Assessing Visual Comfort

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Background

Visual comfort and glare

- Glare measures the physical discomfort caused by either excessive light or contrast
- Does it matter?
  - 80% of designers consider that glare is important (Mogri, 2011)
  - Impact on work productivity
  - As glazing area increases, so does the likelihood of glare
  - Standards are starting to address visual comfort

Glare might lead to visual discomfort, thus, reducing work productivity.
Background

Metrics

- Workplane illuminance may not correlate well with glare – no consensus
- Daylight Glare Probability (DGP)
  - Vertical Eye Illuminance ($E_v$)
  - Source size
  - Scene Luminance
  - Position

DGP $\rightarrow$ Annual DGP (aDGP)

![A synthetic High Dynamic Range (HDR) image produced by Radiance and post-processed as a luminance false color image (left) and as an evalglare HDR (right).]
Background

Daylight Glare Probability (DGP) challenges

- Local – a point and direction at a time
- No modeling guidelines – requires expertise
- Hard to use in conceptual to intermediary design phases
- Slow to simulate

- Where, when, and where to look?
Objectives

Propose a new workflow for glare assessment

- Annual and climate-based
- Visually maps the spatial distribution of glare potential
- Based on a simpler metric – vertical eye illuminance (Ev)
- Detects critical:
  - Locations
  - Points-of-view (POV)
  - Time events

Vertical Illuminance (Hoof et al. 2012).
Approach

- Verification of annual Ev as a glare event marker
  - Based on previous research results
  - Annual Ev and annual DGP comparison
    - Typical overcast annual sky (London, UK)
    - Typical clear annual sky (Phoenix, AZ)

- Workflow development and implementation
  - Based on Radiance’s 3-phase method
  - Implementation for Rhino/Grasshopper
  - Visualization and query functionalities

- Example
  - Typical open space office room

Shoe box model of the experiments conducted in Santos, L. et al. (2018) used in the verification of annual Ev as a glare event marker.
### Visual comfort and vertical eye illuminance (Ev)

- Results based on a lab study (Wienold et al. 2006)
- Reasonable correlation
- $\text{Ev} \geq 2700 \text{ lux}$ as a threshold
- $\text{Ev} \geq 2700 \text{ lux} \rightarrow \text{Potential Glare Event (PGE)}$

Vertical eye illuminance (Ev) versus percentage of uncomfortable people. Adapted from: Wienold, J. et al. (2006).
Can vertical eye illuminance (Ev) detect glare events?

**Overcast sky**

If DGP ≥ Perceptible: Potential Glare Event captures 50.4%

If DGP ≥ Disturbing: Potential Glare Event captures 89%

**Clear sky has a similar trend**

If DGP ≥ Disturbing: Potential Glare Event captures 92%
Workflow

Inputs → Simulation → Post-process → Output

Geometry
- EnergyPlus Weather File
- Radiance Materials
- Sensor Grid

For each sensor:
- Generate 8 Point-of-views (POV)
- For each POV:
  - Calculate Ev

Count Potential Glare Events (PGE)

For each sensor:
- For each POV:
  - Report:
    - Normalized PGE
    - Max Ev
    - Time event

Build Radar Graph Query

Further explore
**Workflow**

**Inputs**
- Geometry
- EnergyPlus Weather File
- Radiance Materials
- Sensor Grid

**Simulation**
- For each sensor:
  - Generate 8 Point-of-views (POV)
  - For each POV:
    - Calculate Ev

**Post-process**
- Count Potential Glare Events (PGE)
- For each sensor:
  - For each POV:
    - Report:
      - Normalized PGE
      - Max Ev
      - Time event

**Output**
- Build Radar Graph
- Query Graph
- Further explore
Workflow

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Count Potential Glare Events (PGE)

Build Radar Graph
Query Graph

Further explore
Workflow

Inputs → Simulation → Post-process → Output


For each sensor:
Generate 8 Point-of-views (POV)
For each POV:
Calculate Ev

Percentage of annual daylit hours

Build Radar Graph
Query Graph

63% of the daylit hours yield a glare potential

Counts Potential Glare Events (PGE)

For each sensor:
For each POV:
Report:
Normalized PGE
Max Ev
Time event

Further explore

Percentage of annual daylit hours

63% of the daylit hours yield a glare potential

Further explore
Workflow

Inputs → Simulation → Post-process → Output

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For each sensor:
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Comparison of design solutions

Count Potential Glare Events (PGE)

For each sensor:
- For each POV:
  - Report:
    - Normalized PGE
    - Max Ev
    - Time event

Build Radar Graph
Query Graph

Further explore

Solution A
Solution B
Example: Modeling assumptions

Glazing solutions

Double Clear Glazing

Light Redirecting System

Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6

Plan

Center for the Built Environment | October 2018
Example: Output and query

<table>
<thead>
<tr>
<th>Double Clear Glazing</th>
<th>Light Redirecting System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical event</td>
<td>Critical event</td>
</tr>
<tr>
<td>POV direction: South</td>
<td>POV direction: South</td>
</tr>
<tr>
<td>Annual PGE: 84%</td>
<td>Annual PGE: 76%</td>
</tr>
<tr>
<td>5 JAN 3 pm: 4057 lux</td>
<td>30 DEC 2 pm: 3725 lux</td>
</tr>
</tbody>
</table>

Example:

Output and query

Sensor #2
Example: Output and query

Double Clear Glazing

Light Redirecting System

Critical event
POV direction: South
Annual PGE: 72%
27 NOV 2 pm: 8008 lux

Critical event
POV direction: South
Annual PGE: 59%
30 DEC 2 pm: 7965 lux
Example: Subsequent detailed studies

<table>
<thead>
<tr>
<th>Sensor #2 :: Selected POV and time event</th>
<th>Sensor #6 :: Selected POV and time event</th>
</tr>
</thead>
<tbody>
<tr>
<td>DGP</td>
<td>Luminance</td>
</tr>
<tr>
<td><img src="image1" alt="Double Clear Glazing" /></td>
<td><img src="image2" alt="Light Redirecting System" /></td>
</tr>
<tr>
<td>Intolerable</td>
<td>Intolerable</td>
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Example:

Subsequent detailed studies

<table>
<thead>
<tr>
<th>Luminance (cd/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000</td>
</tr>
<tr>
<td>2600</td>
</tr>
<tr>
<td>2200</td>
</tr>
<tr>
<td>1800</td>
</tr>
<tr>
<td>1400</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>600</td>
</tr>
<tr>
<td>200</td>
</tr>
</tbody>
</table>
Take-aways

Conclusions

- Ev can be used as a preliminary metric for glare assessments
- The workflow is able to:
  - Spatially map glare potential
  - Identify relevant POV and time events
  - Suitable for parametric or optimization studies
  - Be an alternative to expensive annual glare simulations

Future work

- Full work will be presented and published in PLEA conference proceedings
- Refine the query process
- Address more complicated examples
- Integrate with Building Optimization workflows
Please take a moment to fill out the feedback form.