Informatics and Mathematical Modelling

Technical University of Denmark DTU

Real-Time Indirect Illumination

Jeppe Revall Frisvad

PhD student

Informatics and Mathematical Modelling

Technical University of Denmark

Agenda

- Introduction
- Related work
- Concept
- Method
- Demo
- Conclusion

Why is illumination important?

- To obtain realism in synthetic images
- To simulate reality
- Illumination is crucial for shading in most rendering processes

How do we simulate light?

- We employ the well known *rendering equation*

$$L_o(\boldsymbol{x},\boldsymbol{\omega}) = L_e(\boldsymbol{x},\boldsymbol{\omega}) + \int_\Omega f_r(\boldsymbol{x},\boldsymbol{\omega}',\boldsymbol{\omega}) L_i(\boldsymbol{x},\boldsymbol{\omega}') \cos\theta \, \mathrm{d}\omega'$$

consisting of an *emission* term and a recursive *reflection* term

What is indirect illumination?

- Light reflects (or bounces) off surfaces
- Light that has bounced more than once before reaching the eye is *indirect illumination*
- *Single-bounce* indirect illumination is light that has bounced twice before reaching the eye

Why real-time?

- To allow for more realism in interactive rendering applications

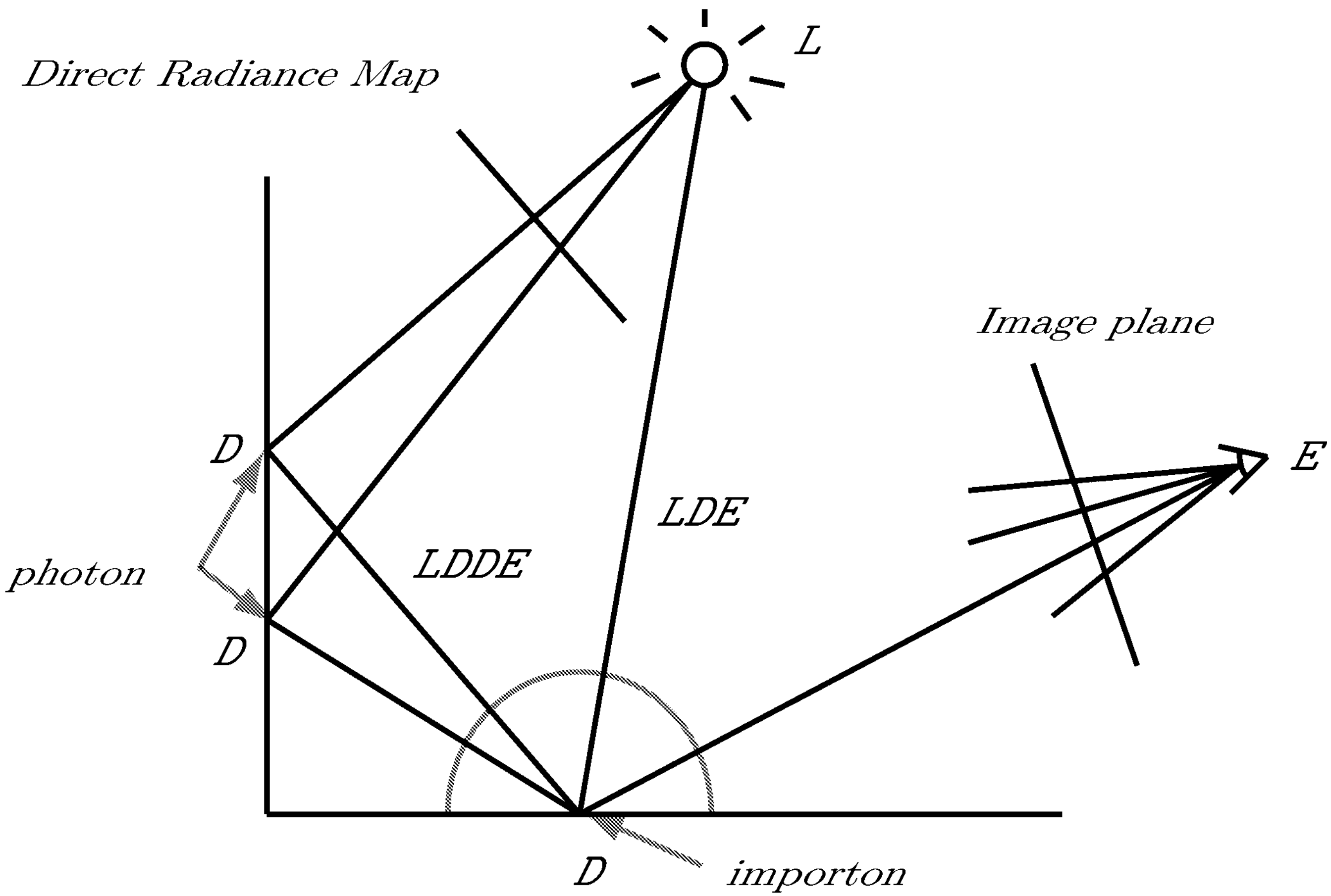
- Application examples:
  - Feature animation pre-view
  - Computer games
  - Reality simulation of emergency scenarios

Related work

- Light mapping
  - Static global illumination
- Refined global illumination solutions
  - Restrictions on scene changes
- Spherical harmonics transfer functions
  - Low-frequency lighting environment

