Daylighting performance assessment of shading devices concerning building’s aesthetic

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Outline

• Background
• Introduction
• Objectives
• Methodology
• Results
• Conclusion
• Future work
Background

• Climate

• Weather
Introduction

• Buildings consume the majority of generated power more than 40%.

• Windows and its attachment play a major role in heat gain or loss from a building.
Introduction

• Buildings/Windows designed to be more sustainable.

• Building owners are fascinated by the appearance of their buildings.
Objectives

• Optimum selection of window elements that:
  • Reducing heat gain
  • Provide an aesthetic façade
  • Ensure visual comfort
Objective Function and Constraints

Objectives

\[ f(x) = \left[ Q_c(x) + Q_h(x) \right] / 3.6 \times 10^6 \]  \hspace{1cm} (1)

\[ f(y) = [E_{Daylighting}(x)] \]  \hspace{1cm} (2)

\[ f(xy) = f_{\text{min}}(x) + f_{\text{max}}(y) \]  \hspace{1cm} (3)

Constraints

\[ c_{1,2}(x) = \sum_{i=1}^{n} z_i / n \]  \hspace{1cm} (4)

\[ z_i = \begin{cases} H_{\text{lux}}, & \text{if } (H_{\text{lux}} > 500) \\ H_{\text{glare}}, & \text{if } (H_{\text{glare}} > 22) \end{cases} \]
Table 1: Design parameters values.

<table>
<thead>
<tr>
<th>Index</th>
<th>Variable</th>
<th>LB</th>
<th>UB</th>
<th>Increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Overhang tilt (°)</td>
<td>90</td>
<td>135</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>overhang projection (%)</td>
<td>0</td>
<td>H/2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>side-fins projection (%)</td>
<td>0</td>
<td>W/2</td>
<td>5</td>
</tr>
</tbody>
</table>
Genetic Algorithm Concept

(a): Crossing-over operation

(b): Mutation operation
Methodology

Simulation-based Optimization

Genetic algorithm (GA) coupled with a building simulation program (EnergyPlus)

A workstation of 48 threads (ENSIMS X3200) powered by 2x Intel Xeon 2.5GHz with a memory size of 64GB RDIMM was allocated to accomplish the computation (up to 56 at a time).
Results
## Results

<table>
<thead>
<tr>
<th>Overhang (m)</th>
<th>Projection Telt (°)</th>
<th>Fins (m)</th>
<th>Glazing Mat</th>
<th>Air Gap</th>
<th>WWR</th>
<th>W</th>
<th>H</th>
<th>Lighting (kWh)</th>
<th>Heating (kWh)</th>
<th>Cooling (kWh)</th>
<th>Total (kWh)</th>
<th>Saving</th>
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<tbody>
<tr>
<td>base</td>
<td>N/A</td>
<td>N/A</td>
<td>Low-e 6mm</td>
<td>12</td>
<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>43.3</td>
<td>26.4</td>
<td>3846.0</td>
<td>3872</td>
<td>0%</td>
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<td>Overhang/</td>
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<td>130</td>
<td>1.0</td>
<td>Low-e 6mm</td>
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<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>49.9</td>
<td>97.5</td>
<td>2738.4</td>
<td>2836</td>
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<td>Sided-fins</td>
<td>0.9</td>
<td>115</td>
<td>1.1</td>
<td>Low-e 6mm</td>
<td>12</td>
<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>46.2</td>
<td>86.8</td>
<td>2899.4</td>
<td>2986</td>
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<tr>
<td></td>
<td>1.1</td>
<td>110</td>
<td>0.7</td>
<td>Low-e 6mm</td>
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<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>45.4</td>
<td>74.1</td>
<td>2976.1</td>
<td>3050</td>
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<td>Simple</td>
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<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>46.7</td>
<td>74.1</td>
<td>2847.9</td>
<td>2922</td>
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<tr>
<td>Overhang</td>
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<td>125</td>
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<td>Low-e 6mm</td>
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<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>44.9</td>
<td>63.8</td>
<td>2983.2</td>
<td>3047</td>
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<tr>
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<td>1.2</td>
<td>110</td>
<td>N/A</td>
<td>Low-e 6mm</td>
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<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>44.7</td>
<td>54.9</td>
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<td>3154</td>
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<tr>
<td>Louvers</td>
<td>1</td>
<td>90</td>
<td>N/A</td>
<td>Low-e 6mm</td>
<td>12</td>
<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>44.1</td>
<td>69.0</td>
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<td>2960</td>
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<tr>
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<td>0.75</td>
<td>90</td>
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<td>Low-e 6mm</td>
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<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>44.0</td>
<td>60.0</td>
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<td>90</td>
<td>N/A</td>
<td>Low-e 6mm</td>
<td>12</td>
<td>50</td>
<td>2.8</td>
<td>2.7</td>
<td>43.5</td>
<td>51.0</td>
<td>3232.2</td>
<td>3283</td>
</tr>
</tbody>
</table>
Results

Illuminance

<table>
<thead>
<tr>
<th>No Shade</th>
<th>Simple Overhang</th>
<th>Overhang+Sided-Fins</th>
<th>Louvers</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-26639 Lux &amp; 0-85.5 DF</td>
<td>0-24387 Lux &amp; 0-78.3 DF</td>
<td>0-23792 Lux &amp; 0-76.3 DF</td>
<td>0-23767 Lux &amp; 0-76.3 DF</td>
</tr>
</tbody>
</table>

