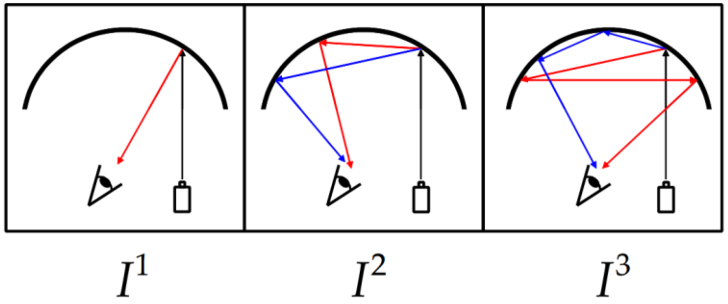
Fast Separation of Direct and Global Images Using High Frequency Illumination

Shree K. Nayar, Gurunandan Krishnan, Michael D. Grossberg, Ramesh Raskar

Presented by: Yiying Li and Harrison Billmers

Related Works

- Inverse Light Transport (Seitz et. al. ICCV 05)
  - Estimates interreflections contribution given the number of reflections
  - Based on Lambertian assumption and large amounts of data need



- Dual Photography (Sen et. al. Siggraph 05)
  - Estimates the transport matrix between camera and projector
  - Still requires a lot of images
  - Don’t need full transport matrix

Direct and Global Components

- Direct Components
  - The radiance of a scene point due to illumination from the source directly
- Global Components
  - Radiance of a scene point due to illumination from other points in the scene
  - Interreflections
  - Subsurface scattering
  - Volumetric scattering
  - Translucency

Scene

Direct

Global

Direct and Global Components

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

Radiance = Direct Component + Global Component

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

The sum of all interreflections from all patches

$$A[i,j]$$

BRDF and Geometry

$$L[i,j]$$

Radiance of patch j in the direction of patch i

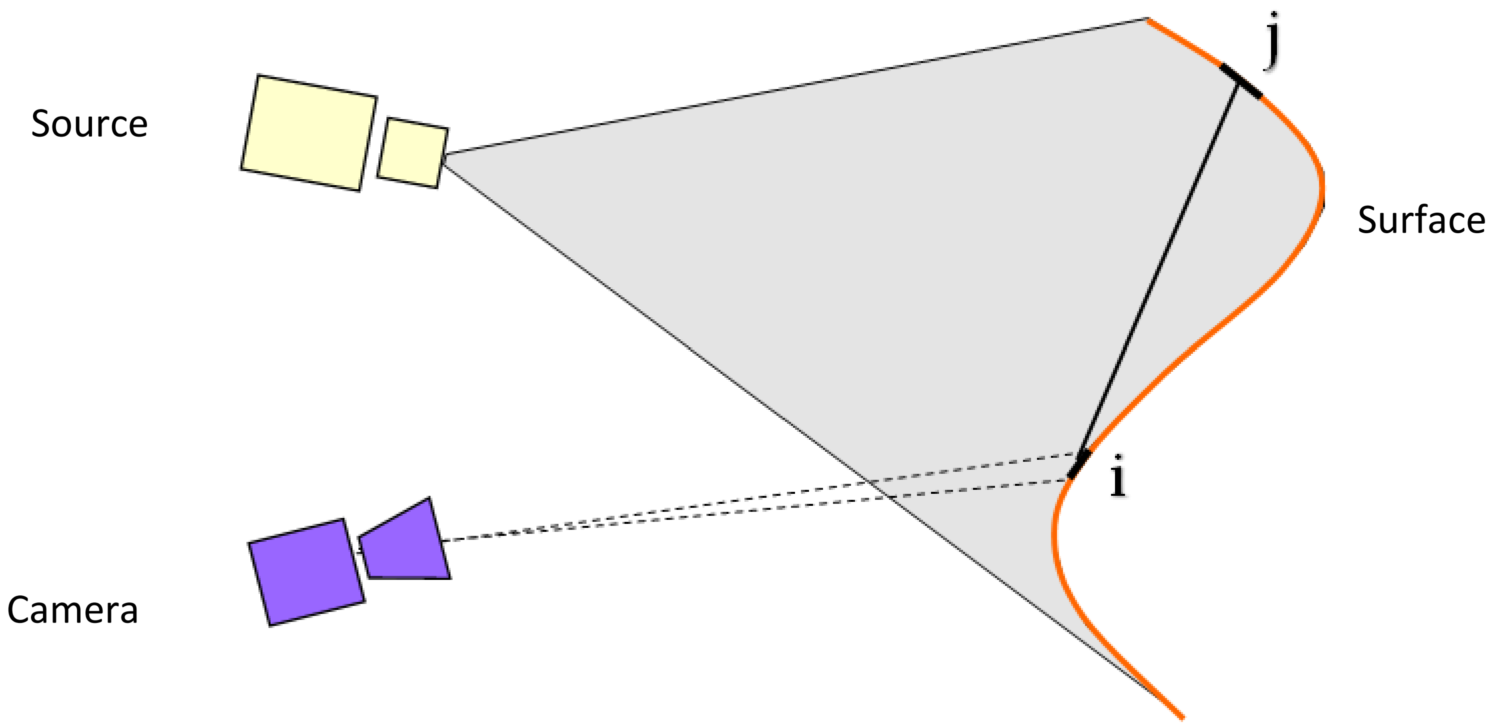
$$L_g[c,i] = L_{gd}[c,i] + L_{gg}[c,i]$$

$$L_{gd}[c,i] = \sum_P A[i,j]\, L_d[i,j]$$

2nd order of the form as above

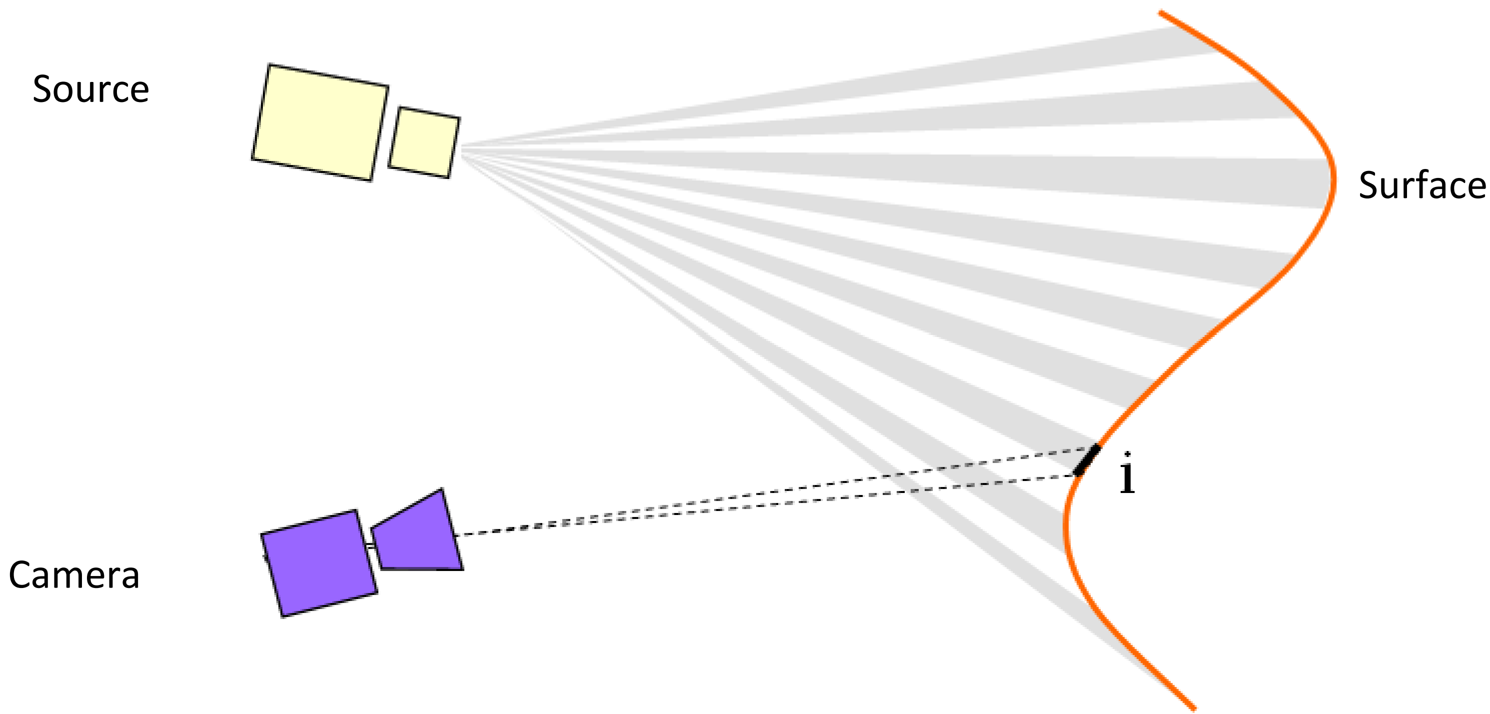
$$L_{gg}[c,i] = \sum_P A[i,j]\, L_g[i,j]$$

Interreflections



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

High Frequency Illumination Pattern



Direct and Global Components

$$L_g[c,i] = L_{gd}[c,i] + L_{gg}[c,i]$$

$$L^{+}_{gd}[c,i] = \sum_{Q} A[i,j]\, L_d[i,j] \qquad L^{-}_{gg}[c,i] = \sum_{P} A[i,j]\, L_g[i,j]$$

