CS482:
Radiosity

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(윤성의)

Course URL:
http://sglab.kaist.ac.kr/~sungeui/ICG

Class Objective (Ch. 11)

- **Understand radiosity**
  - **Radiosity equation**
  - **Solving the equation**

History

- **Problems with classic ray tracing**
  - **Not realistic**
  - **View-dependent**

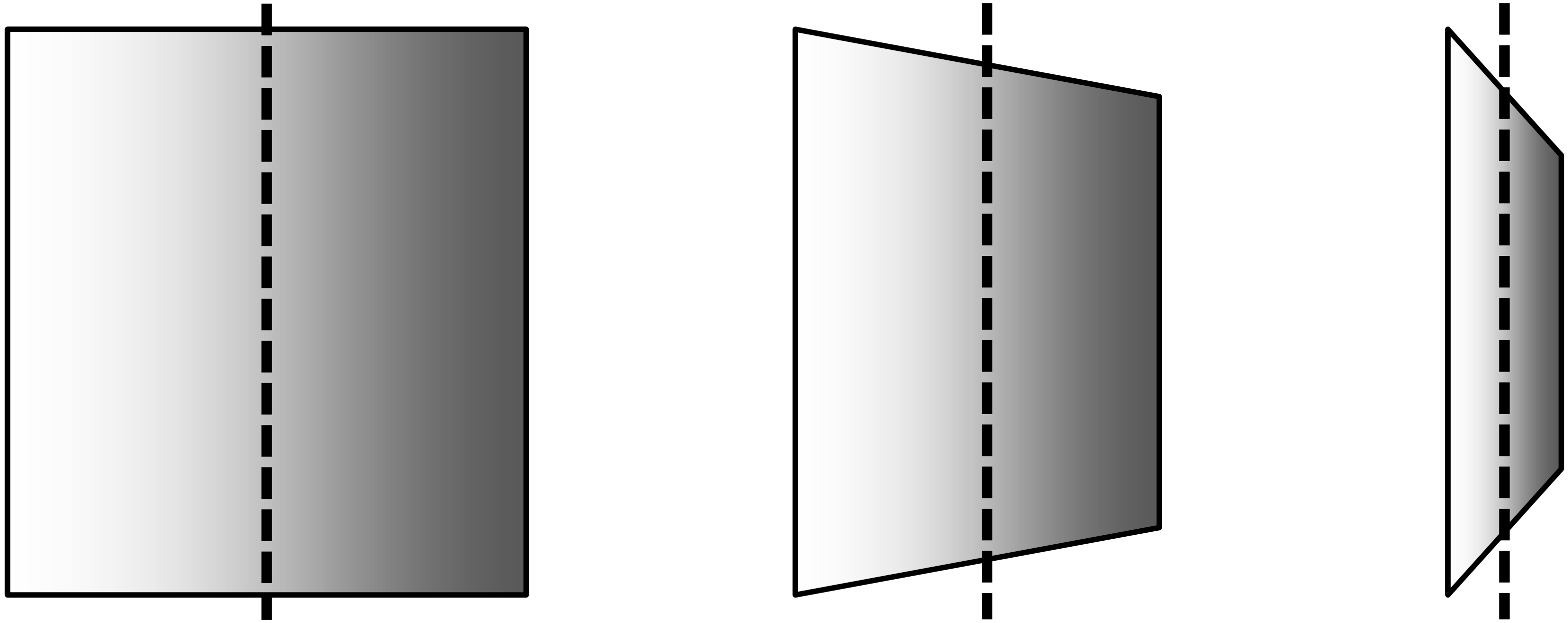
- **Radiosity (1984)**
  - **Global illumination in diffuse scenes**

- **Monte Carlo ray tracing (1986)**
  - **Global illumination for any environment**

Radiosity

- **Physically based method for diffuse environments**
  - **Support diffuse interactions, color bleeding, indirect lighting and penumbra**
  - **Account for very high percentage of total energy transfer**
  - **Finite element method**

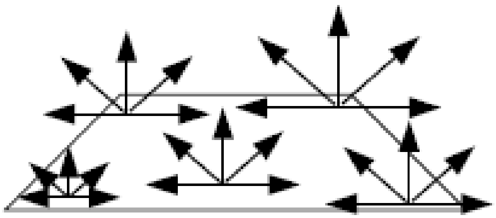
Key Idea #1: Diffuse Only



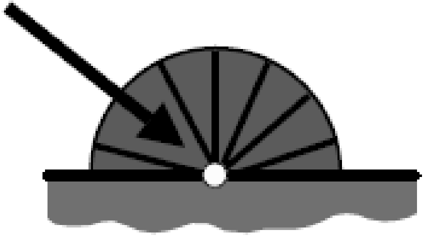
- Radiance independent of direction
  - Surface looks the same from any viewpoint
  - No specular reflection