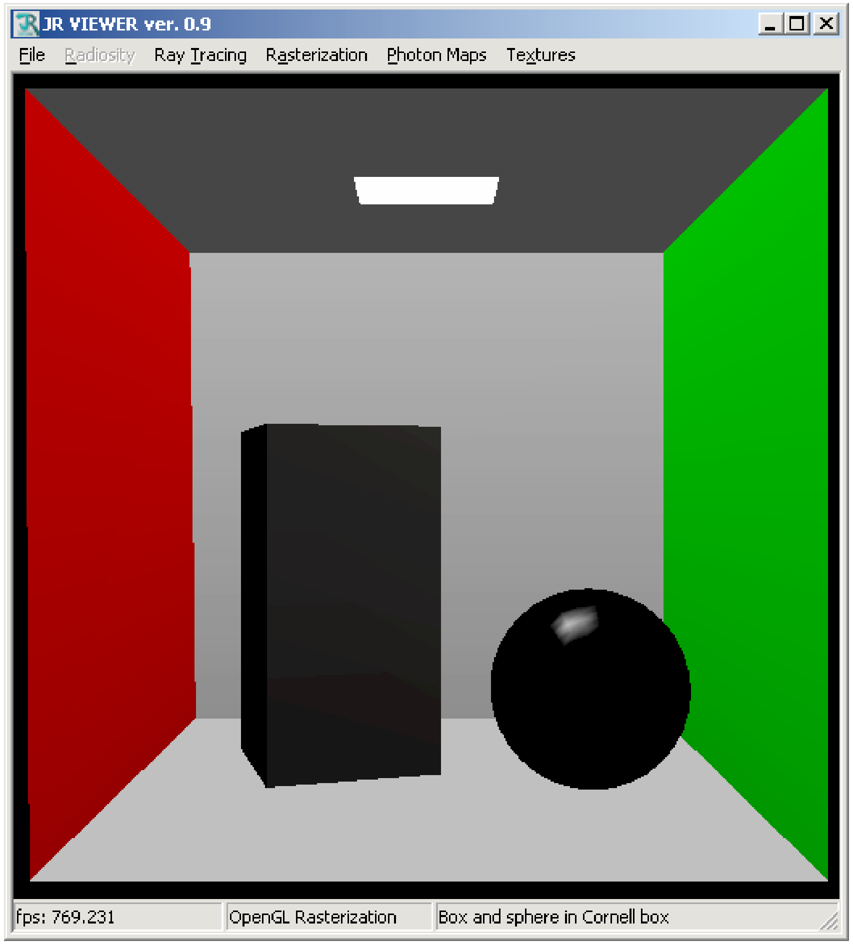
Single-bounce indirect illumination

- A concept related to shadow mapping



Explaining by example

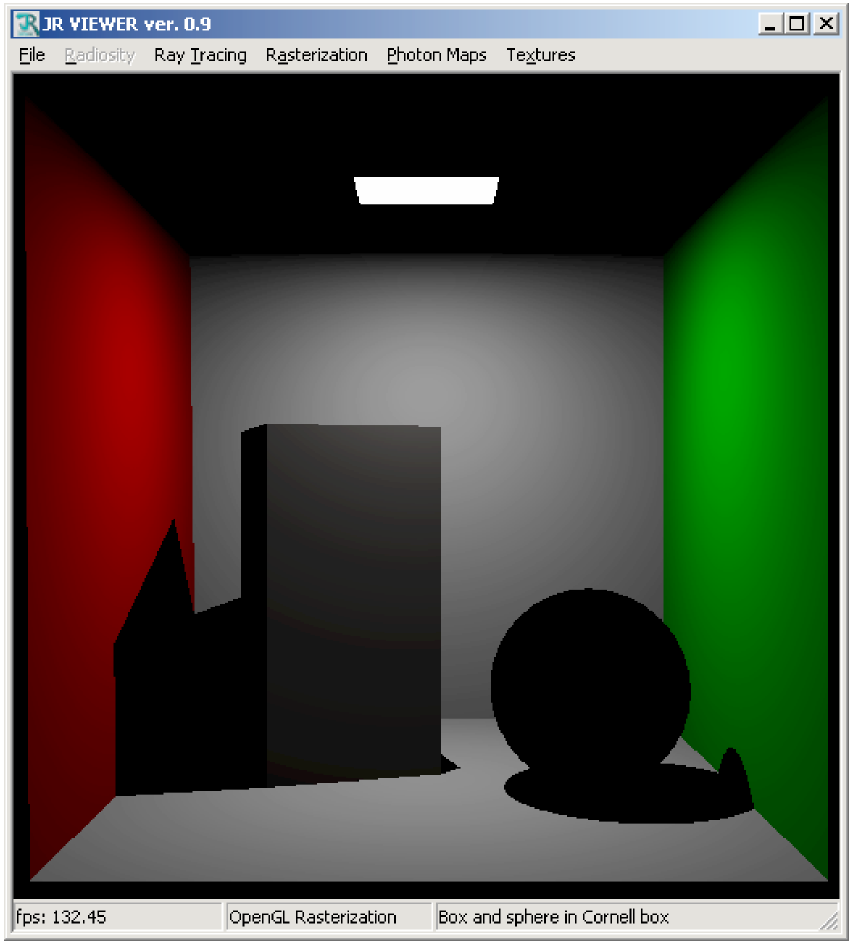
- Case study:
  - Cornell box with tall box and sphere
- Here in a standard OpenGL rendering



