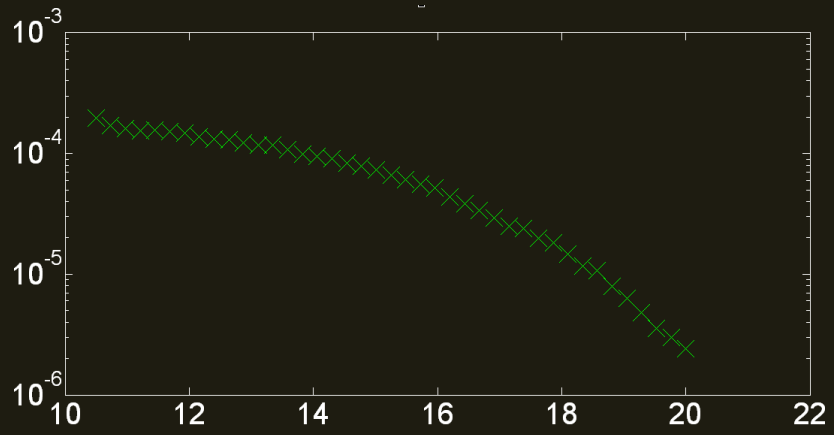
Reflection distribution



Transmission distribution



Reflection profile

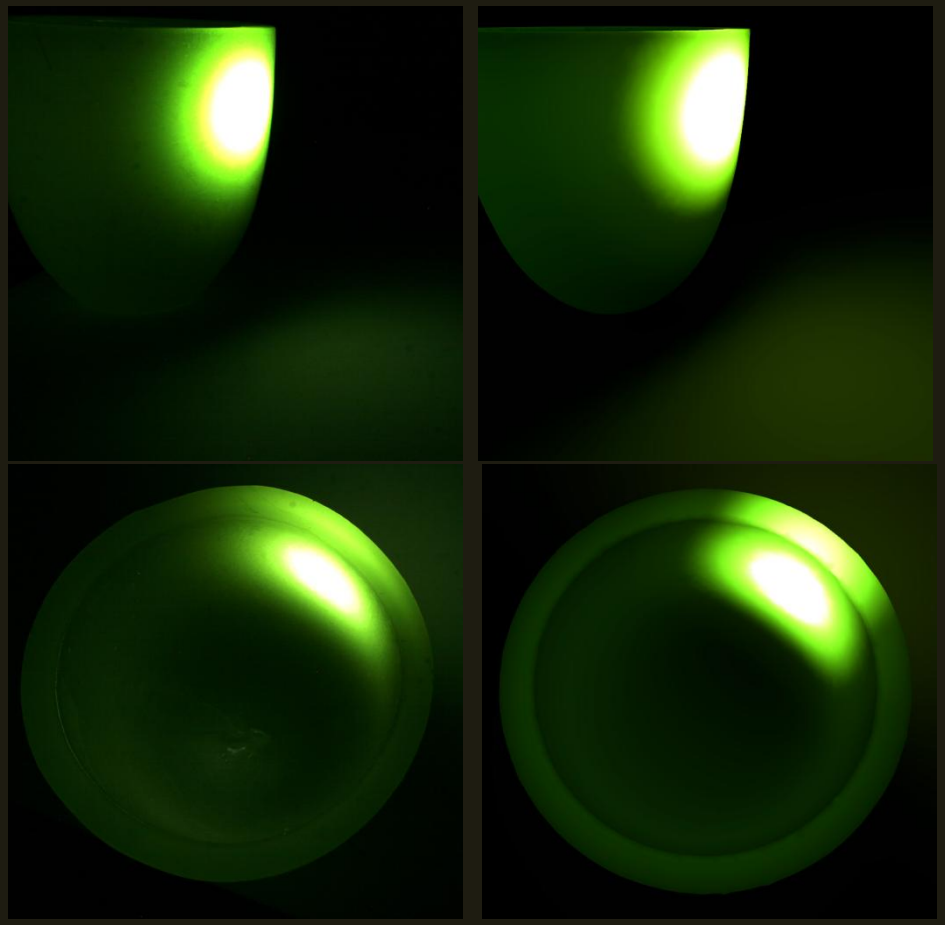


Transmission profile

Validation Results

Photo

Rendering



Rose

Our result

