DCGI

KATEDRA POČÍTAČOVÉ GRAFIKY A INTERAKCE

Radiosity

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Outline

- Radiosity Methods MPG 15.10
  - Assumptions
  - Basic principle
  - Radiosity equation
  - Iterative methods
  - Meshing
  - Instant radiosity

Radiosity - Overview

- Globall Illumination Computation
- Assumption: **Diffuse surfaces**
- Energy transport
  - Balance of emitted and absorbed energy
  - Origin in heat transfer simulation

Example

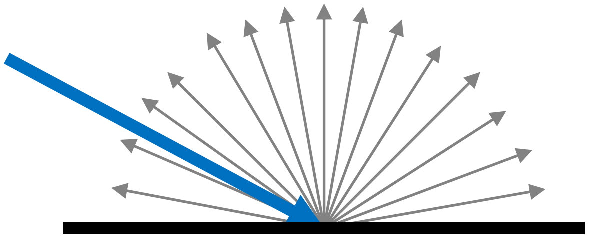
From Cohen, Chen, Wallace and Greenberg 1988

Basic Properties

- Illumination computed for planar patches
  - Finite element method
- View independent solution
  - Long preprocessing (1x)
  - Fast viewing (Nx)
- Cannot simulate specular reflection/refraction
- Good soft shadows, bad sharp shadows

Assumption #1: Diffuse emission and reflection

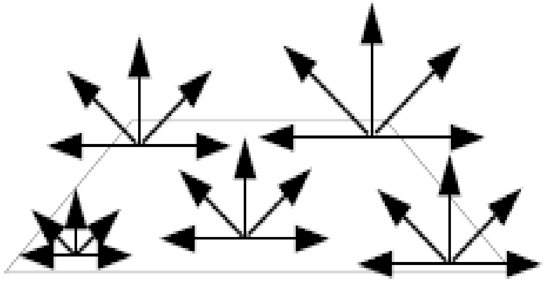
- Directionally independent radiance
- Diffuse emitter
  - Equal radiance in all directions
- Reflection on a diffuse patch



$$B(\boldsymbol{x}) = \rho_d(\boldsymbol{x})\, E(\boldsymbol{x})$$

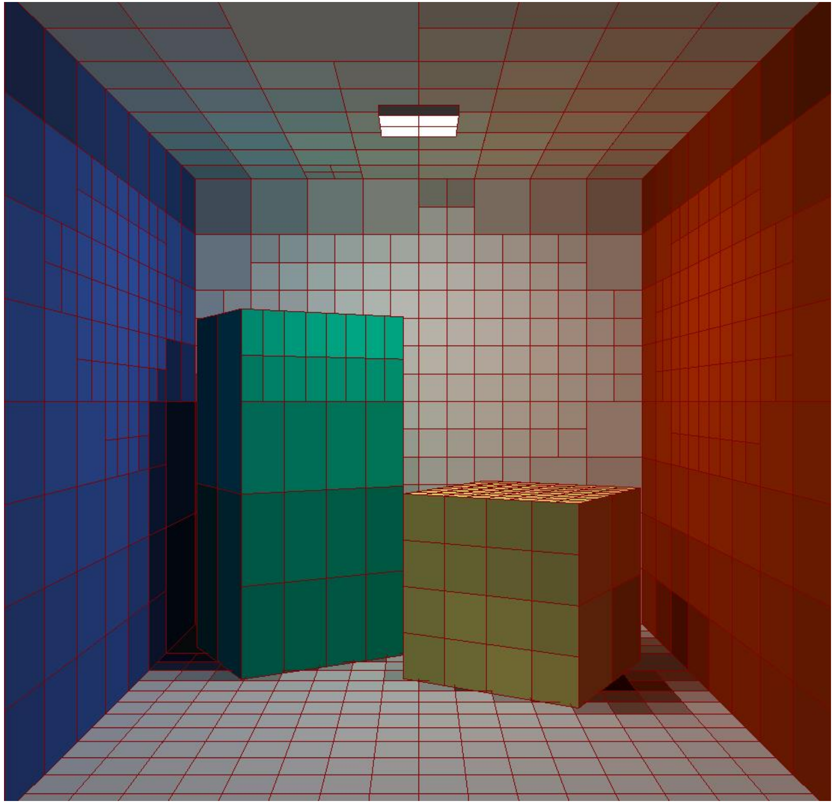
$B(\boldsymbol{x})$ … radiosity [W/m^2]
$E(\boldsymbol{x})$ … irradiance [W/m^2]
$\rho_d(\boldsymbol{x})$ … diffuse reflectivity (albedo)

