Shading

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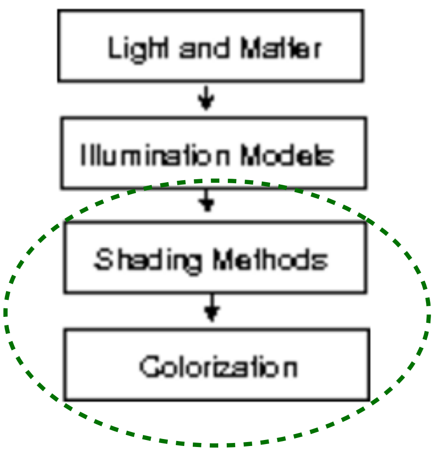
IMPA

Conceptual Framework



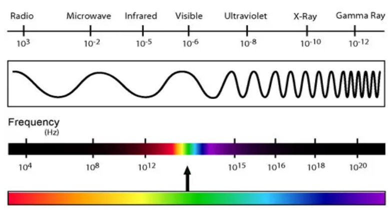
Illumination (Recap)

Study of Light Emission and Propagation

- Light
- Materials
- Transport

Light

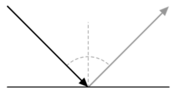
- Dual Model
  - Particle (Photon)
    (Radiant Energy)
  - Wave
    (Electromagnetic Wave)
- Attributes
  - Energy
  - Wavelenght



Transmission

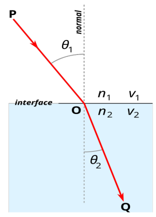
- Geometric Optics
  - Direction
- Interface 2 Medium
  - Reflection

$$\theta_i = \theta_r$$



  - Refraction (Snell's law)

$$\frac{\sin\theta_1}{\sin\theta_2} = n_{21} = \frac{n_2}{n_1} = \frac{v_1}{v_2}$$



- Assumptions
  - No Participating Media

Surface Material

- Boundary Interaction
  - Fresnell Equation
    (function of angle and wavelenght)
- Types
  - Dielectric (Insulating)
    - Translucent (ex: glass)
  - Metal (Conductors)
    - Opaque (ex: copper)
  - Composite (Pigment + Substrate)
    - (ex: plastic, paint)

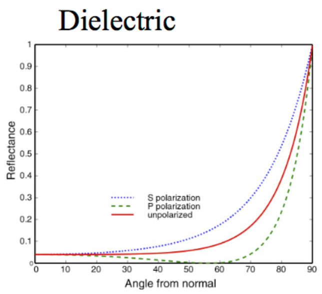
glass

Copper

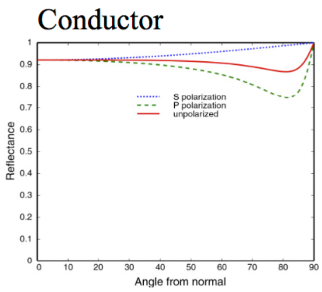
Plastic

Fresnel Reflectance

- **Solution of Maxwell's equations**
  - Depends on: incident angle / light polarization / wavelength



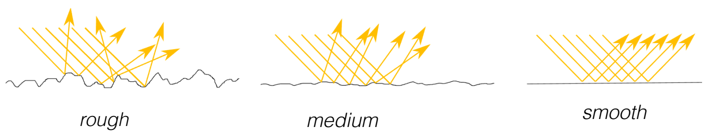
Glass, etc

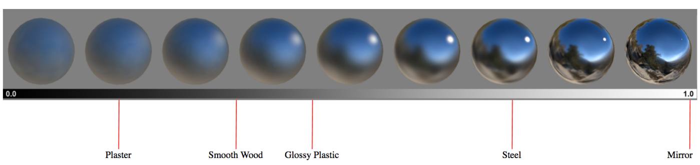


Metals

Surface Geometry

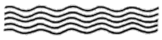
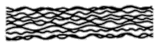
- **Attenuation and Scattering**
  - Microfacet Model
- **Types**
  - Smooth (total transmission / no absorption)
  - Rough (partial transmission / partial absorption)