Diffuse Surfaces

- **Diffuse emitter**
  - $L(x \rightarrow \Theta)$ **= constant over** Θ



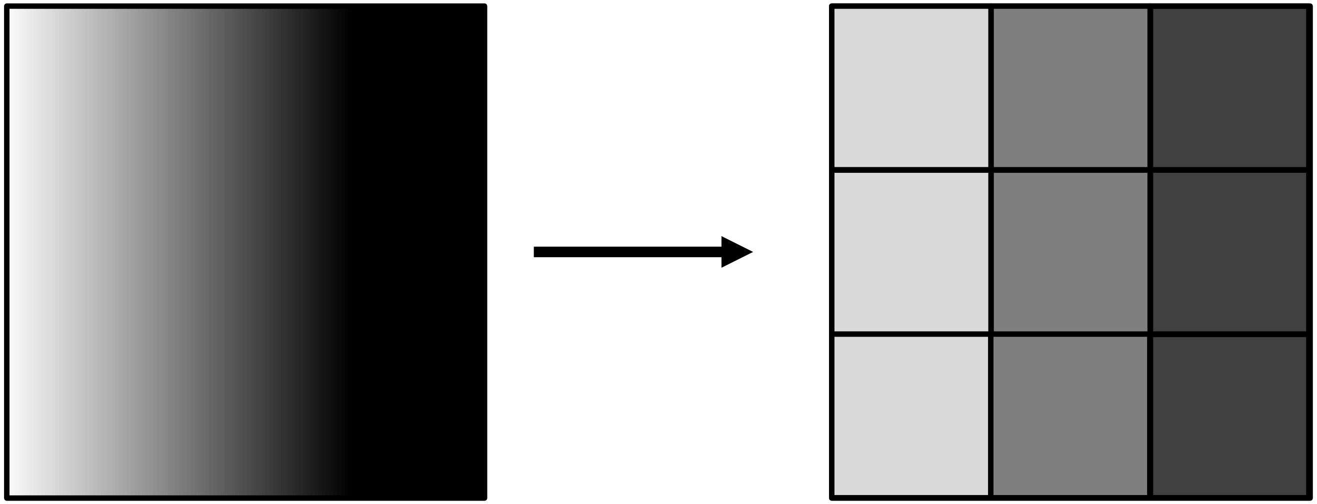
- **Diffuse reflector**
  - **Constant reflectivity**