- View independent reflection

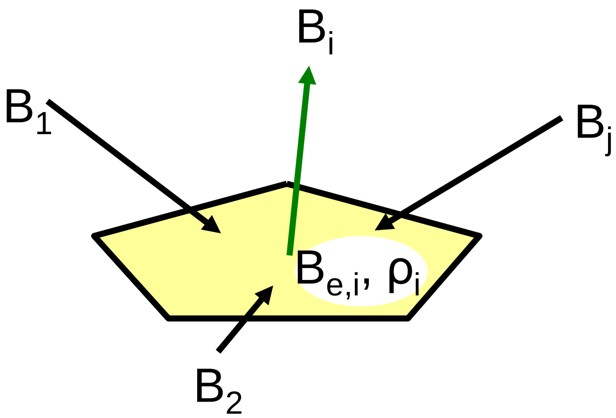


Assumption #2: Constant radiosity on patches

- Scene subdivision to patches
- Piecewise constant approximation of radiosity



Radiosity Equation



$$B_i = B_{e,i} + \rho_i \cdot \sum_{j=1}^{N} B_j \cdot F_{ij}$$

radiosity B_i
self emmision $B_{e,i}$ (E_i)
reflectivity (albedo) ρ_i
form factor F_{ij}

Form Factor

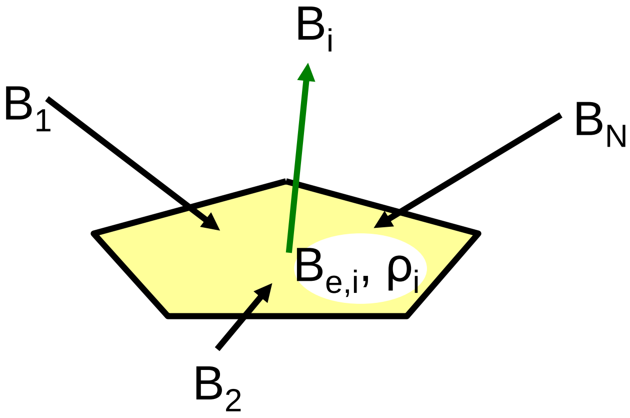
- Form factor F_{ij}
  - Portion of energy from i reaching j (energy i -> j)

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

$$A_i F_{ij} = A_j F_{ji}$$

Radiosity Equation

- Leads to system of N equations with unknowns B_i



$$B_i = B_{e,i} + \rho_i \cdot \sum_{j=1}^{N} B_j \cdot F_{ij}$$

$$A_i B_i = A_i B_{e,i} + \rho_i \cdot \sum_{j=1}^{N} A_j B_j \cdot F_{ji}$$

Power formulation

$$A_i F_{ij} = A_j F_{ji}$$

Solving Radiosity Equation

- Linear system: *N* equations with *N* uknowns (radiosities)
  - B_i … (uknown)
  - $B_{e,i}$ …(known)
  - ρ_i … (known)
  - F_{ij} … form factors
    - Have to be computed, known when solving the system

$$B_i = B_{e,i} + \rho_i \sum_{j=1}^{N} B_j F_{ij}$$

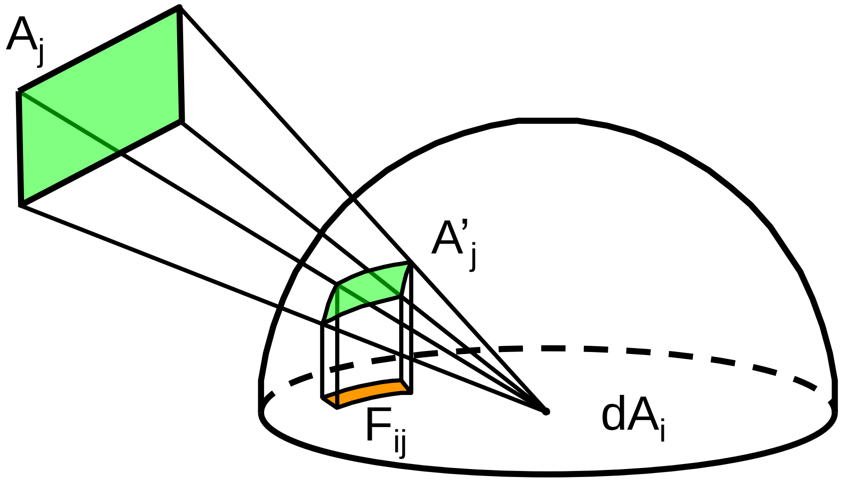
$$\begin{bmatrix} 1-\rho_1 F_{1\to 1} & -\rho_1 F_{1\to 2} & \cdots & -\rho_1 F_{1\to n} \\ -\rho_2 F_{2\to 1} & 1-\rho_2 F_{2\to 2} & \cdots & -\rho_2 F_{2\to n} \\ \cdots & \cdots & \cdots & \cdots \\ -\rho_n F_{n\to 1} & 1-\rho_n F_{n\to 2} & \cdots & 1-\rho_n F_{n\to n} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ \cdots \\ B_n \end{bmatrix} = \begin{bmatrix} B_{e,1} \\ B_{e,2} \\ \cdots \\ B_{e,n} \end{bmatrix}$$

