BRDFs

CS535

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Dimensionality of Appearance

$$(x, y, t, \theta, \phi, \lambda)_{in} \rightarrow (x, y, t, \theta, \phi, \lambda)_{out}$$

General function = 12D

↓ Assume time doesn't matter (no phosphorescence)

Assume wavelengths are equal (no fluorescence, raman scattering)

Scattering function = 9D

↓ Assume wavelength is discretized or integrated into RGB

(This is a common assumption for computer graphics)

Single-wavelength Scattering function = 8D

$$(x, y, \theta, \phi)_{in} \rightarrow (x, y, \theta, \phi)_{out}$$

(this diagram thanks to Srinivasa Narasimhan)

$$(x, y, \theta, \phi)_{in} \rightarrow (x, y, \theta, \phi)_{out}$$

Single-wavelength Scattering function = 8D

Ignore subsurface scattering (x,y) In = (x,y) out

Ignore dependence on position

Bidirectional Texture Function (BTF)

Spatially-varying BRDF (SVBRDF) = 6D

Bidirectional Subsurface Scattering Distribution Function (BSSRDF) = 6D

Ignore direction of incident light

Ignore dependence on position

Ignore subsurface scattering

Light Fields, Surface LFs = 4D

$$(x, y, \theta, \phi)_{out}$$

BRDF = 4D

$$(\theta, \phi)_{in} \rightarrow (\theta, \phi)_{out}$$

Assume isotropy

Assume Lambertian

3D

Measure plane of incidence

Texture Maps = 2D

$$(x, y)_{out}$$

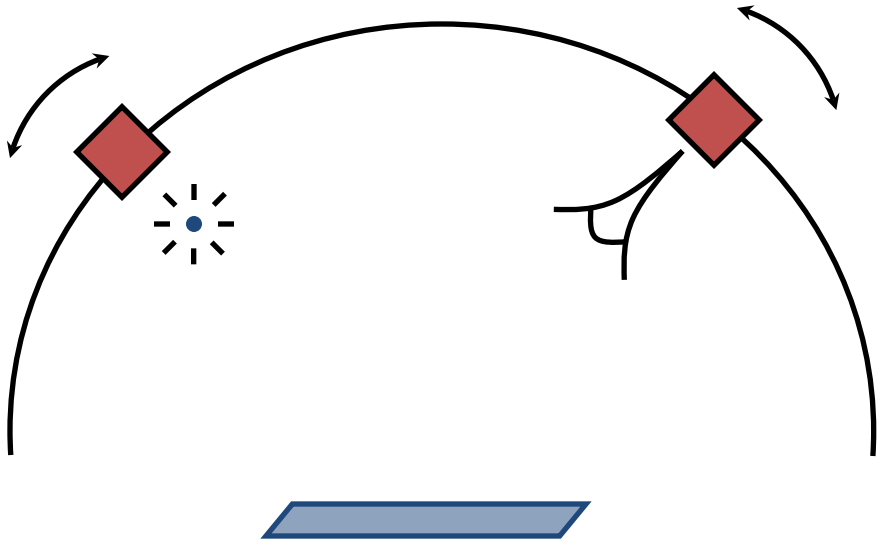
2D

Low-parameter BRDF model

0D

2D/4D BRDF Measurements

- Sample incoming light directions and outgoing reflections over a 1- or 2-D space