First bounce removed

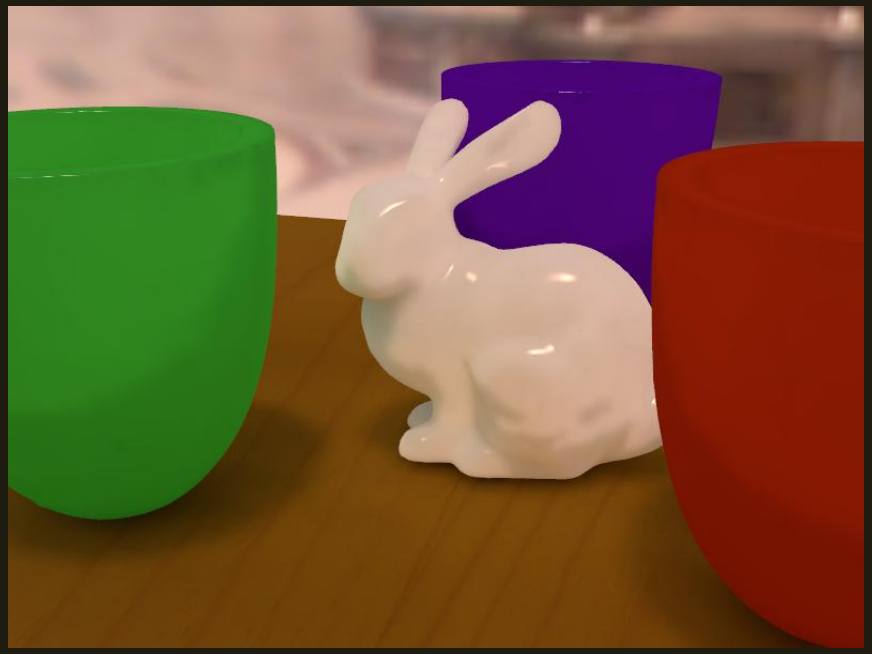
$B - SL$

Diffuse Inter-reflection

$\sum_{i=1}^{\infty} F^i L$

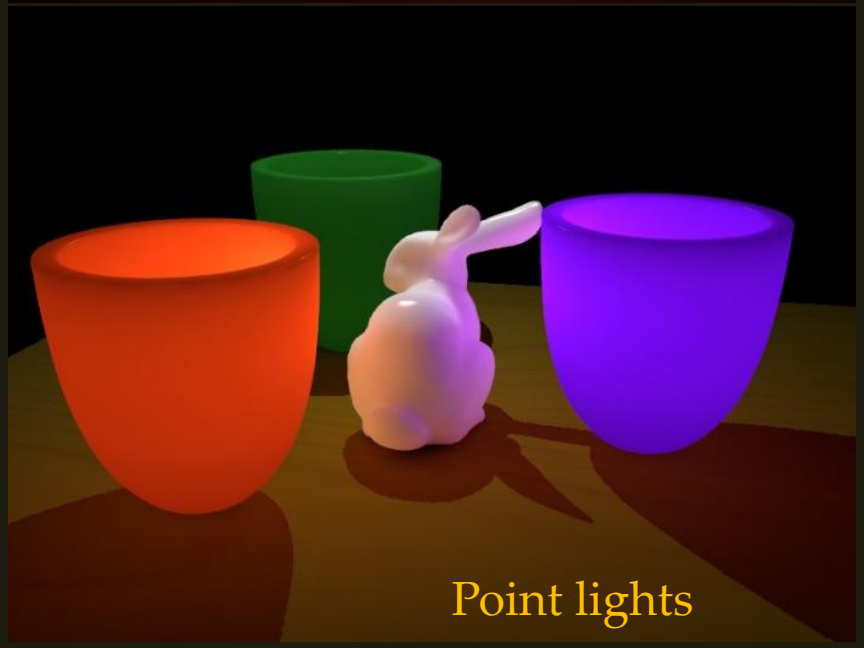
# of polys	Pre-computation (min)	Relighting	Change Trans (fps)
72k	15 + 20	3	0.5

