# Comparing an interactive hybrid global illumination method with Radiance

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## Outline

- Introduction
- Interactive Rendering Method
- Supporting Complex Fenestration Systems
- Comparing with Radiance
- Future work

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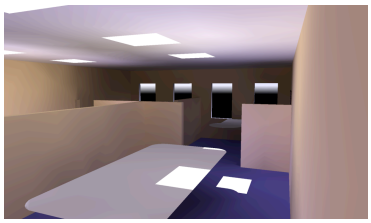
## Project Goals



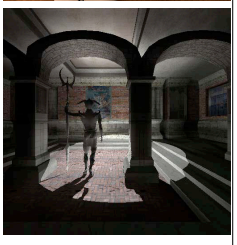
- Providing an interactive, quantitative and qualitative daylighting simulation tool for architectural design
- Appropriate for use in schematic design: an early stage of the architectural design process
- Increase the use of daylighting and thus save energy
- Provide simulation of Complex Fenestration Systems
- A useful complementary tool of Radiance

## Radiance

- Pros
  - High accuracy
  - A release package with a lot of useful tools
- Cons
  - Long rendering time: mins~hours
  - View dependent
  - User needs lots of knowledge to produce quick images

## Related work

- A lot of techniques accelerating rendering speed
  - Carsten, et al. “Implicit visibility and antiradiance for interactive Global Illumination”, SIGGRAPH 2007.
  - Mangesh, et al. “Interactive Global Illumination in Dynamic Environments using commodity Graphics Hardware”, Pacific Graphics 2003.
- Only a few are used in the area of architectural design



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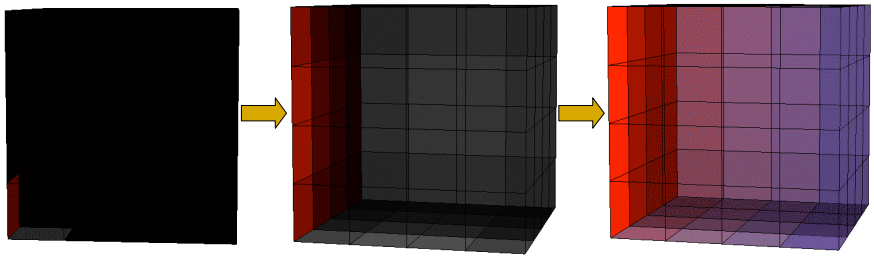
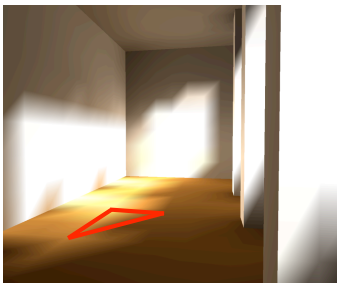
# Radiosity

- Widely used global illumination method
- Can be accelerated by hardware
- Works for diffuse materials
- View independent
- Interactive rendering (1fps)



Goral et al, “Modeling the interaction of light between diffuse surfaces”_

# Radiosity

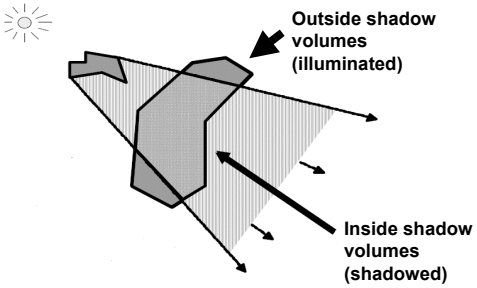


- Why not just using Radiosity?
  - Works for diffuse light
  - Inaccurate shadow due to low resolution mesh
  - We need hard shadows!
- Why do we need hard shadows?
  - More realistic
  - More intuition about scene
  - Previsualize the unexpected illumination caused by Complex Fenestration System.
  - Useful for glare computation

