Radiosity

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Course 600.456: Rendering Techniques, Professor: Jonathan Cohen

Radiosity Concept

- Global computation of diffuse interreflections among scene objects
- Diffuse lighting changes fairly slowly across a surface
  - Break surfaces up into some number of patches
  - Assume diffuse illumination constant across each patch
- Diffuse reflection independent of viewing direction
  - Interactive rendering possible

Cornell Box

from Sillion and Puech, *Radiosity & Global Illumination, 1994*.

Steel Mill (55,000 elements)

from Watt and Watt, *Advanced Animation and Rendering Techniques*, 1992.

Radiosity - fundamentals

Radiosity: energy per unit area leaving a surface patch per unit time

Radiosity x area =

emitted energy + reflected energy

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

Radiosity will be color of rendered surface

- total energy generated by rendering some number of pixels

Form Factor

Describes geometric relationship between two surface patches

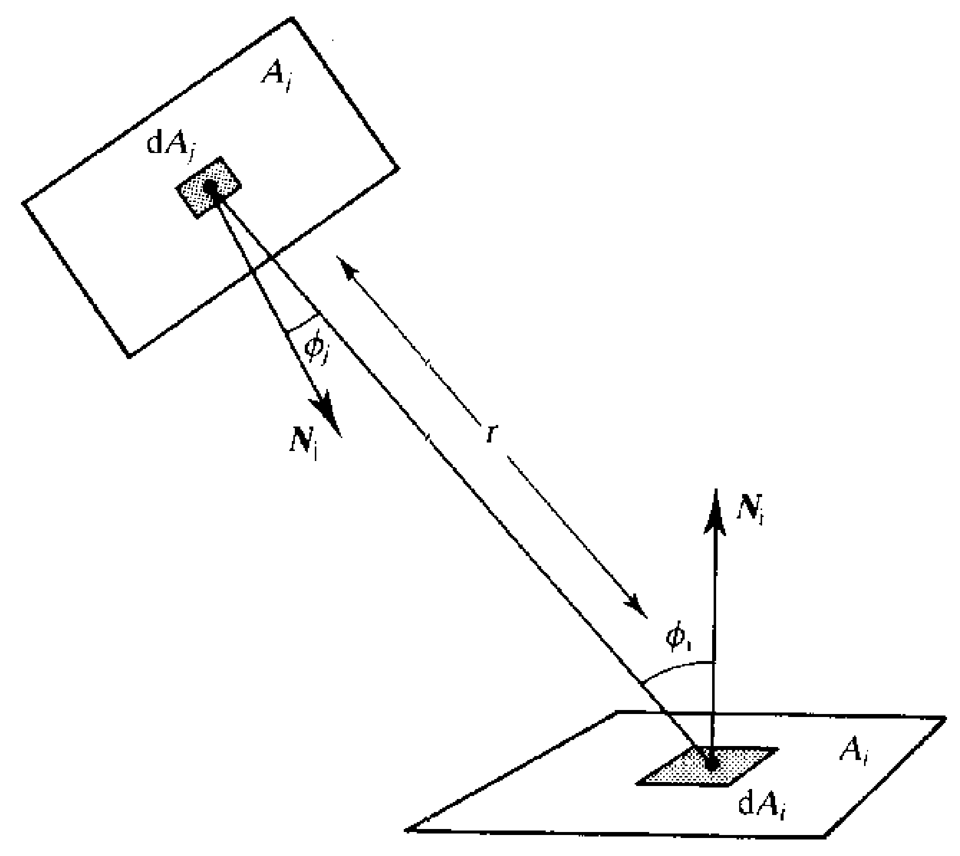
$$F_{ij} = \frac{\text{energy leaving } A_i \text{ that strikes } A_j \text{ directly}}{\text{energy leaving } A_i \text{ over entire hemisphere}}$$

$\Sigma_i F_{ij} = 1$ for all j

$F_{ii} = 0$ for planar patches

Reciprocity relationship: $F_{ij} dA_i = F_{ji} dA_j$

Form Factor Diagram



from Watt, *3D Computer Graphics*, 1993.

$$F_{ij} = 1/A_i \int_{A_i} \int_{A_j} \cos\phi_i \cos\phi_j / (\pi r^2)\, dA_j dA_i$$

