Measurement and modeling of a daylight redirecting component

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Outline

- Application: airport design
  - Role of daylight in the design
  - Controlling irradiance and daylight with glazing

- Sample: a light redirecting mirror array

- Characteristics: available data and measurements

- Modeling: modeling strategies with Radiance
  - Measured data and the data-driven BSDF modifier
  - Geometric model and genBSDF
  - Geometric model and the Radiance Photon Map extension

- Comparison

- Conclusion
Application: Calgary Airport Expansion

**IFP, International Facilities Project**

Architects: DIALOG, Calgary
Structure: RJC, Calgary
Climate/Energy: Transsolar, Munich
Mechanical / Electrical: AECOM, Calgary
Opening: fall 2015
Existing Terminals A – D
1977 - 2004
Net area: 141’000 m²

Expansion: IFP Terminal
2015
Net area: 144’000 m²
Climate- and Energy Concept
Daylight Concept: Optimize natural daylighting
reduce Energy Consumption

Daylight for perimeter zones via facades

Daylight for central areas via skylights
Climate- and Energy Concept

- Insulated roof with triple glazed skylights with micro shed structures
- Stratification in upper level
- Displacement ventilation
- Conventional ventilation
- Double facade with shading device in facade cavity
- Heating and cooling
- Geothermal heat pump bore hole heat exchanger system
Sample: a light redirecting mirror array

Test module of the mirror grid.
Available properties of the module: Glazing composition and transmission / reflection spectra of glass layers.

- Composed of three glass layers (one being laminate) and mirror inlet
- Mirror inlet geometry provided by manufacturer
- Glass properties from International Glazing Database (IGDB), Optics6
Characteristics: measurements

- Bidirectional Scatter Distribution Function
  $\text{BSDF}(\theta_{\text{in}}, \phi_{\text{in}}, \theta_{\text{out}}, \phi_{\text{out}})$

- Scanning Goniophotometer by PAB
  at Lucerne University of Applied Sciences & Arts
Outgoing distributions of the mirror grid

- Visualizations of the outgoing distribution for each incident direction, interpolation by Delauny triangulation

- Projection of the transmission / reflection hemisphere of outgoing directions: $\varphi_{\text{out}}$ as azimuth angle, $\theta_{\text{out}}$ as radius

Daylight redirecting structure. BSDF $\times \cos(\theta_{\text{out}})$ for $\varphi_{\text{in}}=0$, $\theta_{\text{in}}=10, 20, 40$ and 60 degrees.
Modeling: modeling strategies with Radiance

- The distribution does not follow assumptions by any analytical model

- Radiance offers three modeling approaches:
  
  - Interpolation of measured data, variable-resolution BSDF $pabopto2bsdf$
    - Data-driven BSDF includes any information in the measurement
    - High number of measurements of varying incident direction needed

  - Computation of BSDF from geometric model of the structure $genBSDF$
    - Replaces geometric detail in the scene by its resulting BSDF
    - Any mistakes in generating the BSDF lead to entirely wrong result

  - Direct use of geometric model with added forward pass $mkpmap$
    - No preprocessing, no risk of applying BSDF with wrong orientation
    - Keeps all geometric detail in the scene
Measured data and the data-driven BSDF modifier

- Measured distributions (one for each incident direction to interpolant SIR)

```bash
pabopto2bsdf -n 4 0*_*_r.dat > 000_070_r.sir
pabopto2bsdf -n 4 0*_*_t.dat > 000_070_t.sir
pabopto2bsdf -n 4 1*_*_r.dat > 110_180_r.sir
pabopto2bsdf -n 4 1*_*_t.dat > 110_180_r.sir
```

-`n <N>`: number of processes
-`<.dat>`: distribution in pab-format

- Interpolation and data-reduction to BSDF in XML-format

```bash
bsdf2ttree -g 7 -t 85 000_070_r.sir 000_070_t.sir \ 110_180_r.sir 110_180_t.sir > g7_t85.xml
```

-`g <N>`: initial tensor tree resolution $2^N$
-`-t <N>`: remove N % of data from tensor tree when adapting resolution
Measured data and the data-driven BSDF modifier
Geometric model and genBSDF

- genBSDF can compile BSDF of either variable resolution or based on Klems

```
genBSDF -c 10240 -n 12 -t4 6 +f +b +geom meter \ 
-dim -.1 .1 -.1 .1 -.063 0 module_genBSDF.rad > c_10240_t4_6.xml
```

- `-c <N>`: number of samples
- `-t4 <N>`: anistropic 4D BSDF, $2^N$ incident x $2^N$ outgoing directions
- `-f+`: front side BSDF
- `-b+`: back side BSDF
- `-geom <unit>`: units
- `-dim <xmin> <xmax> <ymin> <ymax> <zmin> <zmax>`: bounding box computation of BSDF

- Beware.... genBSDF expects specific orientation:
Geometric model and genBSDF
Geometric model and the Radiance Photon Map extension

- Most transparent approach – just model the fenestration as anything else

- Use of photon ports to „guide“ photons into the space of interest

- Example: 1M global, 8M caustic photons:

  mkpmap -apo photonPortMat \
  -apg pmap/global.pmap 1M -apc pmap/caustic.pmap 8M \ 
  oct/module_pmap.oct
Comparison

Interpolated measurement

270deg

180deg

90deg

genBSDF

Photon map
Conclusion

- Recent developments in Radiance provide us with working methods to model daylight redirecting components

- genBSDF, photon map and interpolated measured BSDF lead to qualitatively comparable results – even for more complex systems

- Geometry will still be required to consider detail of glazing systems, as Radiance does not support spatially resolved BSDF

- Measurements are required to make data-driven BSDF models available and to evaluate computation-based models (genBSDF)
Thank you for your attention!

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