A Two-Pass Solution to the Rendering Equation: A Synthesis of Ray Tracing and Radiosity Methods

Wallace, Cohen, and Greenberg

1987

Rendering Equation

$$I_{out}(\Theta_{out}) = E(\Theta_{out}) + \int_{\Omega} \rho''(\Theta_{out}, \Theta_{in})\, I_{in}(\Theta_{in}) \cos(\theta)\, d\omega$$

I_{out} = the outgoing intensity for the surface

I_{in} = an intensity arriving at the surface from the rest of the environment

E = outgoing intensity due to emission by the surface

Θ_{out} = the outgoing direction

Θ_{in} = the incoming direction

Ω = the sphere of incoming directions

θ = the angle between the incoming direction Θ_{in} and the surface normal

$d\omega$ = the differential solid angle through which the incoming intensity arrives

ρ'' = the bidirectional reflectance/transmittance of the surface

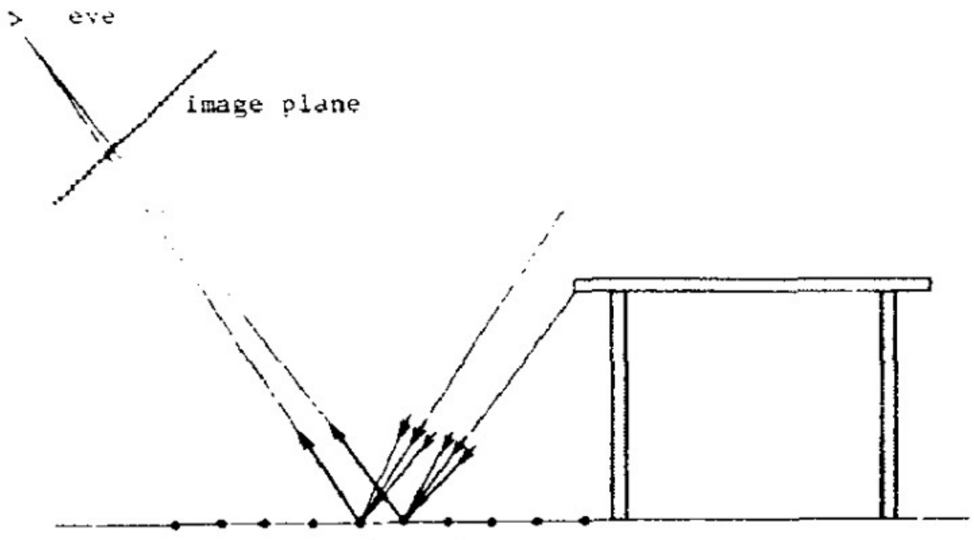
Previous Methods

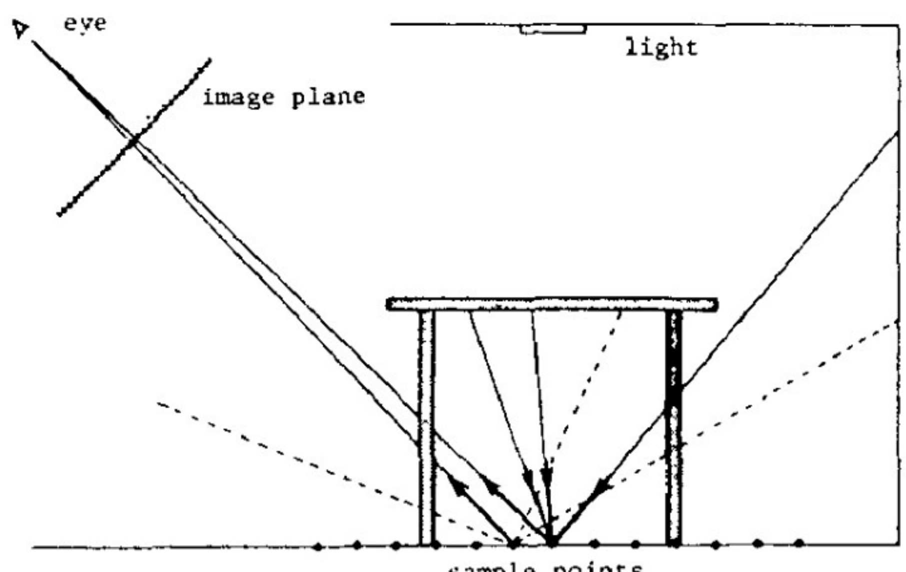
- View Dependent Ray Tracing
  - Captures specular reflection