# Shadow Volumes

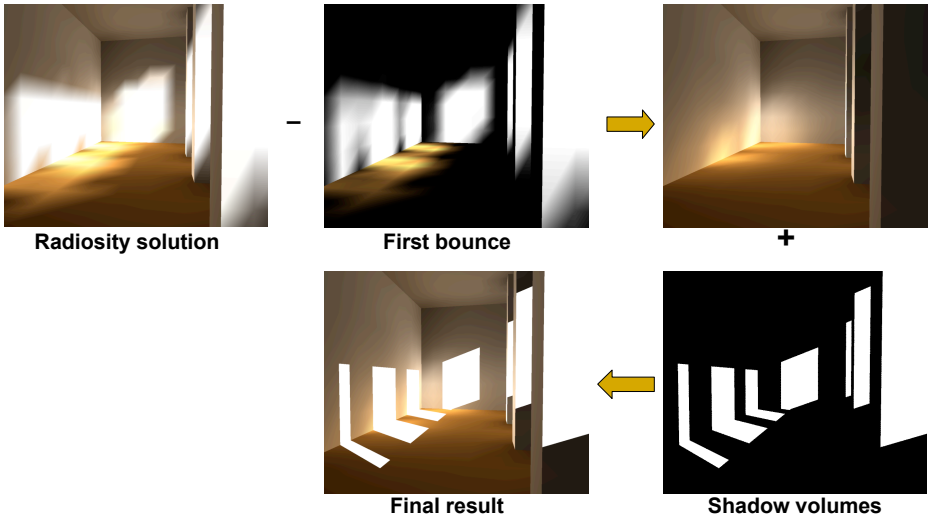
**Shadow volume is used in some games (from Doom3)**

