Validating Radiance methods for parametric analysis of non-coplanar shading system — an update

Radiance Workshop, Aug 22-24, 2017

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i = V T F D s
\[ i = V T F D s \]

maps flux from coplanar window surface to a viewpoint within the space
\[ i = V T F D s \]

BSDF for the operable indoor coplanar shade
maps flux transfer from grey port to window surface including transmission and interreflections through the non-coplanar system
$$i = V T F D s$$

maps flux transfer from sky patches to grey port
Three ways of constructing Façade matrix ports

Rays will be traced from window to ports to capture the optical behavior of the non-coplanar shading system in-between

Simplest: most useful for continuous shading systems (e.g., overhang across the entire length of the building) or narrow shading systems where light coming in from sides is minor.

Relatively simple to construct; still a single sampling hemisphere, misses lights coming from behind the facade.

The most complicated and comprehensive; each port surface has its own sampling hemisphere, thus counting rays from all directions.
Window sub-division at workplane height

Sub-divide window at workplace height to prevent rays entering through the lower portion (A) of the window from being averaged over the entire window.
rfluxmtx glazing_srf(sender) port1(receiver) -i {octree} > fmx_1
rfluxmtx port1(sender) skyglow(receiver) -i {octree} > dmx_1
       >fmx_2
       >dmx_2
       
       >fmx_7
       >dmx_7

rmtxop `dctimestep -of fmx_1 dmx_1` + `dctimestep -of fmx_2 dmx_2` + .. + `dctimestep -of fmx_7 dmx_7` > fdmx

dctimestep vmx shade.xml fdmx sky_matrix | rmtxop -fa -c 47.4 119.9 11.6 - > illuminance.txt
Senders and receivers support the following resolutions:

- Klems (quarter, half, full)
- Reinhart/Treganza N subdivisions
- Shirly-Chiu N square-to-circle mapping
- Uniform

Note: Klems has low resolution at grazing angle, high intensity rays (direct sun) get averaged over a large solid angle.
Matrix Angle Basis Breakdown

<table>
<thead>
<tr>
<th>Angle basis</th>
<th>View matrix</th>
<th>Transmission matrix</th>
<th>Facade matrix</th>
<th>Daylight matrix</th>
<th>Daylight matrix/vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinhart 2 sub-division</td>
<td>n/a</td>
<td>Reinhart 2 sub-division with awning represented by Klems BSDF</td>
<td>Reinhart 4 sub-division</td>
<td>Reinhart 4 sub-division</td>
<td>Reinhart 4 sub-division</td>
</tr>
</tbody>
</table>

For this study, no planar shade (T matrix) is used, which enables us to use Reinhart 2 resolution for Facade and view matrix. For regular 3-phase calculation, resolution will be limited to the Klems BSDF.
Skycam

Mapped to Reinhart Sky Subdivision

gendaylit ... | genhdrvec -m 4 ... > sky.vector
Genhdrvec: modified genskyvec that uses fisheye.cal to map skydome hdr to Treganza sky subdivision
South Window

- 6
- 5
- 4
- 3
- 2
- 1

Sunbrella 4633-0000, Linen
Manufacturer’s data:
Tv, n-n = 0.08
Tv, n-h = 0.044
ρv, n-h = 0.40

LBNL BSDF:
Lambda 950 spectrophotometer with
150 mm integrating sphere plus angle
tube accessory for Lambda 950 Measure
diffuse and direct transmittance &
reflectance at nine angles of incidence
July 10th

Awning: swing arm and facade at 70 deg

Workplane illuminance
Workplane illuminance
Apr 29th, 2017
Awning: swing arm and facade at 125 deg

- Sensor 1 skycam
- Sensor 2 skycam
- Sensor 3 skycam
- Sensor 4 skycam
- Sensor 5 skycam
- Sensor 6 skycam
# Near Window Sensors

<table>
<thead>
<tr>
<th>Daylight Coefficient</th>
<th>5PM</th>
<th>3PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor 1 simulated vs. measured with dc matrix</td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>Sensor 1 simulated vs. measured with 5pm matrix</td>
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<tr>
<td>Sensor 1 simulated vs. measured with 3pm matrix</td>
<td><img src="image" alt="Graph" /></td>
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</tr>
<tr>
<td>Sensor 1 simulated vs. measured with 6pm_f7 matrix</td>
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<td>Sensor 1 simulated vs. measured with 4pm_f7 matrix</td>
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<td>Sensor 1 simulated vs. measured with 6pm_f1h matrix</td>
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</tr>
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</table>
# Mid-room sensors

