Dynamic Visualization of Annual Building Simulation Data

15th Annual Radiance Workshop – Padua, Italy
Alen Mahić, Energy Studies in Buildings Laboratory
University of Oregon
Purpose and scope

- Quantification of energy savings attributed to blinds system.
- Annual daylight and energy modeling of 9-storey office building with roughly 325,000 square feet of floor area.
- Both models to include Lutron motorized shades (MechoShade) and automated controls.
Daylight zoning

- Blinds operation based on zoning of spaces and window groups.
- Four spatial zones per floor.
- Windows grouped as designed and operated as part of each spatial zone.
- 4’x4’ analysis grid spacing.
- Cores excluded.
Daylight zoning

14,386 analysis points. (4’x4’ grids)
Model organization

• Radiance model structure

  • Generation of blinds operation schedules per spatial zone:
    • North-East Zone
    • North-West Zone
    • South-East Zone
    • South-West Zone

  

  Blinds operated result

• Application of blinds schedule to entire floor plate:
  • Whole floor

691 window groups

Direct solar simulations (1)

691 window groups

Ambient simulations per blind condition (2)
Using RAD and OBJ geometry as processing tools

- Generating additional simulation elements using available geometry.
  - Wavefront .OBJ
  - Native .RAD

```plaintext
# Alias OBJ Model File
# Exported from SketchUp, (c) 2000-2012 Trimble Navigation Limited
# File units = meters

mtllib EDITED_US Bank Sketchup 6th floor.mtl

g Mesh1 Group1 Model

usemtl OpenStudio_Floor_Ext
v 7.04808 64.0353 0.0381
vt -262.715 499.317
vn 0 0 -1
v 32.7513 64.0353 0.0381
vt -1274.65 499.317
v 32.7513 50.2002 0.0381
vt -1274.65 -45.375
v -1.5283 50.2002 0.0381
vt 74.9375 -45.375
v -1.5283 56.7708 0.0381
vt 74.9375 213.317
v 0.375115 57.2217 0.0381
vt 0 231.063
f 1/1/1 2/2/1 3/3/1 4/4/1 5/5/1 6/6/1
```

# obj2rad -f usb.obj
# Alias OBJ Model File
# Exported from SketchUp, (c) 2000-2012 Trimble Navigation Limited
# File units = meters

OpenStudio_Floor_Ext polygon Mesh1.Group1.Model.1
0
0
18
  7.04808  64.0353  0.0381
  32.7513  64.0353  0.0381
  32.7513  50.2002  0.0381
  -1.5283  50.2002  0.0381
  -1.5283  56.7708  0.0381
  0.375115  57.2217  0.0381

# Done processing file: usb.obj
# 24 lines, 20 statements, 1 unrecognized
Leverage the R statistical analysis software to generate assets for Radiance simulation.
Radiance three-phase

\[
\begin{align*}
V & = \begin{pmatrix}
1,1 & \ldots & 1,145 \\
\vdots & \ddots & \vdots \\
145,1 & \ldots & 145,145 \\
n,1 & \ldots & n,145
\end{pmatrix} \\
T & = \begin{pmatrix}
1,1 & \ldots & 1,145 \\
\vdots & \ddots & \vdots \\
145,1 & \ldots & 145,145 \\
\vdots & \ddots & \vdots \\
1 & & 2306
\end{pmatrix} \\
D & = \begin{pmatrix}
1,1 & \ldots & 1,2306 \\
\vdots & \ddots & \vdots \\
145,1 & \ldots & 145,2306 \\
\vdots & \ddots & \vdots \\
2306 & & 1
\end{pmatrix} \\
S & = \begin{pmatrix}
1,1 & \ldots & 1,145 \\
\vdots & \ddots & \vdots \\
145,1 & \ldots & 145,145 \\
\vdots & \ddots & \vdots \\
2306 & & 1
\end{pmatrix}
\end{align*}
\]
Adapting Lutron’s automated Quantum operation logic.

- Operates under three primary conditions, with an optional fourth.
- Photosensor-based control
  - Single 60-degree FOV vertical illuminance sensor centered horizontally, 25% from the window head.
  - Two 30-degree FOV vertical illuminance to be placed on opposite sides of a vertical mullion piece, effectively giving a 60-degree FOV.
- Condition 1
  - “Darkness Threshold” – If the sensor sees less than this level, shades attached to it are fully open/retracted.
- Condition 2
  - “Brightness Threshold” – If the sensor sees more than this level, shades attached to it are fully closed/deployed.
- Condition 3
  - If conditions 1 and 2 are not triggered, the penetration depth is calculated based on the sun’s position and if it should exceed the maximum allowed setting then the shades are systematically lowered until below the maximum allowed depth.
- Condition 4 (optional)
  - “Visor” – This sets the fully retracted shade height to a minimum level to help mitigate sky brightness.
Horizontal Profile Angle