Configuration Factor F_{ij}

- Part of energy emmited by patch **i** to patch **j**

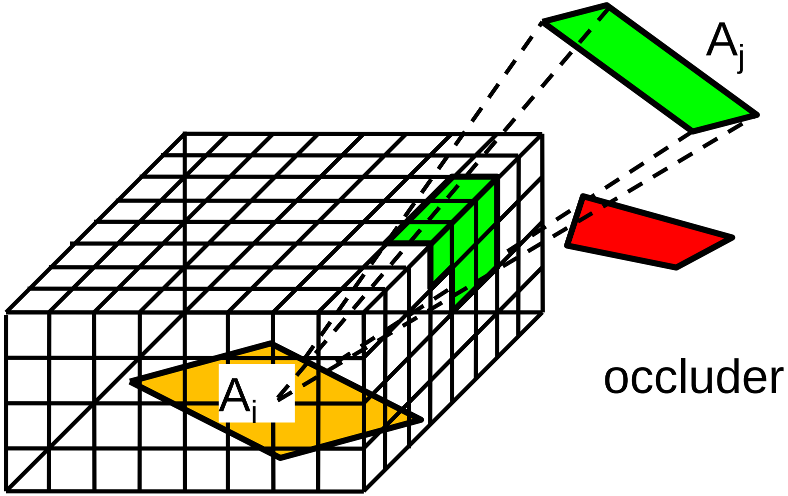
  or

- How patch **i** sees patch **j** (Nusselt analogy)

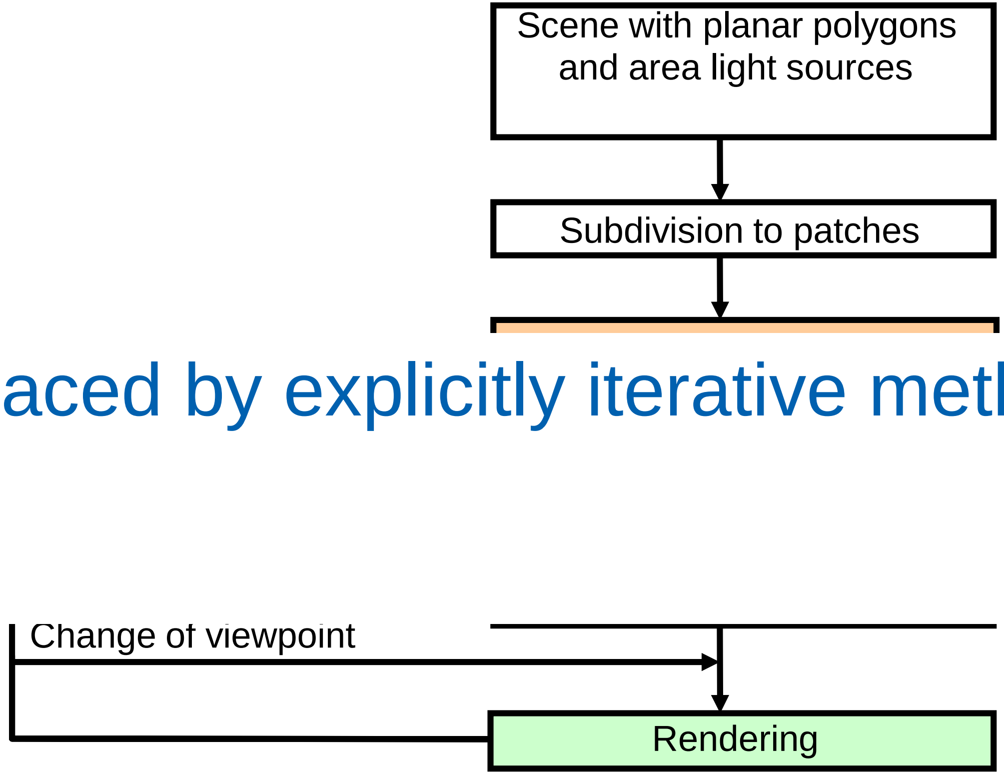


Computing F_{ij} using Hemicube

- Hemicube instead of Hemisphere
- Configuration factors from patch projections
  - Cell weights (δ factors)
  - z-buffer