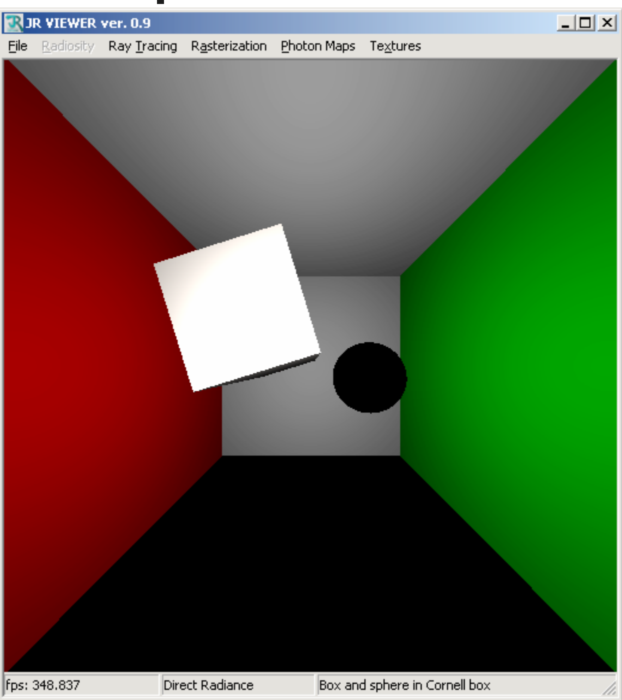
The image plane

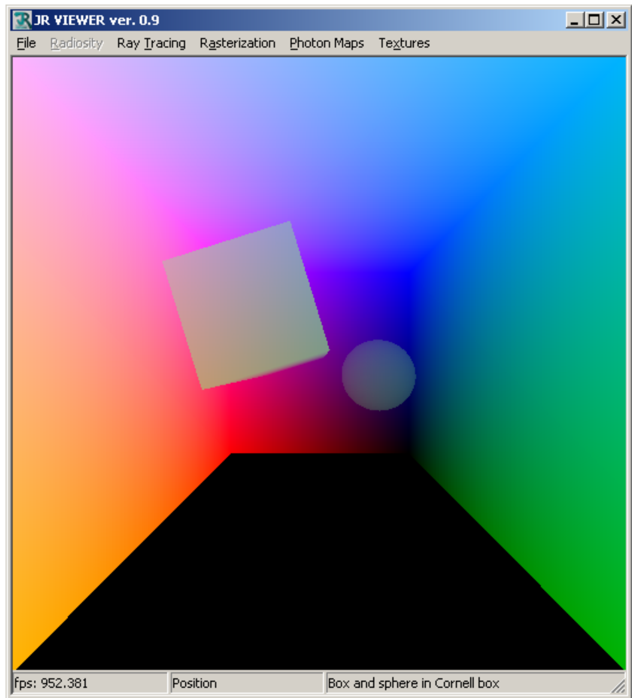
- Direct illumination
  - With shadows found using *shadow mapping* or *shadow volumes*

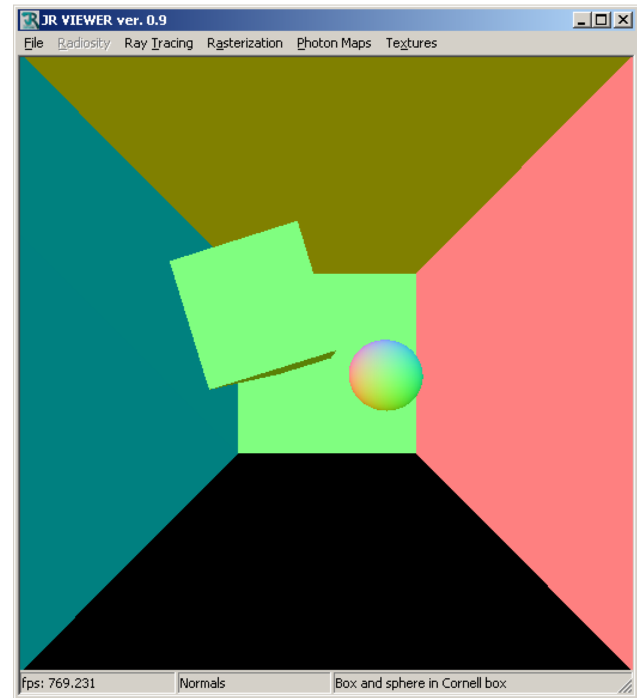
$$L_{o,1}(x,\omega) = L_{e,1}(x,\omega) + \sum_{j=1}^{N_1} f_r(x,\omega'_j,\omega)\frac{\Phi_{s,j}\cos\theta_j\cos\theta'_j}{\pi r_j^2}V_j(x)$$



The direct radiance map





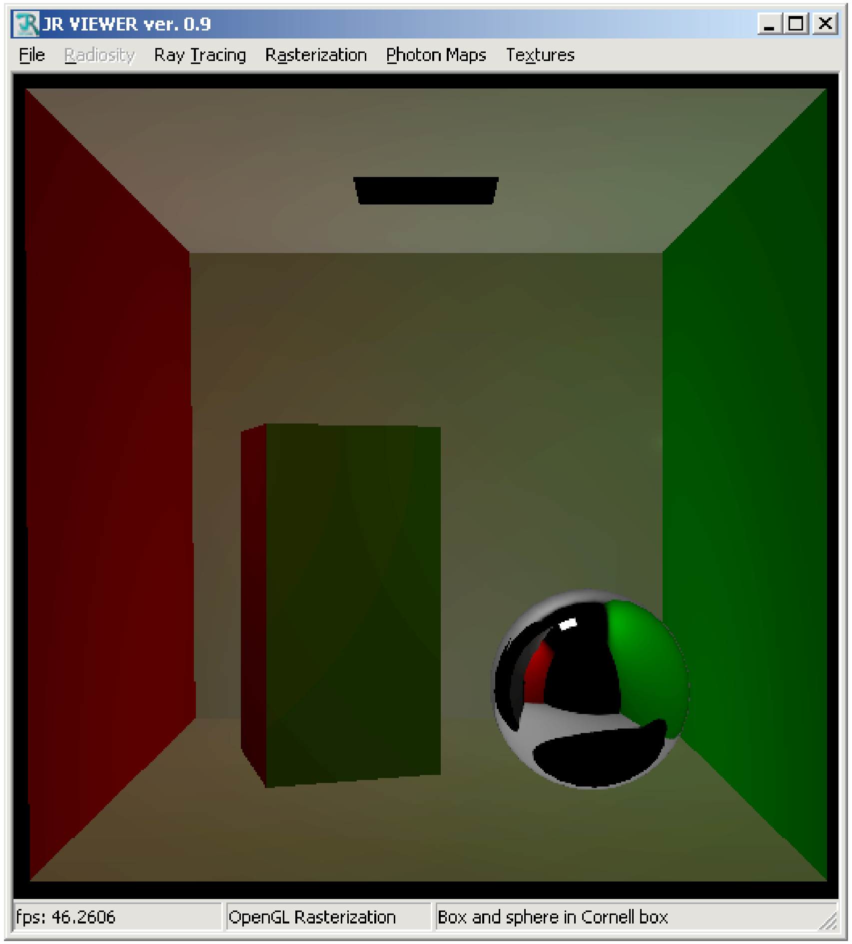


direct radiance positions normals

Single-bounce

- Indirect illumination
  - With specular reflections using *environment mapping* and diffuse reflections using *direct radiance mapping*

