Integrating shading, lighting and glare and achieving reliable results for clients

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How it begins…
Architect:

Here’s our building...
Architect:

Make it daylit!
Consultant:

Sure!
Consultant:

I’d better get started…
What we can test...
...but what should we test?

What does the client want to know?
1. How much does it cost?
2. How much energy will it save?
3. What does it look like?
4. How comfortable will it be for the occupants?
5. What is the perfect solution that is beautiful, energy efficient, and doesn’t cost any more than a standard solution?
…what does that mean?

As a consultant, our job is to:

1. Faithfully describe the building performance conditions
2. Give the client useful information so they can make decisions
3. Not blow the entire fee running too many simulations
4. Convince the client of the “best” option
actionable information

Provide a actionable guidelines for the architect to build on or from
[e.g dimensions, angles, locations, colors, materials]
Example Recommendation for South Facade

Weighing options
dynamic and temporal feedback

Convey the dynamic and temporal qualities of daylighting and lighting to the architect

[e.g. quantity over time over area]
Animations

Animation showing direct solar beam on the 21st of each month
Animations

Animation showing direct solar beam on the 21st of each month
meaningful comparisons

Synthesize not just differences between strategies, but which differences are meaningful
[e.g how much of a change]
Point-in-time illuminance simulations

December 21, 12pm, Clear Sunny Sky with fabric shades
Point-in-time illuminance simulations

December 21, 12pm, Clear Sunny Sky with louvers at 37 degrees
Point-in-time illuminance simulations

December 21, 12pm, Clear Sunny Sky with 40% WWR and fabric shades
Actionable Information
A brief detour
Solar Geometry
Profile Angles as Design Tool
### Direct Sun Shading Profile Angles

Using solar geometry to provide architects with useable dimensions

<table>
<thead>
<tr>
<th>Angle</th>
<th>EAST</th>
<th>SOUTH</th>
<th>WEST</th>
<th>NORTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>25°</td>
<td>Most of the year after 9am</td>
<td>Most of the year until 3pm</td>
<td>Entire year</td>
<td></td>
</tr>
<tr>
<td>30°</td>
<td>Entire year after 10am</td>
<td>Feb 21-Oct 21 until 3pm</td>
<td>Jan 31-Nov 11 until 3pm</td>
<td></td>
</tr>
<tr>
<td>40°</td>
<td>Entire year after 10:30am</td>
<td>Sep 30-Mar 11 until 3pm</td>
<td>Sep 21-Mar 21 until 3pm</td>
<td></td>
</tr>
<tr>
<td>50°</td>
<td></td>
<td></td>
<td>Entire year until 7pm</td>
<td></td>
</tr>
<tr>
<td>60°</td>
<td></td>
<td></td>
<td>Most of the year until 7pm</td>
<td></td>
</tr>
</tbody>
</table>
Screen Offset and Dimensions

25° cut off angle (South, West or East)

30° cut off angle (South, West or East)

40° cut off angle (South, West or East)

If you move the screens anywhere along the diagonal lines, cut off will be achieved for the respective time/facade. The further off of the façade the screen is, the more unobstructed view is available.
Overhangs for Shading

Achieving cutoff

If we wanted to use overhangs to solve the direct sun problem instead of screens, we could design overhangs as above. While the depths of these overhangs are perhaps more than achievable, these represent a “perfect” condition. Overhangs sized slightly smaller, will still achieve cut off during most of the specified time.
Lighting, shading and glare in daylight analysis
How do we achieve reliable results?
DIVA-for-Rhino Background
Objective

• To run a suite of simulations that will describe the behavior of a façade system including the lighting, shading and glare conditions.
Caveats

• This procedure does NOT use the Penn State Daysim
• This procedure uses DIVA-for-Rhino
• Control system algorithms are open loop systems
What are the steps?
Critical inputs

- Modeling geometry
- Selecting a control algorithm
- Setting illumination set points
- Sensor node selection
Shading module – Shading Geometry

1. Physically model each shading state on its own layer
2. Assign a material to that layer

*If you want the shades to operate at all open, halfway down, and all the way down, model the shades halfway down, and all the way down on separate layers. If you want louvers at 90 degrees, 30 degrees and 20 degrees, you would model that geometry on 3 separate layers.*

*Note: you can leave all of the shading layers in the “on” state before running the simulations.*
Shading module – Shading Control Type

3. Select from the available control algorithms, for each group:

- Mechanical
  - Manual
- Automated Thermal Control
- Automated Thermal Control with Occupancy
- Automated Glare Control
- Automated Glare Control with Occupancy
- Electrochromics

Note: The shading behavior in one shading group does not affect the shading behavior of a separate shading group.
Manual shade control

This model assumes that the shades are “reset” once a day in the morning. In reality, without automation, the resetting is unlikely to happen. The algorithm may underestimate the amount of time the shades are down.
Automated Glare Control

Mechanical
  Manual*
  Automated Thermal Control
  Automated Thermal Control with Occupancy
  Automated Glare Control
  Automated Glare Control with Occupancy

Electrochromics

Note: The shading behavior in one shading group does not affect the shading behavior of a separate shading group.