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<tr>
<th>Daylight Coefficient</th>
<th>3PM</th>
<th>6PM_F7</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
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<tr>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
<td><img src="image9" alt="Graph" /></td>
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<tr>
<td><img src="image10" alt="Graph" /></td>
<td><img src="image11" alt="Graph" /></td>
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<tr>
<td><img src="image13" alt="Graph" /></td>
<td><img src="image14" alt="Graph" /></td>
<td><img src="image15" alt="Graph" /></td>
</tr>
<tr>
<td><img src="image16" alt="Graph" /></td>
<td><img src="image17" alt="Graph" /></td>
<td><img src="image18" alt="Graph" /></td>
</tr>
</tbody>
</table>

*Mid-room sensors and their corresponding graphs showing measured vs. simulated illuminance.*
Back room sensors

Daylight Coefficient

3PM

6PM_F7

5PM

4PM_F7

6PM_F1H

6PM_F1

4PM_F1H

4PM_F1
Luminance
July 20th
Awning: swing arm and facade at 125 deg

Floor
Ceiling
Wall
DGP

Simulated

cauised by grainy image?

Measured
### workplane illuminance simulated vs. measured

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Near Window</th>
<th>Mid Room</th>
<th>Back Room</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>6pm_f7</td>
<td>18.9</td>
<td>8.0</td>
<td>9.0</td>
<td>11.6</td>
</tr>
<tr>
<td>dc</td>
<td>13.9</td>
<td>9.8</td>
<td>11.5</td>
<td>11.7</td>
</tr>
<tr>
<td>4pm_f7</td>
<td>19.9</td>
<td>6.9</td>
<td>8.5</td>
<td>11.7</td>
</tr>
<tr>
<td>3pm</td>
<td>19.7</td>
<td>7.2</td>
<td>8.8</td>
<td>11.9</td>
</tr>
<tr>
<td>5pm</td>
<td>18.8</td>
<td>8.2</td>
<td>9.3</td>
<td>12.1</td>
</tr>
<tr>
<td>4pm_f1h</td>
<td>21.5</td>
<td>8.2</td>
<td>8.9</td>
<td>12.9</td>
</tr>
<tr>
<td>6pm_f1h</td>
<td>21.3</td>
<td>8.3</td>
<td>9.3</td>
<td>13.0</td>
</tr>
<tr>
<td>6pm_f1</td>
<td>48.9</td>
<td>28.2</td>
<td>23.6</td>
<td>33.6</td>
</tr>
<tr>
<td>4pm_f1</td>
<td>51.1</td>
<td>30.2</td>
<td>24.5</td>
<td>35.3</td>
</tr>
</tbody>
</table>

### Sample area luminance simulated vs. measured

<table>
<thead>
<tr>
<th></th>
<th>Floor</th>
<th>Wall</th>
<th>Ceiling</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>dc</td>
<td>18.6</td>
<td>17.7</td>
<td>8.2</td>
<td>14.8</td>
</tr>
<tr>
<td>6pm_f7</td>
<td>21.8</td>
<td>15.0</td>
<td>9.1</td>
<td>15.7</td>
</tr>
<tr>
<td>5pm</td>
<td>20.4</td>
<td>17.1</td>
<td>10.1</td>
<td>15.9</td>
</tr>
<tr>
<td>4pm_f7</td>
<td>22.6</td>
<td>16.0</td>
<td>9.6</td>
<td>16.1</td>
</tr>
<tr>
<td>3pm</td>
<td>20.8</td>
<td>16.9</td>
<td>10.5</td>
<td>16.1</td>
</tr>
<tr>
<td>6pm_f1h</td>
<td>21.6</td>
<td>18.9</td>
<td>11.8</td>
<td>17.4</td>
</tr>
<tr>
<td>4pm_f1h</td>
<td>21.9</td>
<td>18.4</td>
<td>12.2</td>
<td>17.5</td>
</tr>
<tr>
<td>6pm_f1</td>
<td>22.6</td>
<td>26.8</td>
<td>19.2</td>
<td>22.9</td>
</tr>
<tr>
<td>4pm_f1</td>
<td>26.3</td>
<td>35.9</td>
<td>28.1</td>
<td>30.1</td>
</tr>
</tbody>
</table>
Conclusion:

1. Constructing a façade matrix enables parametric analysis of non-coplanar shading systems;

2. The optical behavior of the non-coplanar system can be adequately captured given appropriate sampling basis (e.g. Klems vs. Reinhart) and simulation parameters (e.g. ‘-c -ab -ad -lw’) 

3. Out of the three methods of constructing a façade matrix, the FN methods yields the most accurate results against the measured data. FH methods seems to work reasonably well for the test case. F1 demonstrated the worst case scenario, and thus yielded the least accurate result.
Acknowledgment

Dustin Davis, California Energy Commission

Amir Roth, U.S. Department of Energy

GlenRaven
Sunbrella

Chris Humann and Andrew McNeil, Terrestrial Light

Christoph Gehbauer, Jacob Jonsson, Anothai Thanachareonkit, Darryl Dickerhoff, Daniel Fuller, Stephen Selkowitz, LBNL

Https://facades.lbl.gov/