# Radiosity I

10 April 2007
CMPT370
Dr. Sean Ho
Trinity Western University

reference:
*(J.Stewart / Queen's U)*

# Review last time

- Spatial data structures
  - Applications
- Object-centric
  - Bounding volumes: axis-aligned, oriented, hull
  - Hierarchical bounding volumes
- Space-subdivision
  - Grids
  - Octrees
  - k-d trees and BSP trees

# What's on for today

- Radiosity: terminology
  - Assumptions
  - Solid angles
  - Radiometry
  - BRDFs
  - Albedo
  - Radiosity equation
    - Form factors

# Local vs. global illumination

- Local: OpenGL realtime pipeline
  - Light/render each object individually
- Global: ray tracing
  - Image space: render one pixel at a time
  - Reflection/refraction
- Global: radiosity
  - Object space: get colour for each surface patch
    - View-independent
    - Can then render using OpenGL
  - Diffuse surface-to-surface interactions

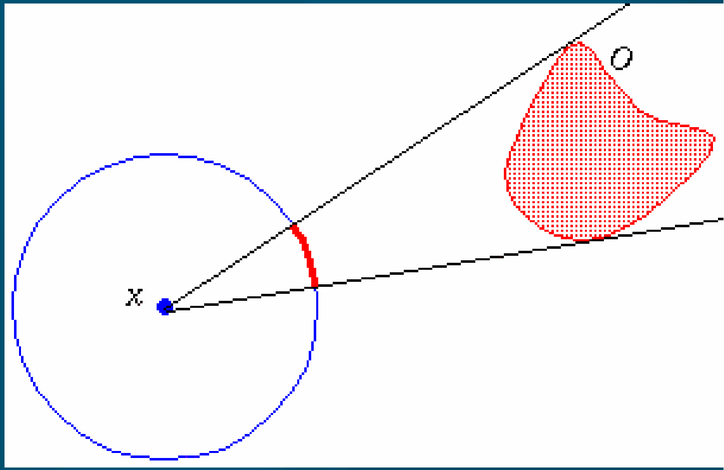
# Assumptions for classical radiosity

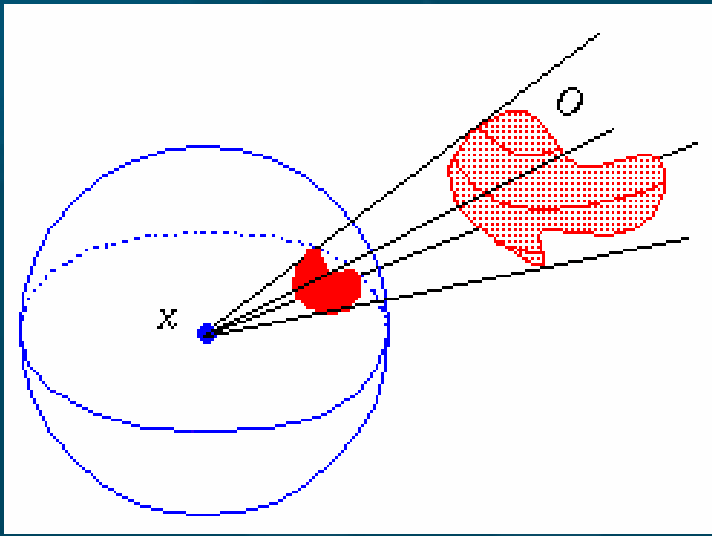
- Model light transfer from one element to another as system of linear equations
- Reflection and emission are diffuse (Lambertian)
  - Independent of direction
- All surfaces opaque
- No fog / atmospheric effects
- Radiosity is constant across each surface element
- Can solve for R, G, B separately

http://gameprog.it/

# Solid angles (steradians)

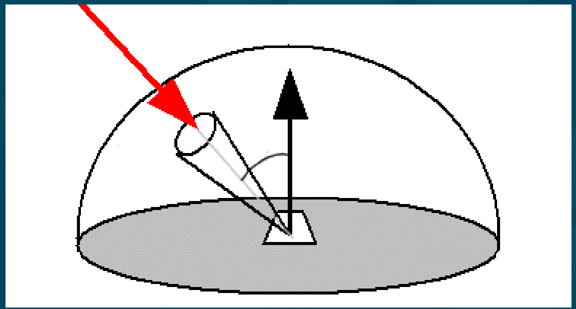
- In 2D: Angle subtended by an object O as viewed from x:
  - Project object onto unit circle
  - Angle in radians, 0 to 2π
- In 3D: Solid angle subtended by an object O as viewed from x:
  - Project object onto unit sphere
  - Solid angle in steradians, 0 to 4π