Local Illumination

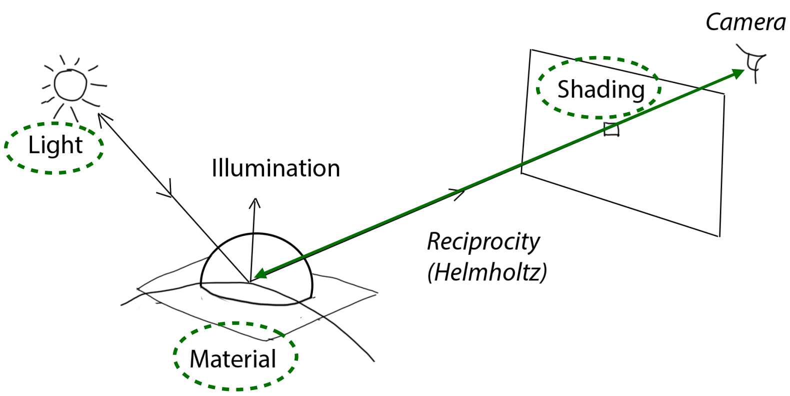
Illumination Mechanisms

- Light Transport
  - Coherent 
  - Incoherent 
- Bidirectional Transport Function

R_M and T_M

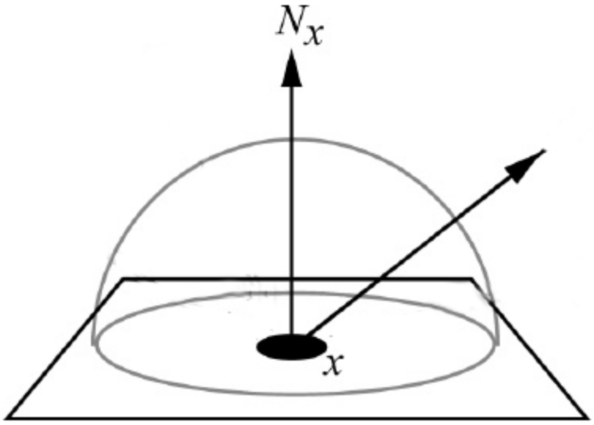
Model (recap)

- **Data Driven Computation**



Render Context

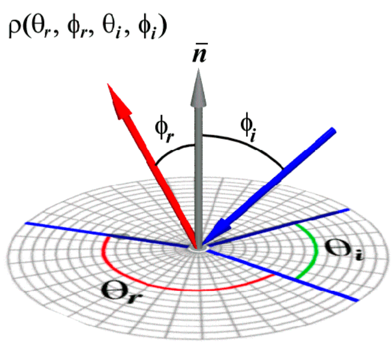
Illumination Hemisphere



- **Tangent plane at point X**

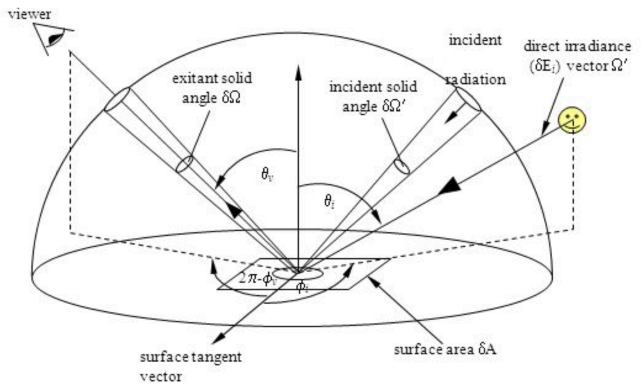
Scattering

- **Bidirectional Reflectance (Transmittance) Function**



Transport Computation

- **Solid Angles / Area Differential**



Configuration of viewing and illumination vectors in the viewing hemisphere, with respect to an element of surface area, δA.

BRDF Representation

- **Analytical Models**
  - Phenomenological / Physical
- **Measured BRDFs**
  - Sampled Data

Bases Functions

Interpolation / Fitting

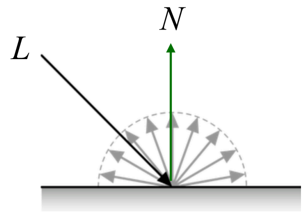
Local Illumination Models

I = Dif + Spec + Trans

Pure Diffuse

(Lambert's law)

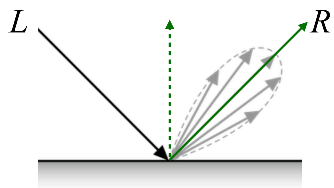
$k_d < N, L >$



Specular

(Phong Approximation)

