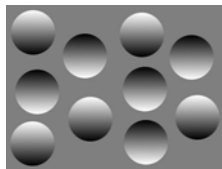


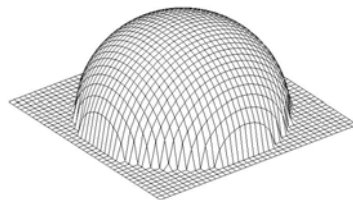
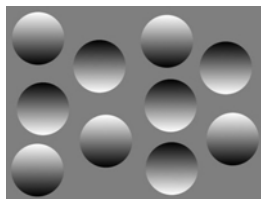
3-D Shape from Shading

Image formation and the shape from shading problem



CS332 Visual Processing
Department of Computer Science
Wellesley College

3D shape from shading



Prados & Faugeras, 2005

Image intensities depend on:



- o 3-D surface shape

- o Surface reflectance properties

- o Illumination in the scene

- o Viewing geometry

Compute
explicitly

General
assumptions

1-3



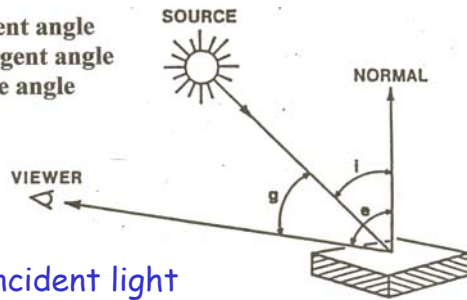
From Woodham, 1984

(images courtesy of Merle Norman Cosmetics)

1-4

Viewing geometry

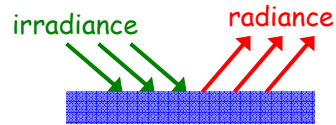
i : incident angle
 e : emergent angle
 g : phase angle



What fraction of the incident light is reflected toward the viewer?

Reflectance Function: $\Phi(i, e, g)$

$$\frac{\text{surface radiance}}{\text{surface irradiance}}$$

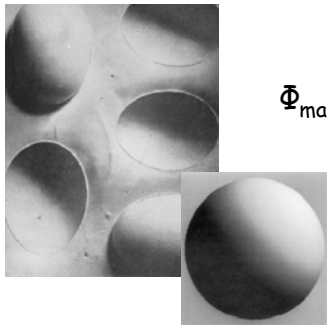
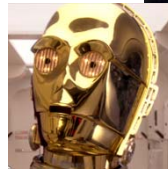


1-5

Reflectance functions

$$\Phi_{\text{mirror}}(i, e, g) = 1 \text{ if } i = e \text{ \& } i + e = g$$

$$= 0 \text{ otherwise}$$



$$\Phi_{\text{matte}}(i, e, g) = \rho \cos i \text{ if } i < 90^\circ$$

$$= 0 \text{ otherwise}$$

ρ : albedo

1-6

More reflectance functions

$$\Phi_{\text{moon}}(i,e,g) = \frac{\rho \cos i}{\cos e} \text{ if } i < 90^\circ$$