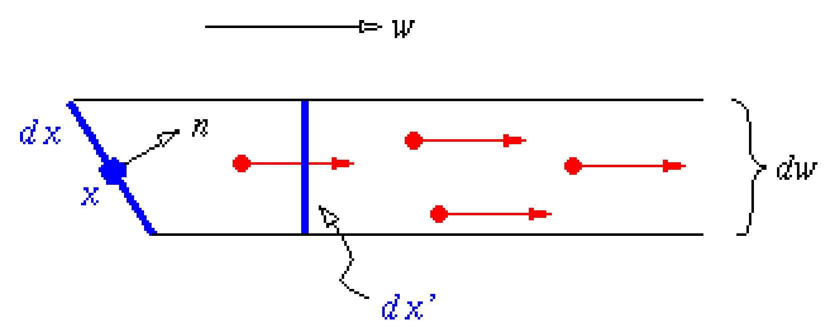
# Radiometry terms

- Light energy: Q (Joules)
- Radiant power: P
  - Power = energy / time (W = J/s)
  - Rate at which light energy is transmitted
- Flux density: Φ
  - Radiant power per unit area of the surface ($W/m^2$)
  - Irradiance: E
    - Flux density incident on surface
  - Radiosity: B
    - Flux density exitant from surface



# Power at a point in a direction

- Flux density at a point x: $\Phi(x) = dP/dx$
- Radiant intensity: I
  - Power radiated by a point source, per unit solid angle (W/sr)
- Radiance $L(x,\omega)$:
  - Flux density at a point x in a direction $\omega$ ($W/m^2 sr$)

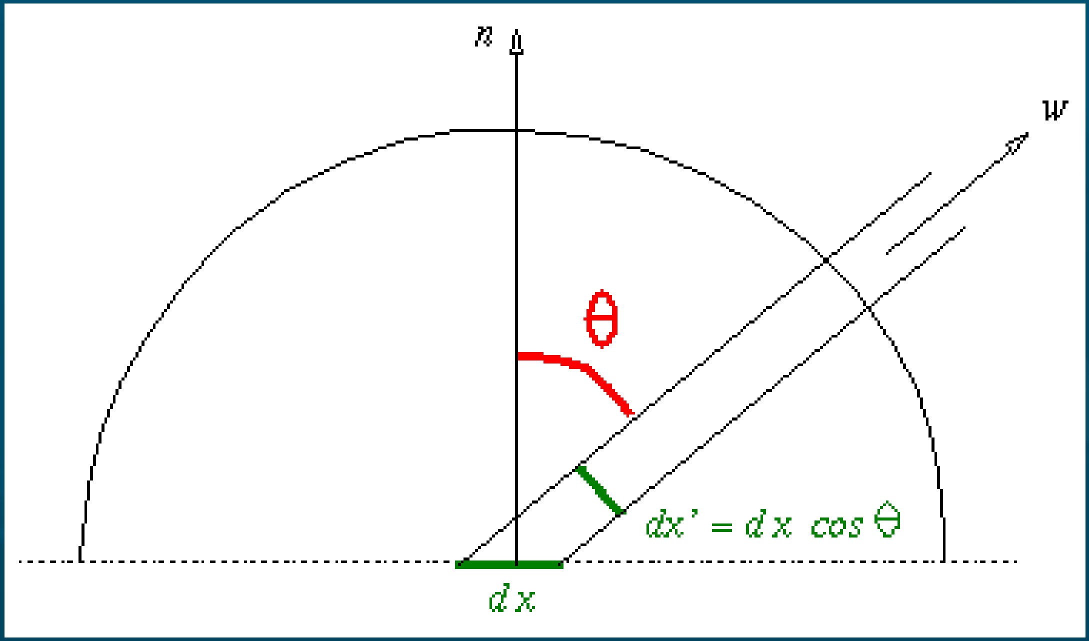



$$L(x,\omega) = \frac{d^2 P}{d\omega\, dx'} = \frac{d^2 P}{d\omega \cos\theta\, dx}$$

# Radiosity vs. radiance

- Radiance L(x,ω): in a direction ω
- Radiosity B(x): integrate over all exit directions

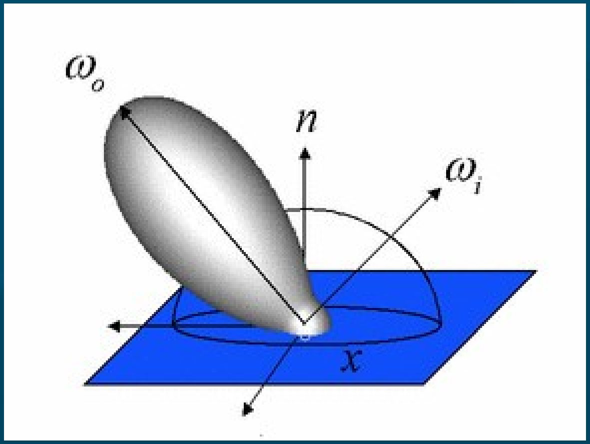
$$B(x) = \int_{\Omega} L(x, \omega) \cos\theta \, d\omega$$