- Real time
- Hardware acceleration
- Proposed by Frank Crow in 1977

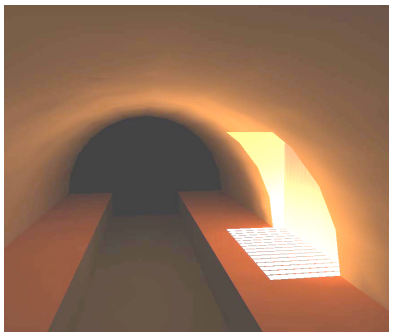


# Hybrid method

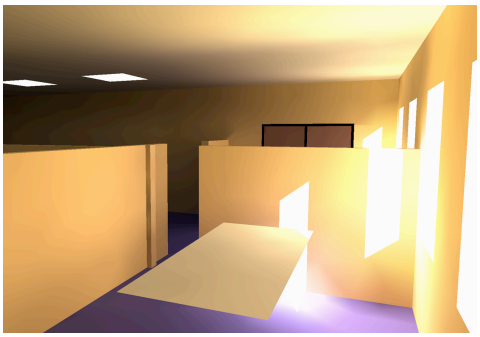
- Radiosity + Shadow Volumes




# Rendering result



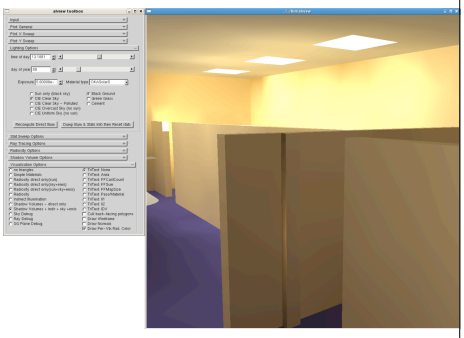
A subway with deep tunnel



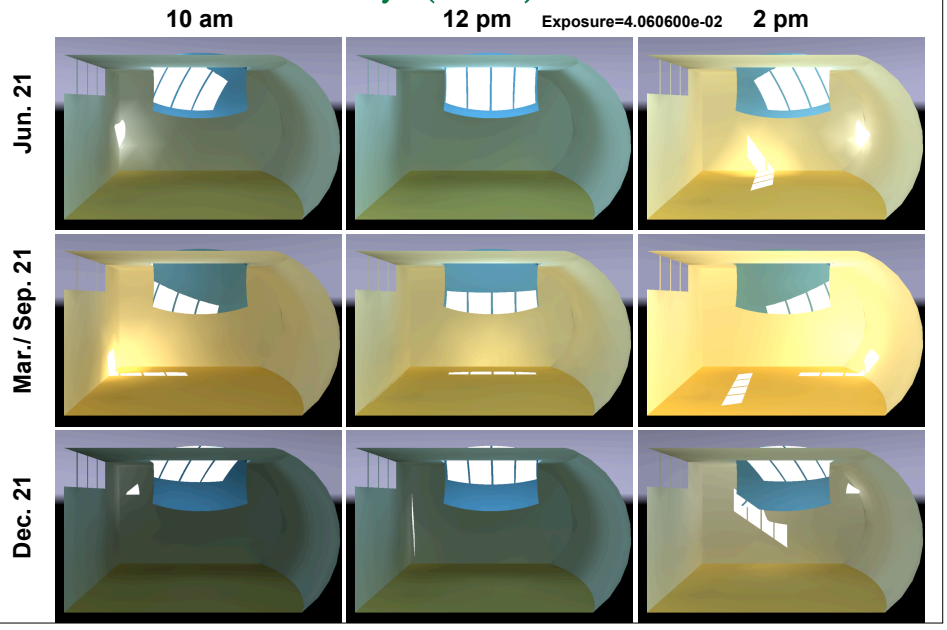
An office illuminated by the sun

# Our System

- Platform: Linux, FreeBSD, Windows (Cygwin)
- User-friendly UI
  - Support mouse gesture: rotation, translation, zoom
  - Different rendering modes
  - Changing time/day
  - Save rendering to images



# Add sun and sky (CIE)



# Video

Play Video

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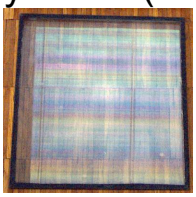
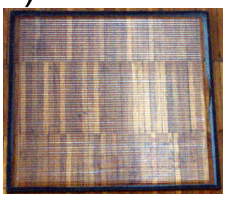
# Complex fenestration systems (CFS)

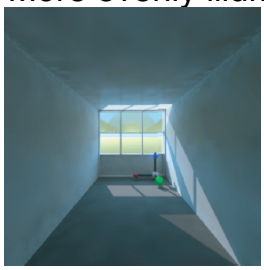
- Complex fenestration systems (CFS)
  - Prismatic panel
  - Laser-cut panel
- Usage:
  - Redirect daylighting
  - More evenly illuminate interior spaces