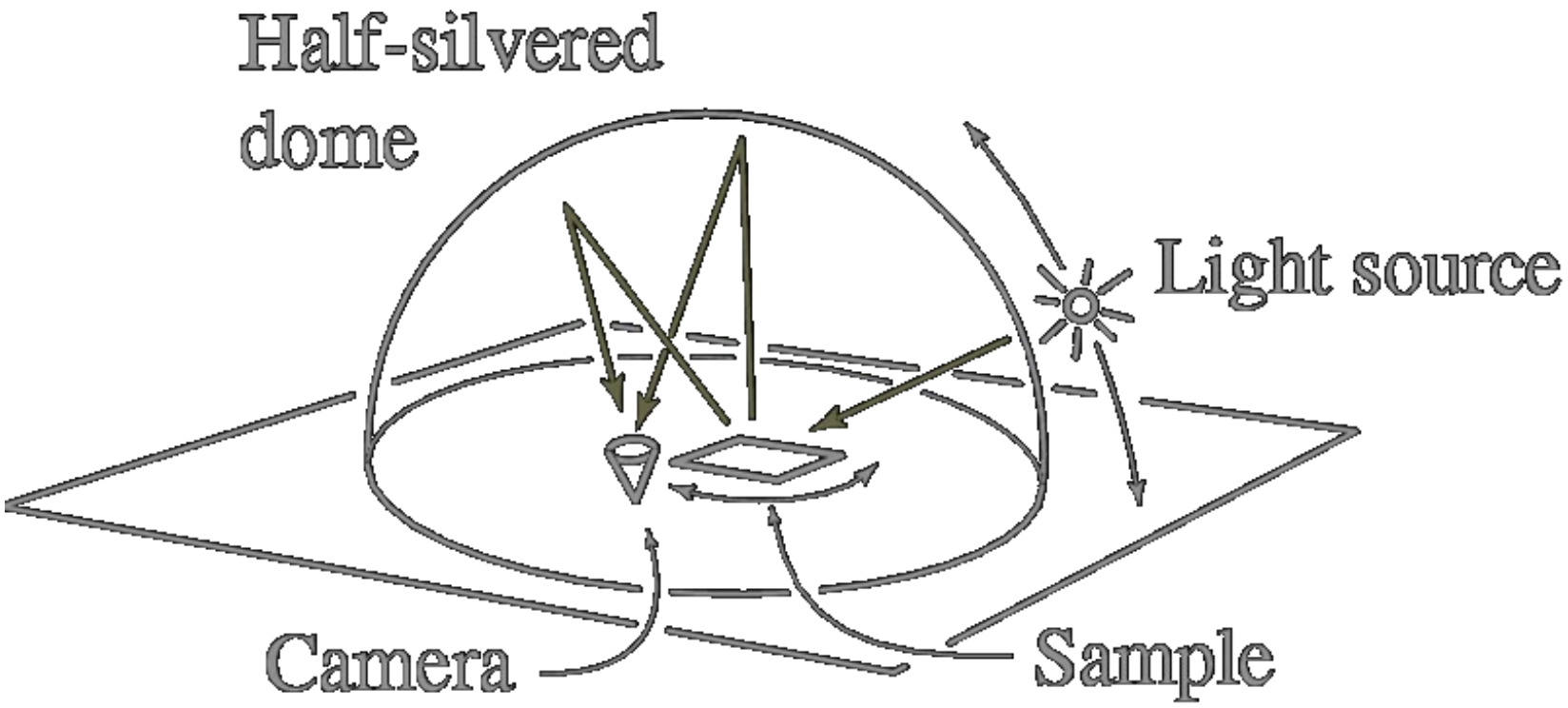


Gonioreflectometers

Image-Based BRDF Measurement

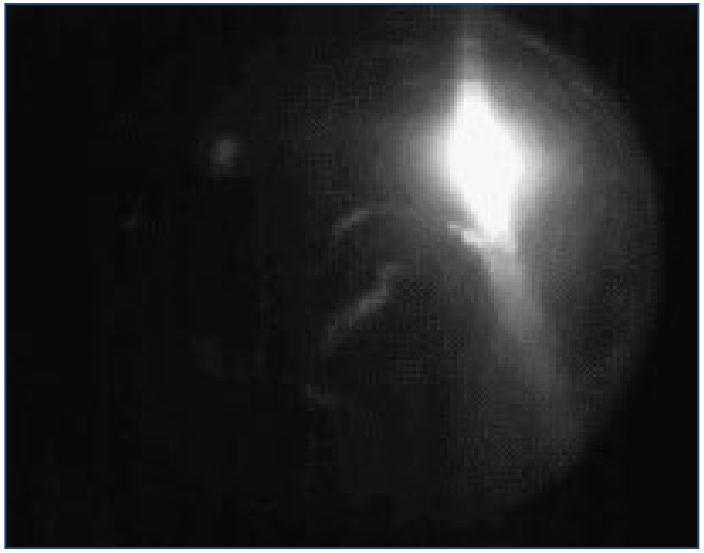
- A camera acquires with each picture a 2D image of sampled measurements
  - Requires mapping light angles to camera pixels