- View Independent Radiosity
  - Captures diffusion

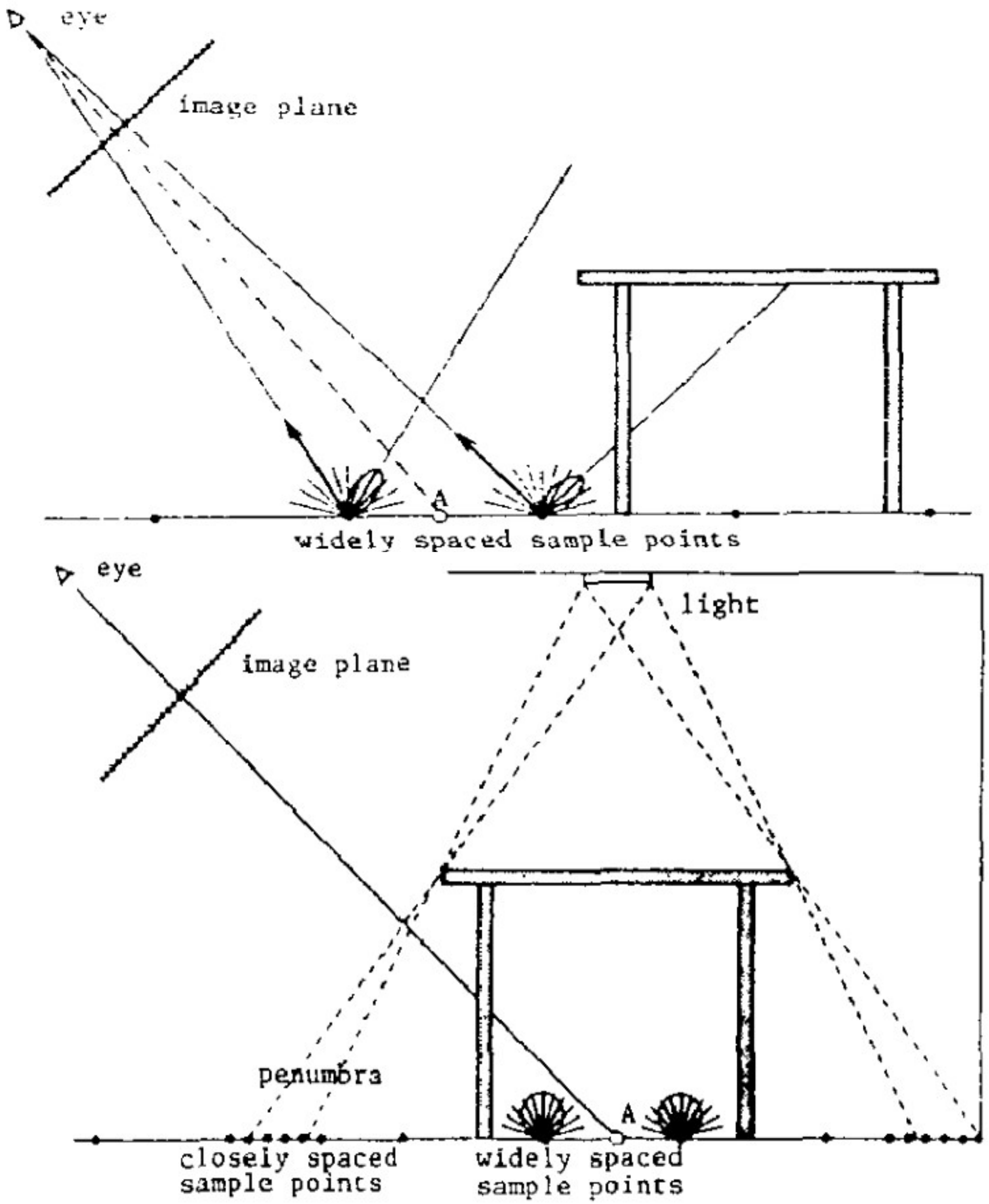
- Both can be extended to account for the other