If A is smoothing and we sample at high enough frequency

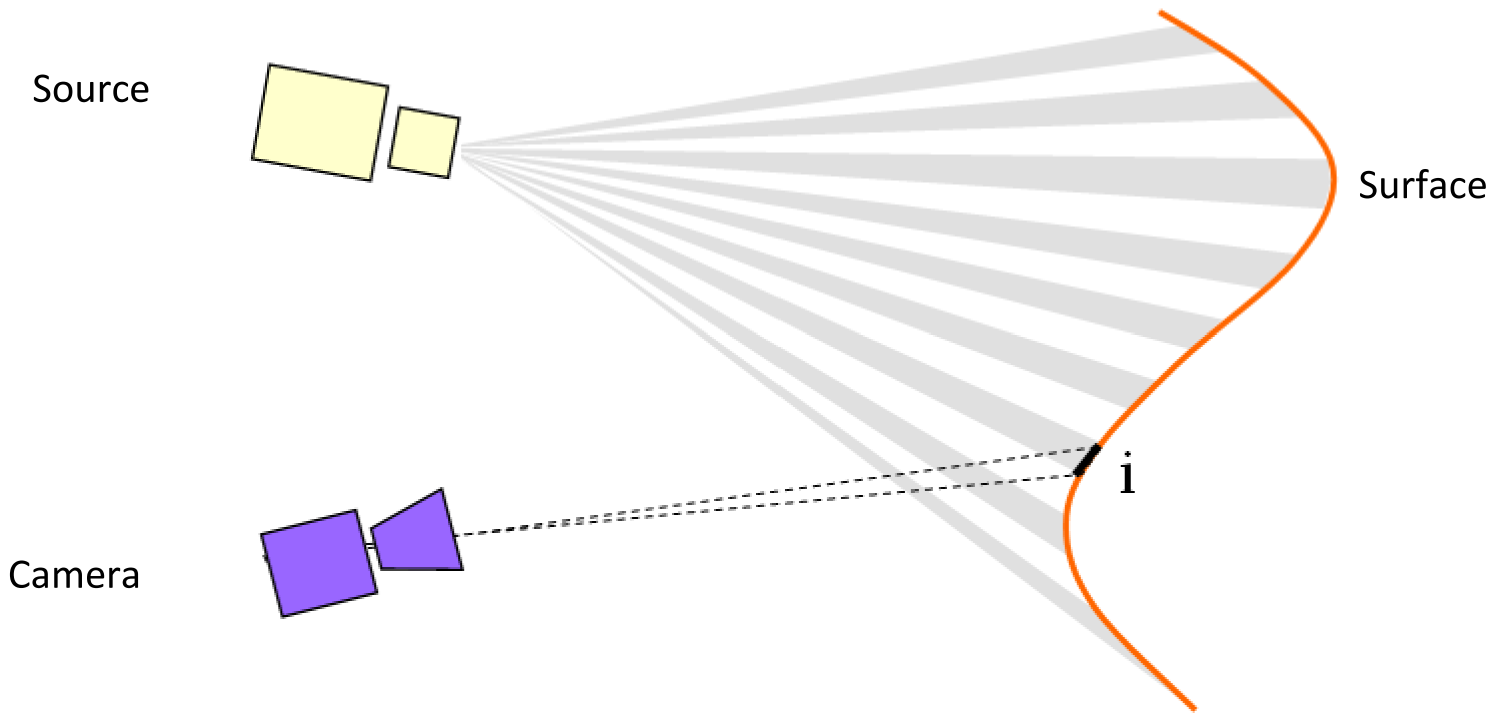
$$L^{+}_{gd}[c,i] = \alpha L_{gd}[i,j]$$

$$L^{+}_{gg}[c,i] = \alpha L_{gg}[i,j]$$

$\alpha =$ Fraction of the patches lit

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

High Frequency Illumination Pattern

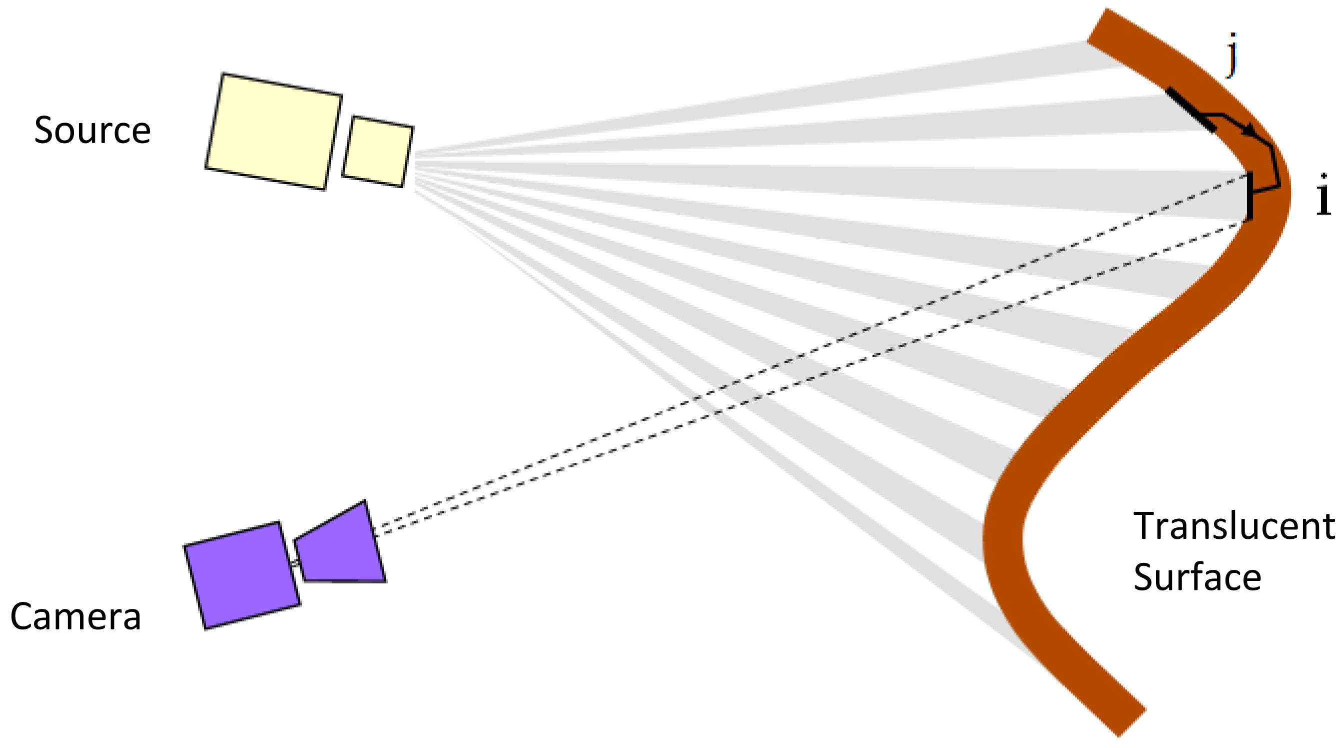


$$L^{+}[c,i] = L_d[c,i] + \alpha L_g[c,i] \qquad L^{-}[c,i] = (1-\alpha) L_g[c,i]$$

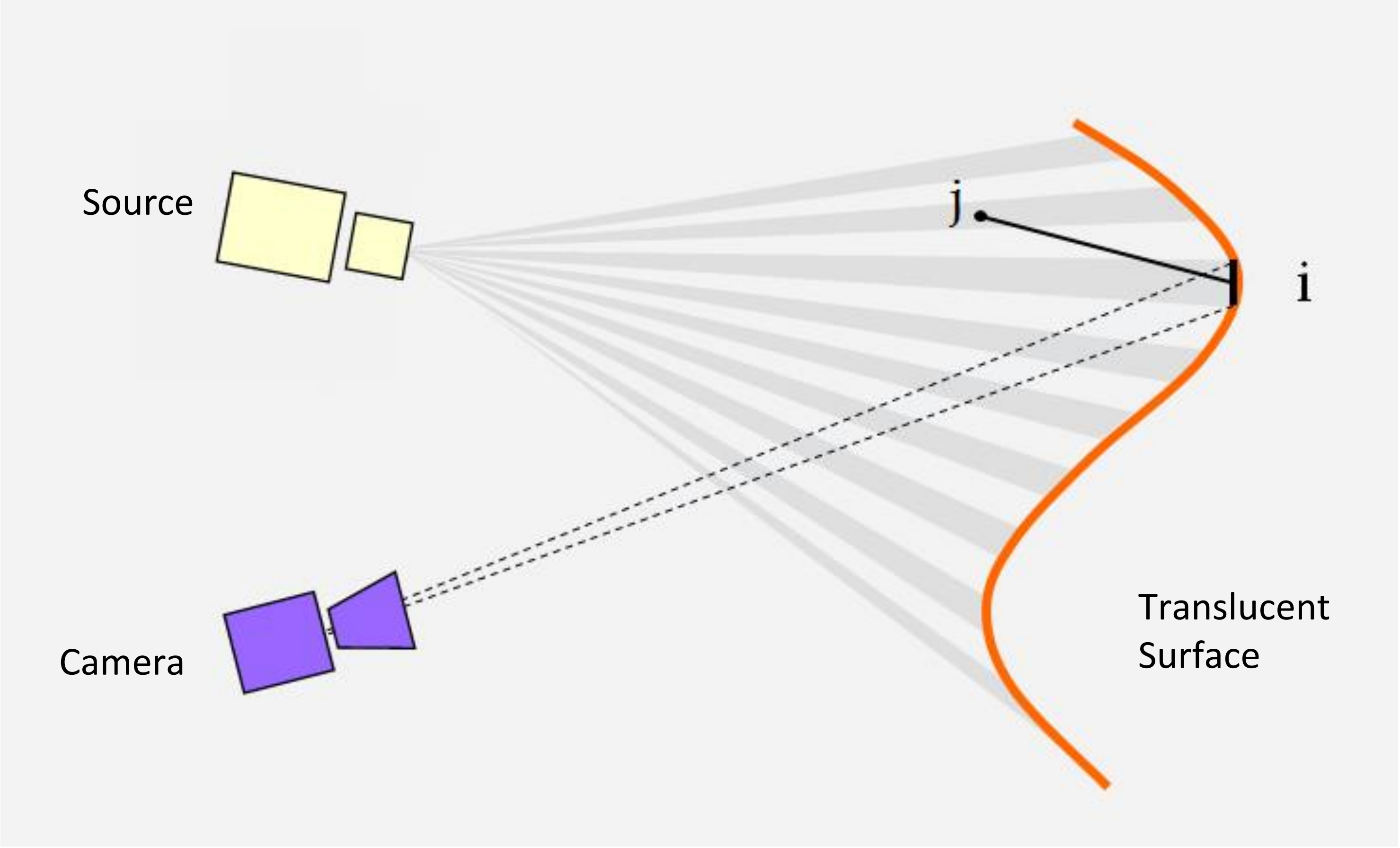
$$L^{+}[c,i] = L_d[c,i] + \alpha L_g[c,i] + b(1-\alpha) L_g[c,i]$$