Ward's BRDF Measurement Setup



Ward's BRDF Measurement Setup

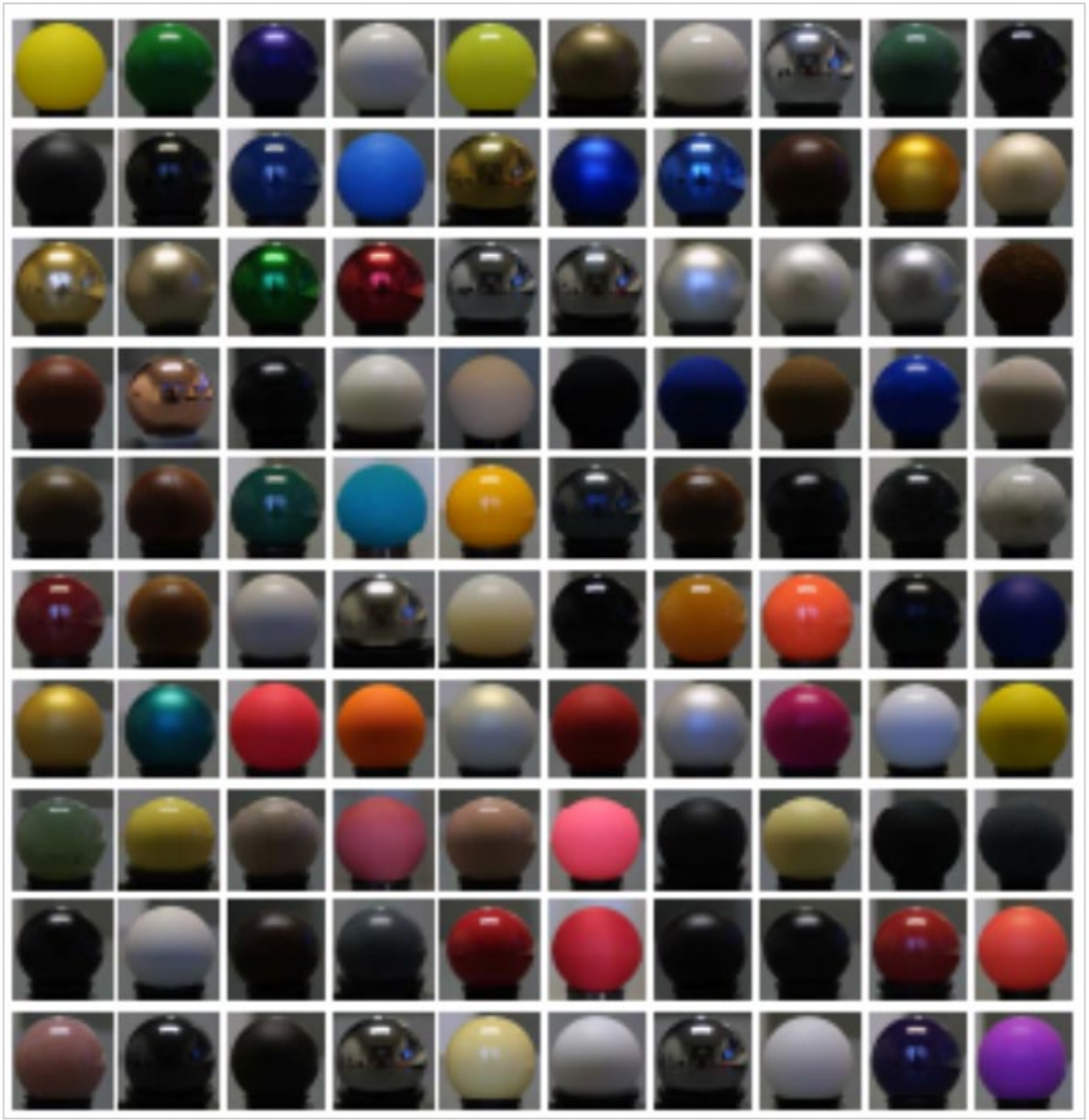
- Each picture captures light from a hemisphere of angles