Differential-Finite Area Form Factor

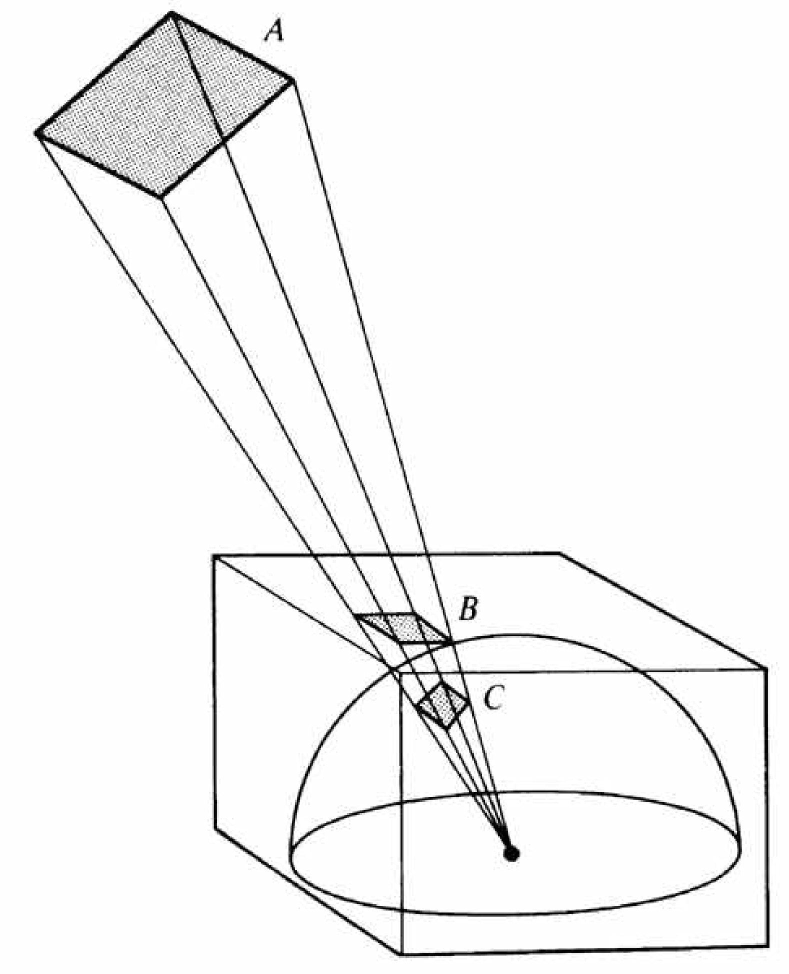
$$F_{dA_iA_j} = \int_{A_j} \cos\phi_i \cos\phi_j / (\pi r^2)\ dA_j$$

- Form factor between dA_i and A_j
- Position dA_i at center of A_i and assume result is valid for entire patch
  - reasonable when r is large with respect to areas
- Now reasonable to consider projection of patch rather than patch itself...