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

Subsurface Scattering

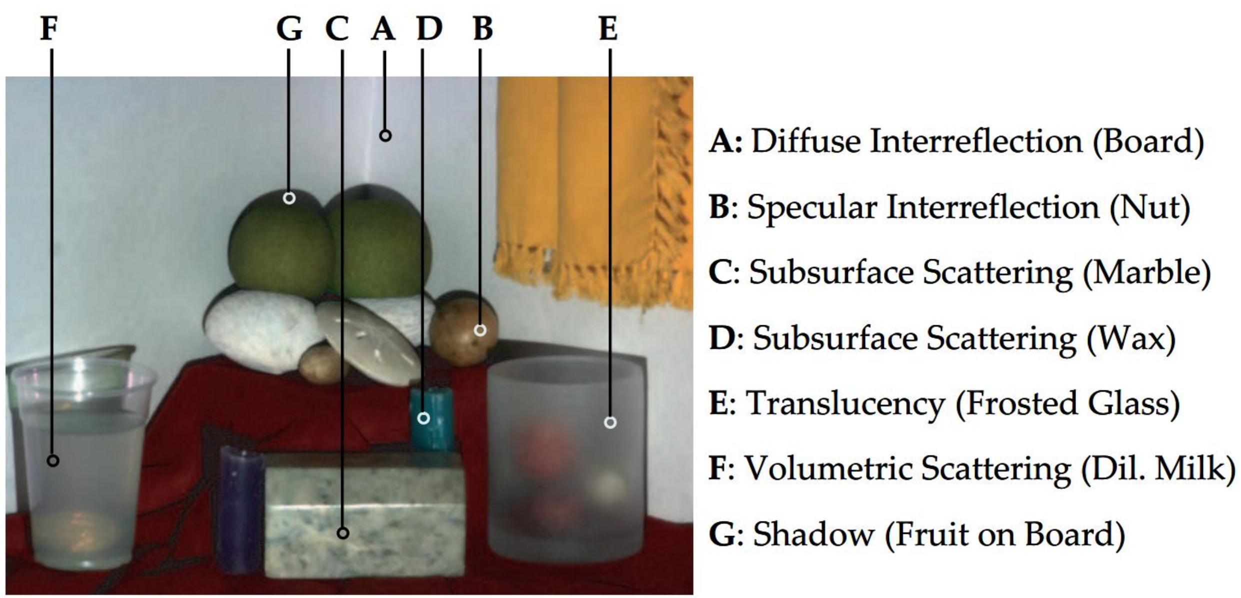


Volumetric Scattering



Experiment System

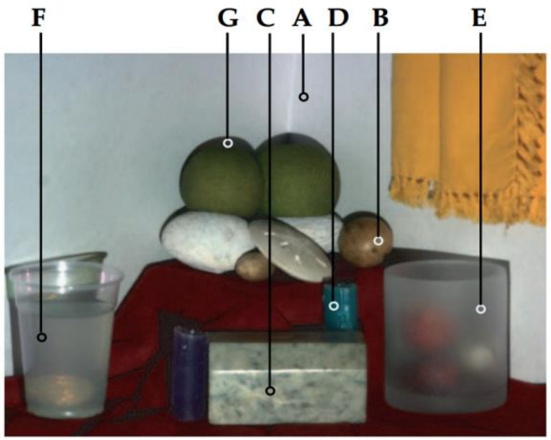
- Using a scene with variety of physical phenomena
- Scene is lit with a 1024x768 Projector
- Images were captured with a same size (1024x768) camera
  - Due to the Bayer filter and the noise it incurs
  - 32 takes of the same scene was averaged per image



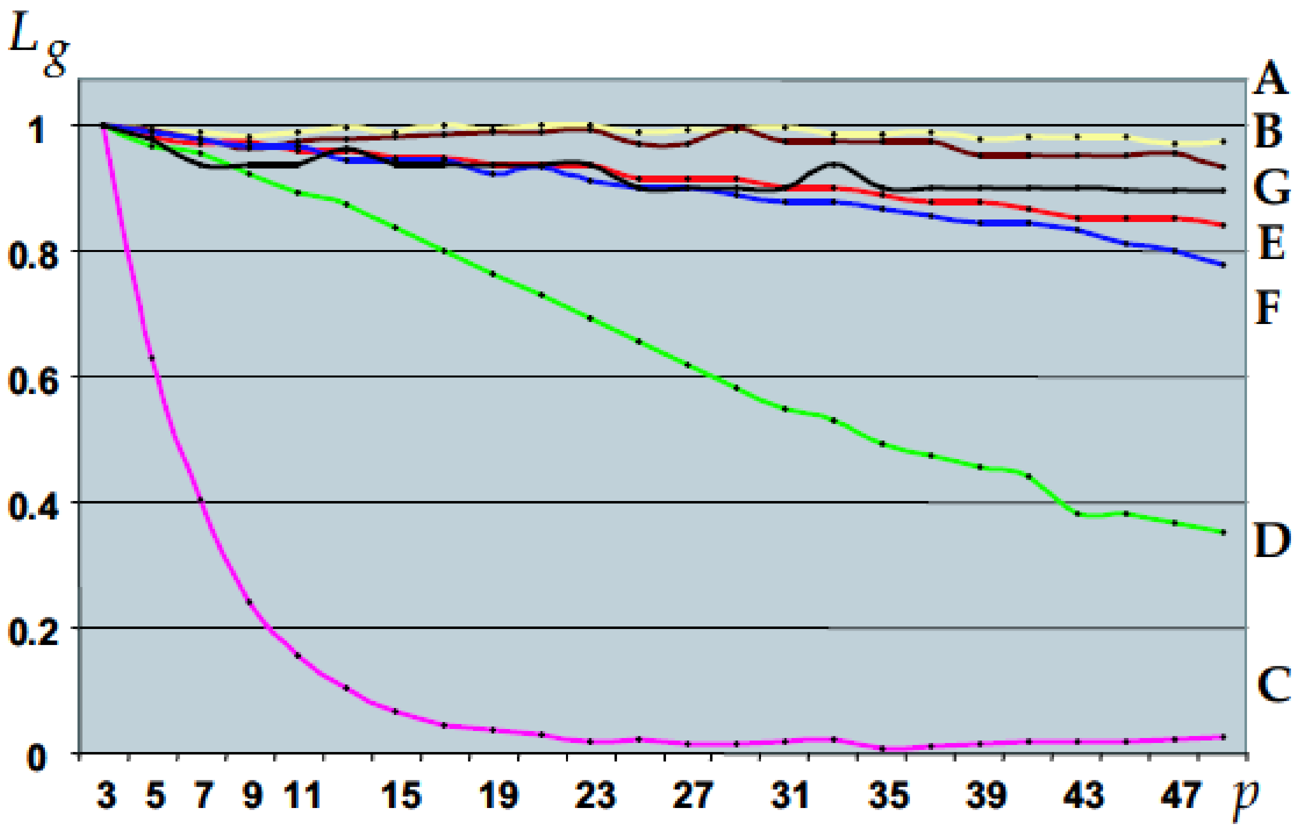
Experiments

- Experiment 1
  - Vary the size of the illumination patch used to construct the high frequency pattern
  - From 3 to 11
- Experiment 2
  - Lit the scene with 100 different illumination patterns
  - Kept points of interests unlit @ 6x6 patch
- Experiment 3
  - Vary alpha
- Experiment 4
  - Vary the frequency of the checkerboard patterns

