Radiosity

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 Illumi-nation, 1994.*

Steel Mill (55,000 elements)

from Watt and Watt, *Advanced Animation and Rendering Tech-niques*, 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

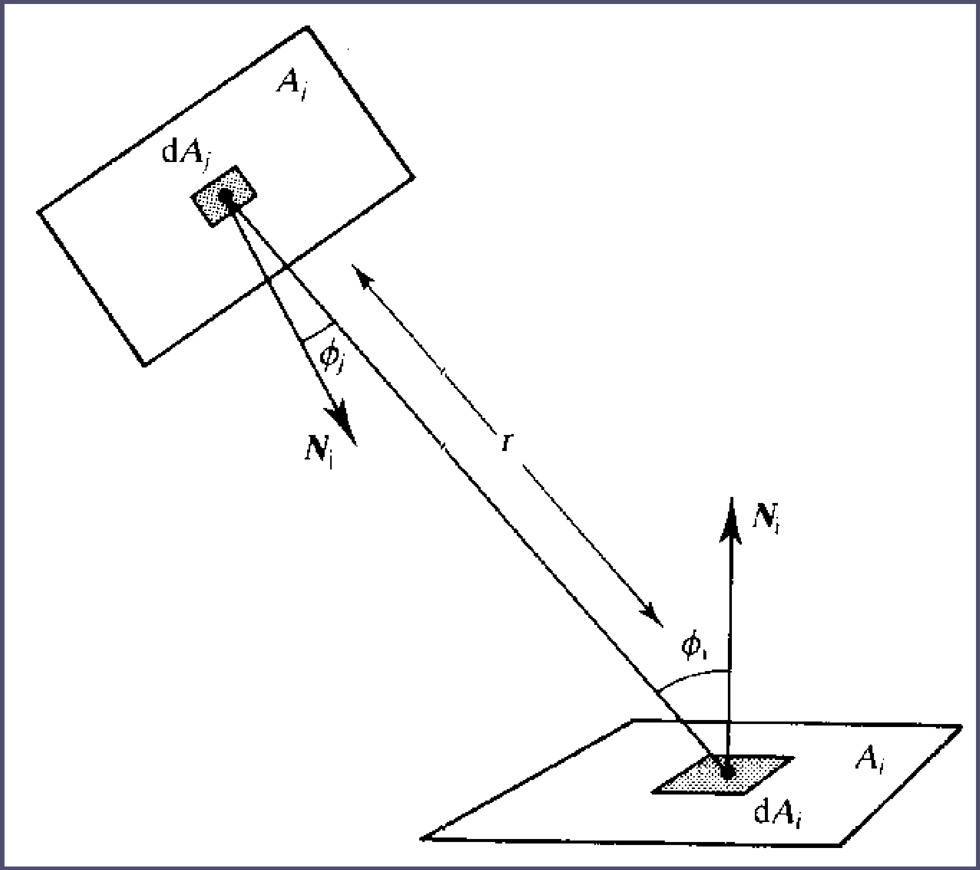
$$F_{ij} = \frac{\text{energy leaving } A_i \text{ that strikes } A_j \text{ directly}}{\text{energy leaving } A_i \text{ over entire hemisphere}}$$

