Realistic Rendering

-- Radiosity Methods--
Radiosity methods...

- were developed to account for the interaction of diffuse light between objects in a scene
  - are excellent for creating interior environments made up of collections of non-specular objects
  - create very realistic looking interiors
  - have created the most realistic and impressive images
  - do not need to use an ambient light constant!
The history of Radiosity...

- ...was formed from research in radiative heat transfer in 1984 to account for heat transfer between objects (i.e., elements in a furnace or on a spacecraft)
- ...is based on a formula for creating an equilibrium of energy within an enclosure
- ...means that all energy emitted or reflected by every surface is accounted for by its reflection or absorption by other surfaces
Radiosity...
- ...is the rate energy leaves a surface
- ...is the sum of the rates reflected or refracted from the surface

Radiosity methods...
- ...are the techniques for computing surface radiosities in an environment
- ...model diffuse light, unavailable with all other methods
Radiosity methods...
  - ...provide for color bleeding from one surface to another
  - ...allow for shading within a shadow envelope
  - ...create penumbral shading along shadow boundaries

Unlike ray tracing, radiosity works on objects to determine the intensity at discrete points...
Unlike ray tracing,

- ...it does not work at the pixel level...
- ...this means radiosity is independent of the viewer's position
- ...radiosity first determines the light interactions in an environment; then, one or more views are rendered
Radiosity methods...
- ...treat the light source just like any other surface that emits or transmits light
- ...this means it allows surfaces to emit light
- ...which ultimately means that light sources are all considered to be area light sources!
- (There are no point light sources with radiosity methods)
- ...or, you could say that all surfaces are perfect diffusers
Radiosity is defined as the energy leaving a *surface patch* (per unit of time)...

- ...where the environment is broken up into a finite number of discrete surface patches

- ...and each surface patch can emit and reflect light uniformly over its entire area

- ...so the sum of the light emitted and reflected is the radiosity for that surface patch

- ...plus concave patches include calculations including their own reflected light when determining radiosity
Since radiosity is calculated per surface patch...

- ...in order to avoid flat shading for each surface patch, the vertex radiosities must be calculated from the patch radiosities
- ...then, Gouraud or some other intensity interpolation shading technique can be used for more realistic shading
Vertex radiosities are determined...

- ...for vertices interior to the surface, by the average of the radiosities for the patches that share that vertex.
- ...for vertices on the edge when averaged with the closest interior vertex, by the average of the radiosities of the patches that share the edge vertex.
Vertex radiosities are determined...

- Radiosity of Vertex A is the sum of Patch 1 and 3 radiosities minus Vertex B's radiosity.
- Radiosity of Vertex B is the average of the radiosities of Patches 1 through 4.
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Radiosity Methods

- Uses form factors...
  - ...to characterize the effects of the geometry of two surfaces when radiative energy is exchanged between them (i.e., light is reflected and refracted between them)
  - ...which are independent of the wavelength and are a function of the geometry only; they do not need to be recomputed if lighting changes!
Uses form factors...

- The form factor is calculated... ...using the angles with the normals made by the ray between the patches, the length of the ray, and whether or not the patch is visible from the other
Form factors between patches...
- ...was developed in 1985 as the hemicube method

Hemicube form factors...
- ...are used to approximate the hemisphere around patches because flat projection planes are less expensive to compute
  - ...constructs a hemicube around center of each patch
  - ...where the patch normal and the hemicube Z axis are coincident
Hemicube form factors...
Hemicube...

- ...faces are divided into cells
- ...projects every other patch in the environment onto this hemicube
- ...where two patches that project onto the same cell can have their depth compared and the further patch rejected, because it cannot be seen from the receiving patch
- ...therefore, the contribution of hidden patches is ignored, like hidden surface removal!
Hemicube faces are divided...
With Hemicube...

- ...each cell defines a portion of a patch's form factor
- ...the contribution of each cell in the hemicube to the form factor is a function of the patches that project onto the cell and its position in the hemicube
- ...patches with the same projection on the hemicube have the same form factor
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Radiosity Methods

- With Hemicube...

Patch normal
Z axis

Projection of patch j (1 pixel example)

Angle i

Angle j

Vector between the hemicube pixel (or cell) and the patch i

Surface patch i
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Radiosity Methods

- Radiosity methods in general...
  - ...are difficult to code
  - ...require extensive computing resources
  - ...have performance dependence on the number of patches in an object since a hemicube calculation is performed for every patch (onto which all other patches are projected)
  - ...have performance dependence on the complexity of the environment and the resolution of the hemicube
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Radiosity Methods

- Aliasing also affects images generated with radiosity methods...
  - ...if a hemicube resolution is too low
  - ...but are in general minimal since diffuse illumination changes slowly across a surface

- Much research is on-going to find faster, more accurate, and less storage intensive techniques to perform radiosity methods...
Using radiosity methods...
- ...the quality of the image is a function of the size of the patches (i.e., the finer the patches the better the results!)

Radiosity methods can be improved...
- ...by subdividing patches where problems occur (i.e., for example along shadow boundaries) ...by a process called substructuring
- ...with sub-patches solved independently among patches
Substructuring uses three steps...

- ...evaluate the radiosity using the patch methods
- ...subdivide patches that exhibit potential problems and calculate the sub-patch form factors
- ...determine the radiosities for the subdivided patches

Subdivision of patches...

- ...can be repeated until achieve desired accuracy
- ...therefore improves the quality of images in the areas that require more accurate treatment
With radiosity methods...

- ...the conventional pipeline is used to achieve global illumination effects needed for diffuse radiosity
- ...the form factors are pre-computed for the entire image before being processed by the viewing and rendering components of the pipeline
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Radiosity Methods -- Pipeline

With radiosity methods...

- Abstract Rendering
- Modeling
- Calculate Vertex Intensities
- View Orientation Transformation
- View Mapping and Clipping
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Radiosity Methods -- Pipeline

- The last five subcomponents use the conventional methods...
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Radiosity Methods -- summary

- Standard radiosity methods...
  - ...provide a solution for diffuse surfaces to interact in a closed environment
  - ...are well suited for diffuse reflectivity since a diffuse surface's reflectivity is constant in all outgoing directions
  - modeled instead of specular (remember form factors!)
    --- once specular light is modeled you MUST know the view!
  - ...were expanded to incorporate ray tracing
Radiosity and ray tracing takes into account the interactions of light for...

- ...diffuse to diffuse reflection,
- ...diffuse to specular reflection,
- ...specular to diffuse reflection, and
- ...specular to specular reflection
Radiosity and ray tracing...

- are combined as a two pass process: view independent and view dependent (preprocessing and postprocessing steps)

Preprocessing...

- first enhances the diffuse reflectivity and takes into account the specular to diffuse reflection (however, this method does limit specular surfaces to perfect mirrors)
Preprocessing...

- ...then it applies a standard radiosity method, using the hemicube to determine the form factors
- ...only takes into account specular reflection enough to determine the impact on diffuse reflection
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Radiosity Methods -- summary

• Postprocessing...
  • ...uses distributed ray tracing and takes into account specular reflection and refraction as well as the viewpoint
  • ...takes the diffuse intensities from the radiosity method and let's them contribute to the intensity of a pixel using linear interpolation