$k_s < R, L >^n$

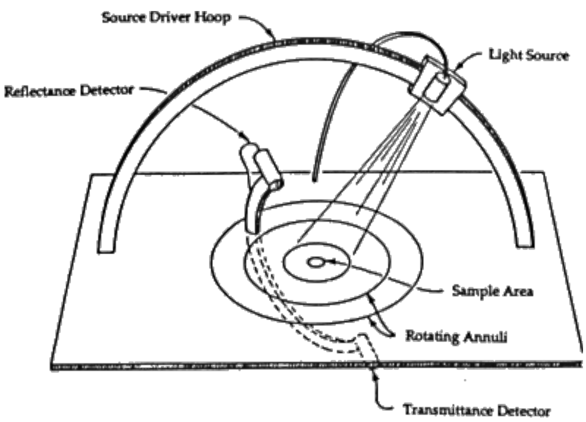


Transmitted

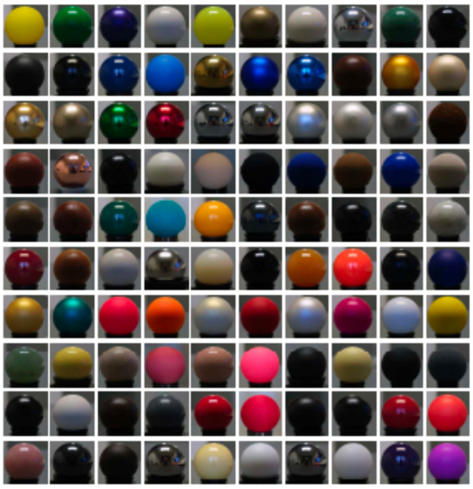
$k_t < T, L >^m$

Measuring BRDFs

- **Apparatus**



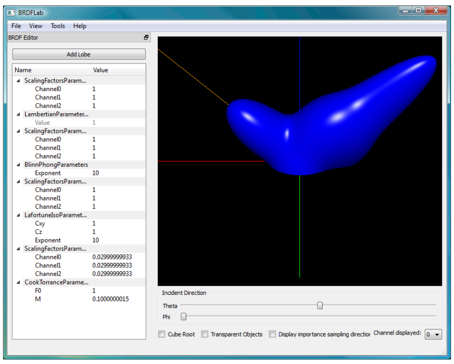
BRDF Measured Data



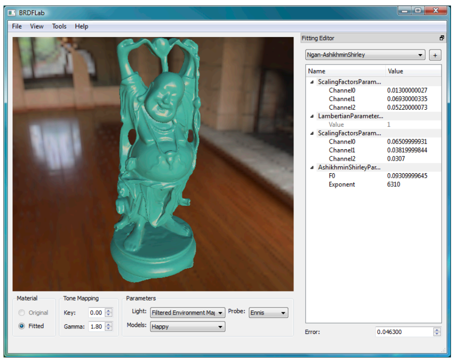
- **MERL BRDF database**

BRDF Lab

- **Design BRDFs**
  - Analytical Models and Measured Data



Display BRDF



Rendering

Materials

Material Types

- Constant
- Matte
- Metal
- Plastic

Boundary Interactions

- BRDF

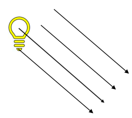
Light Sources

Types

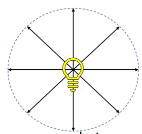
- Directional Light
- Point Light
- Spot Light

Light Coupling

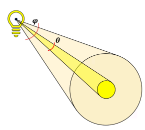
- Visibility



directional



point



spot

Shading

Colorization Function

- Partition

  $$\text{Image} = \cup_i P_i$$

- Domain (continuous)
  - Patches
  - Polygons
  - Micropolygons *
  - Pixels
- Shading
  - Sampling
  - Interpolation

Interpolation Methods

- Flat Shading
  - Constant
- Gouraud Shading
  - Color, Linear
- Phong Shading
  - Normal, Linear