$\Sigma_i F_{ij} = 1$ 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

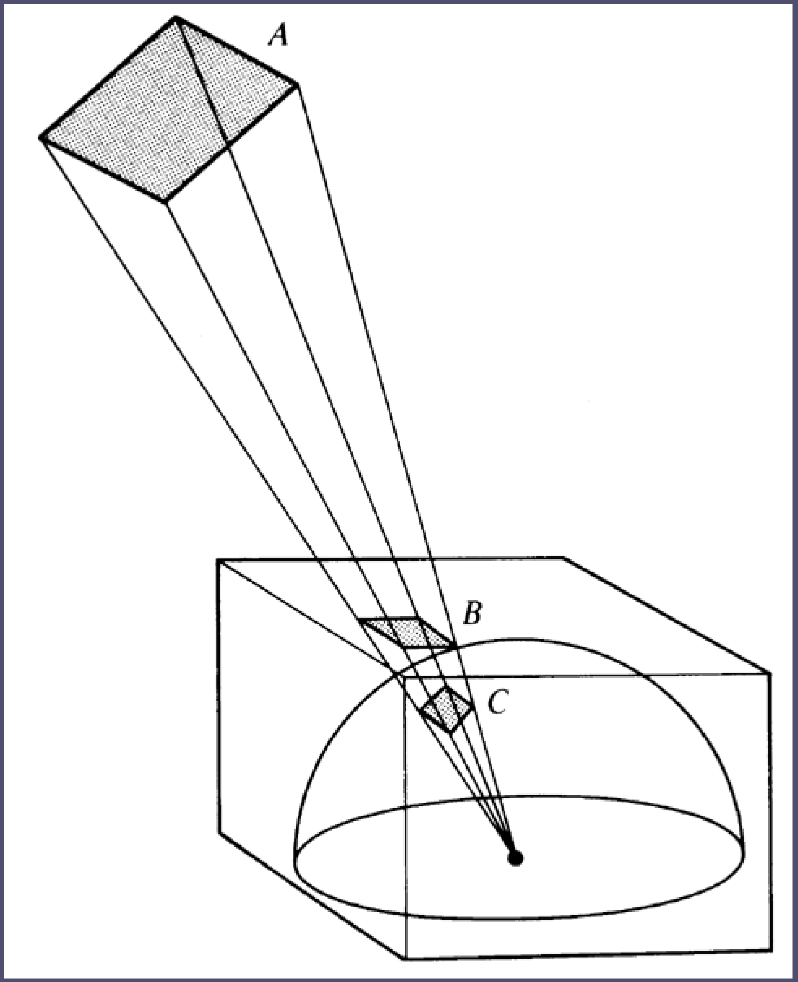
$$F_{dA_iA_j} = \int_{A_j} \cos\phi_i \cos\phi_j / (\pi r^2)\ dA_j$$

