Surface Appearances

- Surface
  - rough, matte, smooth, reflective, …
- Lighting
  - diffused, point, parallel, background, …
- Camera
  - white balance, iris, sensor, …

Surface reflectance models

- Determines how light is reflected by surface
- Essential in surface rendering
- Diffuse, specular, hybrid
- Difficulty in realistic rendering, e.g. skin, material

Surface reflectance function

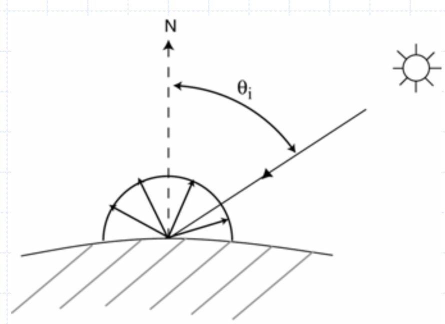
- Bi-directional reflectance distribution function

$$F_{BRD}(\mathbf{t}) = F(\mathbf{s}, \mathbf{n}, \mathbf{v}, \lambda)$$

- **t** : a point on surface
- **s** : light source direction
- **n** : surface orientation
- **v** : viewing direction
- λ : surface reflectance function

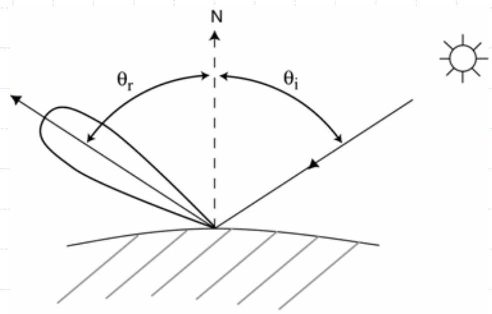
Surface reflectance models

- Lambertian
  - Perfectly diffused
  - Use to provide simple model of matte surfaces



Surface reflectance models

- Phong
  - Diffused + Specular
  - Most widely used model in computer graphics



Lambertian model

$$R(p,q) = \eta \cos(\theta_i) + \sigma$$

- *R* is the reflectance function
- *p* and *q* are partial derivatives of surface ***Z***, with $p = \partial Z/\partial x$ and $q = \partial Z/\partial y$,
- η is the composite reflectance combining light source intensity E_0 and intrinsic reflectance of surface material ρ
- θ_i is the incident angle between surface normal **n**, and light source direction **s**
- σ is the bias intensity

Photometric stereo

- Assume Lambertian reflectance model
- Calibrate light source direction
- Calculate local surface orientations from three reflectance images (why three images?)
- Integrate local surface orientations to obtain surface depth

Photometric stereo

- Simplified image irradiance equation for Lambertian reflectance model

$$E(x,y) = \eta(x,y) \cos(\theta_i)$$

- E(x,y) are the intensity at point (x,y) in image, and

$$\cos(\theta_i) = \mathbf{n} \cdot \mathbf{s} \,/\, |\mathbf{n}||\mathbf{s}|$$

$$\mathbf{n} = (p,q,-1),\ \mathbf{s} = ?$$

Calibration

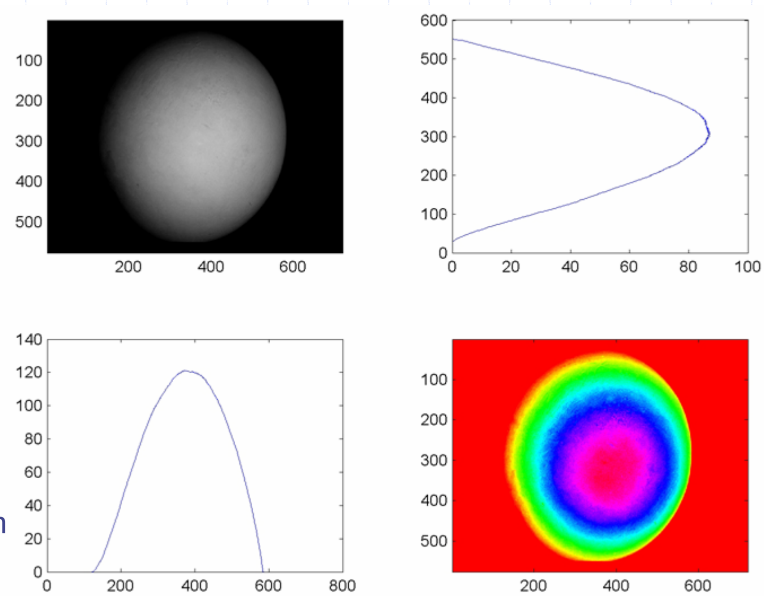
- Calculate the light source direction for each of the three light sources
- Use an object with know surface geometry and reflectance property, e.g. a sphere with diffuse surface
- Equation for sphere:

$$r^2 = x^2 + y^2 + z^2$$

Calibration

Original

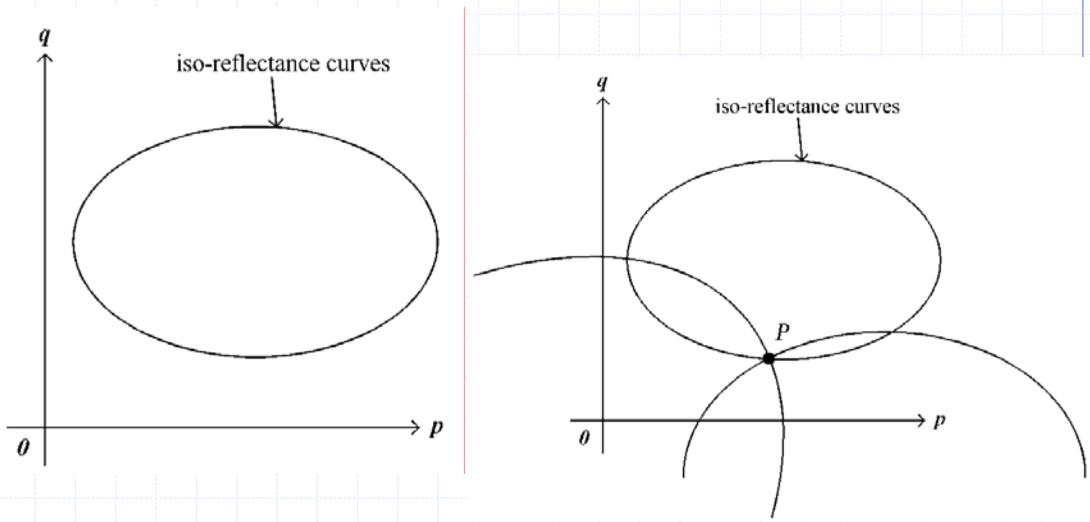
Intensity distribution



Intensity distribution

HSV color map

Calibration



Recovery of surface normal

- Substitute calibrated light source directions back into image irradiance equation

$$E_1 = E_{01}\mathbf{n} \cdot \mathbf{s}_1 / |\mathbf{n}||\mathbf{s}_1|$$
$$E_2 = E_{02}\mathbf{n} \cdot \mathbf{s}_2 / |\mathbf{n}||\mathbf{s}_2|$$
$$E_3 = E_{03}\mathbf{n} \cdot \mathbf{s}_3 / |\mathbf{n}||\mathbf{s}_3|$$

Solve for **n**!

Recovery of surface normal

- Albedo independent PSM (Klette 1996)

$$\mathbf{u} = (E_{01} \cdot E_2 \,|\mathbf{s_2}|\, \mathbf{s_1} - E_{02} \cdot E_1 \,|\mathbf{s_1}|\, \mathbf{s_2}) \times (E_{01} \cdot E_3 \,|\mathbf{s_3}|\, \mathbf{s_1} - E_{03} \cdot E_1 \,|\mathbf{s_1}|\, \mathbf{s_3})$$

- **u** is a vector collinear to **n**
- Calculate surface orientations independently of reflectance values

Integration of surface normal

- Local integration
  - Start from background value, follow predefined path/s to obtain surface depth of future points from surface normals
  - Four paths
- Global integration
  - Transform spatial information into frequency domain, in which an integration becomes division by a factor
  - Frankot-Chellappa

Post-processing of results

- Texture mapping
- Merging of surfaces into 3D model
- Visualisation
  - VRML, PlyView, 3D Studio, …, etc..

Summary

- Background knowledge about various shape recovery approaches (computer vision, non computer vision)
- Understand how reflectance may be used in shape recovery
- Reconstruct a partial 3D surface using the PSM method