prismatic

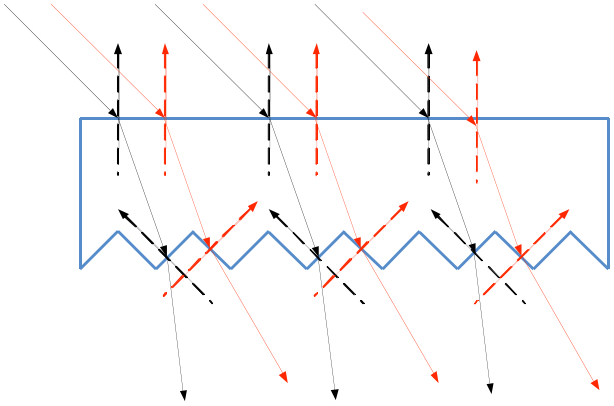


Laser-cut

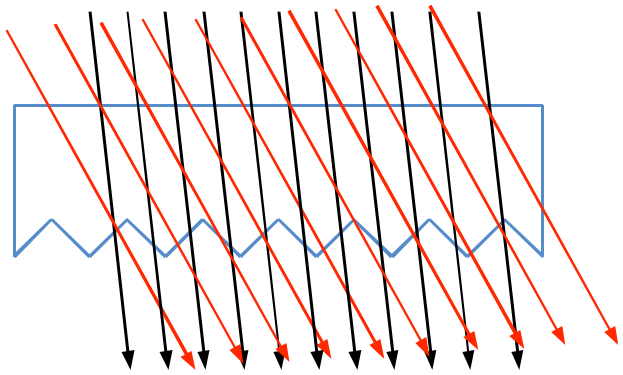


**Rendered by RADIANCE of a laser cut panel (Images from Andersen, 2004)**

# Prismatic Panel



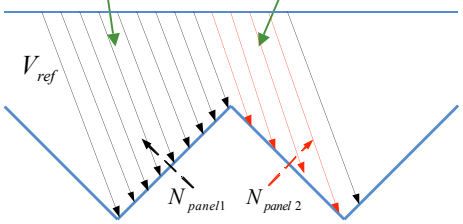
# Directions of virtual lights



# Brightness of virtual lights

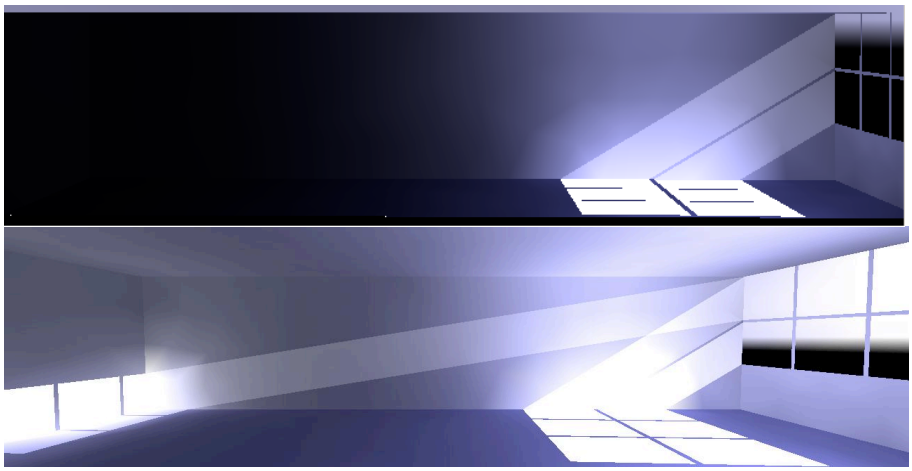
- Each light covers part of the brightness.
- Calculate the brightness of each light by the portion of light rays that reaches each micro-facet.

$$f_1 = |V_{ref} \bullet N_{panel1}| \quad f_2 = |V_{ref} \bullet N_{panel2}|$$

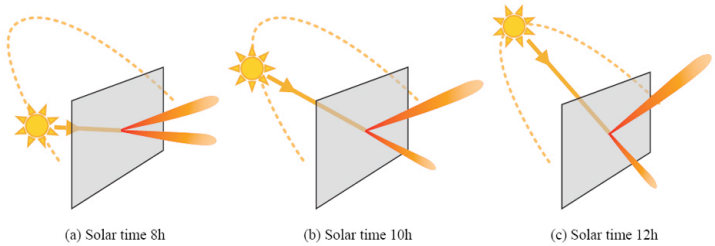



$$b_1 = 1 * f_1 / (f_1 + f_2)$$
$$b_2 = 1 * f_1 / (f_1 + f_2)$$

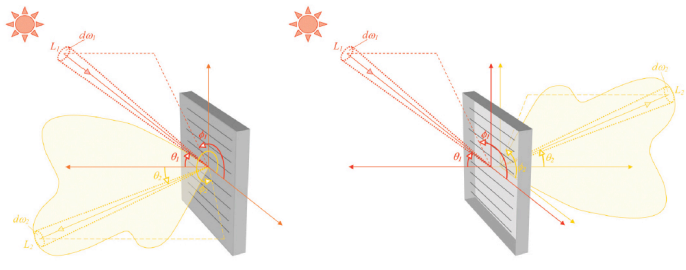
# Simulation Result



# Materials – BRDF & BTDF



(a) Solar time 8h (b) Solar time 10h (c) Solar time 12h

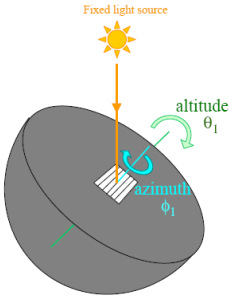


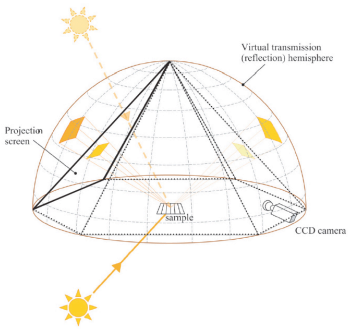
(a) BRDF (b) BTDF

**Images from Andersen, 2004**

# BTDF data collection

- **Video-Goniphotometer**
  - **Collected by Marilyne Andersen, MIT**
- **4D BTDF data**
  - **Incident** (θ, φ)
  - **Outgoing** (θ, φ)