- 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

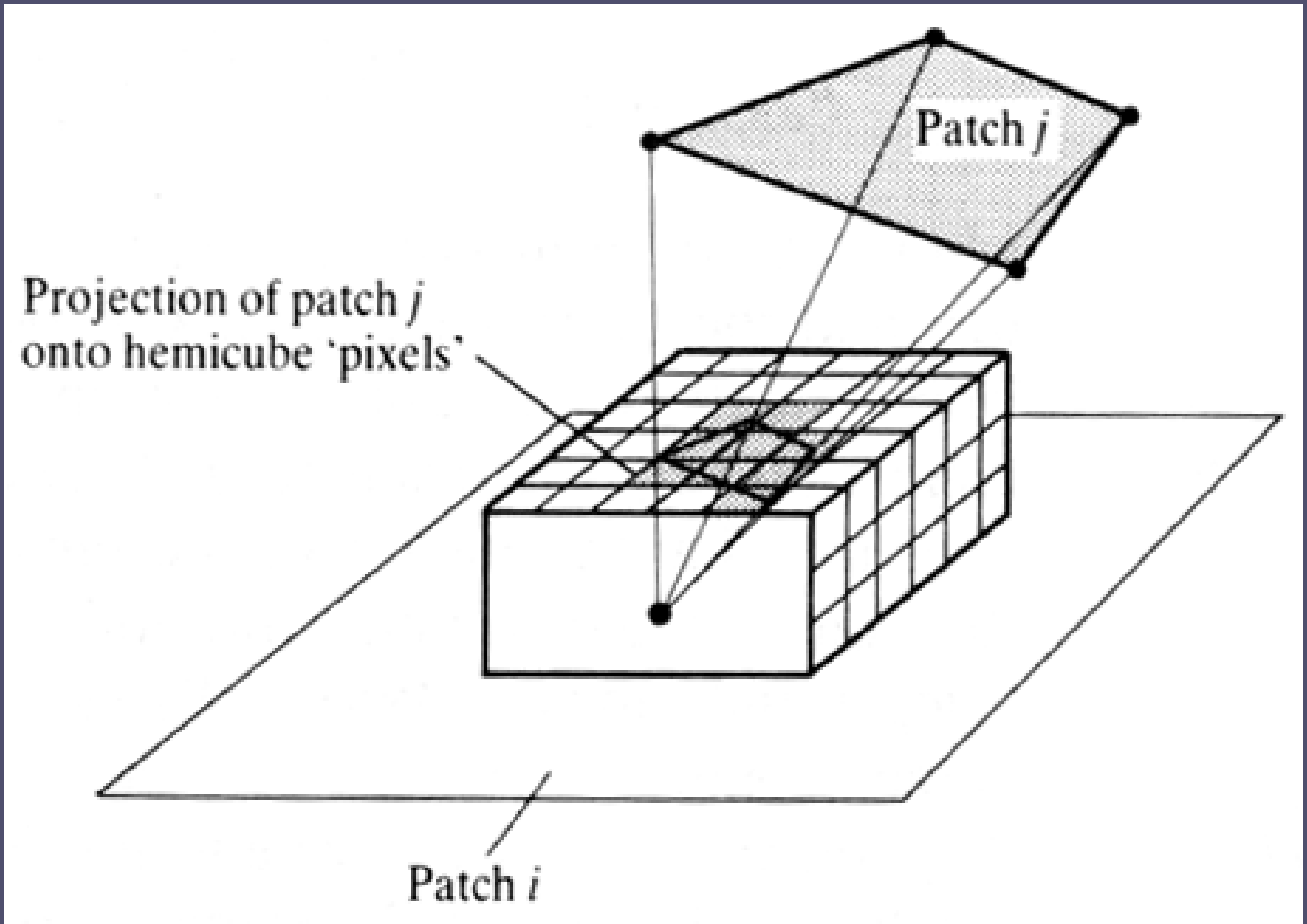
All three representations have the same form factor