Patch Projections

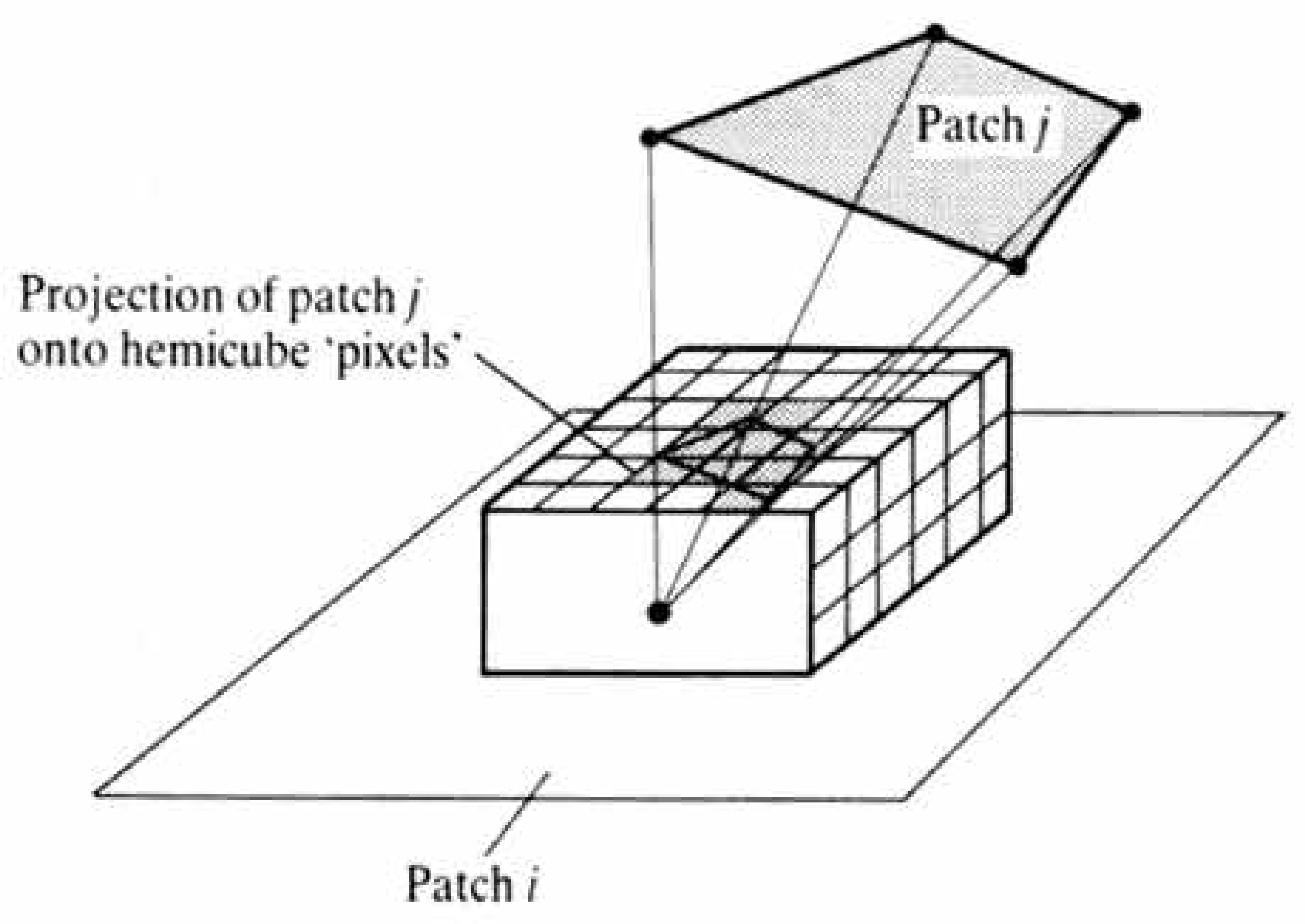
All three representations have the same form factor

A: patch itself
B: patch on hemicube
C: patch on hemisphere



from Watt, *3D Computer Graphics*, 1993.

Hemicube Illustration



from Watt, *3D Computer Graphics*, 1993.

Hemicube Form Factor Method

```
For each patch, i
    For each patch, j
        Render patches into item buffer for each hemicube face (with Z-buffering)
    For each hemicube pixel
        Look up pixel form factor
        Accumulate into form factor for appropriate patch pair (i,j)
```

Radiosity Computation

Compute form factors

Solve NxN matrix equation

$B_i = E_i + R_i \Sigma_j B_j F_{ij}$

$$\begin{bmatrix} 1 - R_1F_{11} & -R_1F_{12} & \ldots & -R_1F_{1n} \\ -R_2F_{21} & 1-R_2F_{22} & \ldots & -R_2F_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ -R_nF_{n1} & -R_nF_{n2} & \ldots & 1-R_nF_{nn} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ \ldots \\ B_n \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \\ \ldots \\ E_n \end{bmatrix}$$