Classical Computation Scheme



replaced by explicitly iterative methods

Progressive Radiosity

Idea: shooting (unshot) energy from brightest patches

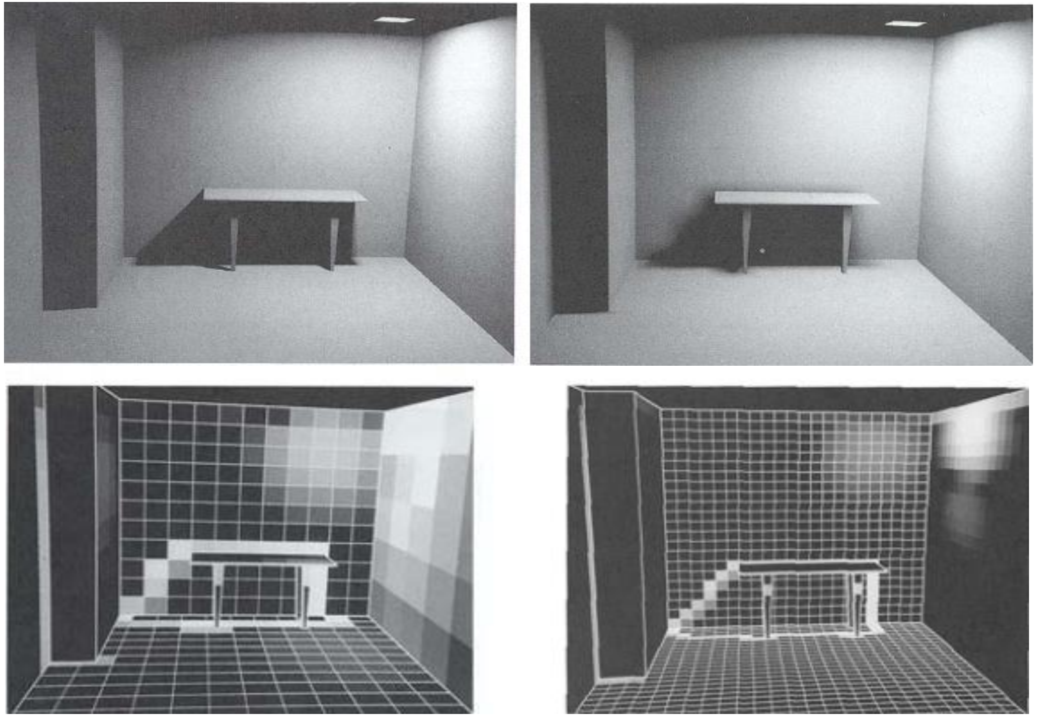
```
generate mesh by subdividing polygons into elements
for each element i
        bi ← ei                 //radiosity
        Δbi ← ei                //unshot radiosity
until convergence (quantitative, or user gets impatient)
        i = index of element with maximum “unshot power” Ai Δbi
        Compute Fij for all elements j using hemicube or ray tracing
        for each element j
                ΔRad ← ρj Δbi Fij Ai / Aj    //incremental radiosity shot from i to j
                bj ← bj + ΔRad               //update total radiosity of element j
                Δbj ← Δbj + ΔRad             //update unshot radiosity of element j
        Δ bi ← 0                             //reset unshot radiosity for element i to zero
        display scene using radiosities bj, if desired
```

Other methods

- Hierarchical radiosity
  - Patches in a hierarchy
  - Energy transfer between hierarchy nodes
- Stochastic radiosity (Monte-Carlo)
  - Using rays to stochastically distribute energy (random walk)
  - Diffuse ray reflection
  - Register #hits per patch
  - No form-factor computation needed!