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

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

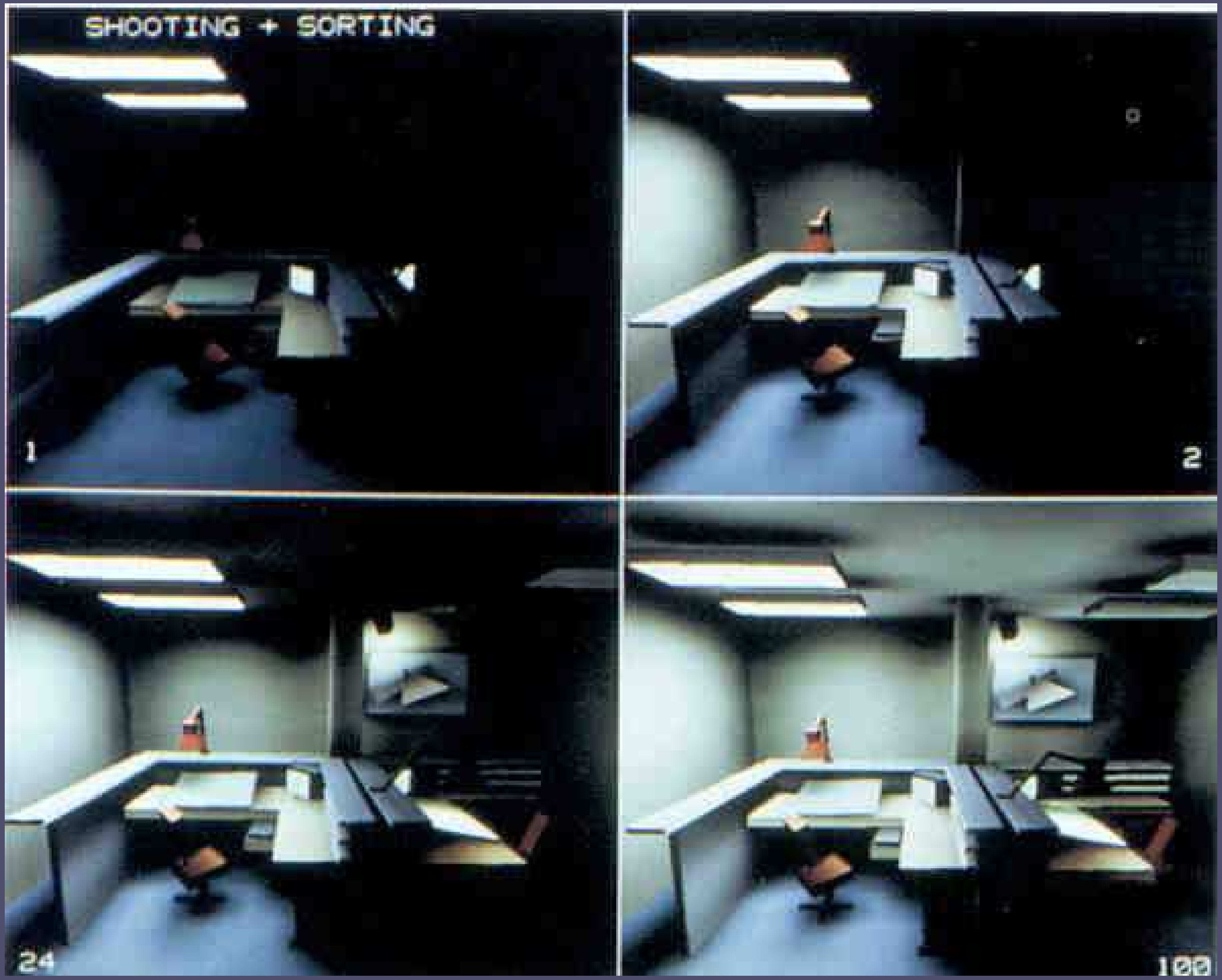
Gathering Method of Radiosity Computation