How to get?

MIT/MERL BRDF Database

- 20-80M reflectance measurements per material
- ~100 materials
- Each material discretized into 90x90x360 = 3M bins per color channel



4D BRDF Reparameterization

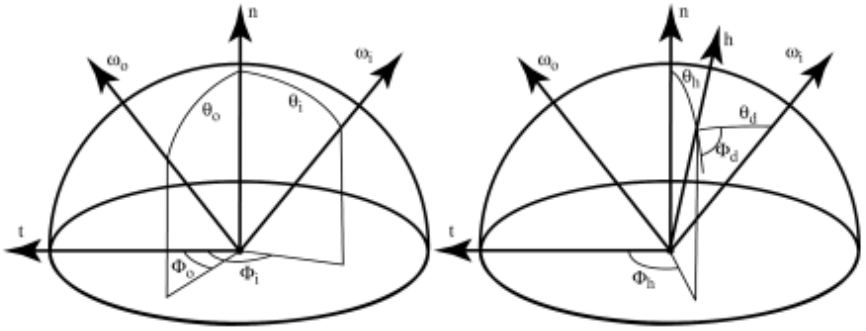
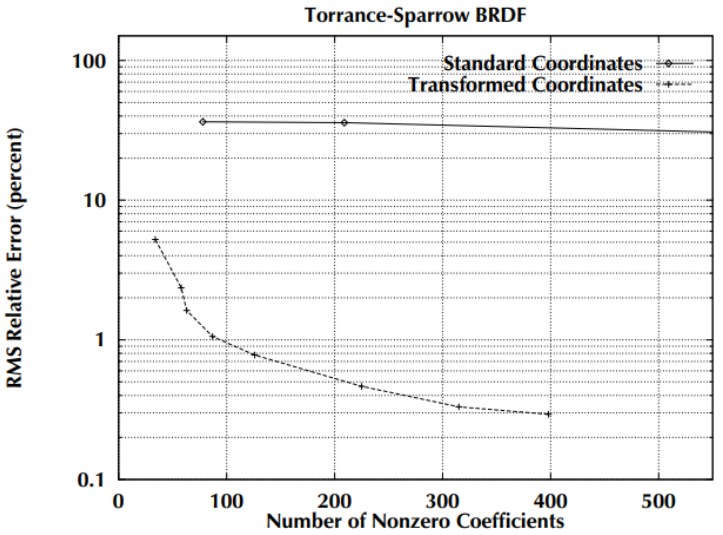


Figure 3: The standard coordinate frame is shown on the left. Rusinkiewicz's coordinate system is shown on the right.