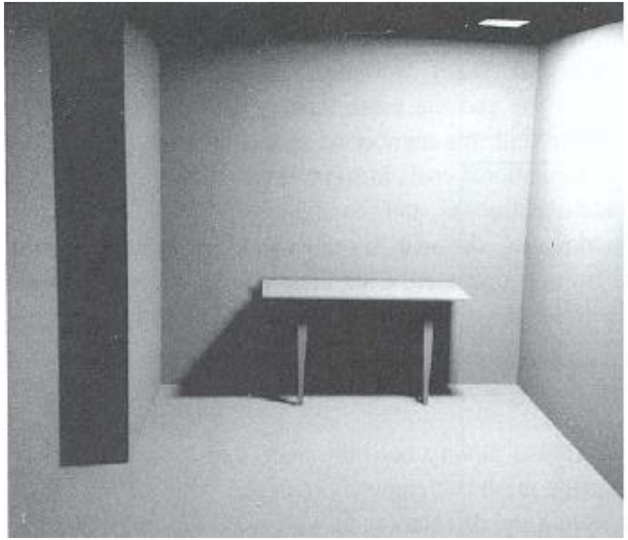
Meshing

Reference solution | Uniform subdivision

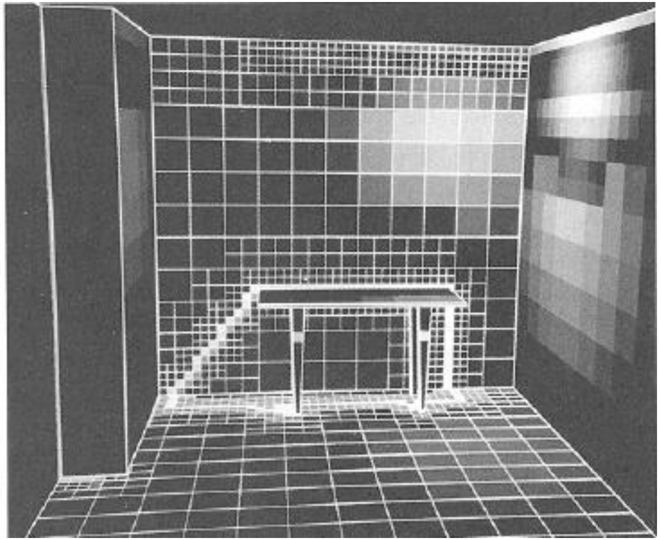


coarse | fine

Adaptive Subdivision



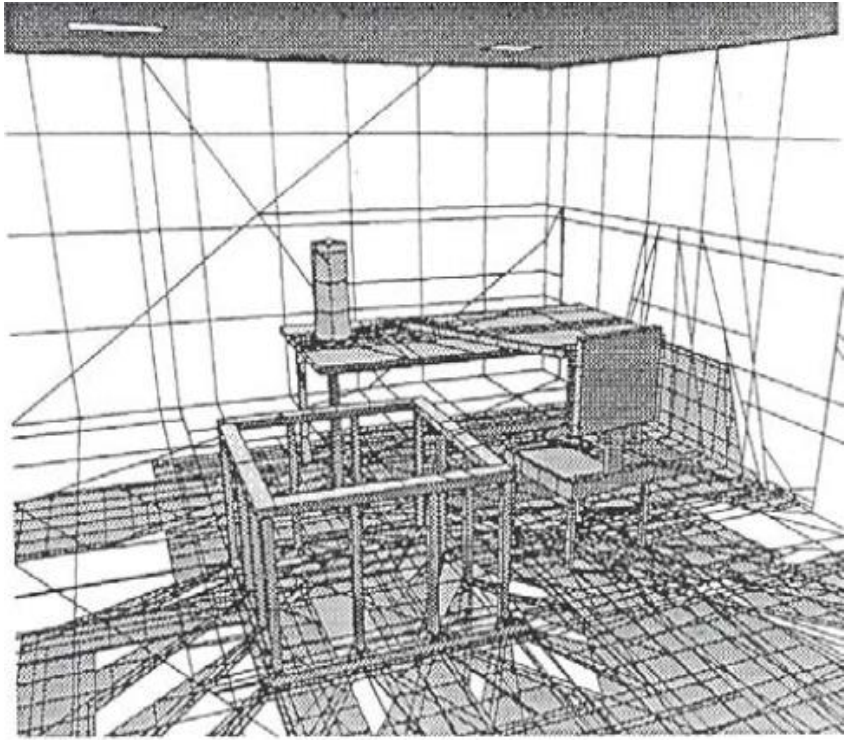
solution



adaptive subdivision

Discontinuity Meshing

- Subdivision along illumination discontinuities



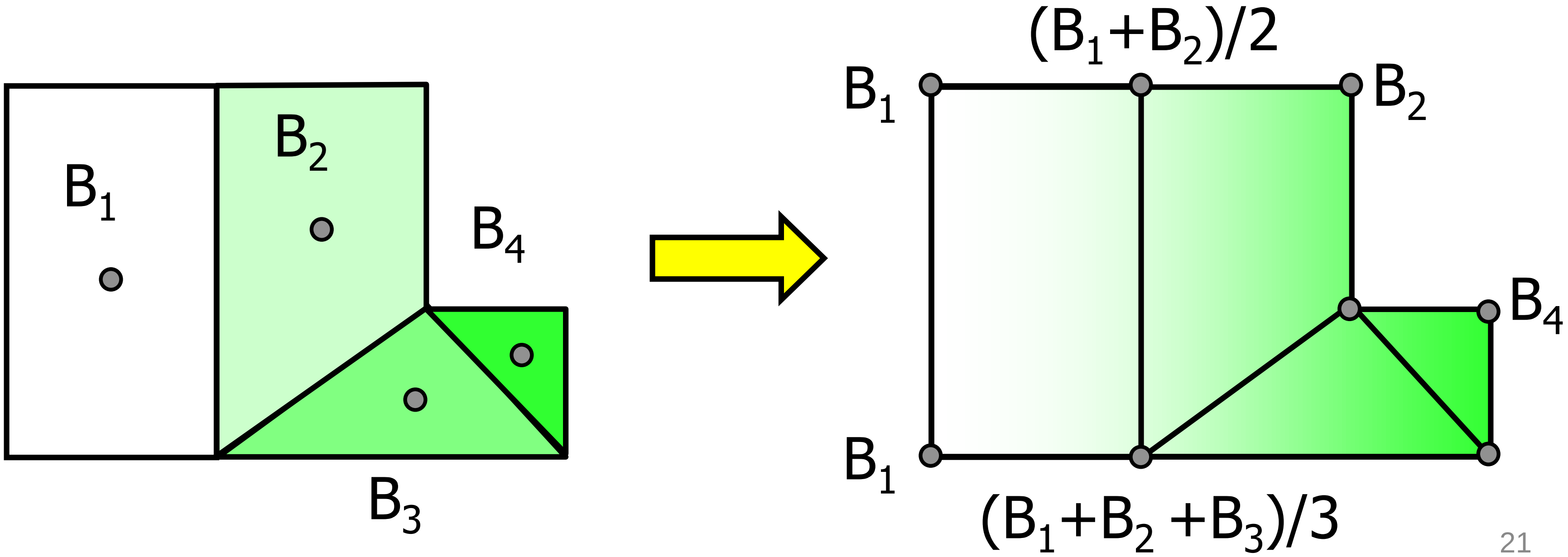
From Campbell et al.