- 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

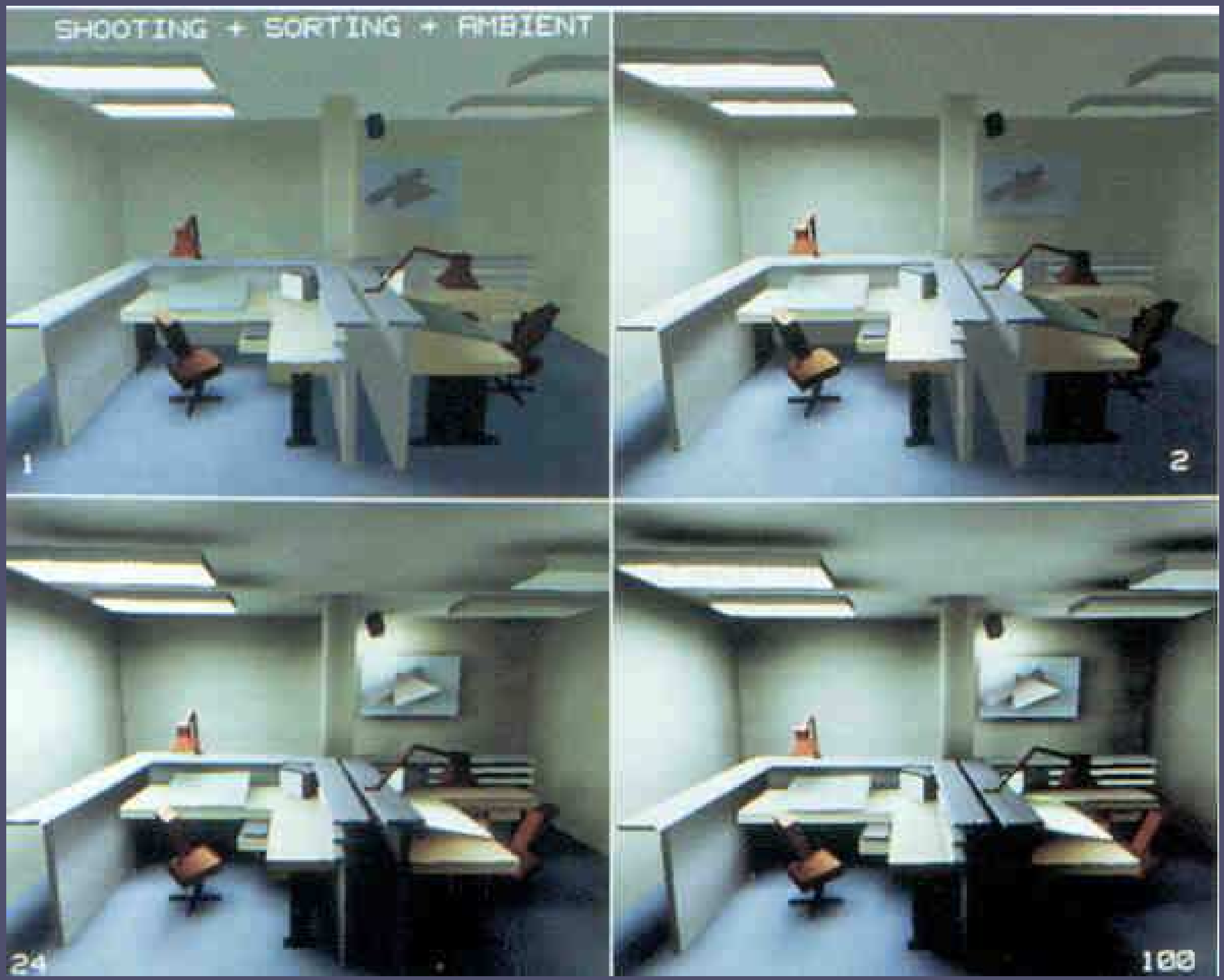
- At each iteration, emit from one patch to all other patches
  - Useful for progressive radiosity
  - Possibly add ambient when viewing preliminary results
- Order the patch emissions by magnitude of energy to be emitted

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)
- Adaptive regular subdivision (on-line)
- Adaptive 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