Experiment 1: Unlit Surrounding Patch

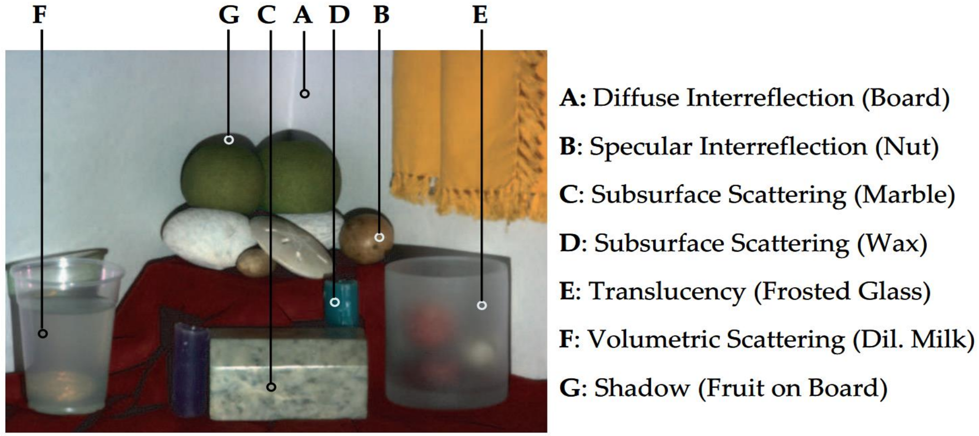


A: Diffuse Interreflection (Board)
B: Specular Interreflection (Nut)
C: Subsurface Scattering (Marble)
D: Subsurface Scattering (Wax)
E: Translucency (Frosted Glass)
F: Volumetric Scattering (Dil. Milk)
G: Shadow (Fruit on Board)



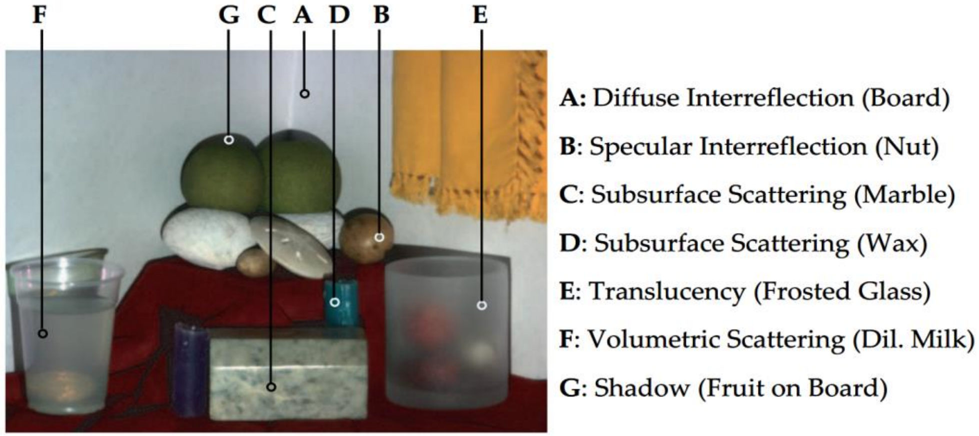
(b)