Enhanced Ray Tracing





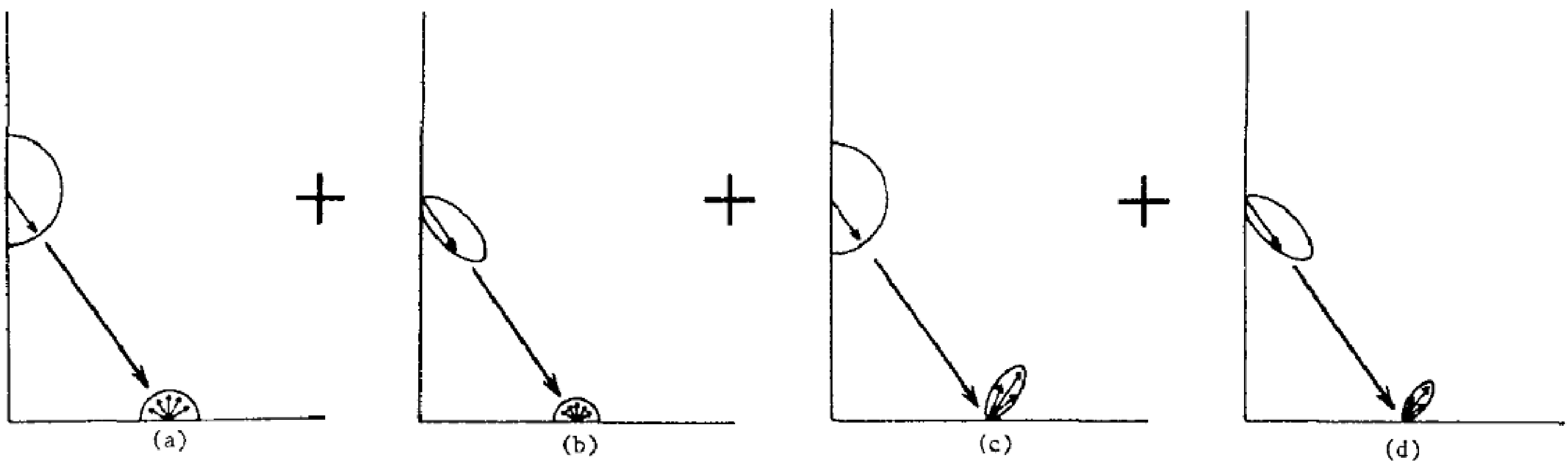
Enhanced Radiosity



Downsides of Each

- Ray Tracing:
  - Lighting in areas which are mostly diffuse surfaces does not change often
- Radiosity:
  - Patches become very small in areas with a high lighting gradient (specular reflections)

Types of Transmission



Algorithm Foundation

- Break BRDF down into specular and diffuse parts

$$\rho''(\Theta_{out},\Theta_{in}) = k_s \rho_s(\Theta_{out},\Theta_{in}) + k_d \rho_d$$

where

k_s = fraction of reflectance that is specular
k_d = fraction of reflectance that is diffuse
$k_s + k_d = 1$

$$I_{out}(\Theta_{out}) = E(\Theta_{out}) + I_{d,out} + I_{s,out}(\Theta_{out})$$