Adaptive 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

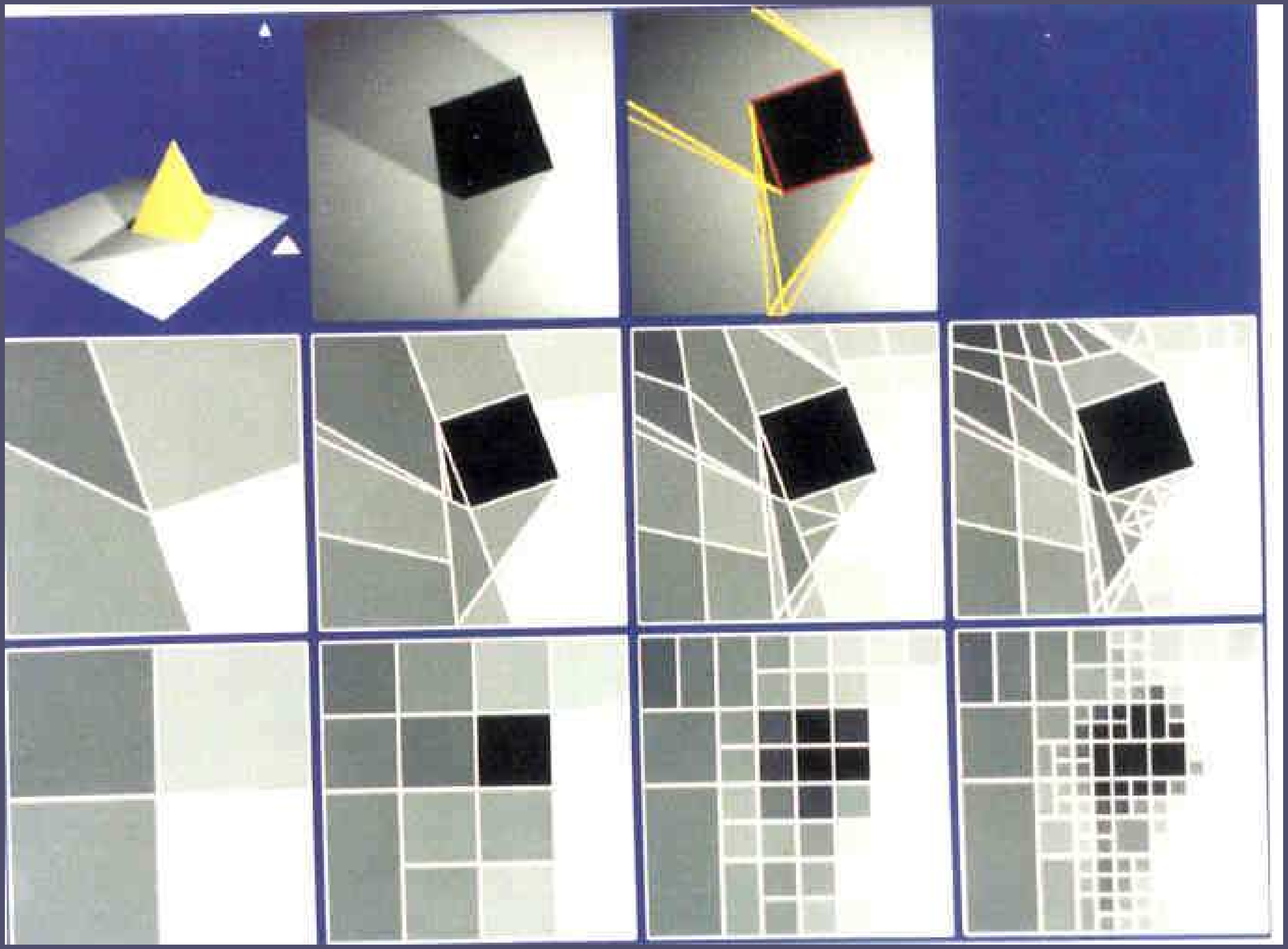
Can be implemented using matrix block operations

- 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 of SIGGRAPH 93*.

Discontinuity vs. Regular Subdivision

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

Other Topics of Interest

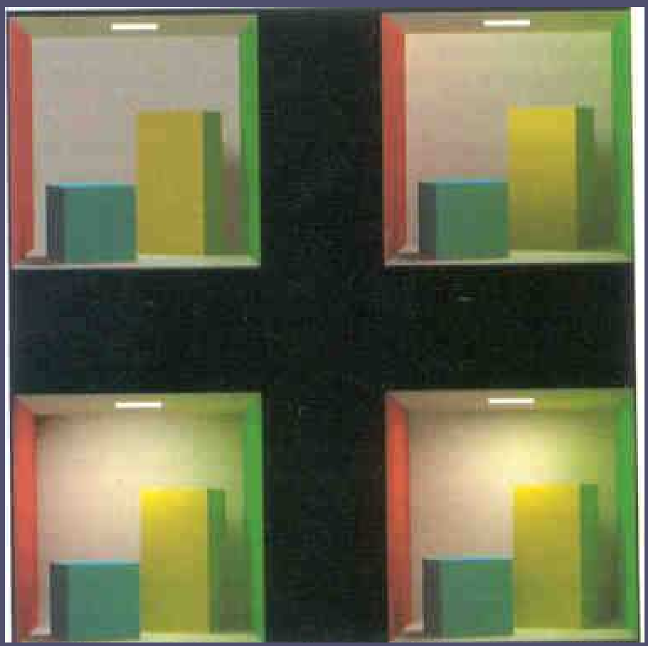
- Combining effects of initial polygons
- Using non-constant patch radiosities
- Rendering polygons with higher-order color interpolation
- Radiosity as textures

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*.