- Using horizontal and parallel profile angles to calculate solar penetration depth.
Photo-sensor representation

- Sensor-based operation
- Captured field of view

```plaintext
# Angle/view cut-off cones...
#
# Cone height/length: 0.1524 meters (6 inches)
# Base/opening radius: 0.0889 meters (3.5 inches)
# Apex radius: 0 meters (0 inches)
# Resulting view angle: 62.28 degrees
#
# Generated for input: "2nd_sensors.pts"
#
void plastic black 0 0 5 0 0 0 0
black cone cutoff.1 0 0 8
26.133921 75.817913 29.2481
26.286575 75.817913 29.2481
0 0.0889
```
Photo-sensor representation
Photo-sensor representation

- 180 degree FOV
- 400 Lux Darkness Threshold
- 5000 Lux Brightness Threshold
- 2.5 meter (8 ft.) penetration depth allowed
- 3+ shade/blind conditions
  - open (100%)
  - intermittent (interval)
  - closed (0%)
Photo-sensor representation

- 180 degree FOV
- 500 Lux Darkness Threshold
- 6000 Lux Brightness Threshold
- 2.5 meter (8 ft.) penetration depth allowed
- 3+ shade/blind conditions
  - open (100%)
  - intermittent (interval)
  - closed (0%)
Photo-sensor representation

- 60 degree FOV
- 500 Lux Darkness Threshold
- 6000 Lux Brightness Threshold
- 2.5 meter (8 ft.) penetration depth allowed
- 3+ shade/blind conditions
  - open (100%)
  - intermittent (interval)
  - closed (0%)
Accounting for blind/shade height

Single-core runtime
6 hours

Single-core runtime
12 hours

Single-core runtime
24 hours

Single-core runtime
48 hours
Blinds operated results
Blinds operated results
June 24th, 9:00
Blinds operated results
June 24th, 10:00
Blinds operated results
June 24th, 11:00
Blinds operated results
June 24\textsuperscript{th}, 12:00
Blinds operated results
June 24th, 13:00
Blinds operated results
June 24<sup>th</sup>, 14:00
Blinds operated results
June 24th, 15:00
Blinds operated results
June 24\textsuperscript{th}, 16:00
Blinds operated results
June 24th, 17:00
Blinds operated results
June 24\textsuperscript{th}, 18:00
Blinds operated results

- Spatial Daylight Autonomy

<table>
<thead>
<tr>
<th>Floor</th>
<th>Zone</th>
<th>Time</th>
<th>DA(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>all</td>
<td>Annual</td>
<td>73.2</td>
</tr>
<tr>
<td>3rd</td>
<td>all</td>
<td>Annual</td>
<td>80.4</td>
</tr>
<tr>
<td>4th</td>
<td>all</td>
<td>Annual</td>
<td>80.1</td>
</tr>
<tr>
<td>5th</td>
<td>all</td>
<td>Annual</td>
<td>71.3</td>
</tr>
<tr>
<td>6th</td>
<td>all</td>
<td>Annual</td>
<td>84.0</td>
</tr>
<tr>
<td>7th</td>
<td>all</td>
<td>Annual</td>
<td>72.9</td>
</tr>
<tr>
<td>8th</td>
<td>all</td>
<td>Annual</td>
<td>81.6</td>
</tr>
<tr>
<td>9th</td>
<td>all</td>
<td>Annual</td>
<td>88.3</td>
</tr>
</tbody>
</table>
EnergyPlus and Radiance sharing geometry inputs.
Overlaying of EnergyPlus thermal zones onto the Radiance analysis grid in order to isolate the points that are inside the zone.

These can be averaged, or a single point specified to generate the fractional lighting schedule.
Energy end uses with 300 Lux level @ workplane

Energy end uses with 500 Lux level @ workplane
Back to the blinds operation data
R building blocks

• Packages
  • sp -- Classes and methods for spatial data
  • plot3D -- Plotting multi-dimensional data
  • plot3Drgl -- Plotting multi-dimensional data in openGL
  • rgl -- 3D visualization using OpenGL

• Functions
  • svg(), png() to set up the file outputs.
  • perspbox() to set up the plot environment, min/max coordinate values.
  • plot(), plot3D(), polygon(), polygon3D() to plot sets of coordinates.
  • RGL-specific:
    • open3d() to initialize RGL.
    • rgl.bg() to set up 3D environment.
    • rgl.points(), rgl.lines(), rgl.spheres(), rgl.triangles(), rgl.quads() to plot and render various geometries.
    • rgl.viewpoint() and rgl.snapshot() to set up a point of view and save as an image file.
Animations available online:

vimeo.com/142585361 (Full year)
vimeo.com/130748828 (RGL June short)
vimeo.com/130748827 (RGL January short)
Thanks to all of our industry partners and great research staff that made this project happen!

And thank all of you for your time!