From kavita's slides

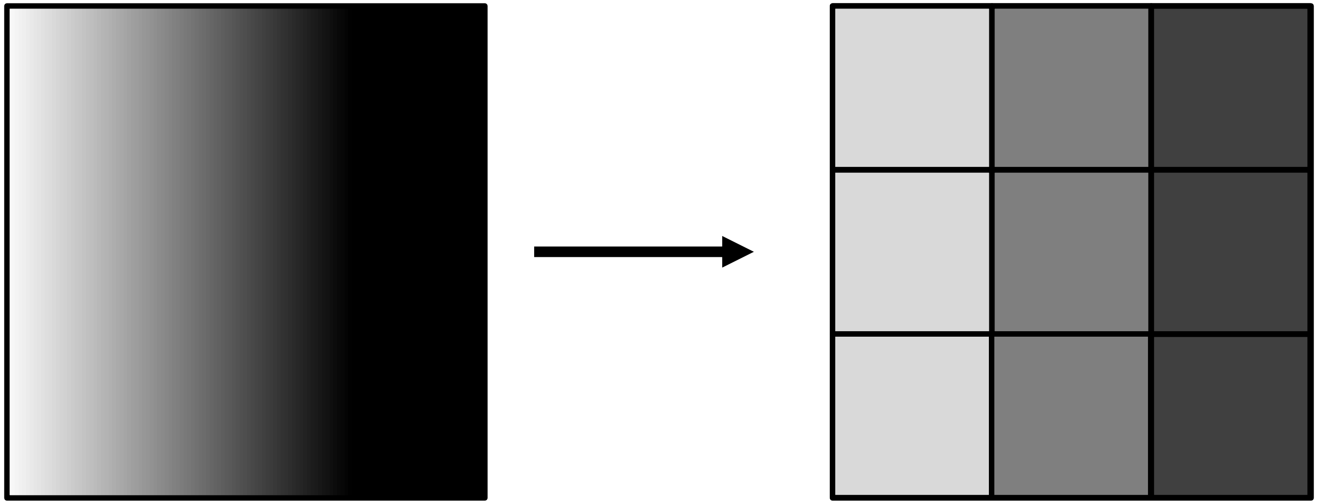
Key Idea #2: Constant Polygons

- Radiosity is an approximation
  - Due to discretization of scene into patches



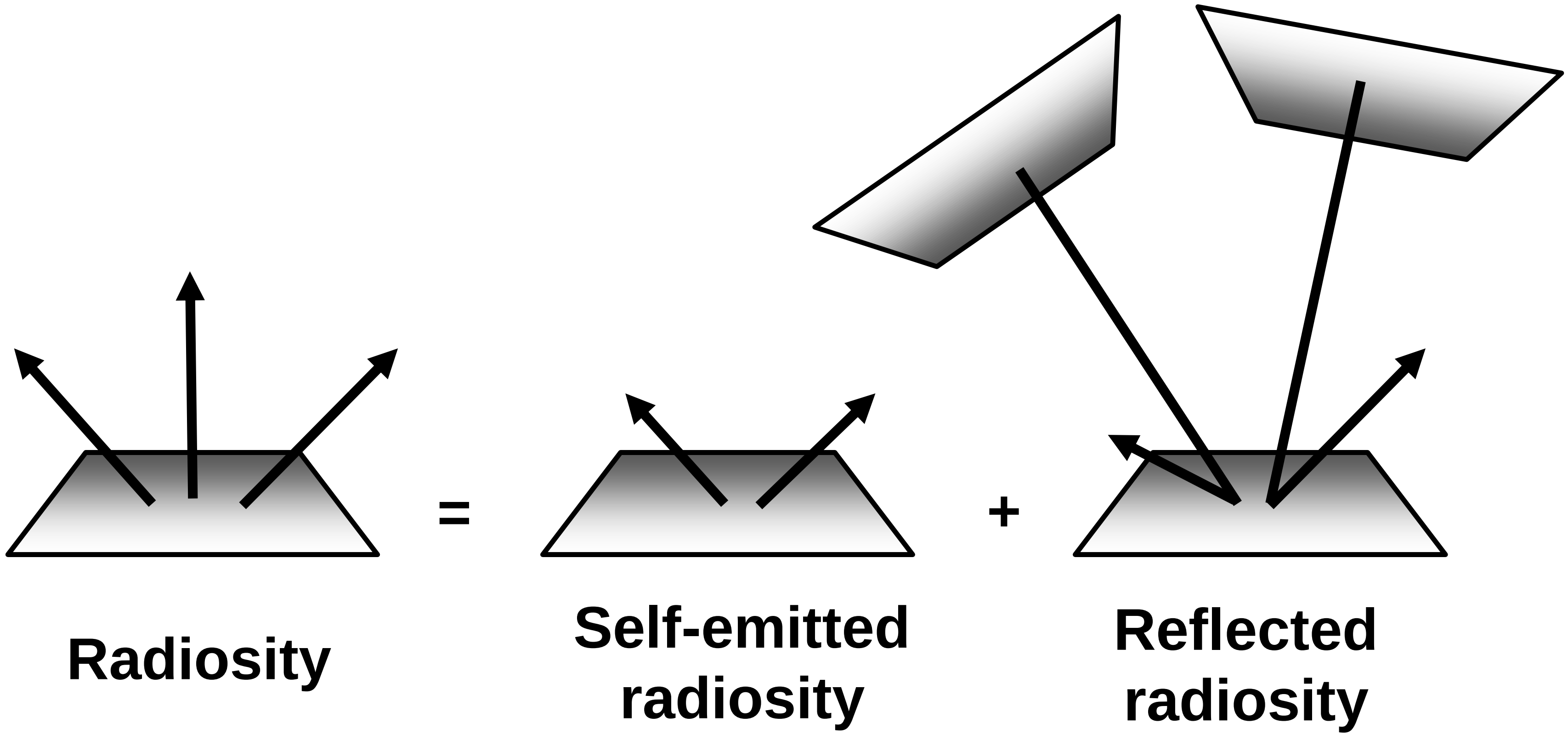
  - Subdivide scene into small polygons

Constant Radiance Approximation



- Radiance is constant over a surface element
  - L(x) = constant over x

Radiosity Equation



$$Radiosity_i = Radiosity_{self,i} + \sum_{j=1}^{N} a_{j \rightarrow i} Radiosity_j$$