* Annual glare schedules are not used to control the operation of the shades. To use the DGP schedules to control the shades, select Manual control and in the climate-based metrics menu, select “Use DGP Schedules”.
Automated Glare Control
Automated Glare Control
Automated Glare Control
Automated Glare Control
Automated Glare Control
4. Set up the shading states

The “Base Geometry Layer” is the default shading state. If that means “shades all the way up”, then select “No fixed shading state.” The case shown here is louvers that start as fully retracted, then can be fully down at 90, 30 or 20 degree rotation angles.
Shading module – State Thresholds

5. Set up the shading thresholds

The shading thresholds are the value (in lux) which control when the system moves from one state to another. In the example to the right, the shading starts as fully open, if the daylight levels on any of the sensors rises above 5000 lux, the program sets the shading position to the next level down (90 degree louver, in this case). If at the next timestep, the light levels are still over 5000 lux, the program proceeds to the next lowest shading level. If, on the other hand, the light levels fall below 1000 lux at the next time step, then the shading reverts to the next highest level.
Shading module – State Thresholds

Off (lx)  On (lx)
300    2500 lux

SDa (300lx 50%):  40%
Shading Open:     39%
Electric Lighting Use Reduction: 85.1%

1000    5000 lux

SDa (300lx 50%):  55%
Shading Open:     78%
Electric Lighting Use Reduction: 92.1%
Setting sensor thresholds

423 fc  1650 fc  1996 fc  1986 fc  1573 fc  1843 fc
6. Select interior nodes (and exterior nodes) for each shading group

*It is up to you how many sensors you select to drive your shades. You can select just one or all of the sensor nodes. (If you do not select any nodes, the program will use all of them).*

*In the example to the right, all nodes on the south side of the building are selected. If light levels on any node reach above 5000 lux, the shades will deploy to their next lowest level. If all of the nodes fall below 1000 lux, at the next timestep, the shades will rise to the next highest level.*
Annual Glare Module
Annual Glare Module – Set Up

Critical inputs

• Set up viewpoints
• User (occupant) adaptability
Annual glare module – Set Up

1. Save the Rhinoceros views you wish to test

Save more than one view if you want to test multiple views, and if you want to give the occupant the ability to adapt based on glare conditions.
Annual glare module – Set Up

2. Select Adaptive Visual Comfort

Select whether or not the user can adapt – that is choose to look in a different direction given the glare conditions.
Lighting and Dimming Module
Lighting Module – Set Up

Critical inputs

- Lighting system power
- Lighting control algorithm
- Sensor node selection
Lighting module - Set up

1. Enter lighting system information

*Lighting Power (W):* total lighting power for the group of light fixtures being controlled

*Ballast Loss Factor (%):* percent of lighting power increased or decreased by the ballast (mostly an issue with fluorescents)

*Standby Power (W):* any power used when the system is either fully dimmed or off
Lighting module - Set up

2. Select the lighting control algorithm

None
Manual
Switch off with Occupancy
Switch on/off with Occupancy
(Photosensor Controlled) Dimming w. Occupancy Off Sensor
(Photosensor Controlled) Dimming w. Occupancy On/Off Sensor
Lighting module - Set up

3. Select sensor nodes

Similarly to the shading nodes, it is up to you to decide how many nodes you will select as triggers, and where those sensors should be.

Mistrick and Casey suggested selecting nodes as follows, “The critical work plane point is usually located between the dimmed lighting zone and the non-dimmed lighting zone where the required output from the controlled group of luminaires is greatest when considering the presence of daylight.”

Annual Simulation Runs

Critical inputs

- Lighting system power
- Lighting control algorithm
- Sensor node selection
Annual Simulation Runs

Critical inputs

- Simulations to run
- Simulation settings
- Use DGP Schedules, Use Adaptive Comfort
Annual simulations combining glare, shading and lighting

Results of a full Climate-Based Metrics run including (2) lighting/dimming groups and one shading group with outputs: Daylight Autonomy falsecolor grid, dimming and shading schedules, and annual glare simulation (with shade operation). The occupancy, lighting and shading schedules are also output as a .csv file which can be used in energy simulations to for more accurate evaluations of the lighting performance.
Annual simulations combining glare, shading and lighting

### Daylight Simulation Report

- **Daylight Area (DAR90%)**: 57% of floor area
- **Mean Daylight Factor**: 2.8%
- **Occupancy**: 3650 hours per year
- **Shading Group 1 open**: 43% of occupied hours

**Design Factor:** The DAR90% of all 90° incident windows is 57% of floor area. Assuming that the sensors are evenly distributed across all spaces, the overall mean DLF is 2.8%.