Gathering Method of Radiosity Computation

Compute form factors

Solve matrix equation using Gauss-Seidel iteration

Solve for one patch radiosity at a time

Plug solution into matrix for solutions to future radiosities

Iterate until it converges

Shooting Method of Radiosity Computation

At each iteration, emit from one patch to all other patches

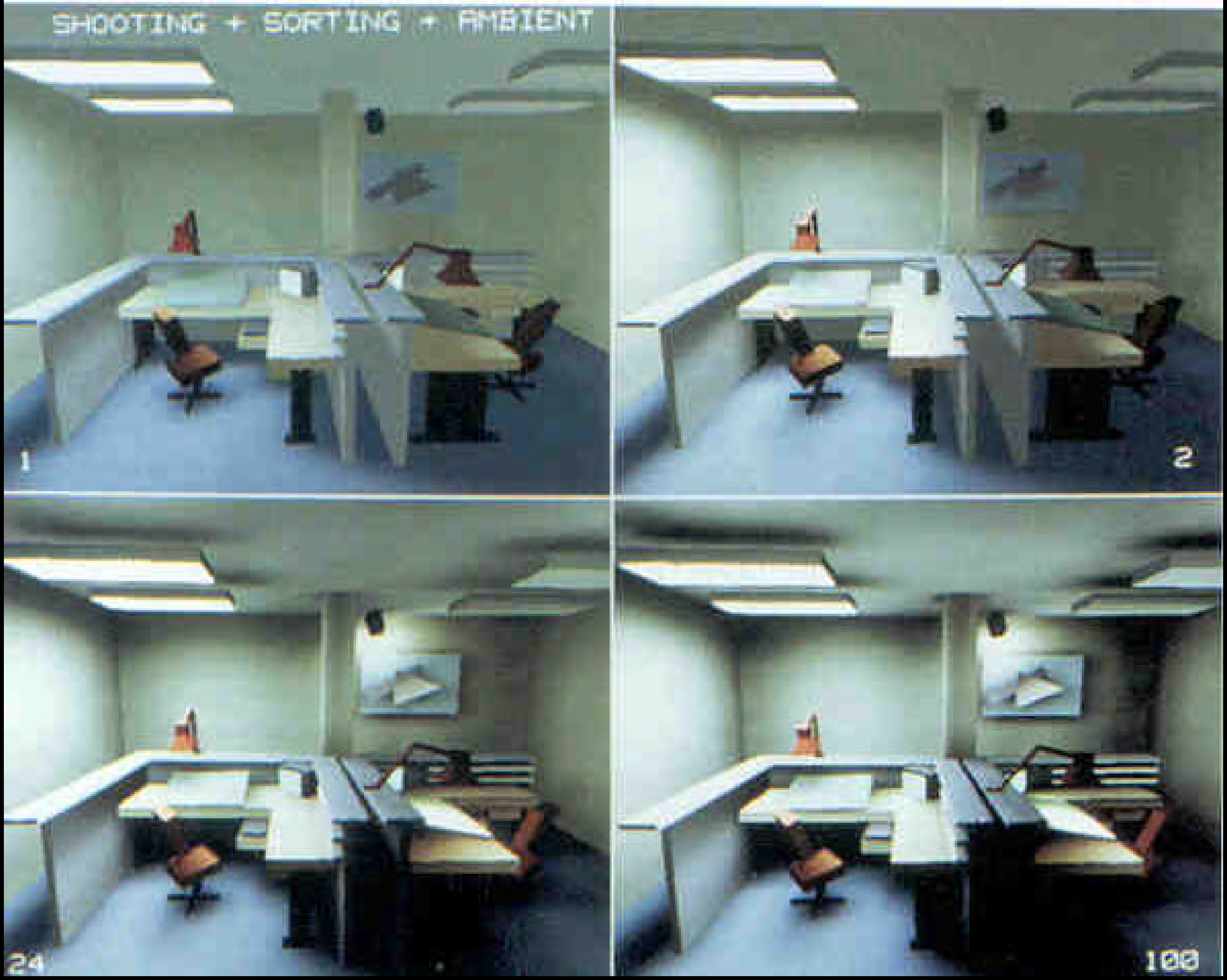
- Useful for progressive radiosity
- Possibly add ambient when viewing preliminary results

Order the patch emissions by magnitude of energy to be emitted

Shooting Example

from Sillion and Puech, *Radiosity & Global Illumination, 1994.*

Shooting + Ambient Example



from Sillion and Puech, *Radiosity & Global Illumination, 1994.*

Creating Patches from Polygons

Uniform subdivision (pre-process)