Radiosity Equations

- **Radiosity for each polygon i**

$$Radiosity_1 = Radiosity_{self,1} + \sum_{j=1}^{N} a_{j\to 1}\, Radiosity_j$$

$$\vdots$$

$$Radiosity_i = Radiosity_{self,i} + \sum_{j=1}^{N} a_{j\to i}\, Radiosity_j$$

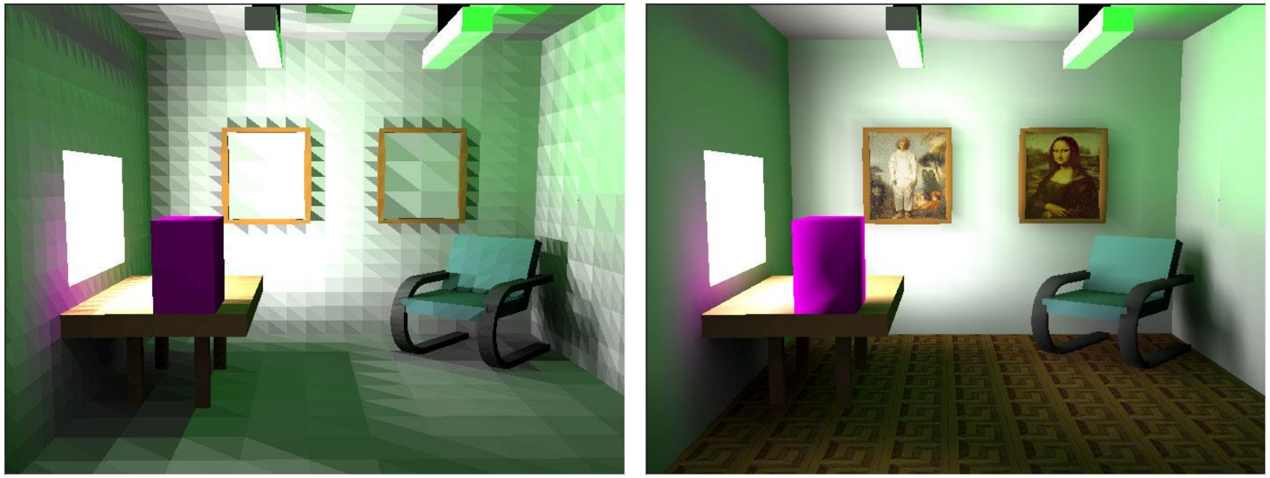
$$\vdots$$

$$Radiosity_N = Radiosity_{self,N} + \sum_{j=1}^{N} a_{j\to N}\, Radiosity_j$$

- **N equations and N unknown variables**

Radiosity Algorithm

- Subdivide the scene in small polygons
- Compute a constant illumination value for each polygon
- Choose a viewpoint and display the visible polygon
  - Keep doing this process



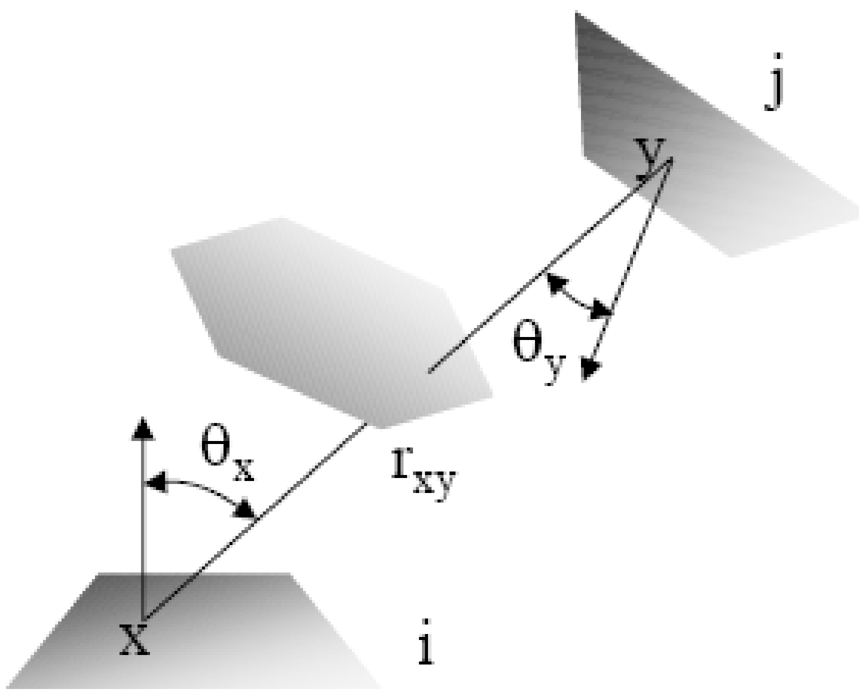
From Donald Fong's slides

Radiosity Result

Theatre Scene

Compute Form Factors

$$F(j \rightarrow i) = \frac{1}{A_j} \int_{A_i} \int_{A_j} \frac{\cos\theta_x \cdot \cos\theta_y}{\pi \cdot r_{xy}^2} \cdot V(x, y) \cdot dA_y \cdot dA_x$$