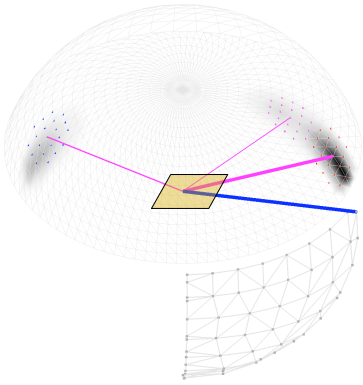


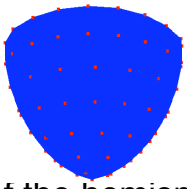

**Images from Andersen, 2004**

# Laser Cut Panel

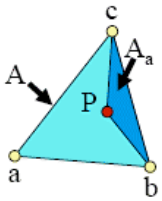
- We don't have the geometry
- Approximate 4D BTDF data with
  - K specular lobes
  - Coverage angle α
  - Rank the lobes
- We use
  - K=3
  - α= 22°
  - 82-100%



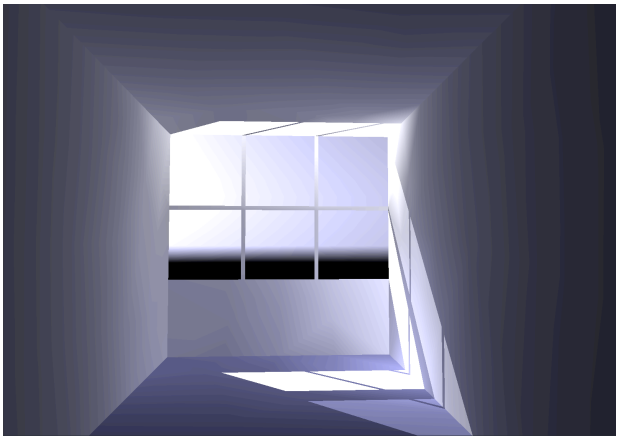
# Interpolation for arbitrary direction



- Triangulation
  - Delaunay triangulation
  - 56 sample on one quarter of the hemisphere
- Triangle Interpolation
  - barycentric coordinates
  - P= αA + βB + γC
  - A, B, C – directions of different lobes

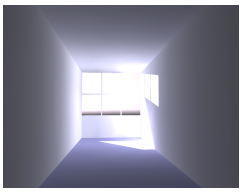



# Simulation Result

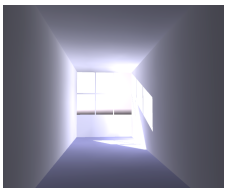


**Laser cut panel, time: 10am, March 21**
**Hard for architects to do by hand**

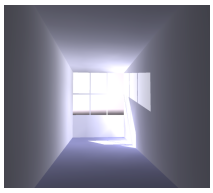
# More fenestration materials



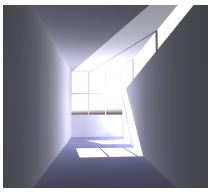
Optical film (exterior)



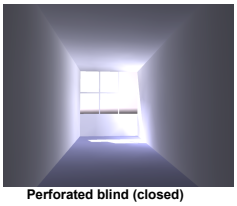
Optical film (interior)



Holographic film

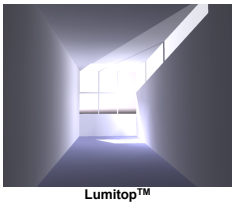


Perforated blind (open)



Perforated blind (closed)

Mirrored Venetian blind



Lumitop™

Serraglaze™

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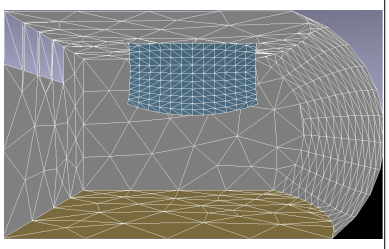
# Comparing rendering with Radiance

- Comparison renderings
  - Our rendering
  - Ground truth rendering by Radiance
    - Ambient: bounce14, accuracy .1, resolution 256, division 4096, super-samples 1024
    - Secondary source presampling density: 8192, direct threshold: .05
    - Limit: reflection 24, weight .0002
  - Fast rendering by Radiance
    - Ambient: bounce 5, accuracy .1, resolution 64, division 1024, super-samples 128
    - Secondary source presampling density: 1024, direct threshold: .1
    - Limit: reflection 10, weight .001
- Two comparison directions
  - Rendering speed
  - Rendering accuracy (Qualitatively and quantitatively)