Regular subdivision (on-line)

Irregular subdivision (on-line)

Uniform Subdivision

Subdivide polygons with regular grid before any radiosity computation

Set some threshold to determine level of subdivision

- number of patches per polygon
- maximum patch size

Doesn’t provide much control in error of form factor or radiosity computation

Regular Subdivision

- Begin with coarse (or no) uniform subdivision of polygons
- After computing radiosities, measure gradient between adjacent patches (using differences)
- Subdivide patches with high gradient
- Incrementally update radiosity solution

Reducing Subpatch Computations

Initialize subpatch radiosities from patch radiosity

Compute only subpatch-patch form factors

- not patch-subpatch form factors
- not subpatch-subpatch form factors

Subdivision effectively increases matrix from NxN to MxN (but not MxM)

Hierarchical Radiosity

Apply regular subdivision to patches that require refinement

For each patch-patch interaction, use an appropriate level of subdivision

Can be implemented using matrix block operations

- portions of matrix are computed as block
- bounds on computational error used to determine which computations may be grouped

Irregular Subdivision (Discontinuity Meshing)

Subdivide patches along discontinuities, rather than regular subdivision

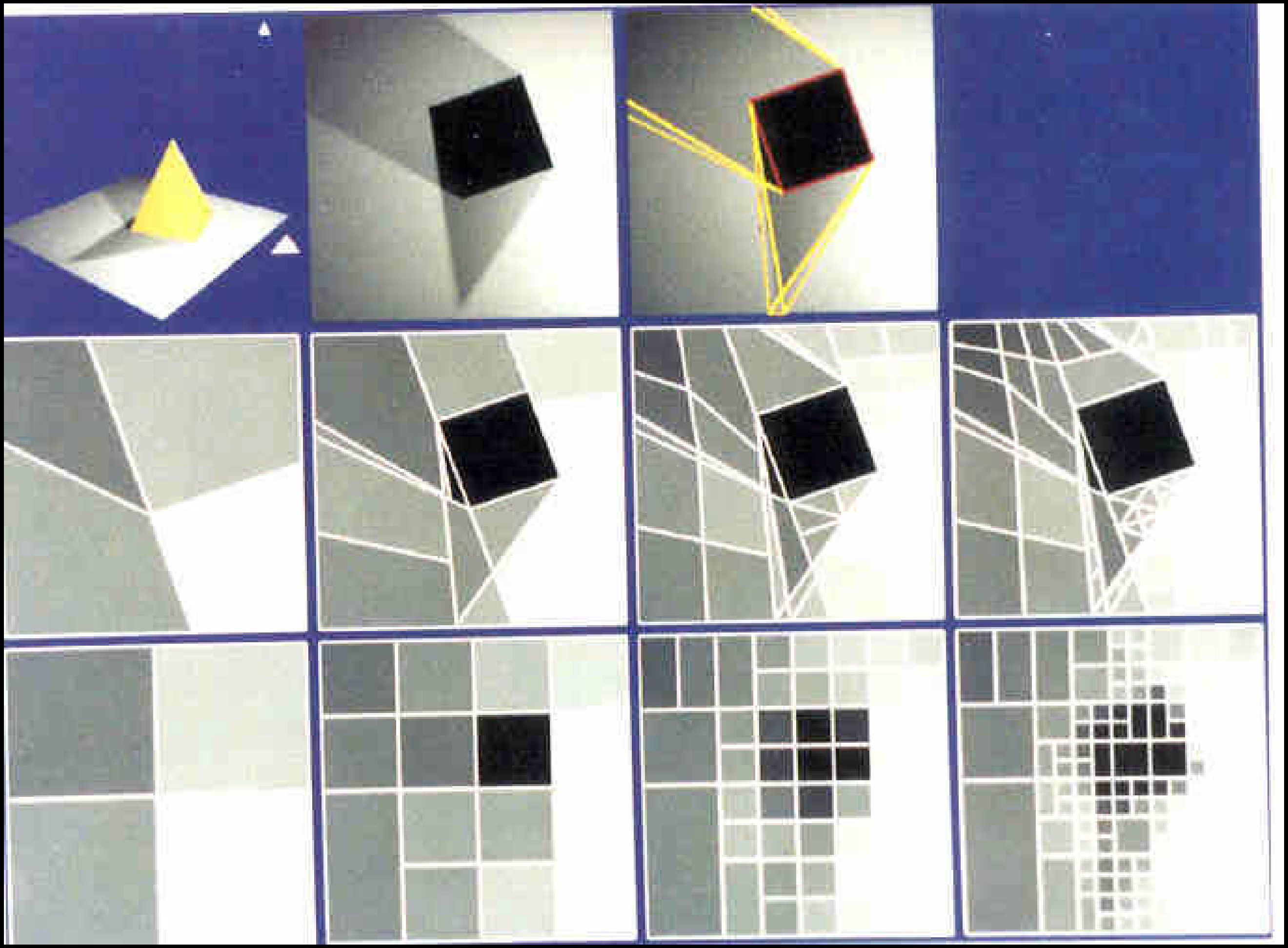
Discontinuities

- 0 order: contacts between surfaces