Discontinuity Meshing - Example

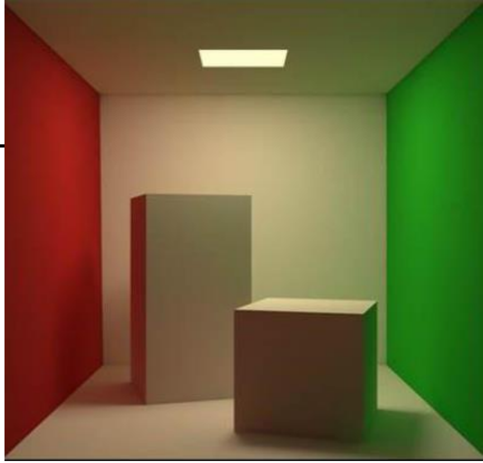
From Lischinski, Tampieri, Greenberg 1992

Radiosity and Shading

- Radiosity determines patch color at patch center
- For Gouraud shading values at vertices needed

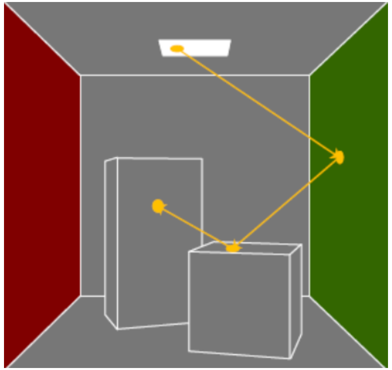


Instant Radiosty

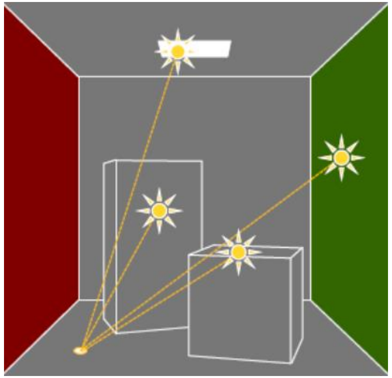


- Use many virtual point lights (VPLs)
- No patch subdivision needed!