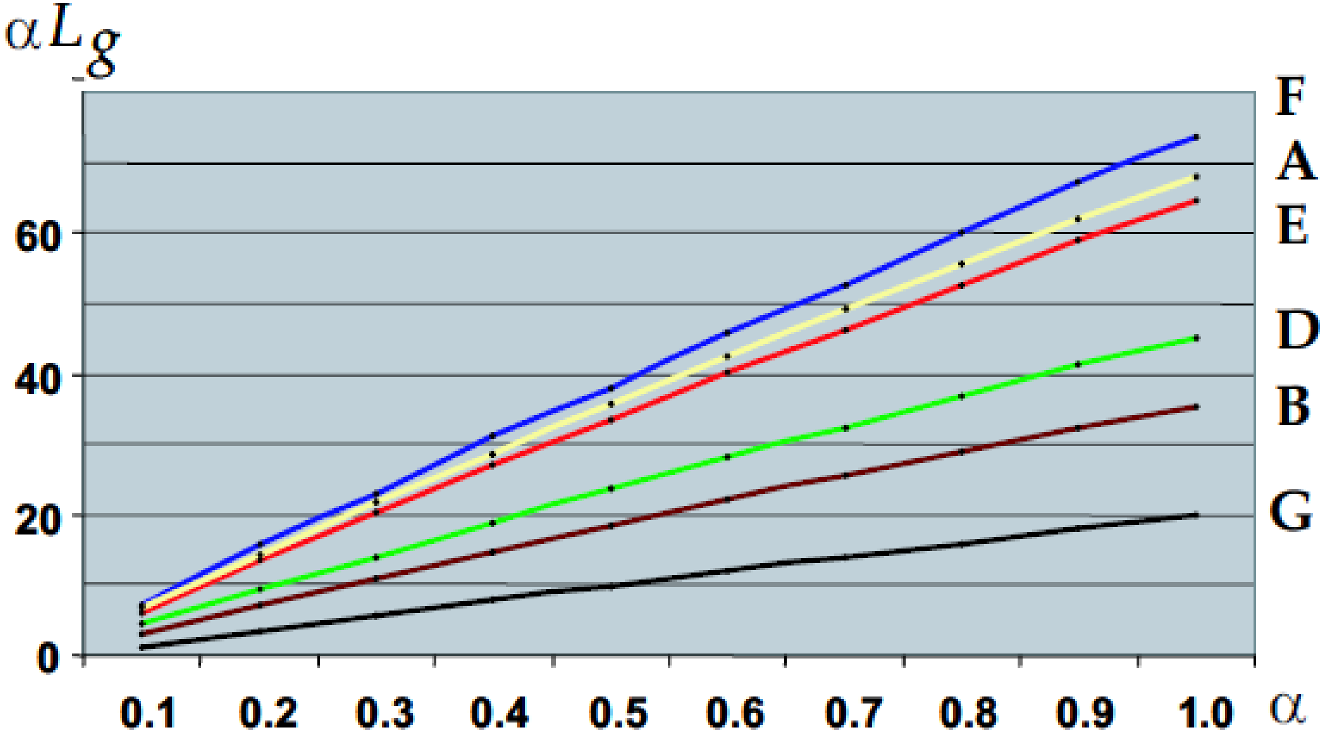
Experiment 2: Randomized Lighting



	A	B	D	E	F	G
mean	68.2	35.1	43.8	67.4	72.4	18.7
std. dev.	2.3	2.2	5.5	2.3	7.1	0.9

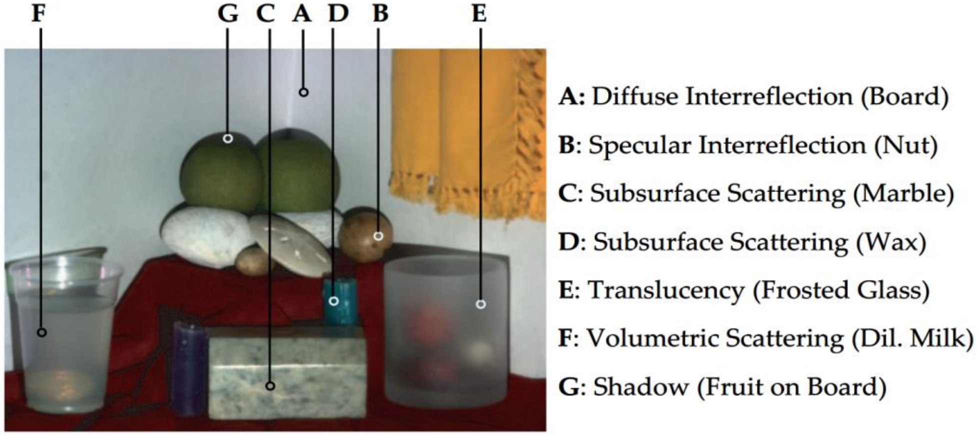
Experiment 3: Alpha Variation

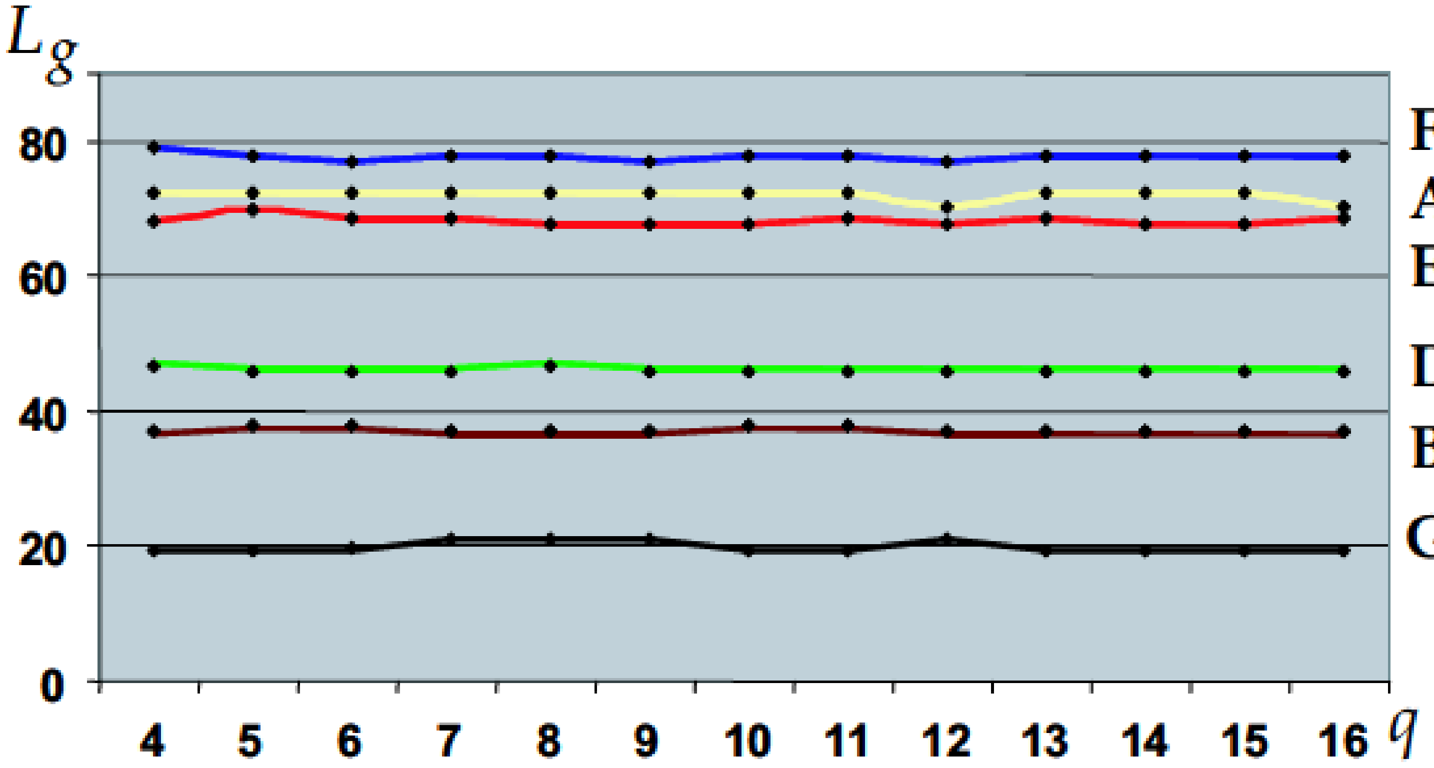




(d)

Experiment 4:
Vary Checkerboard Frequency





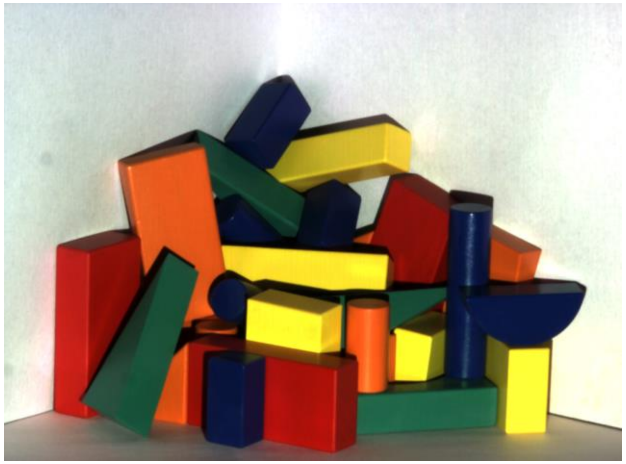
(e)

Checkboard Illumination Shifts

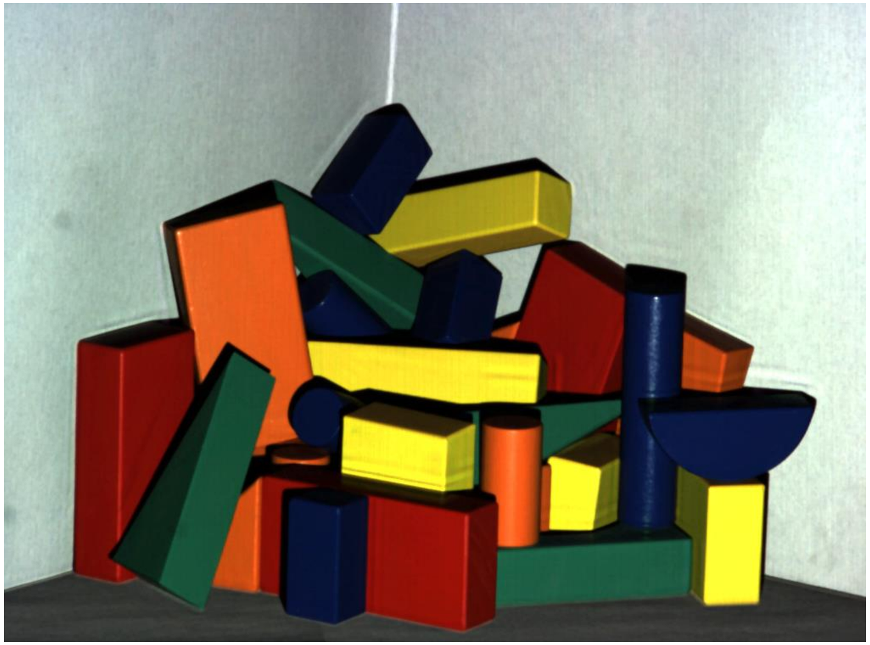
Due to some light-leakage and defocusing from the projector, more than two images were taken to minimize error.

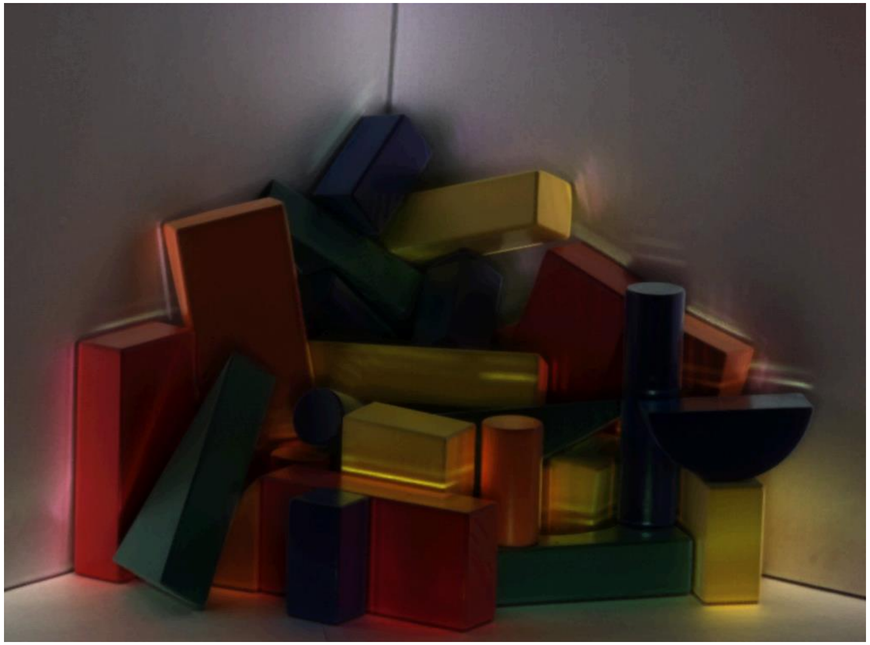
A 8x8 pixel checkboard pattern (alpha = 0.5) was advanced by 3 pixels 5 times in each direction, for a total of 25 images. The min and max (L_{min}, L_{max}) were found per pixel, in turned used for computing direct and global illumination (L_d, L_g)