- Instead of (θ_i, ϕ_i) and (θ_o, ϕ_o), use half-angle (θ_h, ϕ_h) and diff angle (θ_d, ϕ_d)
  - (recall half angle is halfway between incidence+reflection)
- Why? Why?
  - New parameterization can move compactly represent BRDF characteristics, thus needing less bins, and less dimensions

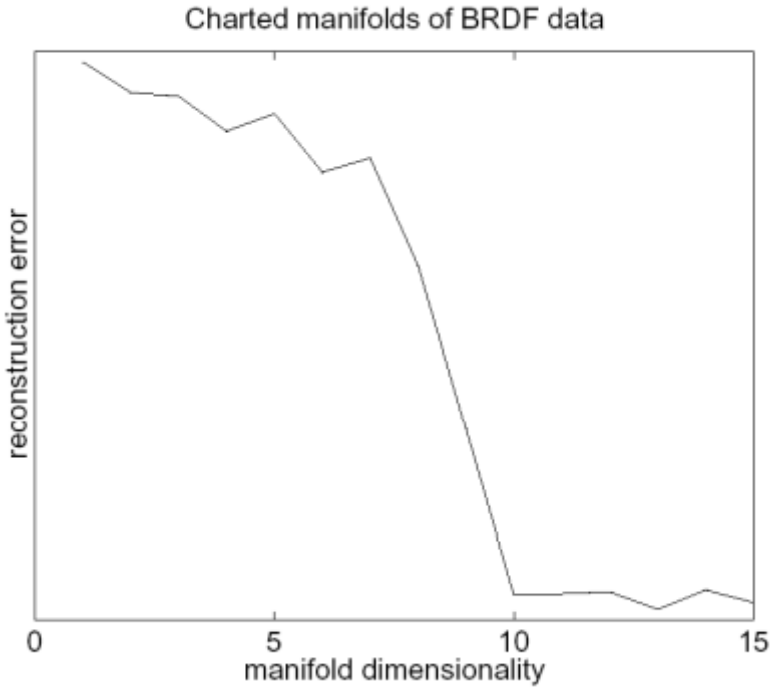


Basis Analysis

- Linear embedding
  - Each 3 color BRDF assembled into a 4M dimensional vector
  - Total of 104 materials
  - 4374000 x 104 measurement matrix X
  - SVD applies to $X^T X$
  - Shows about 30-40 principal components sufficient (at 45, error is <1%)
  - However, this space allows non-physical materials

Basis Analysis

- Nonlinear dimensionality reduction
  - Various methods studied
  - 10-15 dimensions more than enough



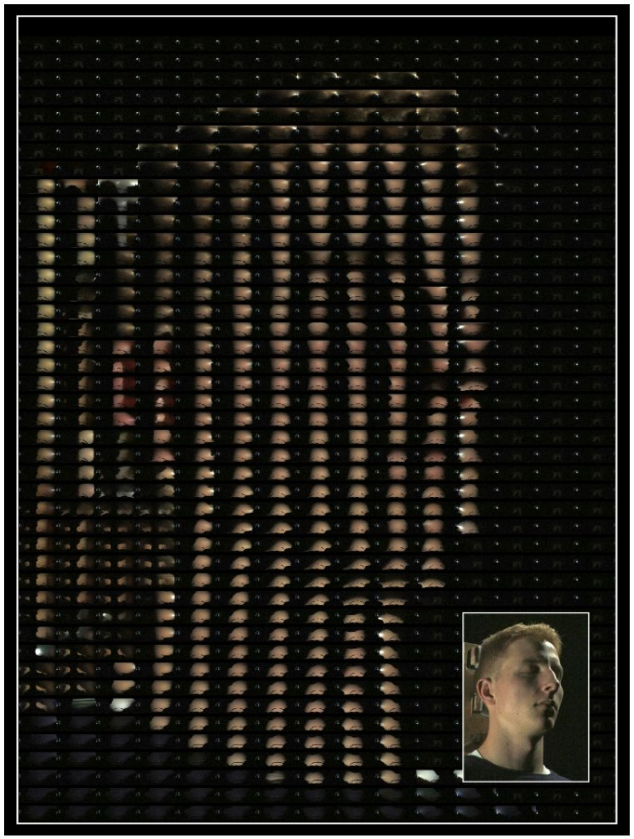
MIT/MERL BRDF Database

- Example usage…

Figure 6: Rendered teapots using BRDFs from our database: nickel, hematite, gold paint, and pink fabric.