Radiosity Equation

- **Radiosity for each polygon *i***

$$B_i = B_{e,i} + \rho_i \sum_j B_j F(i \to j)$$

- **Linear system**
  - B_i : radiosity of patch i (unknown)
  - $B_{e,i}$: emission of patch i (known)
  - ρ_i : reflectivity of patch i (known)
  - $F(i \to j)$: form-factor (coefficients of matrix)

Linear System of Radiosity

Known — Known

$$\begin{bmatrix} 1-\rho_1 F(1\to 1) & -\rho_1 F(1\to 2) & \dots & -\rho_1 F(1\to n) \\ \vdots & \vdots & \ddots & \vdots \\ -\rho_n F(n\to 1) & -\rho_n F(n\to 2) & \dots & 1-\rho_n F(n\to n) \end{bmatrix} \begin{bmatrix} B_1 \\ \vdots \\ B_n \end{bmatrix} = \begin{bmatrix} B_{e,1} \\ \vdots \\ B_{e,n} \end{bmatrix}$$

Unknown

How to Solve Linear System

- **Matrix inversion**
  - **Takes $O(n^3)$**
- **Gather methods**
  - **Jacobi iteration**
  - **Gauss-Seidel**
- **Shooting**
  - **Southwell iteration**

Iterative Approaches

- **Jacobi iteration**
  - **Start with initial guess for energy distribution (light sources)**
  - **Update radiosity of all patches based on the previous guess**

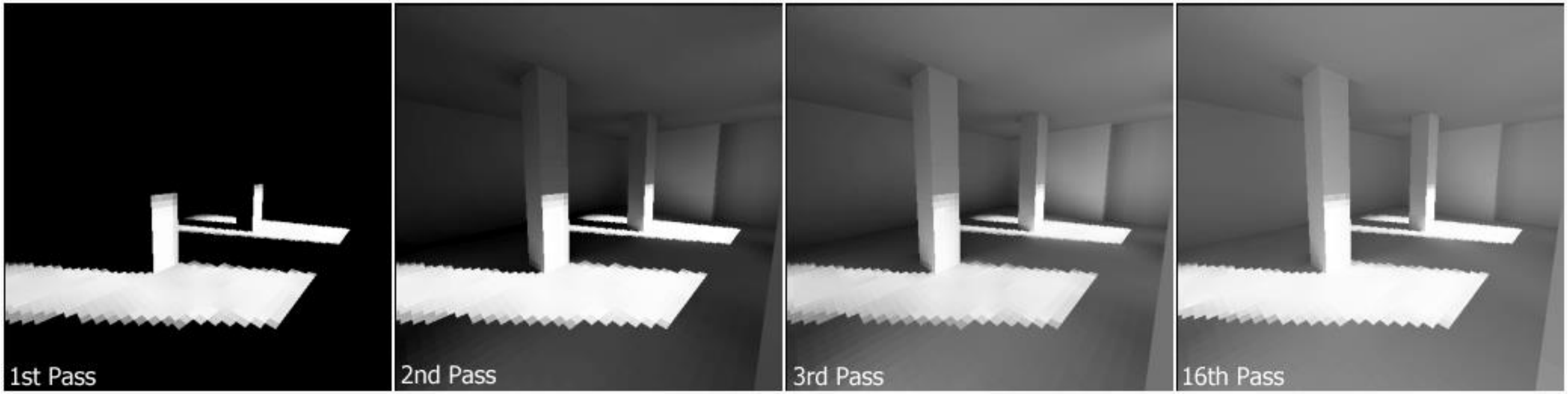
$$B_i = B_{e,i} + \rho_i \sum_j B_j F(i \rightarrow j)$$

New values (B_i) — Old values (B_j)

  - **Repeat until converged**
- **Guass-Seidel iteration**
  - **New values used immediately**

Progress of Update Steps

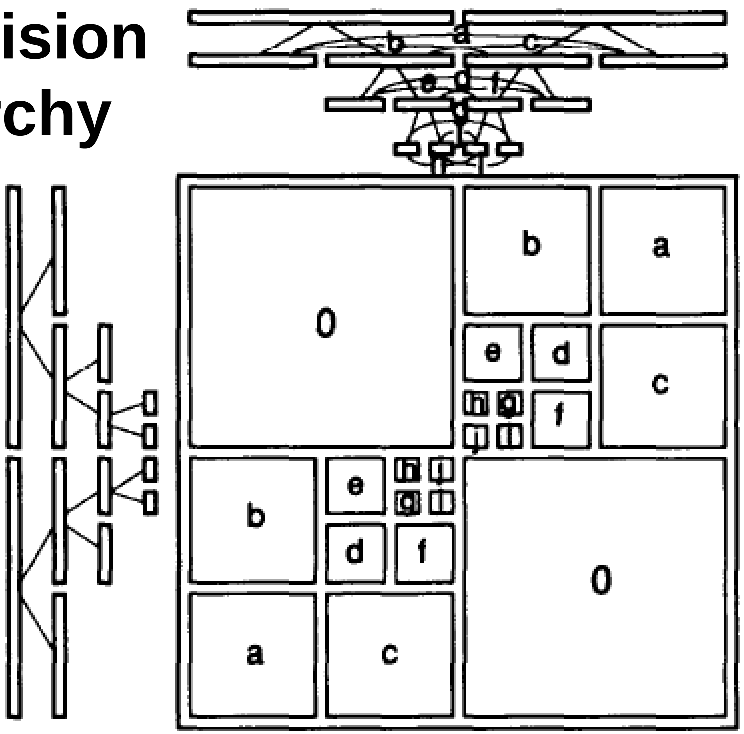
- **Update step supports the light bounce**