Results



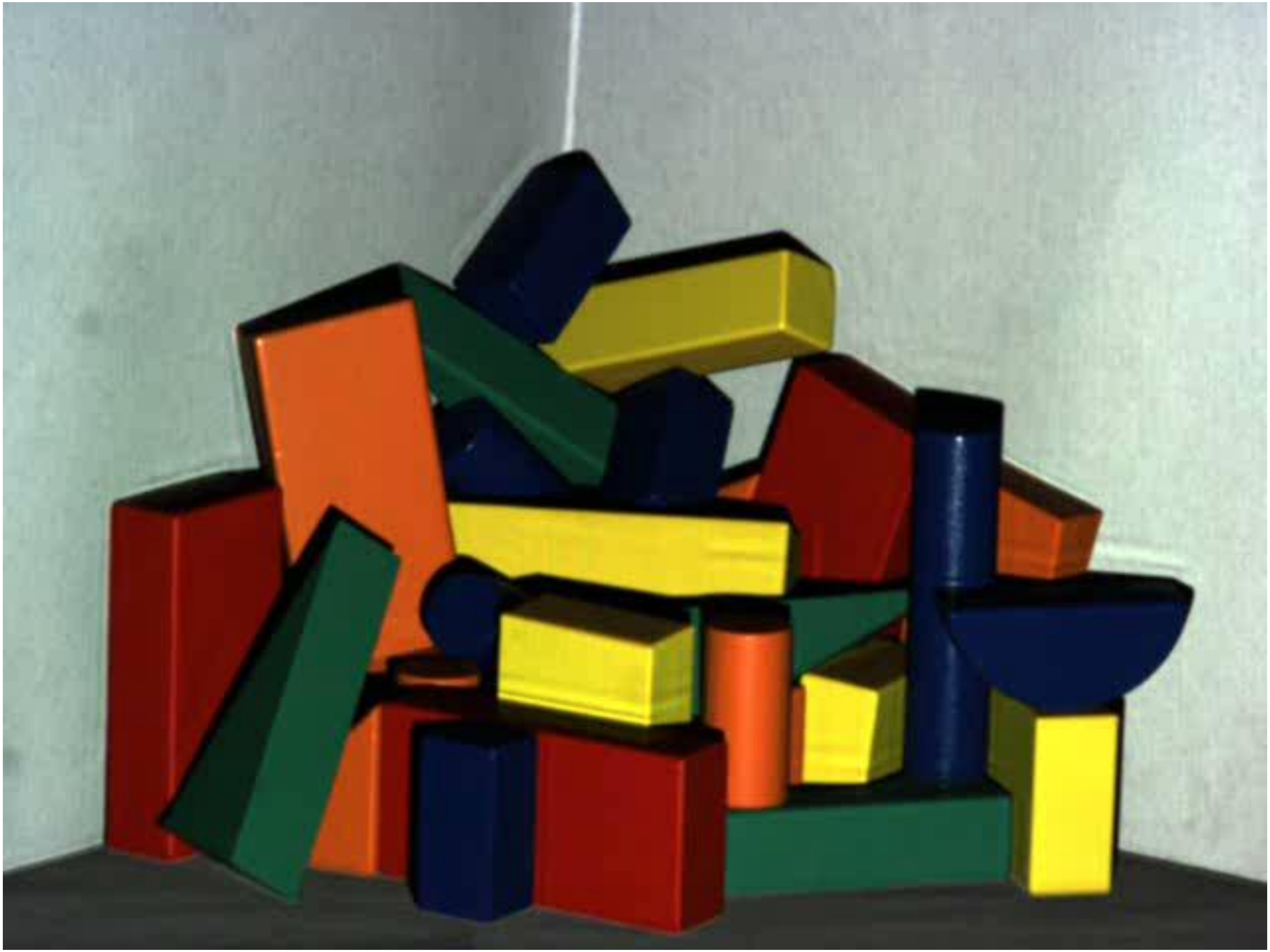
Scene





Direct

Global



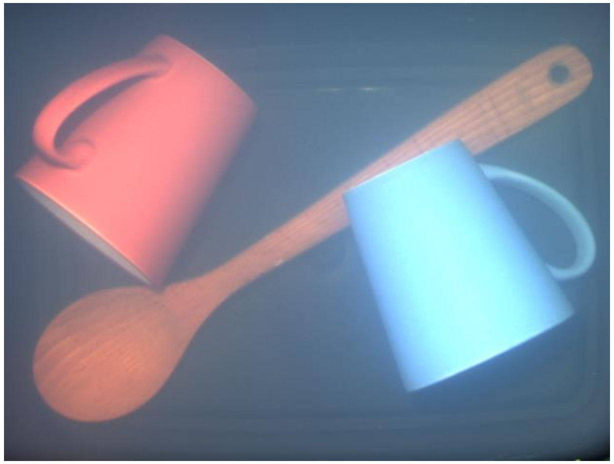
Results

Scene

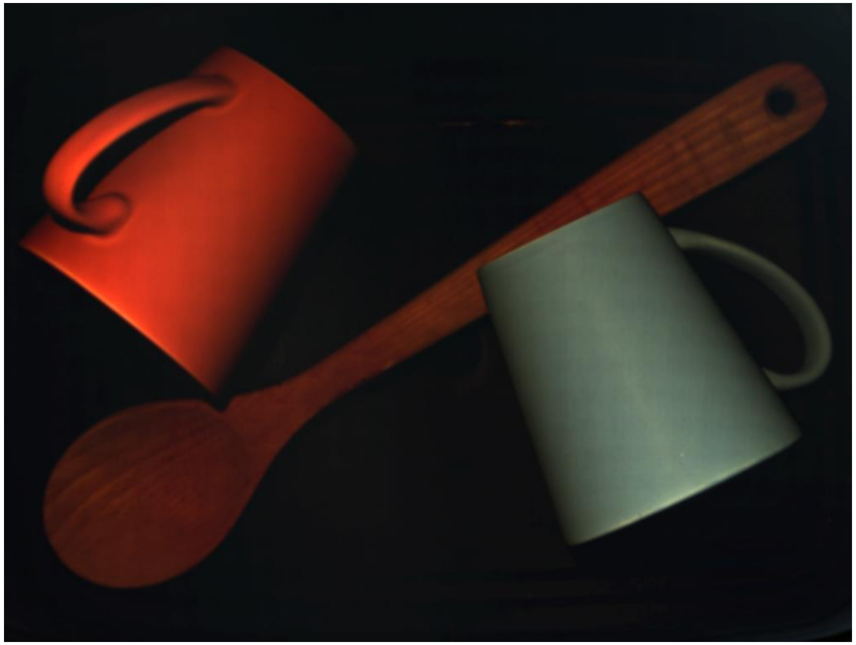
Direct

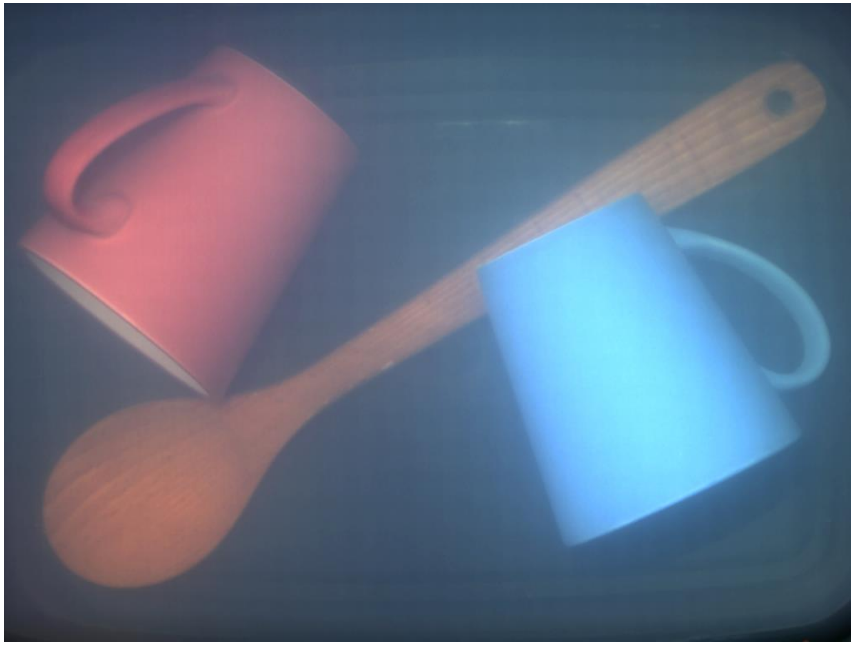
Global

Results



Scene

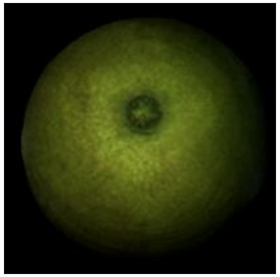


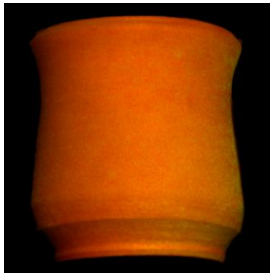


Direct

Global

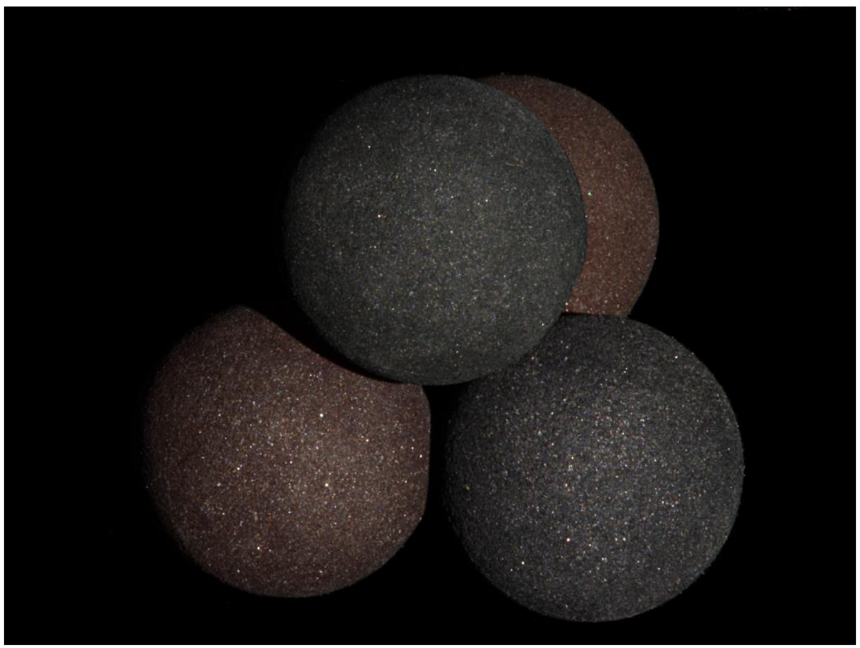
Novel Image

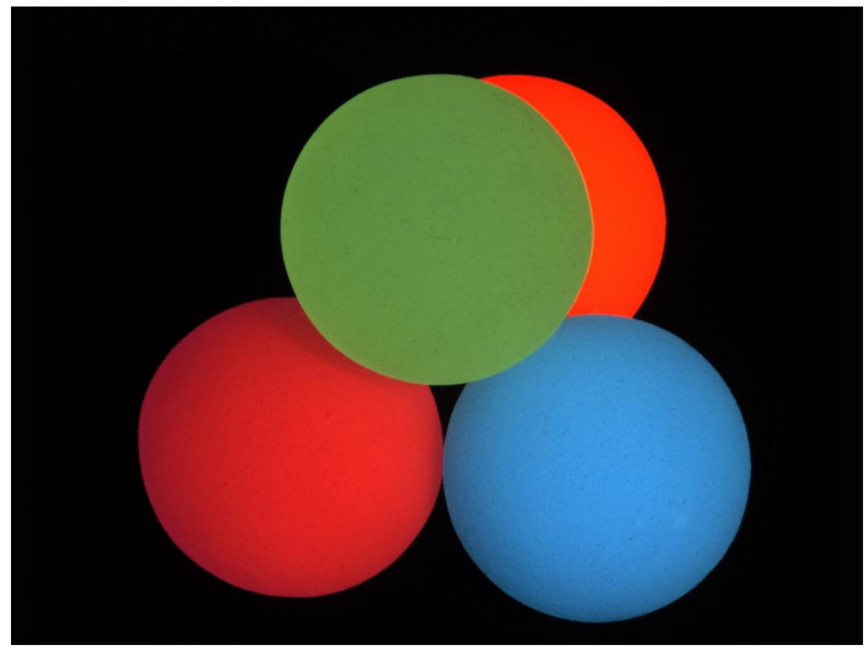




Results

Scene



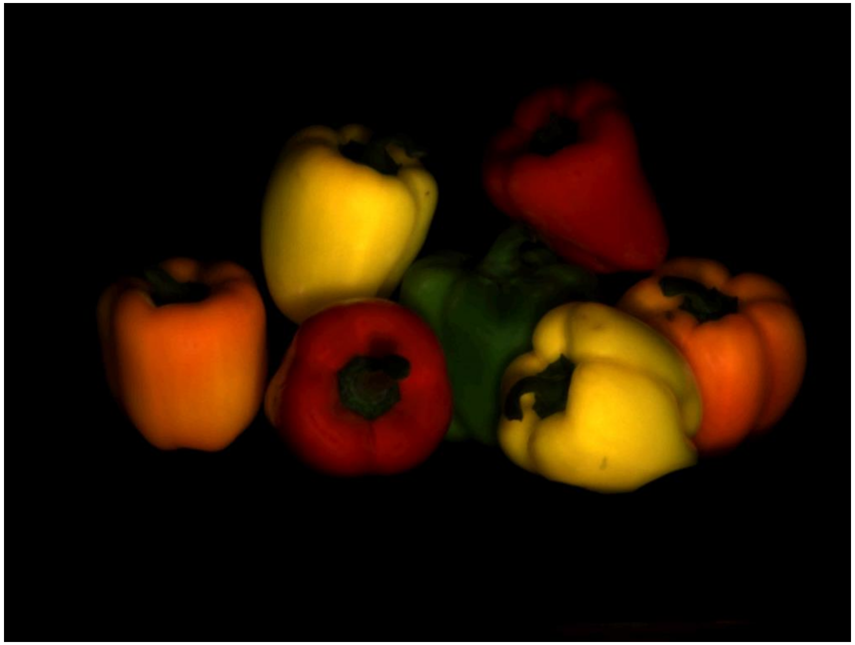


Direct

Global

Results

Scene

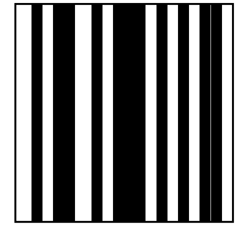


Direct

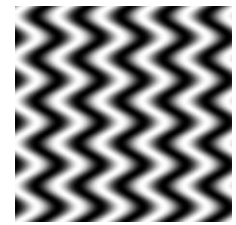
