Image-Based Reflectometry

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Why Measure Reflectance?

- Faithfully represent real materials
- Avoid manual parameter tuning
- Discover how real surfaces behave
- Develop new reflectance models
BRDF

\[ \rho(\omega_i, \omega_e) = \frac{dL_e}{dI_i} = \frac{\text{exitant radiance}}{\text{incident irradiance}} \]

“Bidirectional Reflectance Distribution Function”
BRDF Properties

- Reciprocity
- Energy conservation
- Isotropy
Modes of Reflection

Lambertian

Specular

Off-Specular
Modes of Reflection

- Retroreflection
- Near Horizon
Measurement Challenges

• High-dimensional domain
  – 4 dimensions of angle; 5 with wavelength
  – Many samples required; slow measurements

• Confounding reflectance and geometry

• Dynamic range
A Simple Gonioreflectometer

3 DOF: 2 detector, 1 source

Nicodemus et al. 77
Another Gonioreflectometer

3 DOF: 2 sample, 1 detector

Torrance & Sparrow 65; Dana et al. 96
Image-Based Measurement

- Image sensor replaces mechanical DOFs
- Advantages
  - speed
  - simplicity of apparatus
  - use of off-the-shelf parts
2 DOF: 2 sample

Karner, Mayer, & Gervautz 96
Ward 92

4 DOF: 2 image, 1 source, 1 sample

Half-Silvered Dome

Light source

Camera Sample

Castonguay 93
2+ DOF: 1 image, 1 source (plus 1 sample)
Our Technique

3 DOF: 2 image, 1 camera
Our Generalized Technique

3 DOF: 2 image, 1 camera

Ikeuchi & Sato 91; Sato, Wheeler, & Ikeuchi 97
BRDF Measurement Setup
BRDF Measurement Setup

Camera

Subject

Light Source

Camera
Calibration

• Geometric
  – photogrammetric targets
  – image locations give transformations
  – 3 sets: sample, source, stationary
  – result: automatic, totally flexible calibration
Calibration

• Radiometric
  – camera flat field
  – camera linearity
  – source flat field
  – absolute reflectance
BRDF Measurement Data

Geometry used
Measurement Results: Squash

30°

60°
Measurement Results: Squash
BRDF Measurement Data
Measurement Results: Skin

30°

60°
Measurement Results: Skin
Advantages & Limitations

• Advantages
  – measures curved samples
  – requires little time
  – requires little equipment w/o scanner

• Limitations
  – measures curved samples
  – measures homogeneous samples
  – requires scanner for arbitrary shapes
Future work

- Get rid of scanner: visual hull
- Video for more frames
- Higher dynamic range Debevec & Malik 97
Future Directions

- Integrated approach to surface appearance
  - BRDF
  - milligeometry
  - reflectance variation