- December, 21 at 9 am:
  - No Shade: 0-2089 Lux & 0-4.2 DF
  - Simple Overhang: 0-1813 Lux & 0-3.6 DF
  - Overhang+Sided-Fins: 0-1373 Lux & 0-2.7 DF
  - Louvers: 0-1840 Lux & 0-3.7 DF

- December, 21 at Noon:
  - No Shade: 0-1133 Lux & 0-4.7 DF
  - Simple Overhang: 0-1004 Lux & 0-4.2 DF
  - Overhang+Sided-Fins: 0-695 Lux & 0-2.9 DF
  - Louvers: 0-976 Lux & 0-4.1 DF

- December, 21 at 3 pm:
  - No Shade: 0-26639 Lux & 0-85.5 DF
  - Simple Overhang: 0-24387 Lux & 0-78.3 DF
  - Overhang+Sided-Fins: 0-23792 Lux & 0-76.3 DF
  - Louvers: 0-23767 Lux & 0-76.3 DF
## Results

### Illuminance

<table>
<thead>
<tr>
<th>No Shade</th>
<th>Simple Overhang</th>
<th>Overhang+Sided-Fins</th>
<th>Louvers</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-41269 Lux &amp; 0-73.6 DF</td>
<td>0-38445 Lux &amp; 0-68.6 DF</td>
<td>0-38446 Lux &amp; 0-68.6 DF</td>
<td>0-38307 Lux &amp; 0-68.3 DF</td>
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<tr>
<td>September, 21 at 9 am</td>
<td>0-2296 Lux &amp; 0-3.1 DF</td>
<td>0-1927 Lux &amp; 0-2.6 DF</td>
<td>0-1964 Lux &amp; 0-2.6 DF</td>
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<tr>
<td>0-1374 Lux &amp; 0-3.0 DF</td>
<td>0-1227 Lux &amp; 0-2.6 DF</td>
<td>0-916 Lux &amp; 0-2.0 DF</td>
<td>0-1251 Lux &amp; 0-2.7 DF</td>
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<tr>
<td>September, 21 at Noon</td>
<td>0-1374 Lux &amp; 0-3.0 DF</td>
<td>0-1227 Lux &amp; 0-2.6 DF</td>
<td>0-916 Lux &amp; 0-2.0 DF</td>
</tr>
<tr>
<td>September, 21 at 3 pm</td>
<td>0-1374 Lux &amp; 0-3.0 DF</td>
<td>0-1227 Lux &amp; 0-2.6 DF</td>
<td>0-916 Lux &amp; 0-2.0 DF</td>
</tr>
</tbody>
</table>
# Results

## Illuminance

<table>
<thead>
<tr>
<th></th>
<th>No Shade</th>
<th>Simple Overhang</th>
<th>Overhang+Sided-Fins</th>
<th>Louvers</th>
</tr>
</thead>
<tbody>
<tr>
<td>June, 21 at 9 am</td>
<td>0-46427 Lux &amp; 0-69.6 DF</td>
<td>0-45404 Lux &amp; 0-68.1 DF</td>
<td>0-44840 Lux &amp; 0-67.2 DF</td>
<td>0-45070 Lux &amp; 0-67.6 DF</td>
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<tr>
<td>June, 21 at Noon</td>
<td>0-4310 Lux &amp; 0-4.6 DF</td>
<td>0-3209 Lux &amp; 0-3.4 DF</td>
<td>0-2359 Lux &amp; 0-2.5 DF</td>
<td>0-3061 Lux &amp; 0-3.3 DF</td>
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<td>June, 21 at 3 pm</td>
<td>0-1509 Lux &amp; 0-2.4 DF</td>
<td>0-1341 Lux &amp; 0-2.2 DF</td>
<td>0-1024 Lux &amp; 0-1.6 DF</td>
<td>0-1395 Lux &amp; 0-2.6 DF</td>
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</tbody>
</table>
Results

Annual - sDA

<table>
<thead>
<tr>
<th>No Shading</th>
<th>Simple Overhang</th>
<th>Overhang/sided-fins</th>
<th>Louvers</th>
</tr>
</thead>
</table>

![Diagram showing various shading solutions with annual sDA results.](image-url)
Results

Annual - ASE

No Shading  Simple Overhang  Overhang/sided-fins  Louvers
Results
Annual-UDI

<table>
<thead>
<tr>
<th>No Shading</th>
<th>Simple Overhang</th>
<th>Overhang/sided-fins</th>
<th>Louvers</th>
</tr>
</thead>
</table>

![Diagram of four different shading types: No Shading, Simple Overhang, Overhang/sided-fins, Louvers.](image)
Conclusions

• Shading devices, overhang/sided-fins, louvers, and simple overhang, in East orientation saved 27, 25, and 24% respectively.

• It is only 3% different between the optimum solutions.

• Illuminance and annual daylighting proved that the louvers shadings performed the best.

• Louvers shading was less risk to visual discomfort as interpreted by the ASE assessment.

• Consequently louvers shading has a better UDI.

The architect can select optimum efficient shading devices that keep the building’s aesthetic to their preferences without prejudicing the energy efficiency.
Future Work

- The effect of including INTERIOR BLINDS might enrich the analysis.
- Optimum shading devices of OTHER orientations.
- LIFE-CYCLE COST ANALYSIS of optimum solutions.
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