Global

Variants of Separation Method

- Coded Structured Light

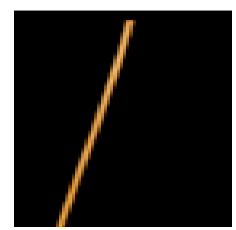


- Shifted Sinusoids

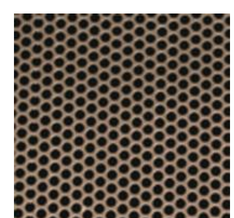


Rather than using a projector, utilize a natural light source and occlude.

- Shadow of Line Occluder



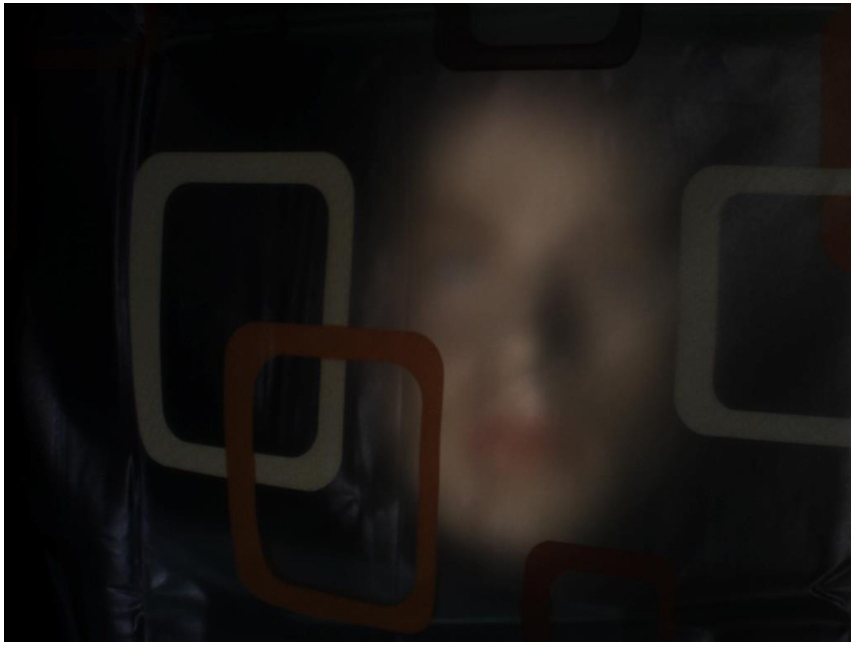
- Shadow of Mesh Occluders



Results

Scene

Direct



Global

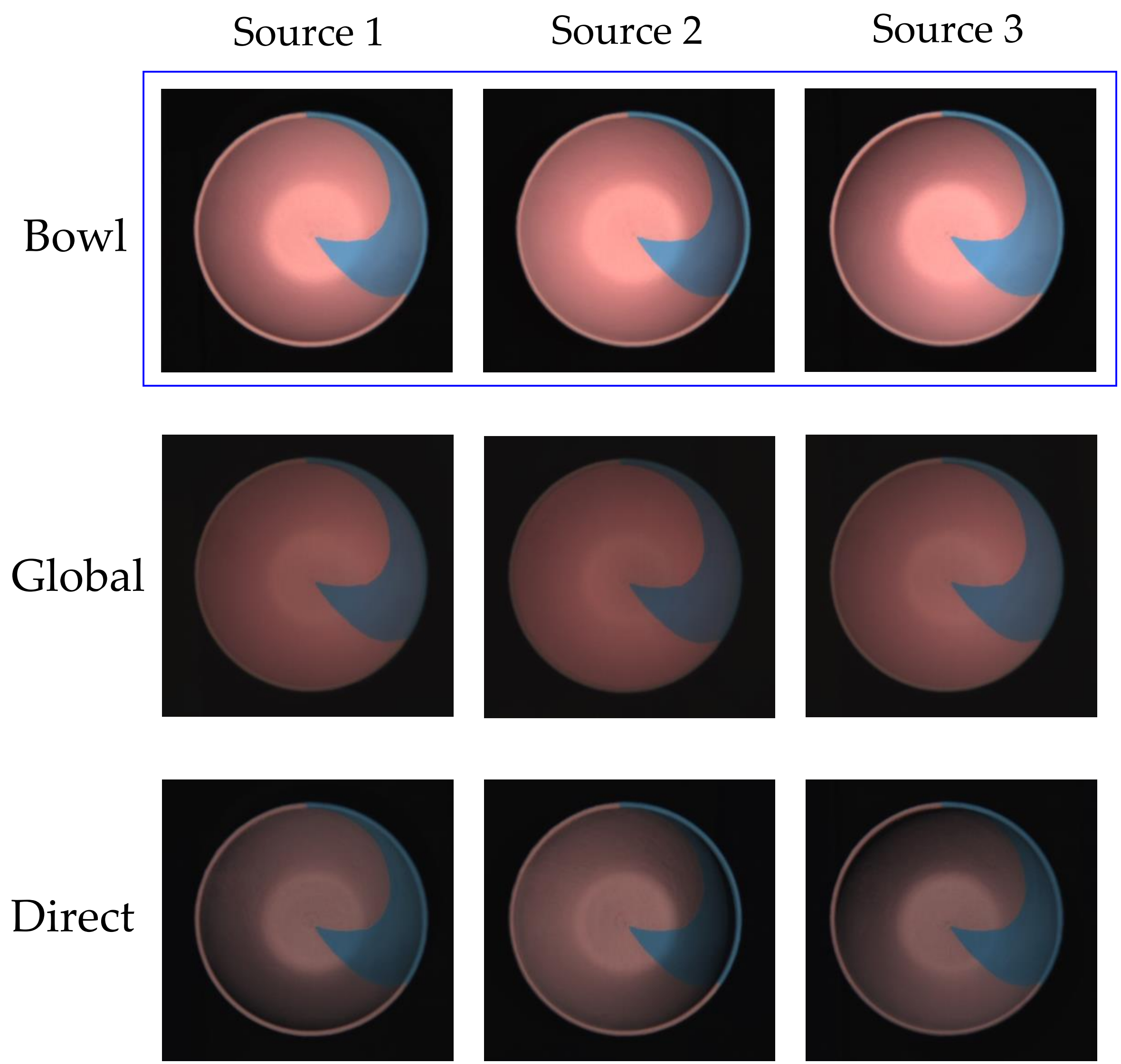
Results

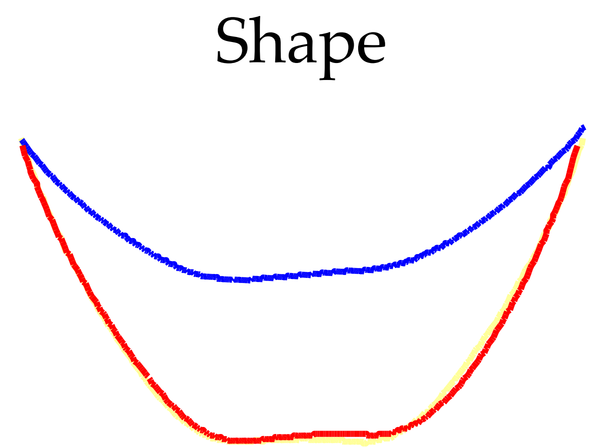
Scene

Direct

Global

Photometric Stereo using Direct Images





Nayar et al., 1991

Single Image Separation

Utilize an n by m window around pixels.