$$I_{d,out} = k_d \rho_d \int I_{in}(\Theta_{in}) \cos(\theta)\, d\omega$$

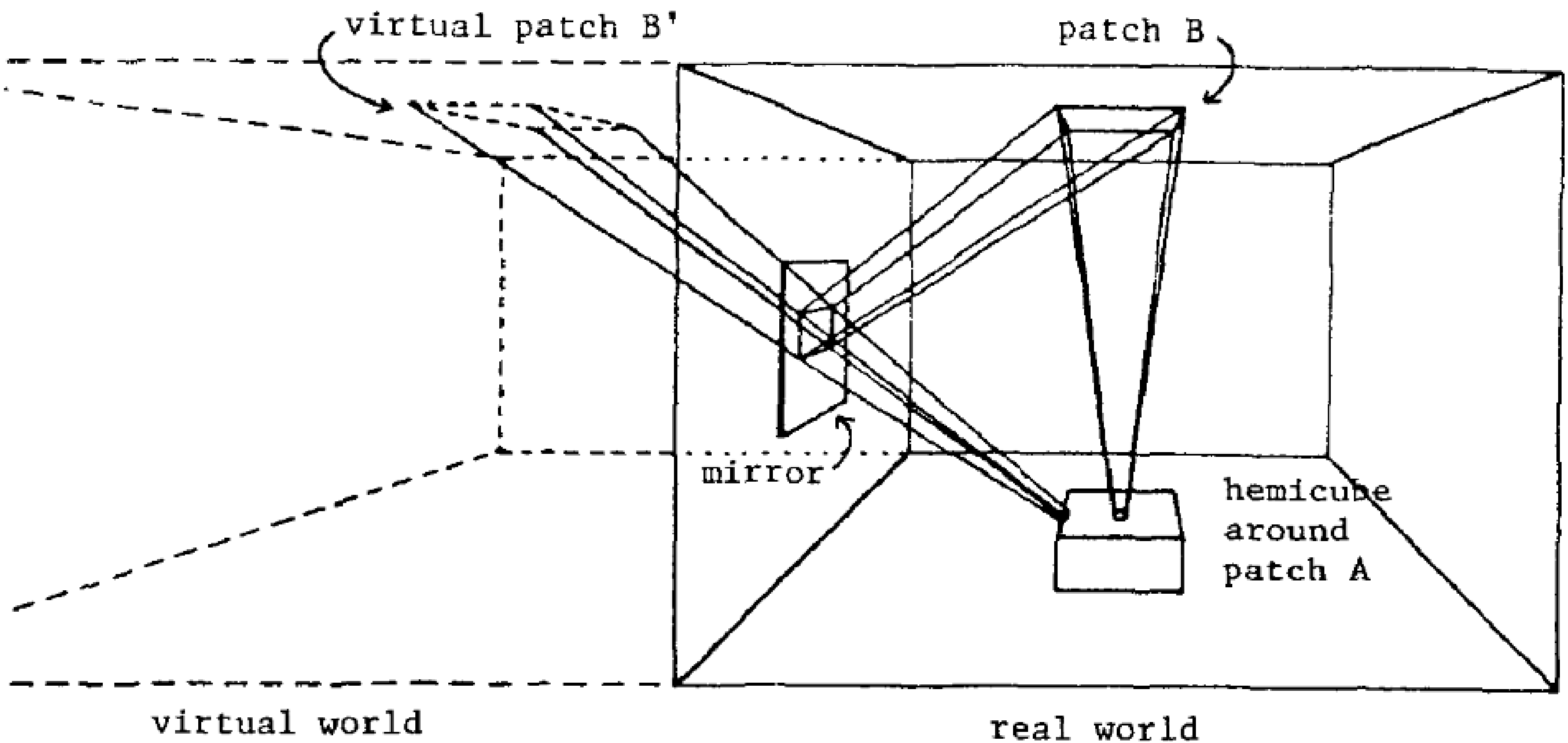
$$I_{s,out}(\Theta_{out}) = k_s \int \rho_s(\Theta_{out},\Theta_{in})\, I_{in}(\Theta_{in}) \cos(\theta)\, d\omega$$

Pass 1 – Modified Radiosity

- Standard radiosity algorithm (hemi-cube)
- Extend to account for translucency
- Extend to account for specular-diffuse transport