1. Create VPLs
   - Shoot photons
   - Random walk



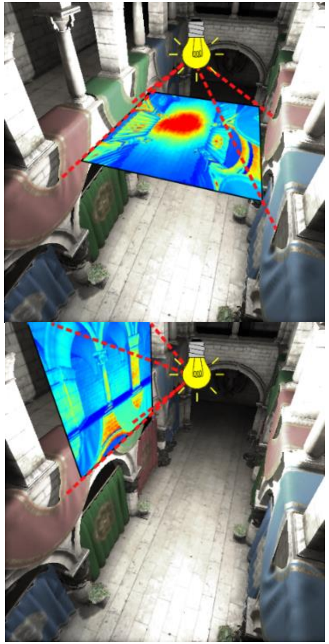
2. Render
   - For each VPL
   - Render with shadows

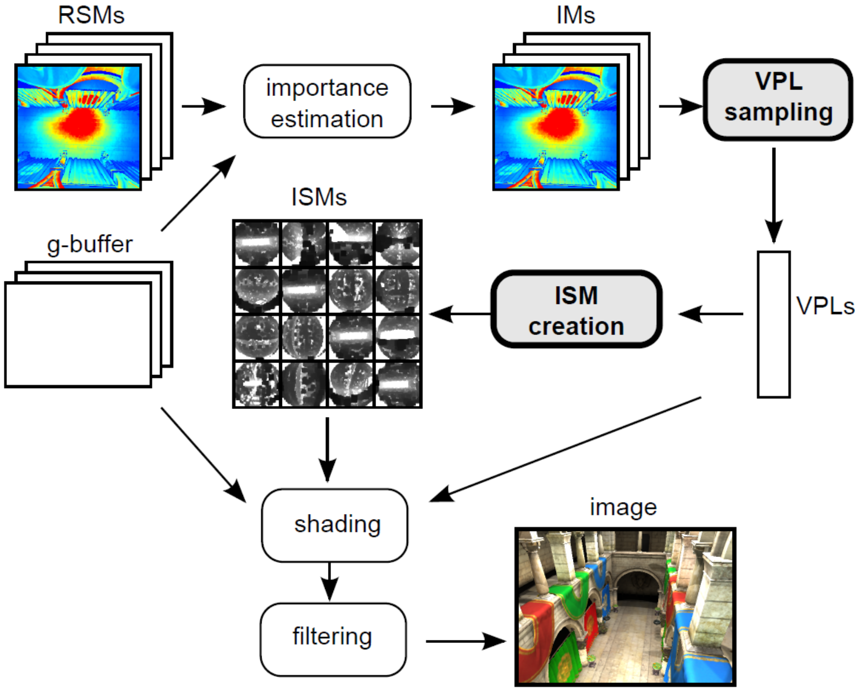


Images courtesy of M. Hasan

Temporally Coherent VPL Sampling

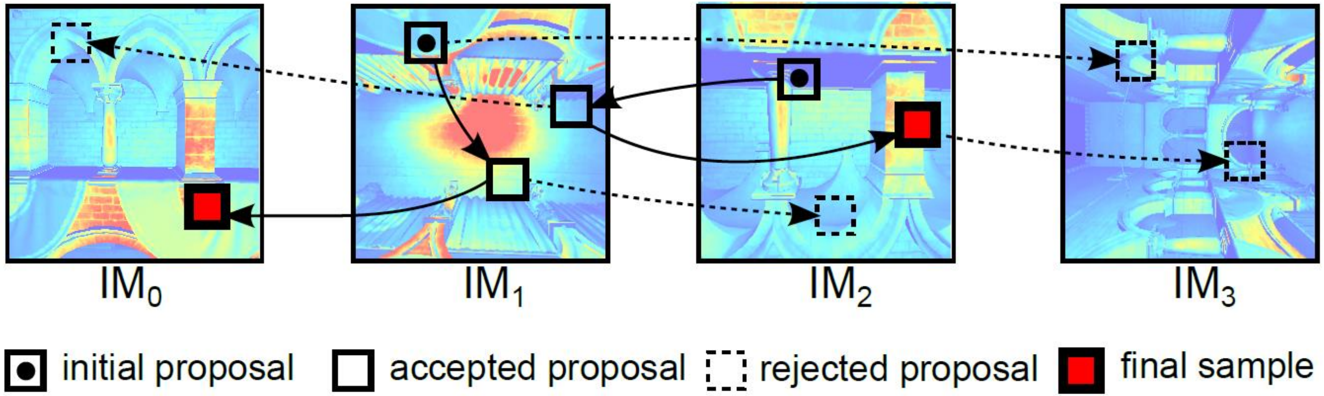
- Global illumination using instant radiosity (many VPLs)
- Improve stability of adaptive VPL sampling





