Johns Hopkins
Engineering for Professionals

605.767 Applied Computer Graphics

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Module 4A
Radiosity

Radiosity

- Radiosity overview
- Introduction
- Form factors
- Progressive radiosity solution

Radiosity in POV-Ray

POV-Ray Hall of Fame - http://hof.povray.org

Radiosity

RRV - Radiosity Renderer and Visualizer http://dudka.cz/rrv/gallery

Many good illustrations of progressive nature of the algorithm

Radiosity

- Radiosity along with ray-tracing are the 2 major approaches to rendering objects with global illumination
  - Differ in both algorithm and nature of the images
    - Radiosity methods model diffuse reflections
    - Ray tracing strength is specular reflections
- Radiosity method attempts to solve diffuse interactions in a closed environment
  - Subdivide the environment into patches over which light is constant
  - Conservation of energy
  - View independent
  - High processing cost
- A primary use in architectural design
  - Produces very good images of building interiors

Radiosity (cont.)

- Development mostly at Cornell University
  - First introduced in 1984
  - Tested by comparing computer generated views with real views of simple environments
    - Subjects did no better distinguishing the two than by guessing
- Ability to model soft shadows and distributed light sources are primary strengths of the method
  - Also supports color bleeding
    - Diffuse inter-reflections cause an object’s color to appear on adjacent objects
      - White walls appear pinkish near red carpet
      - Haines and Moller Figure 9.57
- Solution obtained from a set of linear equations describing the patch interaction
  - Not as amenable to efficiency improvements
  - Major developments involved means of viewing partial solutions at early stages
- Siggraph radiosity overview
  - https://education.siggraph.org/static/HyperGraph/radiosity/overview_1.htm

Radiosity Theory

- Radiosity owes its theoretical basis to theory of heat transfer between surfaces
  - System of equations describing the inter-reflections between surfaces in a closed environment
  - Surfaces assumed to be perfect diffusers, emitters, or reflectors (Lambertian)
    - Reflect light in all directions with equal intensity
  - Environment is divided into a set of rectangular areas or patches
    - Radiosity over a patch is constant
    - Accuracy of the solution depends on the level to which the environment is subdivided
- Radiosity (B_i) of a patch is the total rate of energy leaving the surface
  - Sum of emitted and reflected energies
  - Units are energy x time^{-1} x area^{-1} (watts / m^2)
  - **Form factors** describe geometric relations between patches

Radiosity Equation

- Energy interchange between two patches is a function of geometric relations:
  - Distance and orientation
  - High interaction when surfaces are close to each other and near parallel

$$B_i dA_i = E_i dA_i + R_i \int_j B_j F_{ji} dA_j$$

  - Radiosity x area = emitted energy + reflected energy
  - Reflected energy = reflection coefficient x energy incident on the patch from all other patches
  - E_i is the light emitted from the patch
  - R_i is the reflectivity of the patch
    - Fraction of light incident on the patch that is reflected back into the environment
  - F is the form factor between the patches
    - Fraction of energy leaving patch j that arrives at patch i

Radiosity Solution

- Closed environment an energy equilibrium is reached
  - Set of linear equations formed by repeating the radiosity equation
    - For each patch in the environment
- $B_i A_i = E_i A_i + R_i \sum B_j F_{ji} A_j$
  - Assume B and E are constant across the patch
- Form factors are reciprocals
  - Energy interchange depends only on the relative geometry of the patches
  - $F_{ij} A_i = F_{ji} A_j \leftrightarrow F_{ij} = \dfrac{F_{ji} A_j}{A_i}$
  - Then (dividing through by A_i and using above relationship):
  - $B_i = E_i + R_i \sum_{j=1}^{n} B_j F_{ji}$

$$\begin{bmatrix} 1 - R_1 F_{11} & \text{-}R_1 F_{12} & \dots & \text{-}R_1 F_{1\mathrm{n}} \\ \text{-}R_2 F_{21} & 1 - R_2 F_{22} & \dots & \text{-}R_2 F_{2\mathrm{n}} \\ \dots & \dots & \dots & \dots \\ \text{-}R_\mathrm{n} F_{\mathrm{n}1} & \text{-}R_\mathrm{n} F_{\mathrm{n}2} & \dots & 1 - R_\mathrm{n} F_{\mathrm{nn}} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ \dots \\ B_\mathrm{n} \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \\ \dots \\ E_\mathrm{n} \end{bmatrix}$$

Solving the Radiosity Equations

- E_i values are non-zero only at surfaces that produce illumination
  - Represent the light sources - input illumination into the system
  - Equation set is an expression of energy equilibrium for a particular wavelength
    - Must be solved for each wavelength (RGB)
  - Note that form factors are assumed to be independent of wavelength
- Also $F_{ii} = 0$
  - None of the radiation leaving a planar surface will strike itself directly
  - Convex surface all form factors between patches of the same surface will be 0
- Form factor matrix is diagonal-major
  - A solution exists
- Sum of any row of form factors is 1
- Can solve the matrix of simultaneous equations by the Gauss-Seidel method

Rendering the Radiosity Solution

- Solution of the set of equations yields a single radiosity value for each patch in the environment
  - Solution is view independent
- Radiosity values can be used in a standard Gouraud renderer
  - Any number of views in the environment can be constructed
  - Well suited to walkthrough
  - Can average radiosity at each vertex
    - Average the radiosity of all patches sharing the vertex