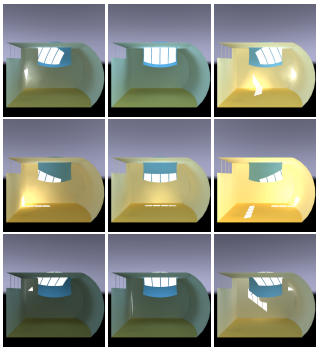
# Rendering speed

- Hardware info: (CPU: Intel Core 2 E6400, Memory: 2G)
- Scene: 1222 Triangles
- Our rendering
  - Radiosity computed on CPU
  - Shadow computed by graphics card
  - Statistics data:
    - Precomputation time: 10s
    - Changing time/day: 1.5s
    - Changing camera: < 0.1s
- Radiance – Ground truth
  - 45 minutes for one camera position
- Radiance – Fast rendering
  - 5 minutes 16 seconds for one camera position

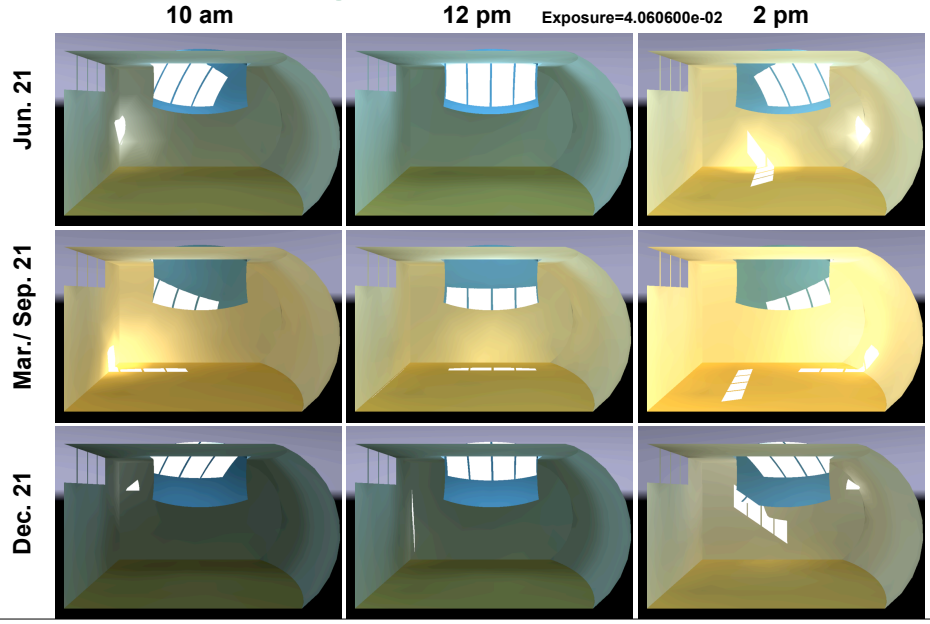


# Accuracy

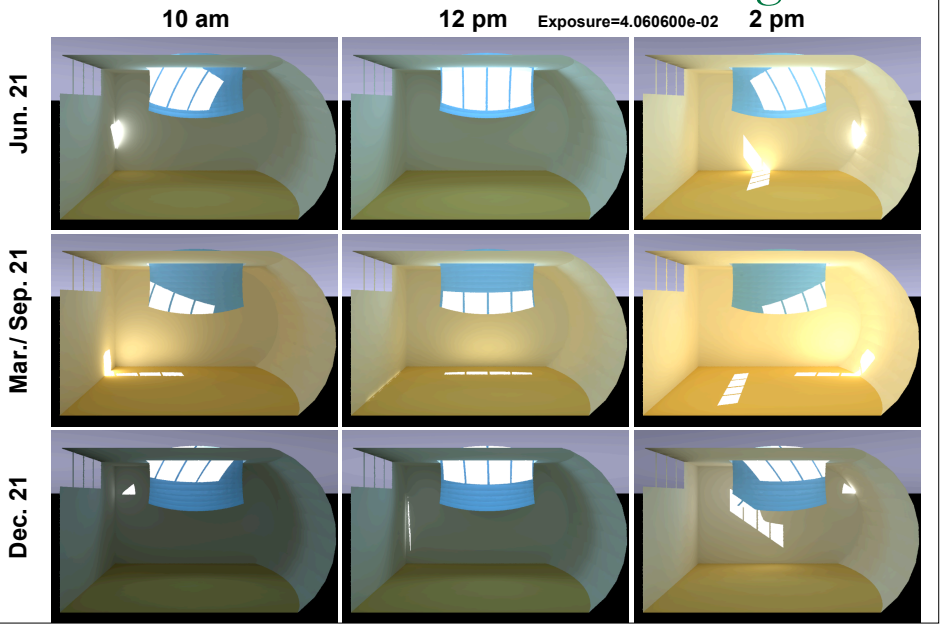
- The same day, time, same latitude, longitude
- The same view file, the same exposure.
- Qualitatively
  - Visual effects
- Quantitatively
  - Comparison with Ground truth rendering
    - our rendering, fast Radiance rendering
  - Comparison criteria
    - Average pixel brightness difference
    - Maximal pixel brightness difference
    - RMS pixel brightness difference