- 1st, 2nd order: changes in visibility

Requires less refinement along discontinuities than regular subdivision

Typically try to subdivide so most patch elements completely visible or invisible

Discontinuity Mesh Examples



From Lischinski et al., "Combining Hierarchical Radiosity and Discontinuity Meshing," ***Proceedings o*** ***SIGGRAPH 93.***

Discontinuity vs. Regular Subdivision

From Lischinski et al., "Combining Hierarchical Radiosity and Discontinuity Meshing," ***Proceedings of SIGGRAPH 93*****.**

Other Topics of Interest

Combining effects of initial polygons

Using non-constant patch radiosities

Rendering polygons with higher-order color interpolation

Radiosity as textures

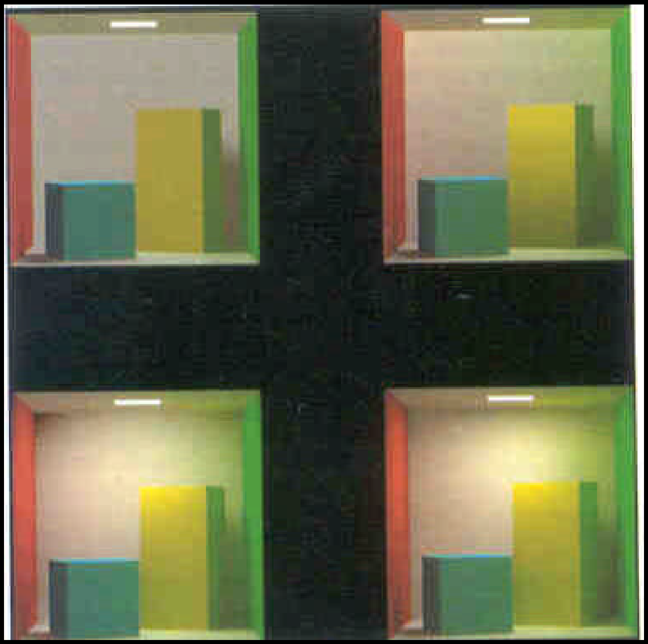
Combining Polygon Contributions

For polygonal curved surfaces, simplification allows hierarchical representation

Possibly combine light contributions through volumes of space

Non-constant Patch Radiosities

Require fewer patches by allowing radiance to vary across a patch



from Zatz, "Galerkin Radiosity," *Proceedings of SIGGRAPH 93*.

Higher-order Color Interpolation

- Using higher-order color interpolation decreases number of polygons rendered
- Higher-order color interpolated polygons take longer to render
- Determine optimum mode for rendering each patch based on number of polygons and rendering cost
- Explored on Pixel-Planes 5 hardware ~1995