**Design Assumptions:** The overall mean DLF is 2.8% for active occupancy. The percentage of the space with a DLF > 1.0% is 43% for active occupancy.

### Simulation Assumptions

**Simulation Description:**
The building is located in Sydney (33.8°S by 151.2°E).

**Lighting Assumptions:**
- Lighting Group 1: Lighting area
- Lighting Group 2: Lighting area

Additional information can be found in the report output at the end of the DIVA simulation.
Meaningful Comparisons

A
Overhang with automated interior roller shades

B
Overhang, with interior light shelf, with automated interior roller shades above and below the glazing

C
Captured sandwich venetian blind glazing assembly with no external overhang or internal lightshelf
A Overhang

Spatial Daylit Autonomy (300lx 50%): 55%
Shades Open: 78%
Electric Lighting Use Reduction for daylit zone: 92.1%
B Overhang with Light Shelf

Spatial Daylit Autonomy (300lx 50%): 57%
Shades Open: 75%
Electric Lighting Use Reduction for daylit zone: 92.7%
C Venetian Blinds Glazing Unit

Spatial Daylit Autonomy (300lx 50%): 73%
Shades Open: 57%
Electric Lighting Use Reduction for daylit zone: 92.7%
A1 Overhang - Automatic Shades (Glare Control)

Spatial Daylit Autonomy (300lx 50%): 55%
Shades Open: 78%
Electric Lighting Use Reduction for daylit zone: 92.1%
A2 Overhang – Manually Controlled Shades

Spatial Daylit Autonomy (300lx 50%): 48%
Shades Open: 52%
Electric Lighting Use Reduction for daylit zone: 88.2%
A3 Overhang – Assume shades down always

Spatial Daylit Autonomy (300lx 50%): 31%
Shades Open: 0%
Electric Lighting Use Reduction for daylit zone: 66.6%
Comparing Strategies – Daylit Area

Daylit Area (DA 300lux 50%)

| Manual Overhang one shade | None Shades down | Automated Glare Control Overhang | Automated Glare Control Overhang + Lightshelf one shade | Automated Glare Control Schuco Type venetian blind windows |

This marker indicates the likely performance between manual operation in which the shades are faithfully opened by the occupants, and the condition in which the shades are always left down.
Comparing Strategies – Shading Group Open

Shading Group 1 Open

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Overhang one shade</td>
<td>0%</td>
</tr>
<tr>
<td>None Shades down</td>
<td>10%</td>
</tr>
<tr>
<td>Automated Glare Control</td>
<td>20%</td>
</tr>
<tr>
<td>Automated Glare Control Overhang</td>
<td>30%</td>
</tr>
<tr>
<td>Automated Glare Control Overhang + Lightshelf one shade</td>
<td>40%</td>
</tr>
<tr>
<td>Automated Glare Control Schuco Type venetian blind windows</td>
<td>50%</td>
</tr>
</tbody>
</table>

Diagram showing the comparison of different strategies for shading group open.
Comparing Strategies – Reduction in Electric Lighting Use

% Reduction in Electric Lighting Use in Daylit Zone

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>None</td>
</tr>
<tr>
<td>Overhang, one shade</td>
<td>50.0%</td>
</tr>
<tr>
<td>None</td>
<td>55.0%</td>
</tr>
<tr>
<td>Automated Glare Control</td>
<td>60.0%</td>
</tr>
<tr>
<td>Overhang</td>
<td>65.0%</td>
</tr>
<tr>
<td>Shades down</td>
<td>70.0%</td>
</tr>
<tr>
<td>Automated Glare Control + Lightshelf</td>
<td>75.0%</td>
</tr>
<tr>
<td>Overhang, Schuco Type venetian blind</td>
<td>80.0%</td>
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<tr>
<td>windows</td>
<td>85.0%</td>
</tr>
<tr>
<td>Automated Glare Control + Lightshelf</td>
<td>90.0%</td>
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<tr>
<td>Overhang, Schuco Type venetian blind</td>
<td>95.0%</td>
</tr>
<tr>
<td>windows</td>
<td>100.0%</td>
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</table>
actionable information

dynamic and temporal feedback

meaningful comparisons
Thank you