# Our rendering

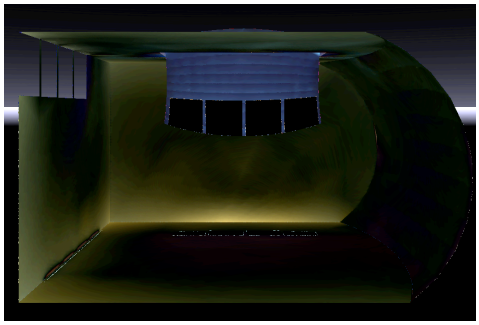


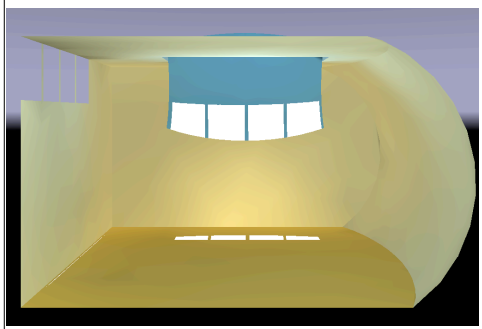
# Radiance Ground truth rendering

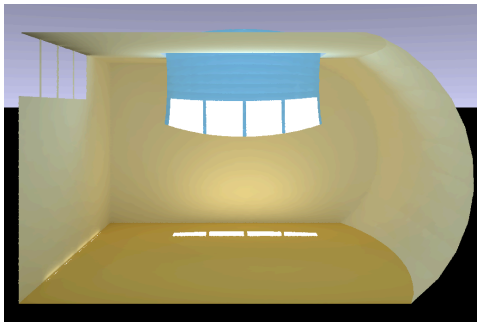



# Example A

Difference image
brightness*2





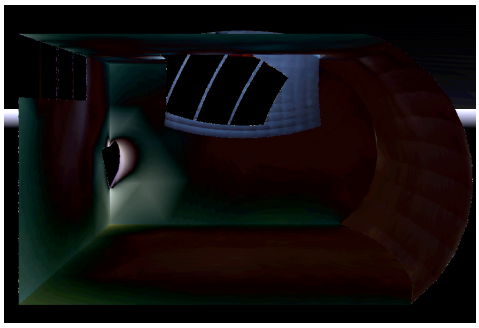


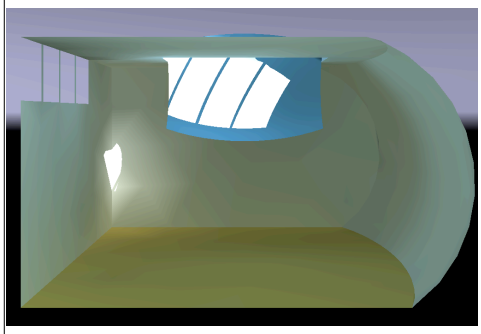
Our rendering

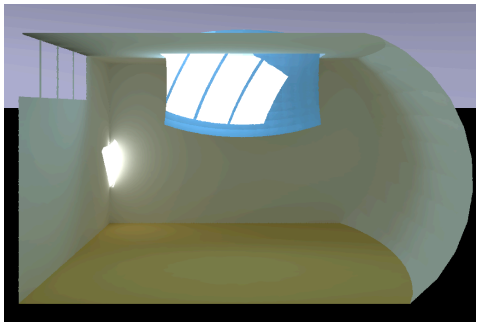
Radiance Ground truth

# Example B

Difference image
brightness*2



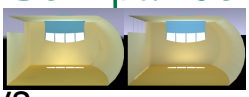


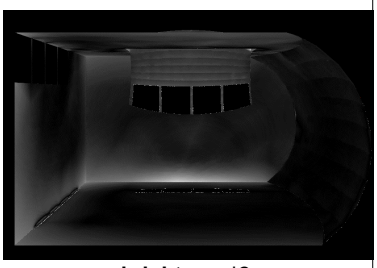


Our rendering

Radiance Ground truth

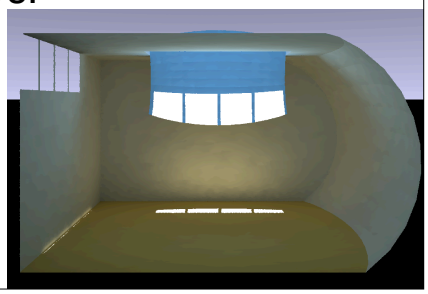
# Quantitative Comparison (Example A)





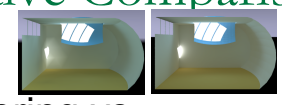
brightness*2

- Our rendering vs. Radiance Ground truth
  - Average brightness diff: 0.047
  - Maximal brightness diff: 0.646
  - RMS brightness diff: 0.065
- Fast Radiance rendering vs. Radiance Ground truth
  - Average diff: 0.241
  - Maximal diff: 0.767
  - RMS brightness diff: 0.25

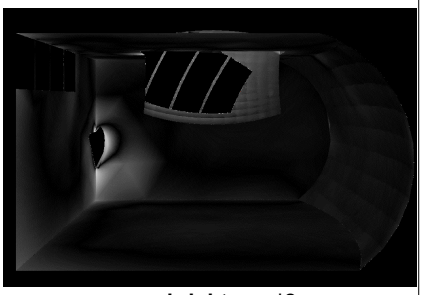


Fast rendering

## Quantitative Comparison (Example B)



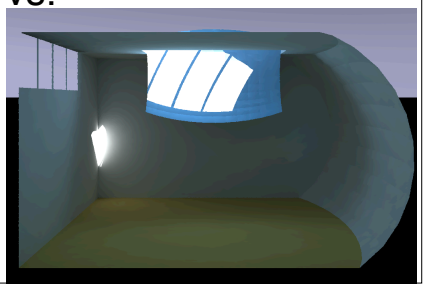