Multi-Resolution Approach

- **A Rapid Hierarchical Radiosity Algorithm, Hanrahan, et al, SIGGRAPH 1991**

Subdivision hierarchy



Block diagram of the form factor matrix

- **Refine triangles only if doing so improves the foam factor accuracy above a threshold**

Hybrid and Multipass Methods

- **Ray tracing**
  - **Good for specular and refractive indirect illumination**
  - **View-dependent**

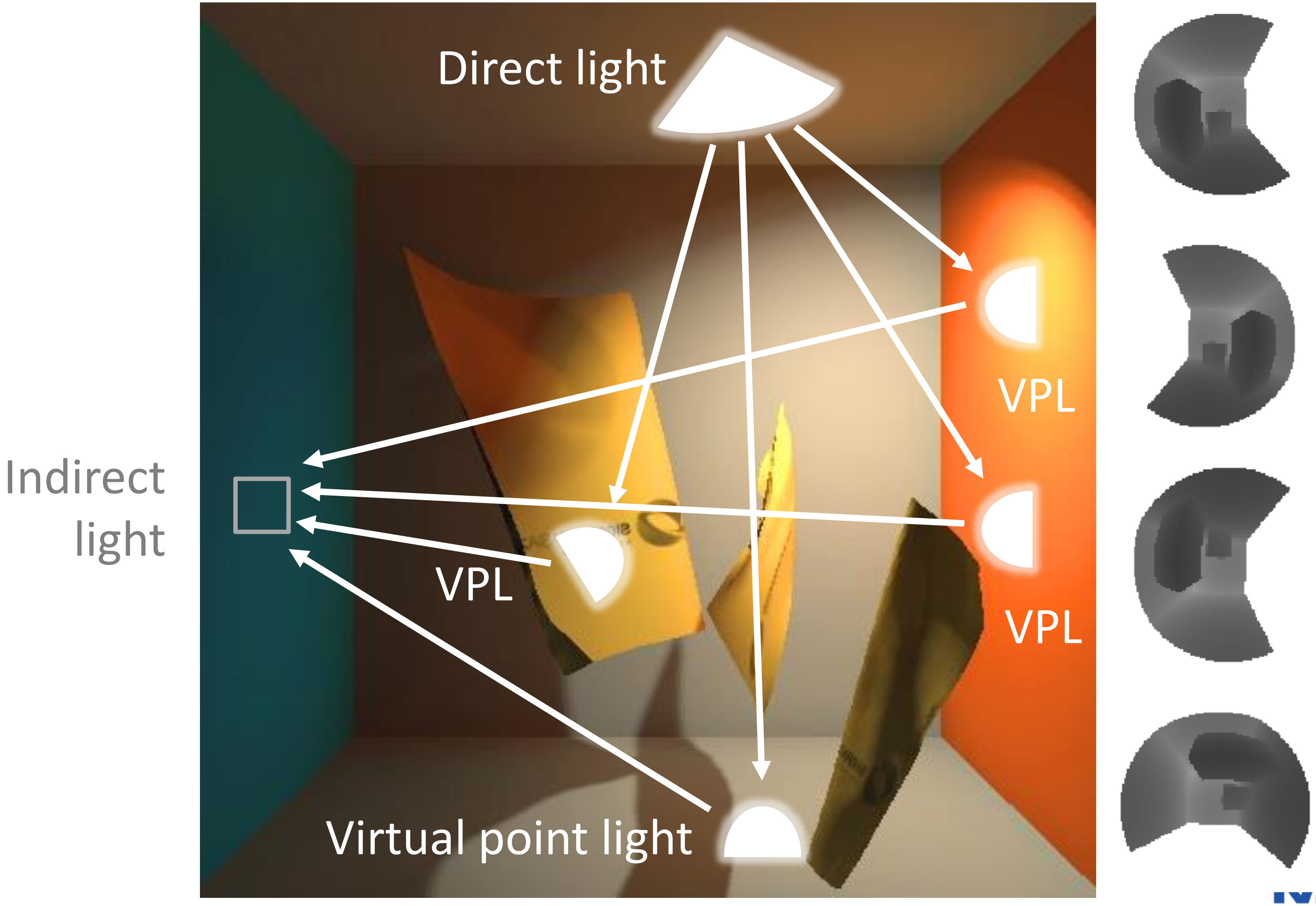
- **Radiosity**
  - **Good for diffuse**
  - **Allows interactive rendering**
  - **Does not scale well for massive models**