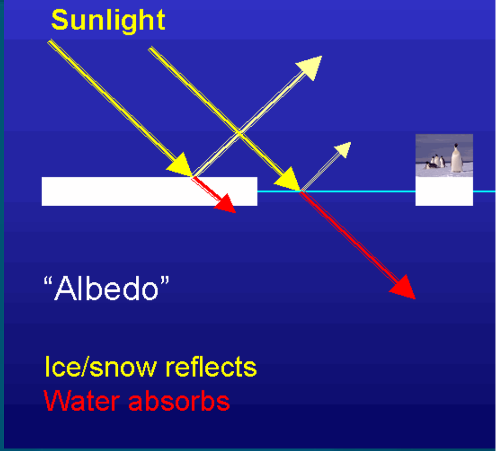
# Bidirectional reflectance distribution

- The bidirectional reflectance distribution (BRDF) at a point x gives the ratio of
  - incoming radiance from one direction $\omega_i$
  - to outgoing flux density to another direction $\omega_o$

$$\rho_{BD}(\omega_i, \omega_o) = \frac{L_o(x, \omega_o)}{L_i(x, \omega_i)\cos\theta_i \, d\omega_i}$$



# Lambertian BRDFs: albedo




- We assume Lambertian surfaces
  - Constant BRDFs (independent of direction):

$$\rho_{BD}(\omega_i, \omega_o) = \rho_{BD}$$

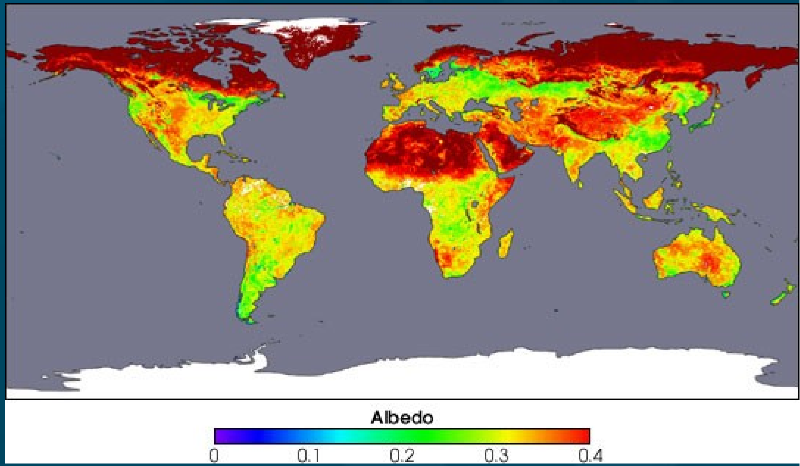
- Then the radiosity B(x) and irradiance E(x) (total incoming/outgoing flux density) are proportional:

$$B(x) = \iint_{\Omega} \rho_{BD}(\omega_i, \omega_o) L_i(x, \omega_i) \cos\theta_i \, d\omega_i \cos\theta_o \, d\omega_o$$

$$\ldots = \rho_{BD} \iint_{\Omega} L_i(x, \omega_i) \cos\theta_i \, d\omega_i \cos\theta_o \, d\omega_o$$

$$\ldots = \rho_{BD} E(x) \int_{\Omega} \cos\theta_o \, d\omega_o$$

$$\ldots = \pi \rho_{BD} E(x)$$




- The ratio $\rho = \pi\rho_{BD}$ is the albedo

# Radiosity equation

- Interaction between a surface element i and all other surface elements j:

$$A_i B_i = A_i E_i + \rho_i \sum_j F_{ji} A_j B_j$$

  - $A_i$: area of element i (known)
  - $B_i$: radiosity of element i (unknown)
  - $E_i$: irradiance (emission) of element i (given)
  - $\rho_i$: reflectance of element i (given)
  - $F_{ji}$: form factor from j to i (computable)

# Form factors $F_{ji}$

- The form factor $F_{ji}$ is the fraction of light leaving element j that arrives at element i
- Depends on:
  - Shape of the elements i, j
  - Relative orientation of the patches
  - Distance between the patches
  - Occlusion by other patches
- Can be computed from the geometry of the scene

# Radiosity pipeline

- Compute form factors $F_{ji}$ between all elements
- Solve radiosity equation to calculate radiosity of each element
  - Very large linear system: iterative solutions
  - Radiosity is view-independent
- Render final view using OpenGL
  - Flat-shaded with colours coming from radiosity

# TODO

- Lab5 due this Thu 12Apr
  - Virtual world
    - Creative, interesting scene
    - Lights and materials
    - Texture map
    - Bezier evaluator or NURBS
    - Pick objects
  - Final deadline for late labs: Thu 19Apr