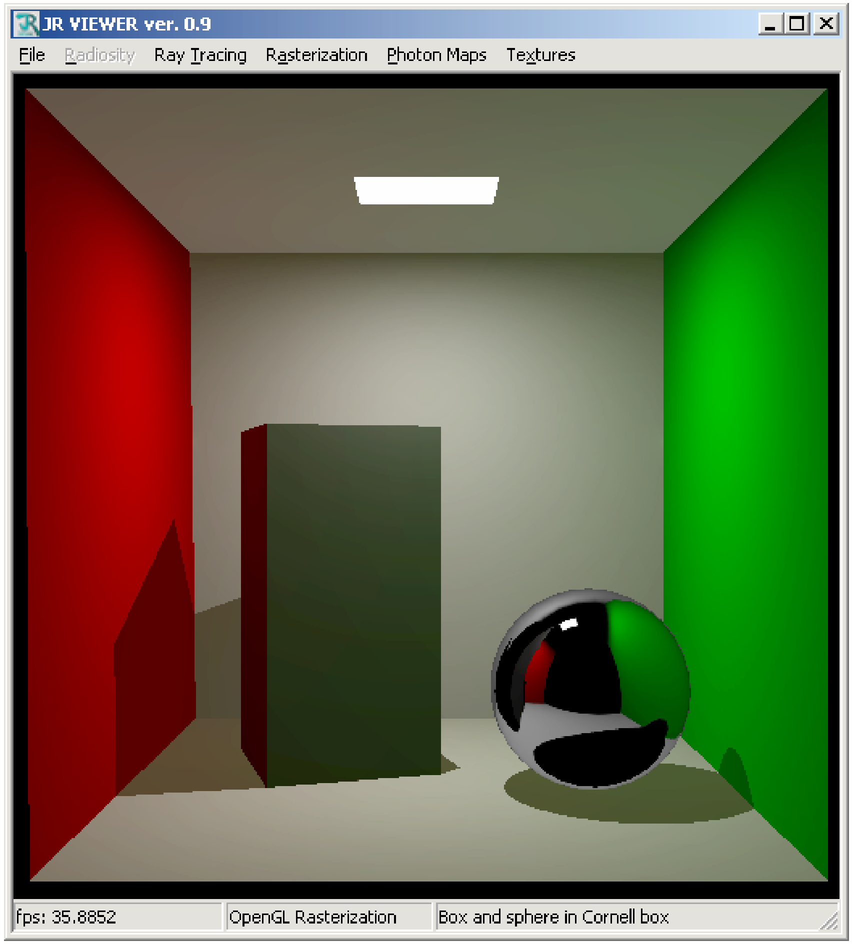
$$L_{r,\text{importon}}(x,\omega) \approx \sum_{j=1}^{M} f_r(x,\omega_j',\omega) L_{o,\text{photon},j}(x,\omega_j') \cos\theta_j \Delta\omega_j'$$



Resulting image

- Direct and single-bounce indirect illumination
  - Adding up the terms

$$L_o(x,\omega) = L_{o,1}(x,\omega) + L_{r,importon}(x,\omega)$$

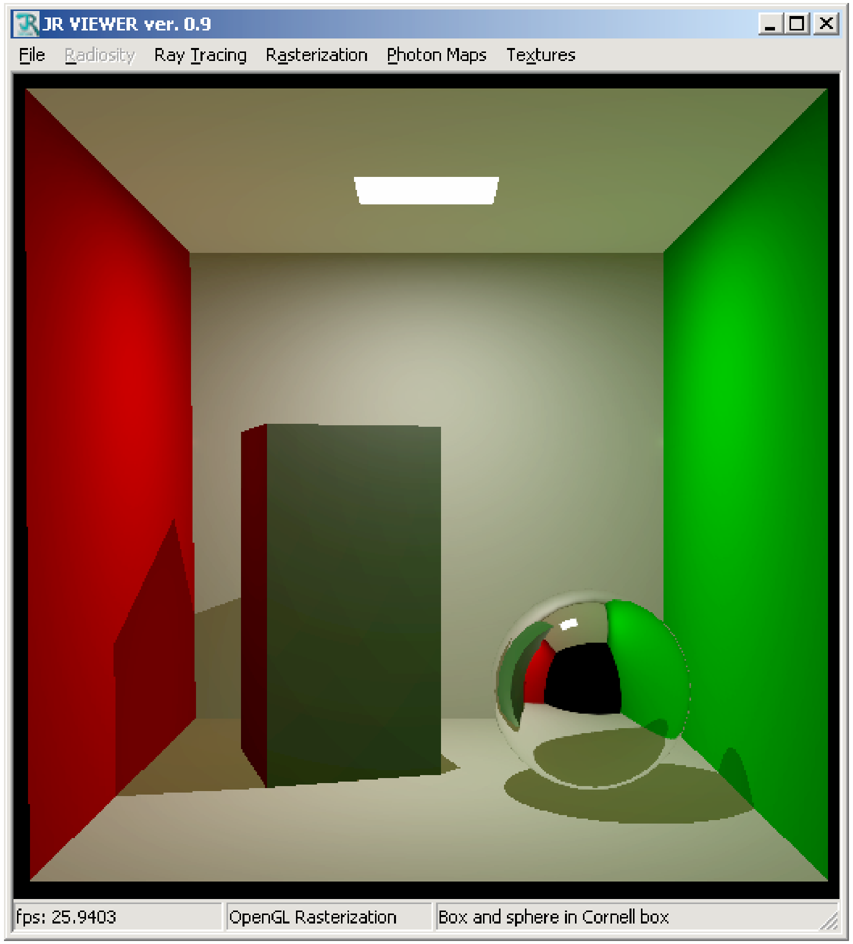


Getting additional bounces

- Including DRM in the environment map for specular reflections
  - Light paths: $LD?D?S_{rt}*E$
- Including environment mapping in the direct radiance map
  - Light paths: $LS_{rt}*DDS_{rt}*E + LD?S_{rt}*E$
- Including DRM in the Direct Radiance Map
  - Light paths: $L(S_{rt}*D)+DS_{rt}*E + LD?S_{rt}*E$