- For both extensions, introduce new form factors

Pass 1 – Modified Radiosity

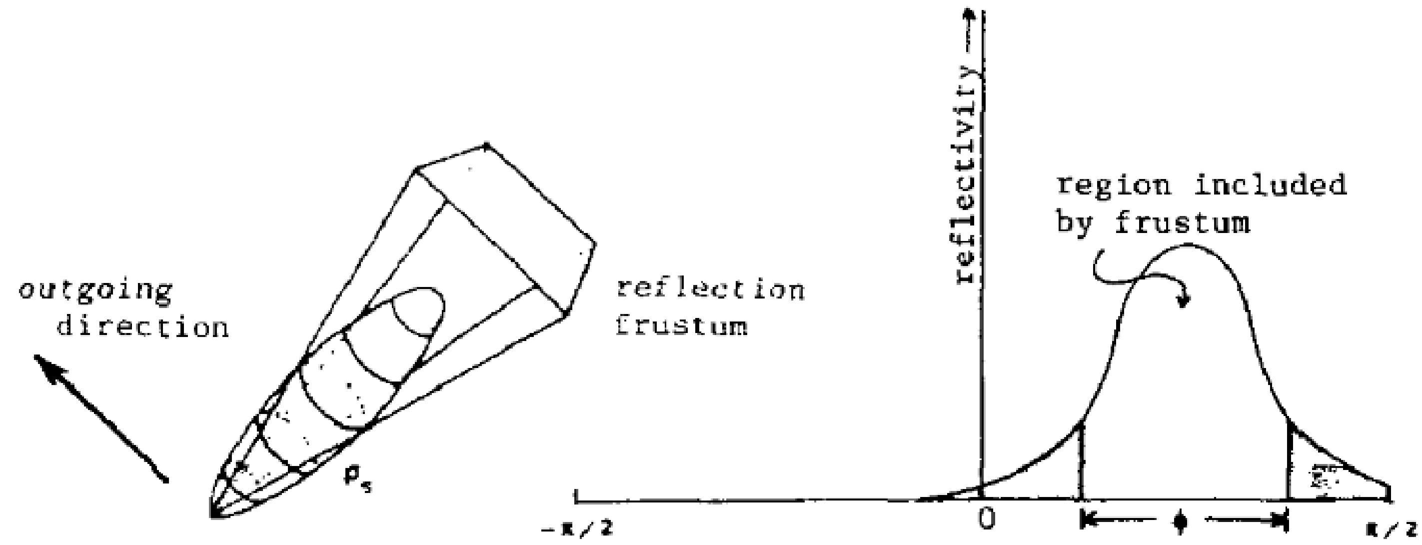


Pass 2 – Modified Ray Tracing

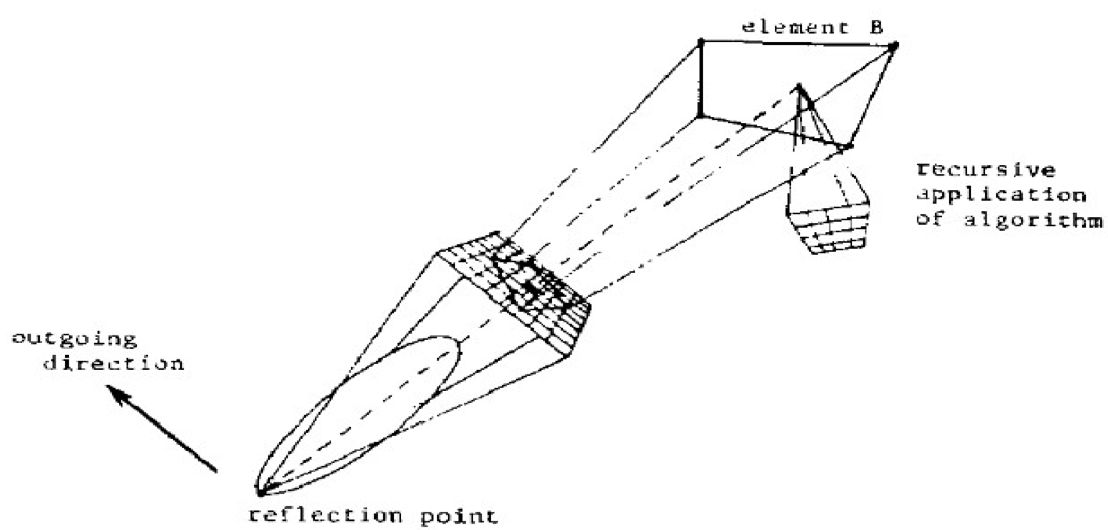
- Specular-specular reflection is captured well by classical ray tracing
- Extend ray tracing to take into account arriving diffused light as well

- Light arrives over entire hemisphere, but is only influential over small solid angle due to BRDF. This area can be discretized

Pass 2 – Modified Ray Tracing



(a) (b)



All Terms Are Now Known

$$\rho''(\Theta_{out},\Theta_{in}) = k_s \rho_s(\Theta_{out},\Theta_{in}) + k_d \rho_d$$

where

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$$I_{out}(\Theta_{out}) = E(\Theta_{out}) + I_{d,out} + I_{s,out}(\Theta_{out})$$

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$$I_{s,out}(\Theta_{out}) = k_s \int \rho_s(\Theta_{out},\Theta_{in})\, I_{in}(\Theta_{in}) \cos(\theta)\, d\omega$$