Radiosity as Textures

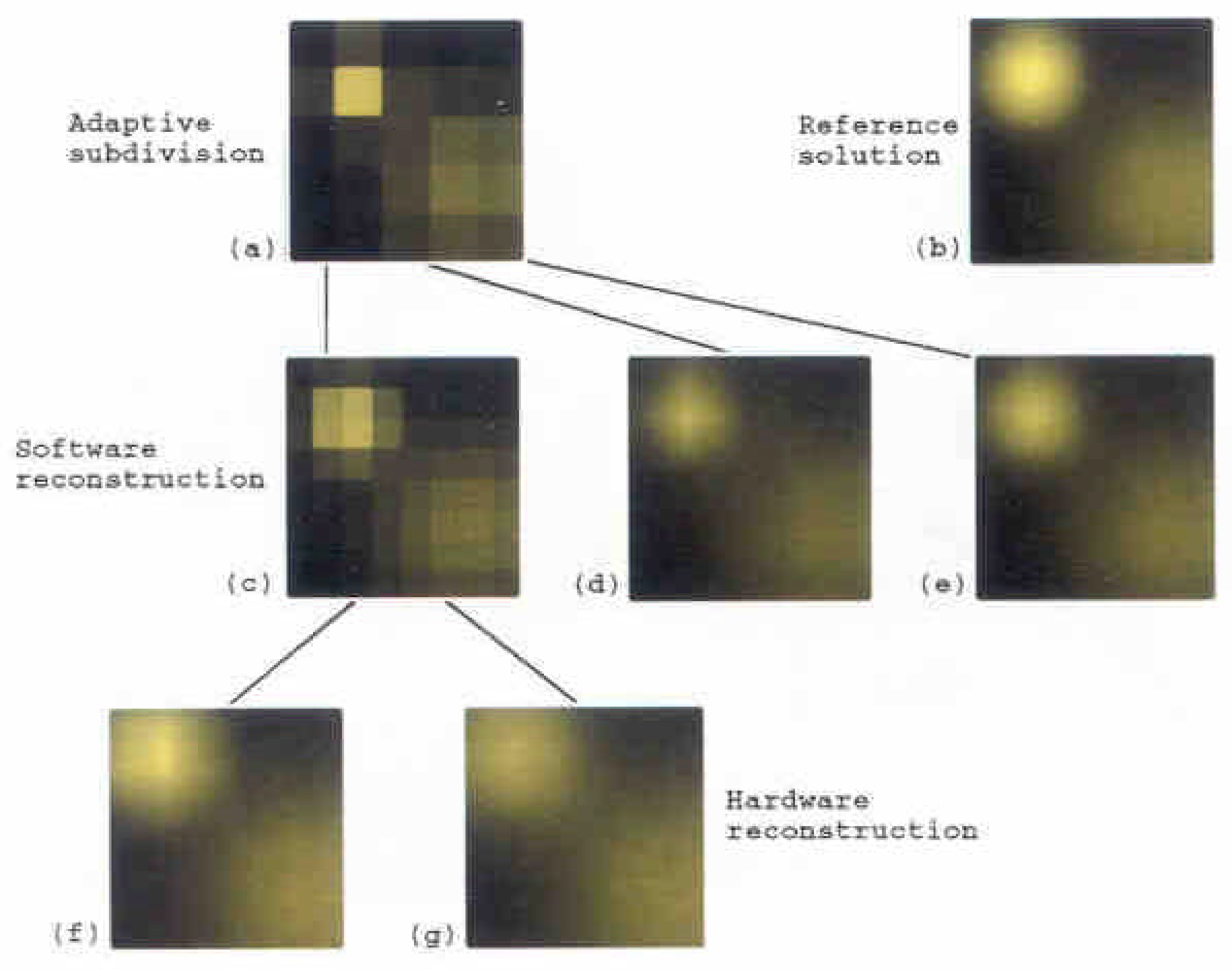
Accurate radiosity dramatically increases polygon count

- Extra geometry is redundant
- All new information is about colors

Create textures for new color information and use original geometry

Like higher-order interpolation, texture-mapping is more expensive than color interpolation, so optimize cost/benefit

Radiosity as Textures Resampling



from Bastos et al., “Efficient Radiosity Rendering using Textures and Bicubic Reconstruction,” ***Proceedings of the 1997 Symposium on Interactive 3D Graphics.***

Video

Bastos, Rui. Michael Goslin, and Hansong Zhang. “Efficient Radiosity Rendering using Textures and Bicubic Reconstruction.” *Proceedings of the 1997 Symposium on Interactive 3D Graphics.*