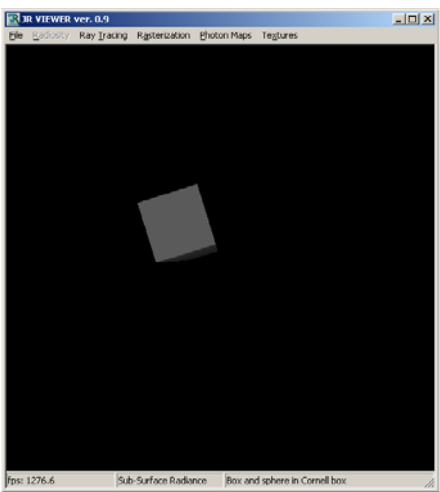
Multi-bounce results

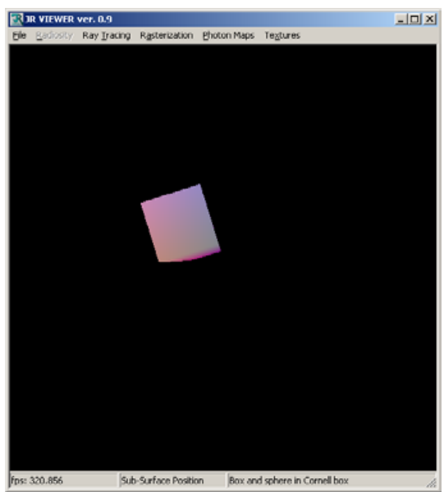
- Including DRM in the environment map for specular reflections
- Including environment mapping in the direct radiance map
- Including DRM in the Direct Radiance Map

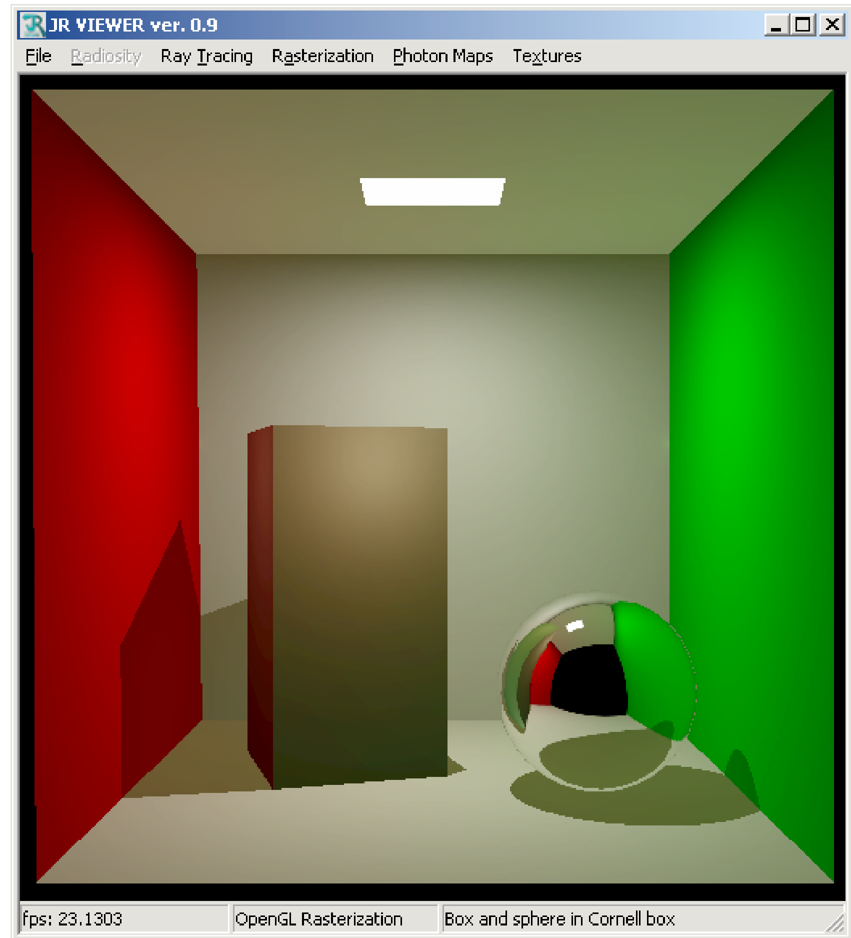


Subsurface scattering expansion

- Including subsurface scattered radiance and positions in the direct radiance map