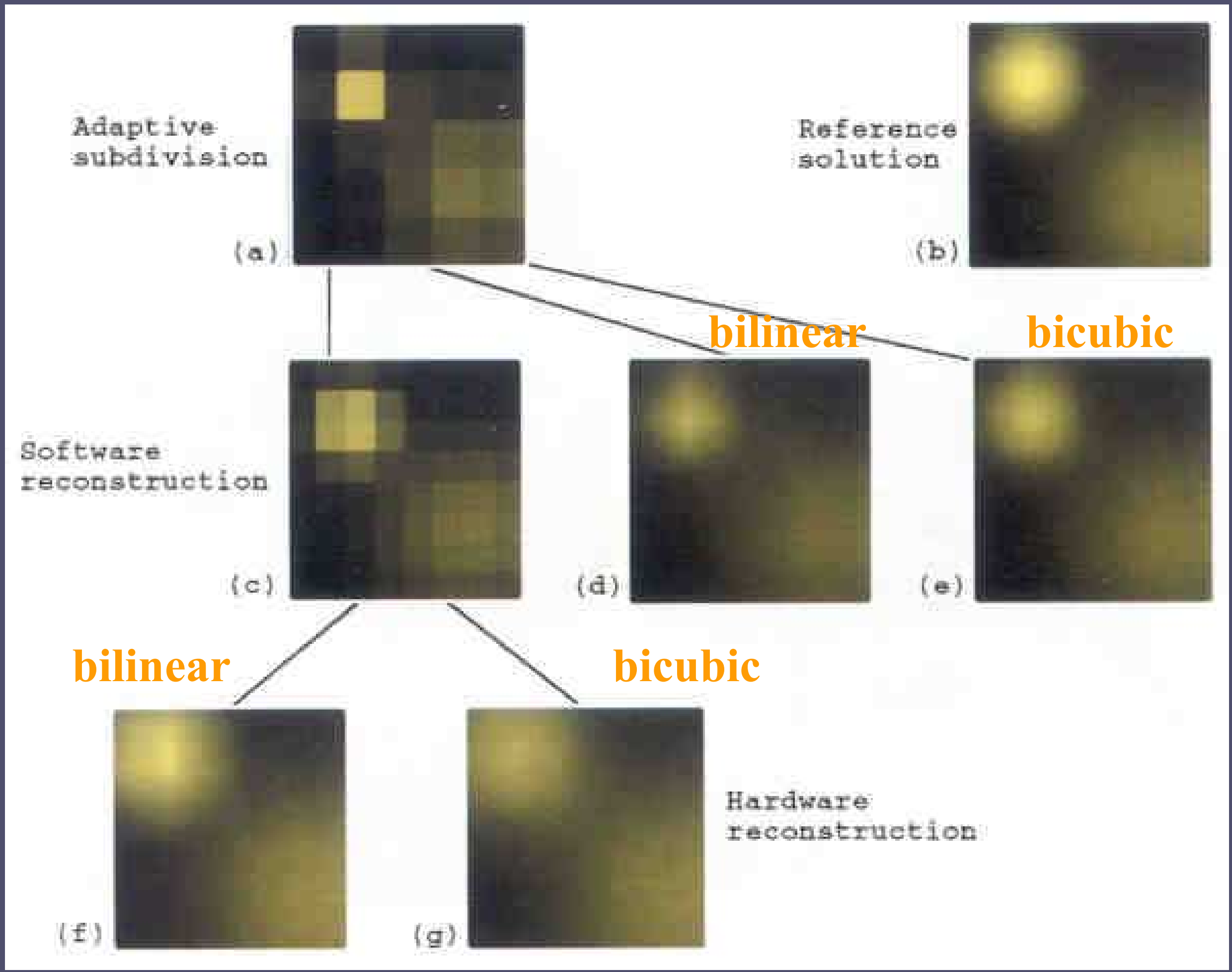
Higher-order Color Interpolation

- 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.***