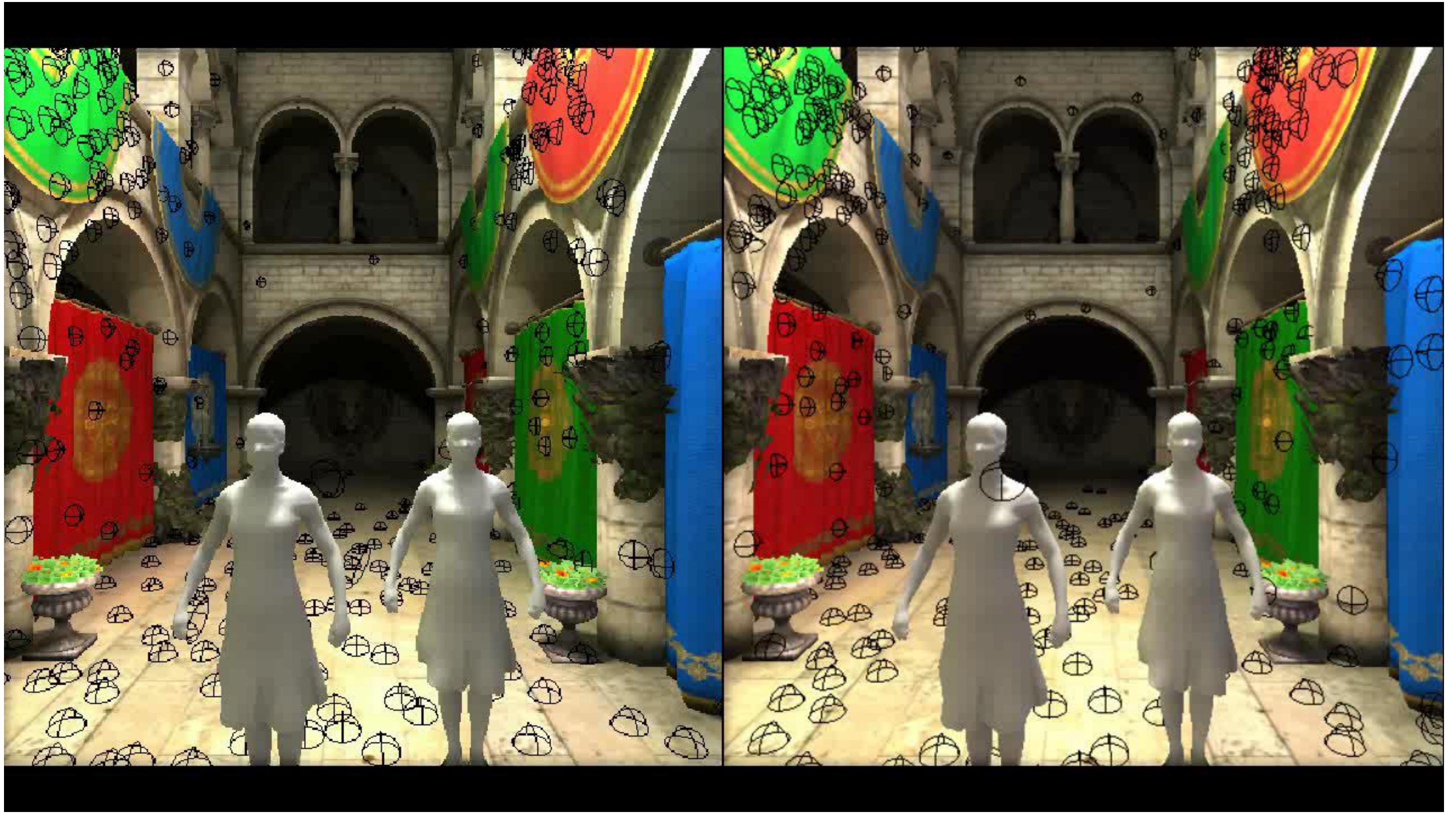
Temporally Coherent VPLs

- Metropolis-Hastings sampling
- Independent Markov chain



[Temporally Coherent Adaptive Sampling for Imperfect Shadow Maps (2013)]

Temporally Coherent VPLs



CDF sampling | Our method

Radiosity - DEMO

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  - Radiosity equation
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Questions?