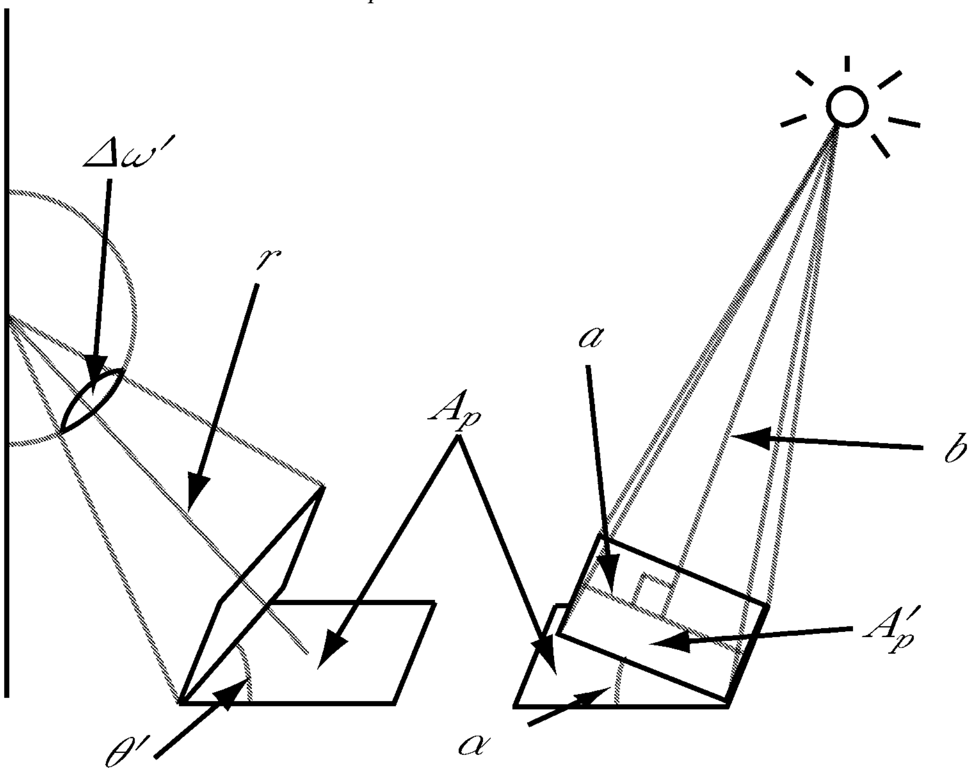


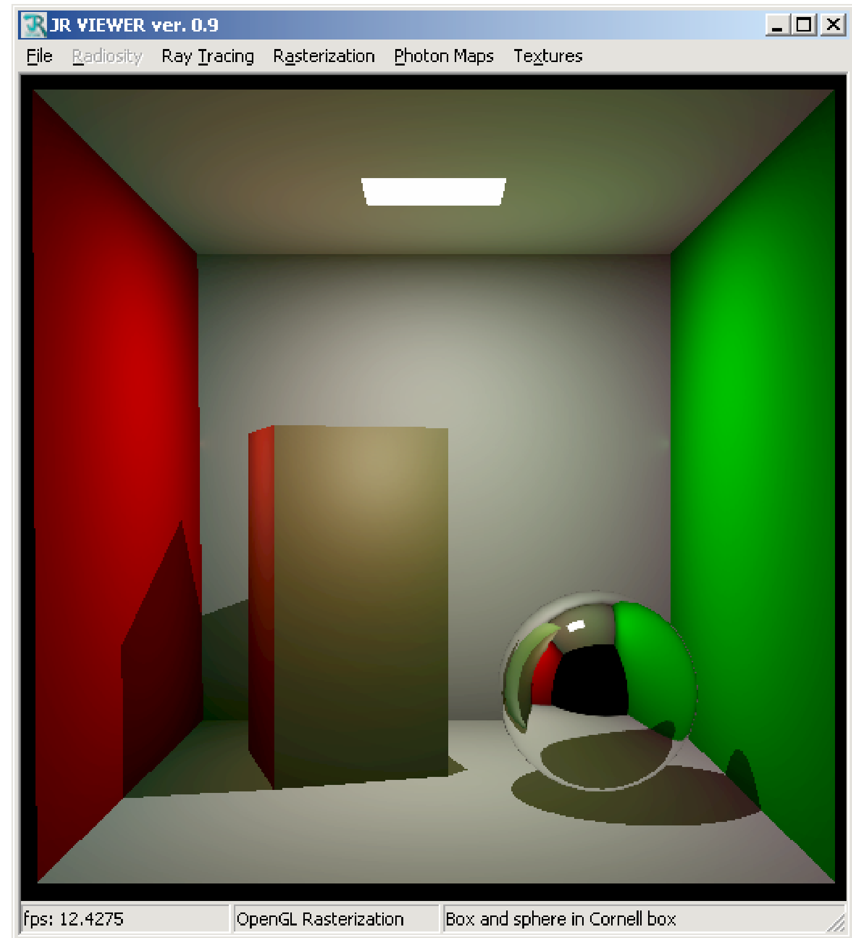




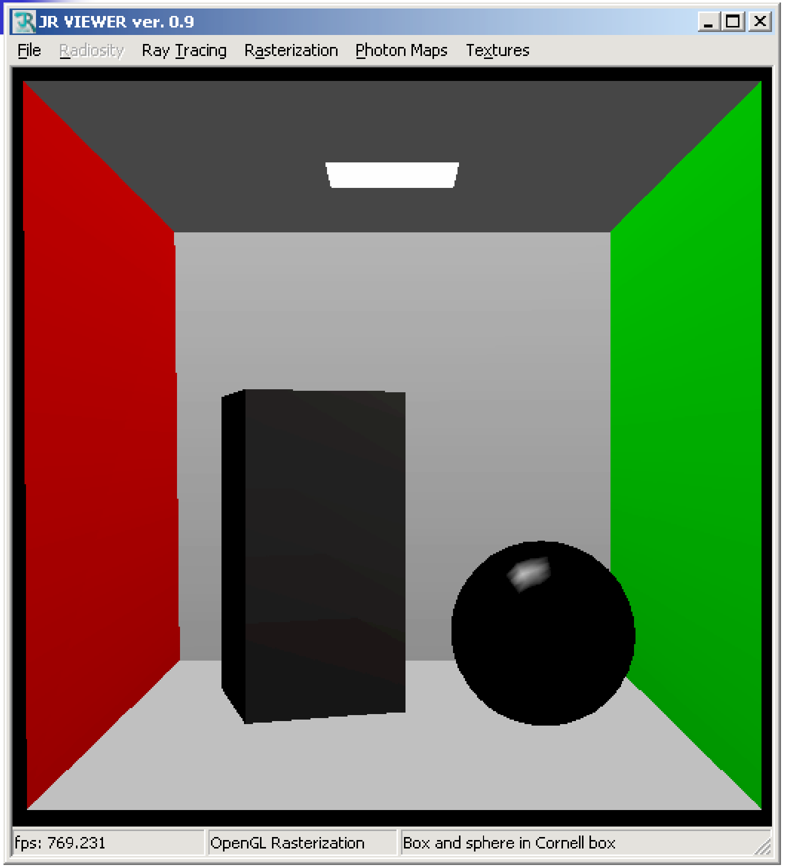
Computing solid angles in DRM

$$\Delta\omega' \approx \cos\theta' \frac{A_p}{A_p + r^2} \quad , \quad A_p \approx \frac{A'_p}{\cos\alpha}$$