- Our rendering vs. Radiance Ground truth
  - Average diff: 0.029
  - Maximal diff: 0.652 (alias)
  - RMS diff: 0.045



brightness*2

- Fast Radiance rendering vs. Radiance Ground truth
  - Average diff: 0.157
  - Maximal diff: 0.803
  - RMS diff: 0.165

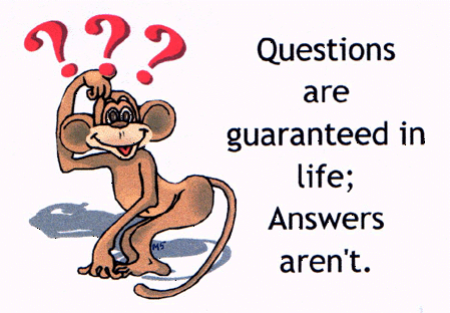
Fast rendering



## Future work

- Compare CFS rendering with Radiance
  - Get Radiance to do renderings with BTDF data
    - Greg Ward's work
    - Jan de Boer
  - Hopefully, we can get similar comparison results, but perhaps more due to our simulation of BTDF data
- Use GPU
  - Improve the rendering speed and interactivity

**Thanks and Questions?**




## Radiance Rendering commands

- Ground truth rendering by Radiance
  - rpict -ab 14 -dp 8192 -ar 256 -ms 0.033 -ds .07 -dt .05 -dc .75 -dr 3 -sj 1 -st .01 -aa .1 -ad 4096 -as 1024 -lr 24 -lw .0002 -x 1024 -y 1024
- Fast rendering by Radiance
  - rpict -ab 5 -dp 1024 -ar 64 -ms 0.03 -ds .15 -dt .1 -dc .95 -dr 3 -sj 1 -st .03 -aa .1 -ad 1024 -as 128 -lr 10 -lw .001 -x 1024 -y 1024