- **Hybrid methods**
  - **Combine both of them in a way**

Instant Radiosity

- Use the concept of radiosity
- Map its functions to those of classic rendering pipeline
    - Utilize fast GPU
- Additional concepts
    - Virtual point lights
    - Shadow maps

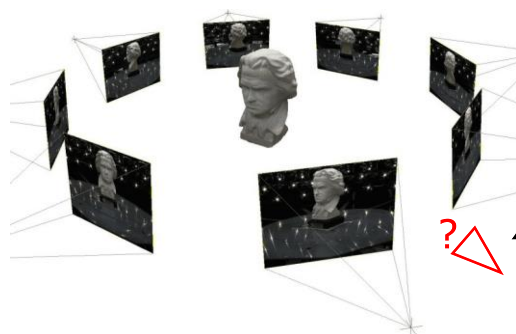
Instant Radiosity



NeRF: Neural Radiance Fields ECCV 2020 Oral - Best Paper Honorable Mention

The goal of NeRF is to synthesize photorealistic images from novel camera viewpoints.

Input: images from various camera viewpoints



Output: images from novel camera viewpoints

Source: https://theaisummer.com/nerf/

Examples (synthesized from novel views)

Videos: https://www.youtube.com/watch?v=JuH79E8rdKc&t=191s

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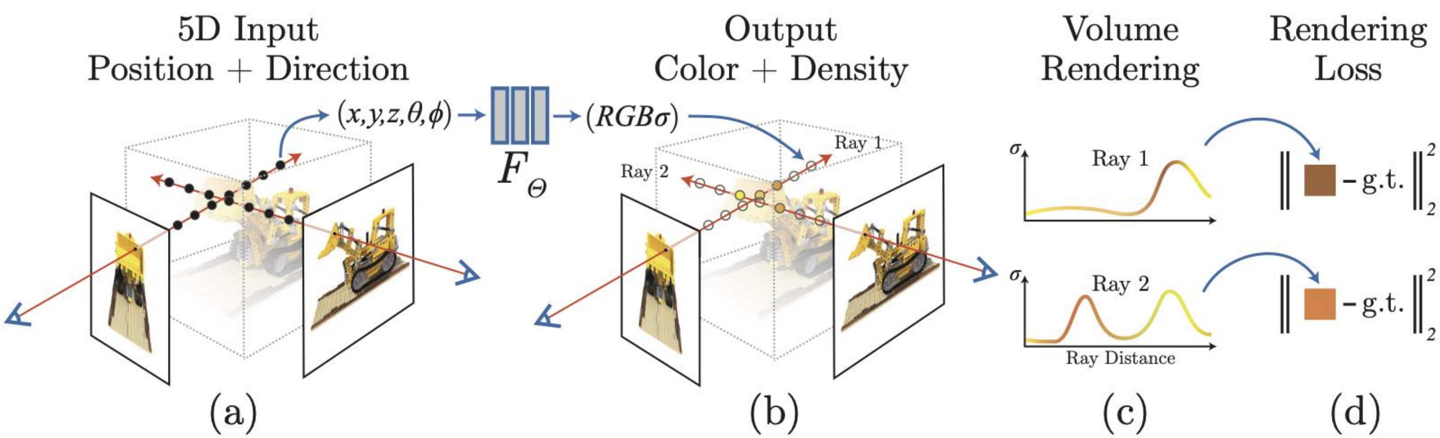
https://www.matthewtancik.com/nerf

Neural Radiance Fields ECCV 2020 Oral - Best Paper Honorable Mention



$$C(\mathbf{r}) = \int_{t_n}^{t_f} T(t)\sigma(\mathbf{r}(t))\mathbf{c}(\mathbf{r}(t),\mathbf{d})dt\,, \text{ where } T(t) = \exp\left(-\int_{t_n}^{t}\sigma(\mathbf{r}(s))ds\right)$$