Bunny



Environment light

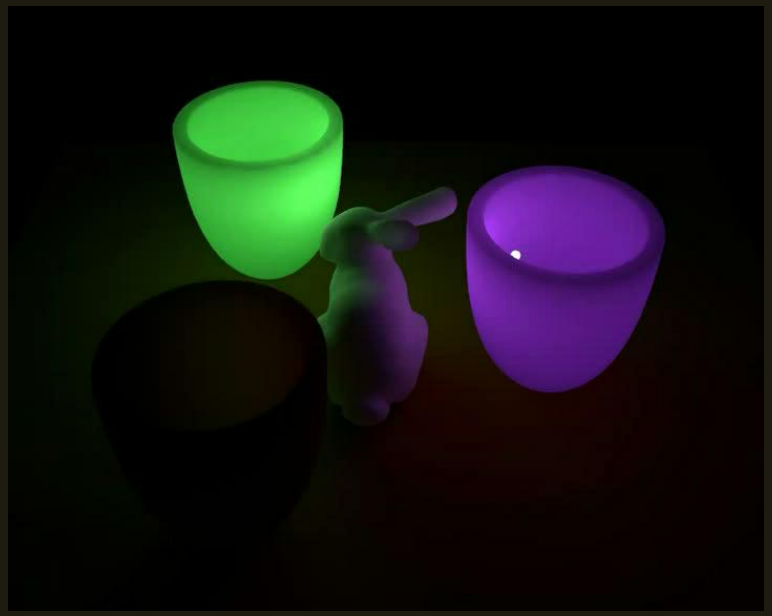
Spot lights



Point lights

Bunny

Camera 1

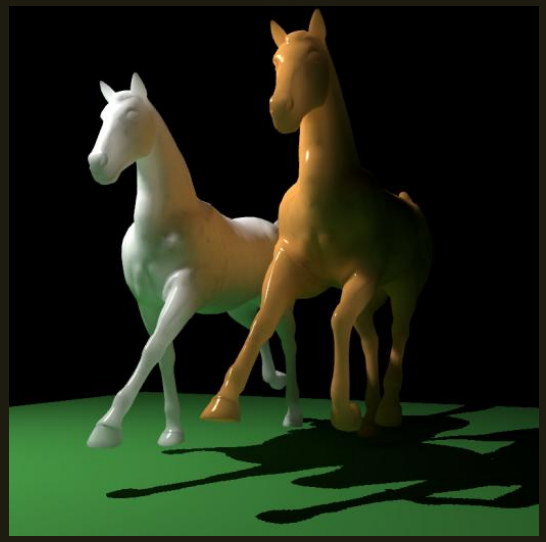


Camera 2

# of polys	Pre-computation (min)	Relighting (fps)	Change Trans (fps)
73k	10 + 12	3	0.25

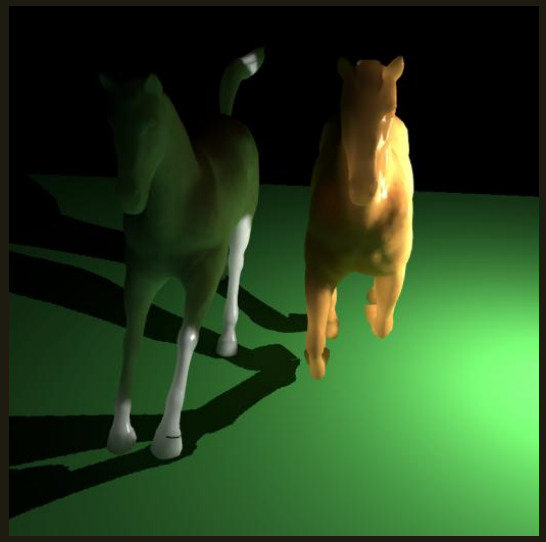
Horses

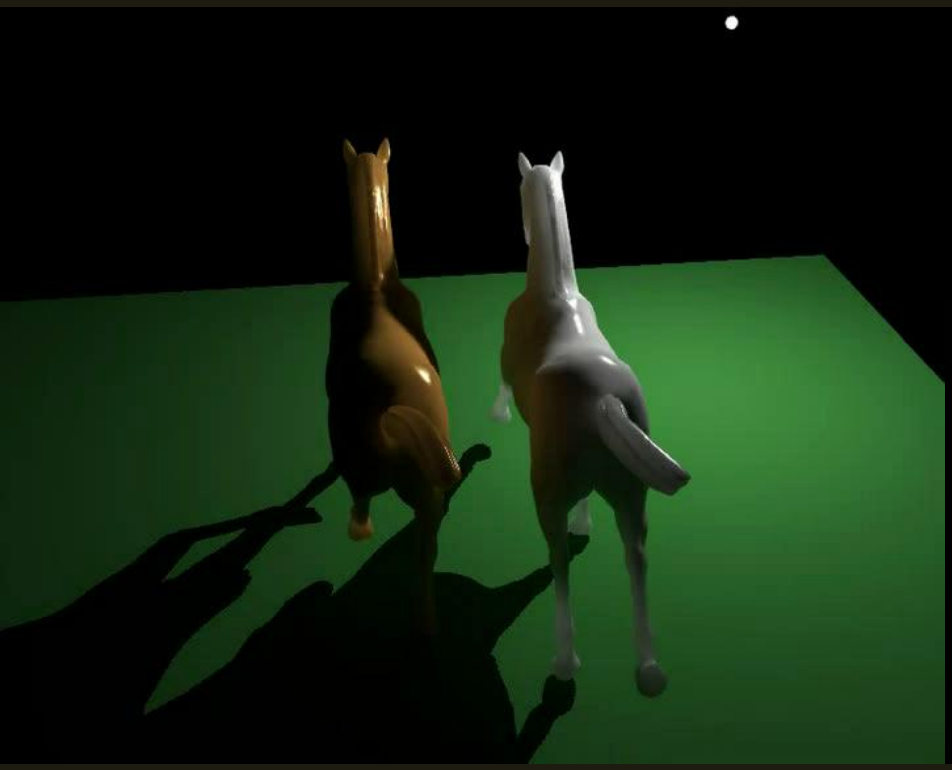
Our result



First bounce removed

$B - SL$





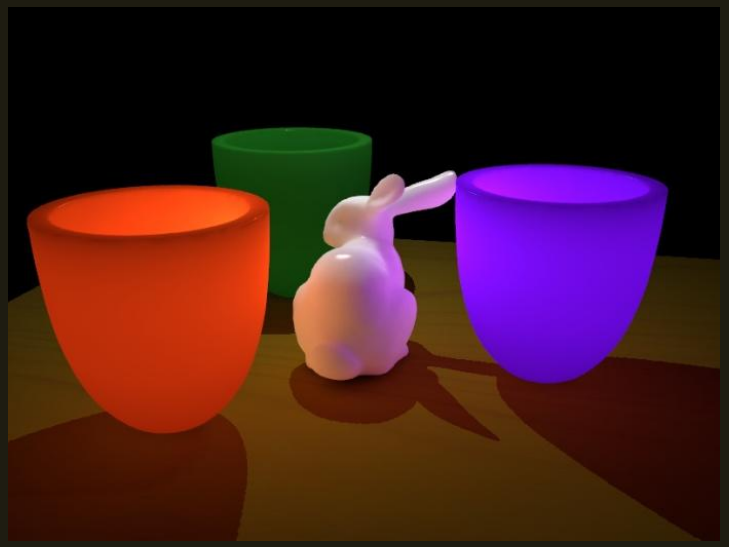
Our result

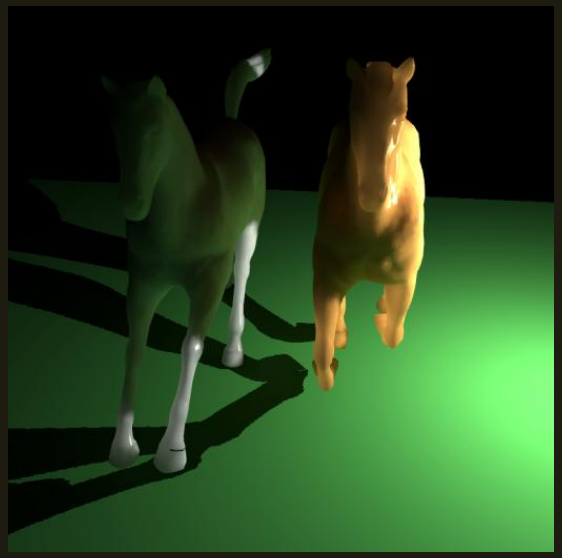
First bounce removed
$B - SL$

# of polys	Pre-computation (min)	fps
63k	(9 + 10) * 48	0.05

Future Work

- Reduce memory consumption
  - Hierarchical method ([Willmott et al. 1999 ; Mertens et al. 2003])
- Multiple bounces of specular reflection
- Interactive rendering of dynamic scenes with translucent objects





Radiosity in Computer Games

Coarse radiosity solution

Fine interpolated result

DICE & Geometrics
(Battle field 3)

Summary

- Analytic model combining subsurface scattering and inter-reflection
- Supports both homogeneous and heterogeneous materials
- Interactive change in viewpoint, lighting and translucency