Another option…

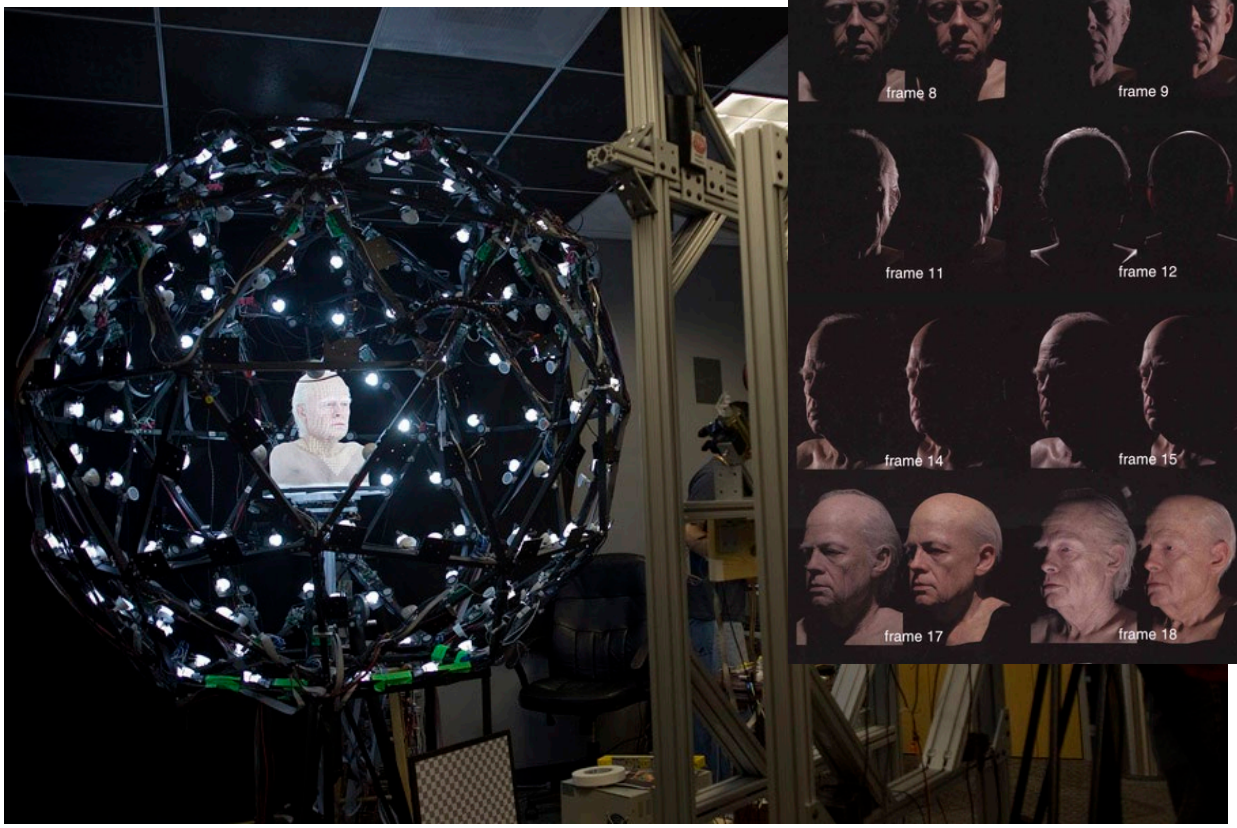
- Don’t bother with resampling and reconstruction, just acquire all options!



Debevec et al.: Light Stage 1

Benjamin Button…

- Light Stages



Light Stages

- Up to 8M in diameter
- Up to 6,666 LED lights
- Up to 990 Hz frames per second

  (33 repeating light conditions)