Ray color | Transmittance | Density | Color

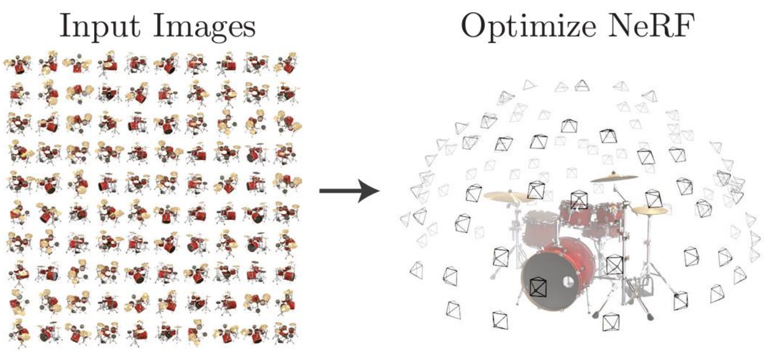
$$\mathbf{r}(t) = \mathbf{o} + t\mathbf{d}$$

Position | Direction

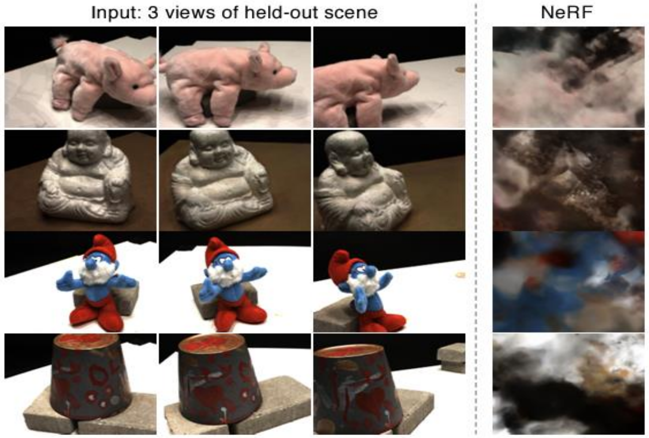
Cons of NeRF

Requires Dense camera viewpoints

> **Since NeRF is under-constrained** it produces blurred or distorted results with sparse-view inputs.
> => Learning accurate 3D representation of an object requires dense views.



Dense camera viewpoints are required (e.g., 50+ source images)



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pixelNeRF: Neural Radiance Fields from One or Few Images, CVPR'21

Class Objectives were:

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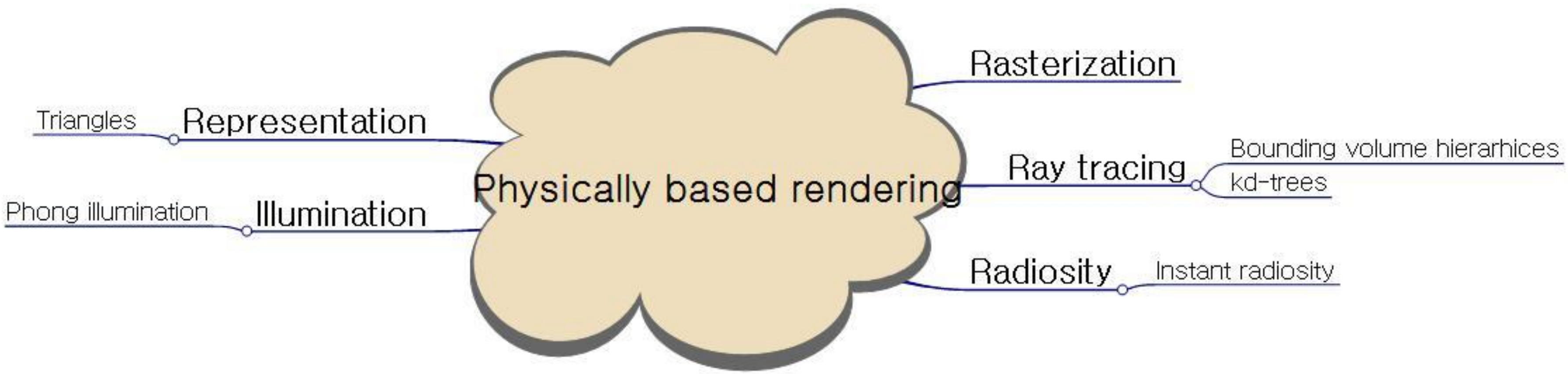
  - **Solving the equation**



Homework

- **Go over the next lecture slides before the class**
- **Watch 2 paper videos and submit your summaries every Mon. class**
  - **Just one paragraph for each summary**

Example:

Title: XXX XXXX XXXX
Abstract: this video is about accelerating the performance of ray tracing. To achieve its goal, they design a new technique for reordering rays, since by doing so, they can improve the ray coherence and thus improve the overall performance.

Any Questions?

- **Submit four times in Sep./Oct.**
- **Come up with one question on what we have discussed in the class and submit at the end of the class**
  - **1 for typical questions**
  - **2 for questions that have some thoughts or surprise me**

Next Time

- **Radiometry and rendering equation**