Save the value if it is the min or max in it’s window.

Interpolate to generate full resolution image.

Reduce resolution by a factor of k through averaging.

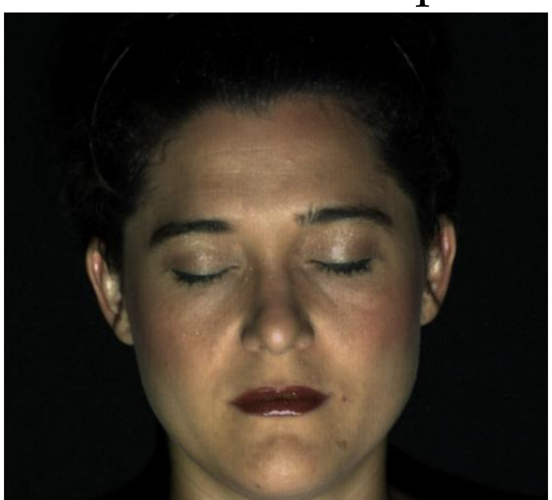
Face: Without and With Makeup

Without Makeup

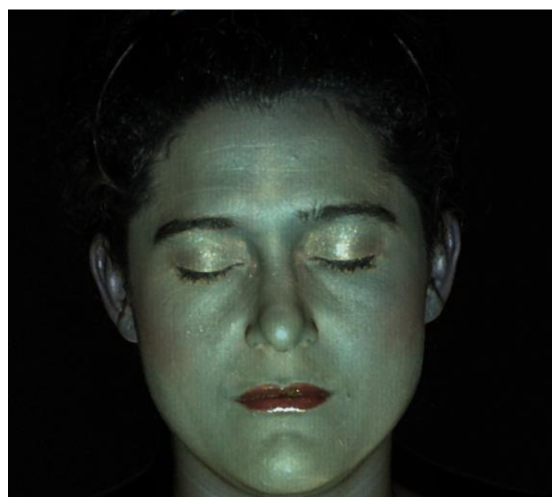
Direct

Global

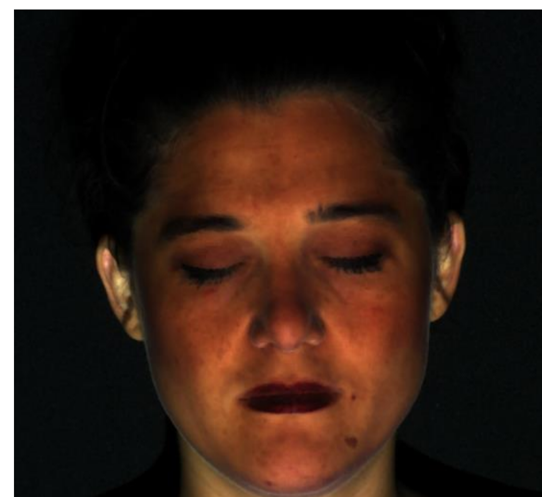
With Makeup



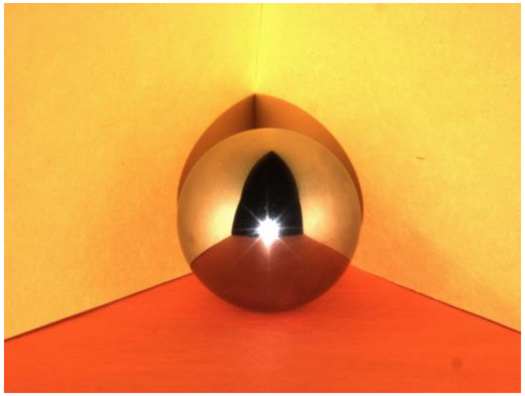
Direct



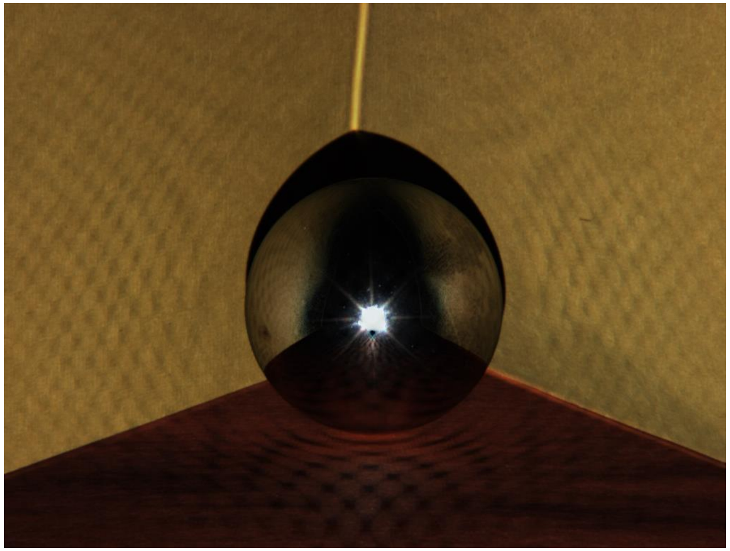
Global

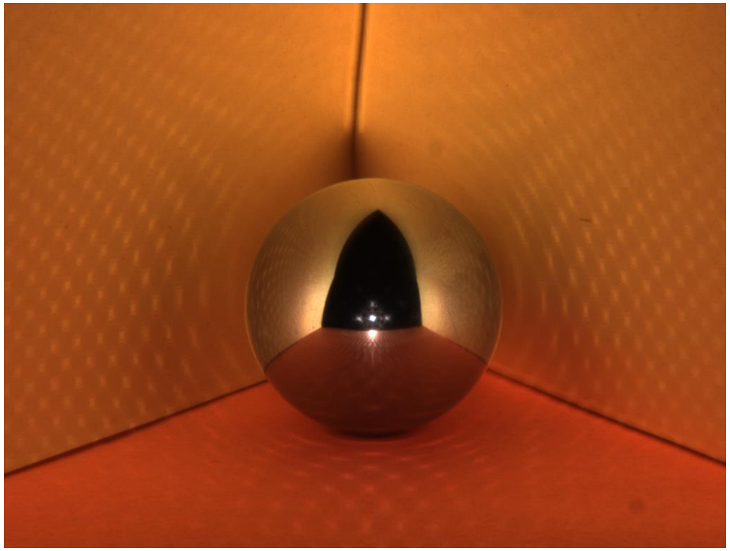


Failure Case



Scene





Direct

Global

Score: 2 (accept)

Pros:

- Simple Concept
- Lots of results
- Photometric Stereo confirmation

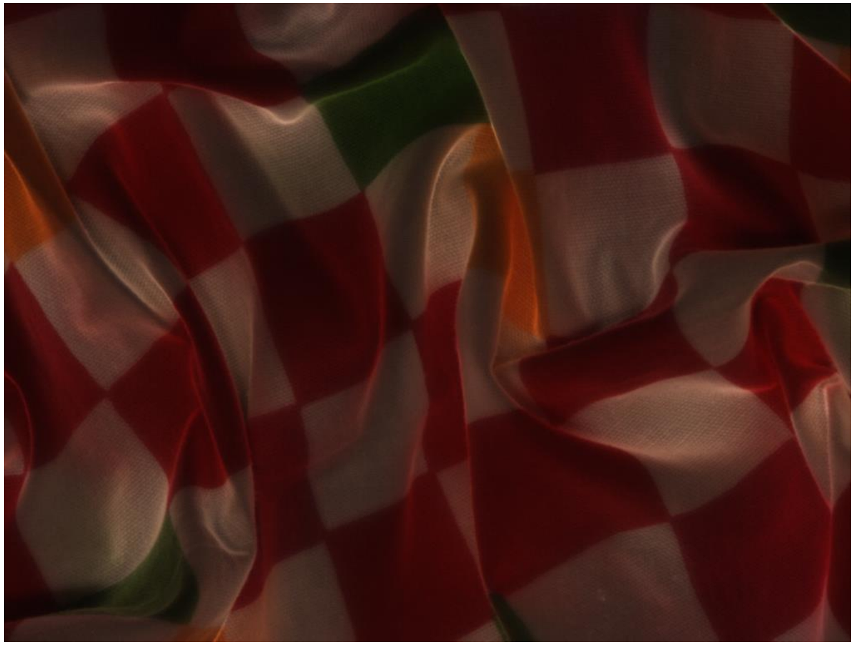
Cons:

- Mainly qualitative approach for proving effectiveness
- Appendix could be clarified
- No details on how source occluders were removed from images

Additional Results

Results

Scene



Direct

Global

Results

Scene

Direct

Global