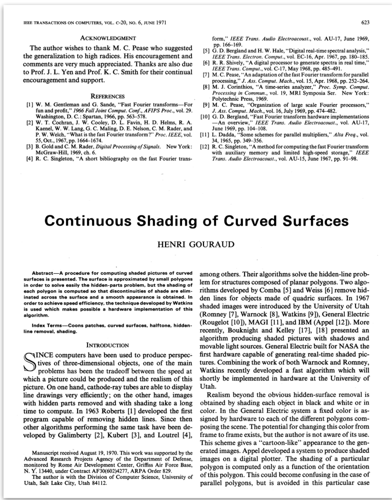
Coloring Functions

- Tone Mapping

Shading Methods

A Bit of History

- From Diffuse to Specular Material Shading



Continuous Shading of Curved Surfaces

HENRI GOURAUD

Gouraud Diffuse Shading

Graphics and Image Processing

W. Newman Editor

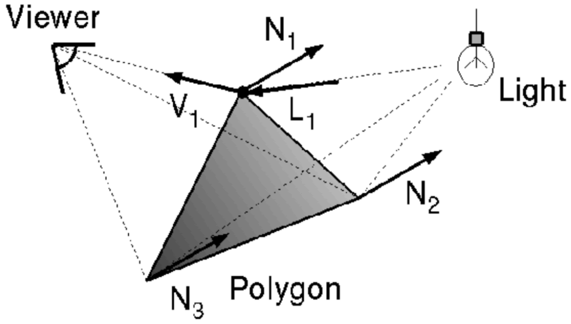
Illumination for Computer Generated Pictures

Bui Tuong Phong
University of Utah

Phong Specular Shading

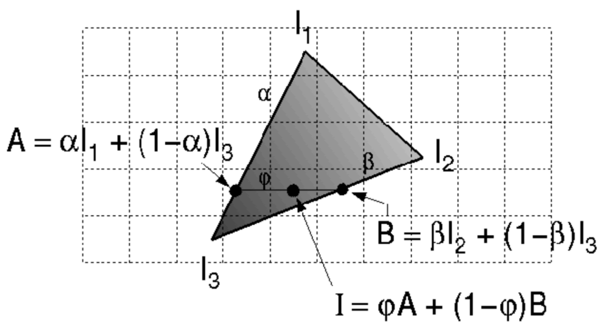
Gouraud Shading

- **Illumination Sampling**
  - One lighting calculation per vertex
    - Assign pixels inside polygon by interpolating colors computed at vertices



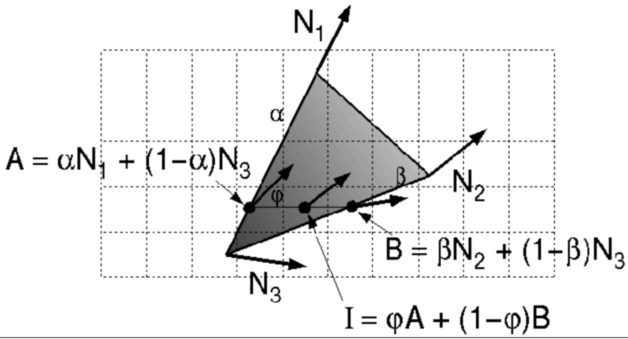
Gouraud Colorization

- **Colorization Function Reconstruction**
  - Bilinearly <u>interpolate colors</u> at vertices down and across scan lines



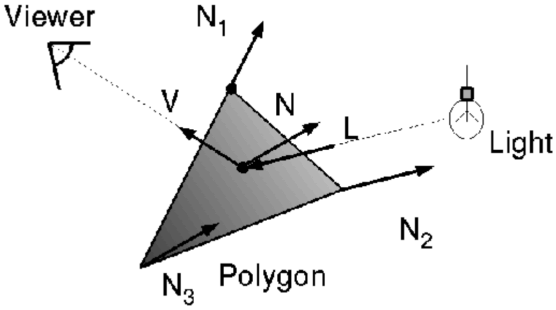
Phong Shading

- **Geometry Reconstruction**
  - Bilinearly interpolate surface normals at vertices down and across scan lines



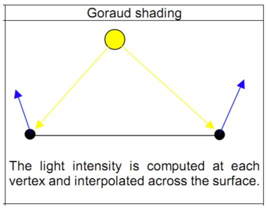
Phong Shading

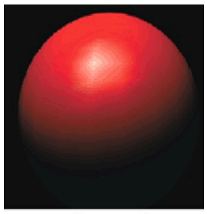
- **Illumination Sampling**
  - One lighting calculation per pixel
    - Approximate surface normals for points inside polygons by bilinear interpolation of normals from vertices



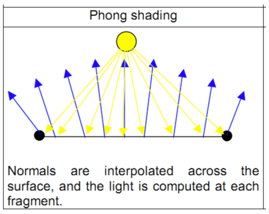
Comparison

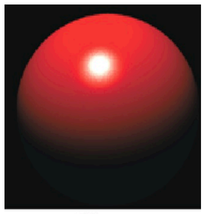
- Diffuse vs. Specular Materials





Gouraud





Phong