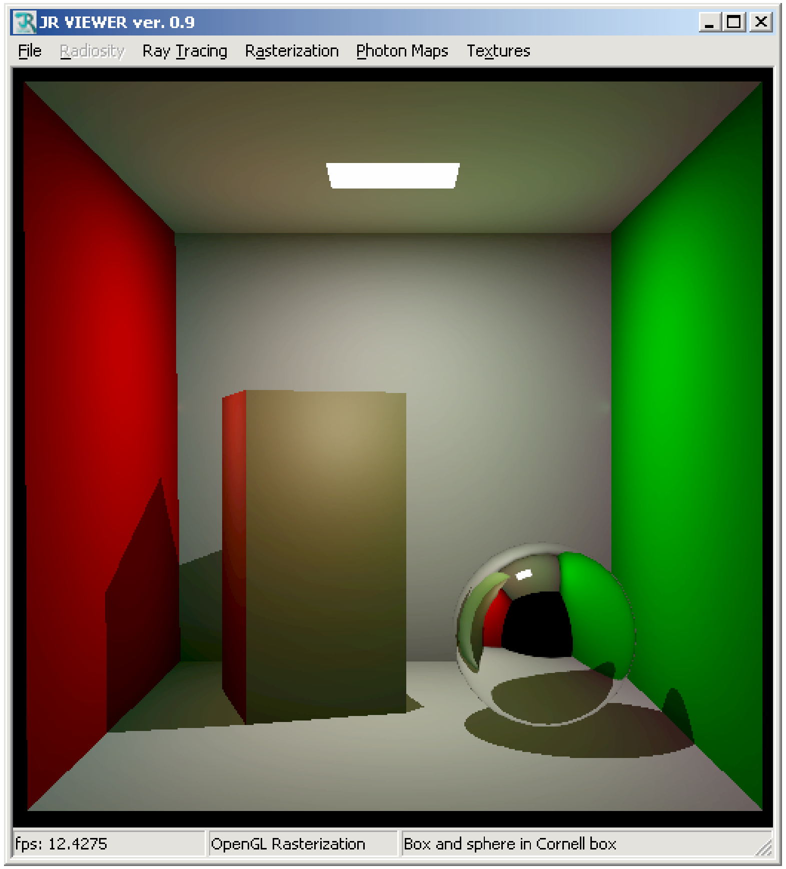




Comparison 1

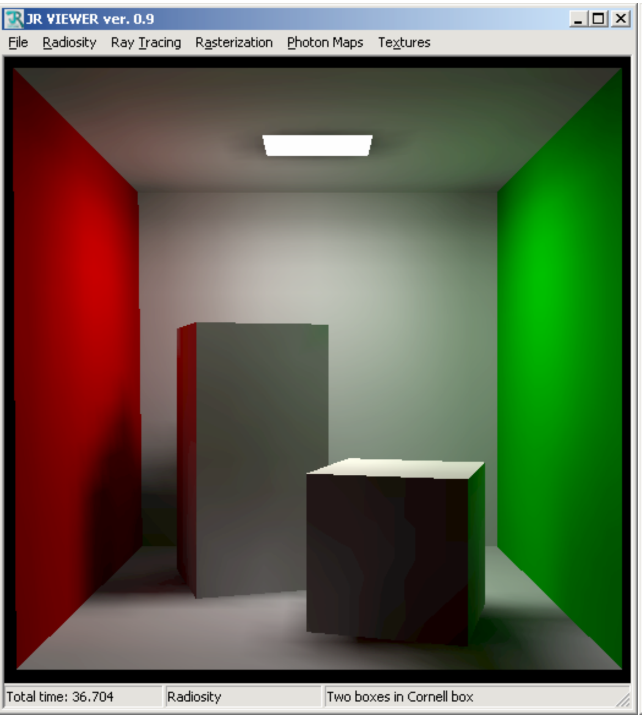


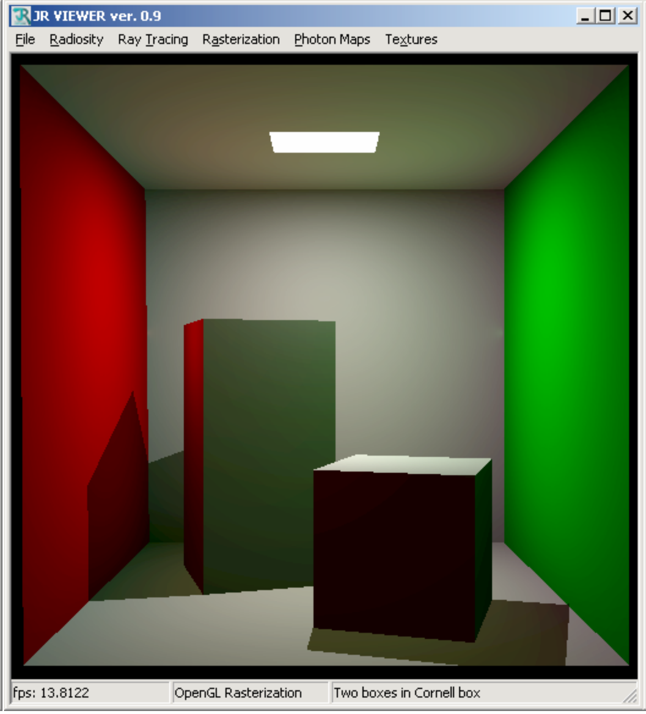
Standard OpenGL

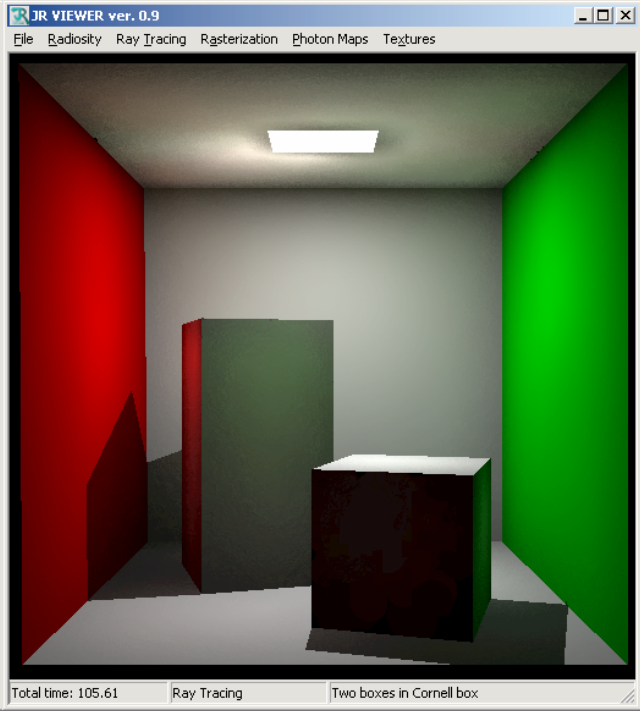


Direct Radiance Mapping

Comparison 2



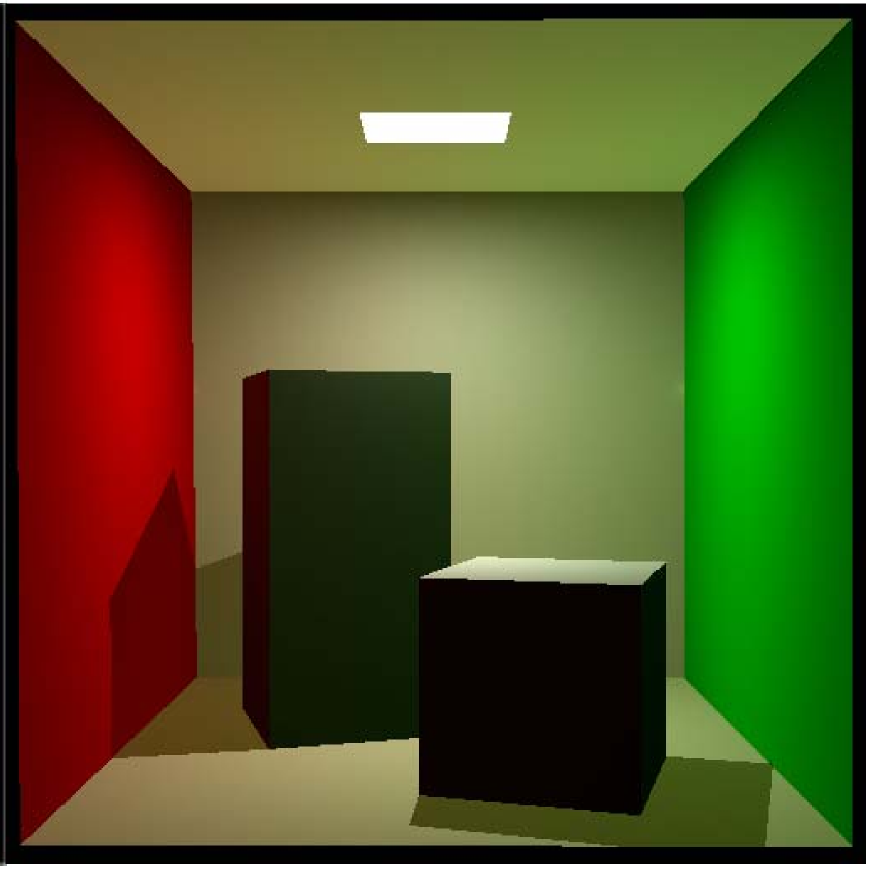




radiosity DRM photon mapping

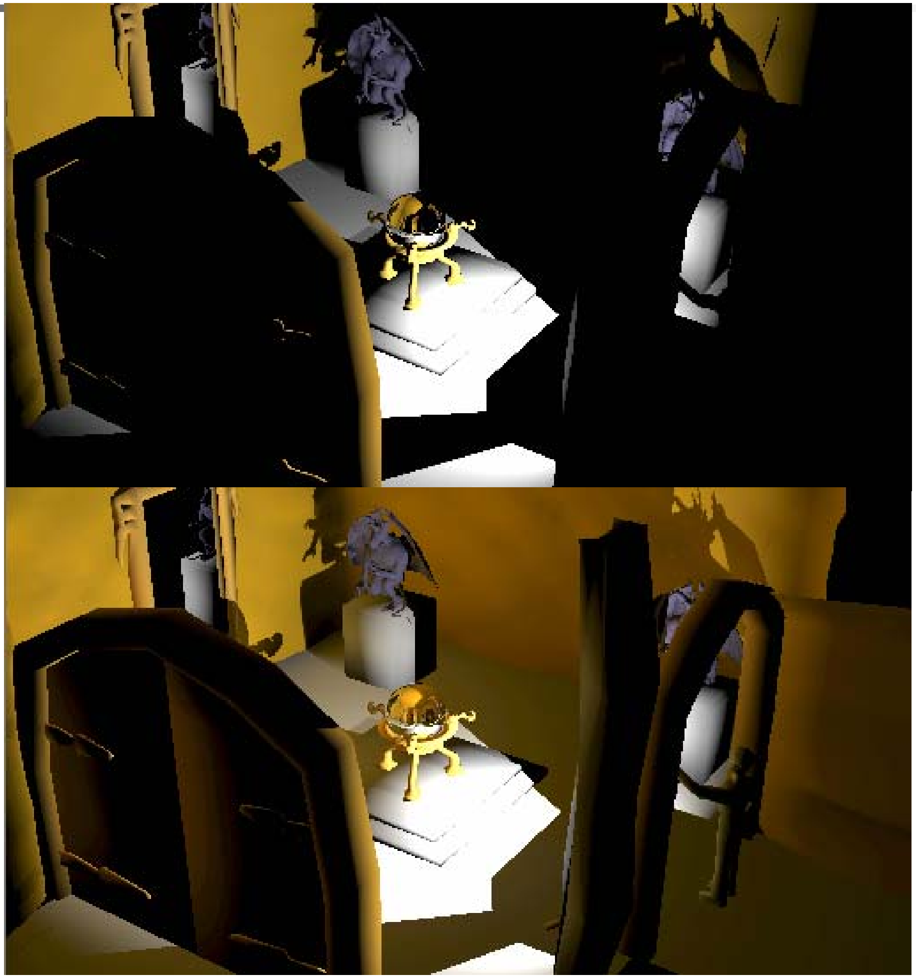
Comparison 3

Cornell Reference



Direct Radiance Mapping

Demo



Limitations

- Conceptual limiations
  - No indirect shadows
  - No caustics
- Problems due to limited processing power
  - Too low frame rate for games
  - A direct radiance map is needed for each light source
  - Objects are assumed to be perfectly diffuse or perfectly specular
  - Few samples result in color bleeding artifacts

Conclusion

- Direct Radiance Mapping (DRM) is a fast approximate method for real-time indirect illumination
- DRM is independent of scene changes
- Much is achieved with simple means

Thank you for your attention

Questions/comments

?