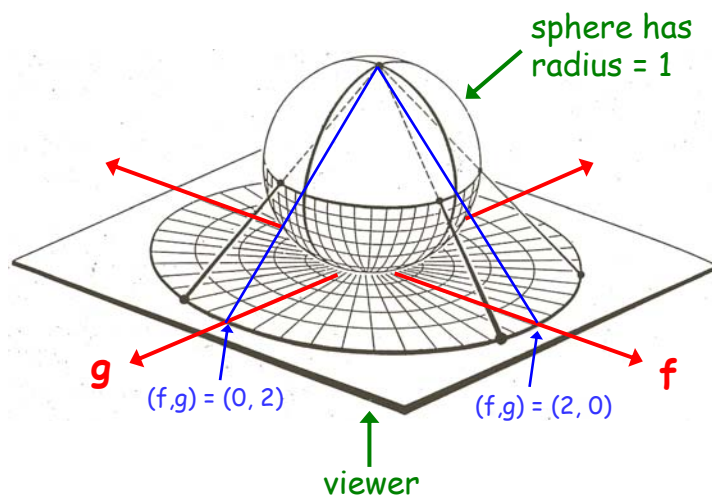
$$= 0 \text{ otherwise}$$



$$\Phi_{\text{SEM}}(i,e,g) = 1 / \cos e$$

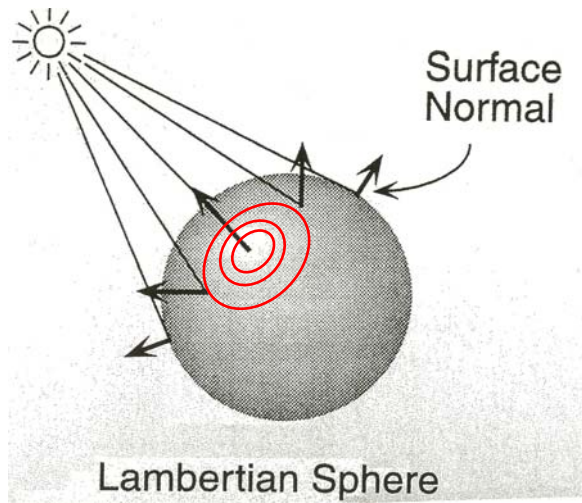
1-7

Representing surface orientation using stereographic projection



1-8

Given surface brightness, can we determine surface orientation?

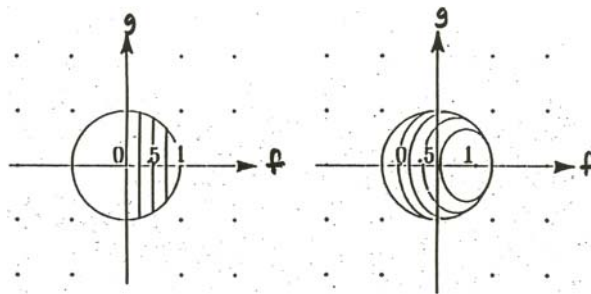


1-9

Reflectance Map $R(f,g)$

Given:

- (1) light source
- (2) viewer position
- (3) surface reflectance properties



$R(f,g)$ relates brightness to surface orientation

Image Irradiance Equation:

$$I(x,y) = I_0 * \rho(x,y) * R(f,g)$$

1-10

Ikeuchi & Horn shape-from-shading algorithm

Three sources of constraint:

(1) image intensity $I(x,y)$

$$I(x,y) = I_0 * \rho(x,y) * R(f,g)$$

(known viewer direction,
light source direction,
surface reflectance
properties)

(2) surface smoothness

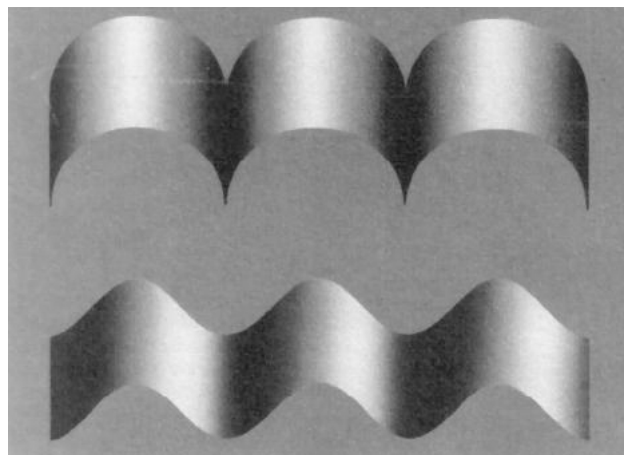
e.g. minimize total variation in surface

(3) points of known surface orientation

e.g. occluding boundaries, shadow boundaries

1-11

Boundaries influence shape perception



Ramachandran, 1988

1-12