Visual & Thermal comfort with Electrochromic glass
using a adaptive control strategy

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Living Lab smart office space

We are a small team under Prof. Dr. Sabine Hoffmann working on

- Thermal comfort
- Visual comfort
- Context aware lighting
- Activity recognition
- Personal heating/cooling devices like climate chairs and movable partitions etc.
Architectural plan – Living Lab
View points – Living Lab

south view

north view

head height = 1.2 m

smart office space
Challenges

• Visual discomfort
  • Direct glare from Sun
  • Exterior & interior Reflections

• Thermal Discomfort
  • Direct radiation on head
  • High indoor temperature(solar heat gains)

• Energy Consumption
  • Internal heat gains
  • Increase in cooling and heating Loads
Solution – Electrochromic Glass
Zoning

3 Zones

Upper zone -1.10m
Middle zone - 1.10m
Lower zone - 0.80m
# States

<table>
<thead>
<tr>
<th>NFRC_ID</th>
<th>T\text{vis}</th>
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<tbody>
<tr>
<td>8905</td>
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<tr>
<td>8906</td>
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<tr>
<td>8908</td>
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<td>8909</td>
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**Tools**

**Simulation**
- SketchUp & Groundhog
- EnergyPlus
- Daysim & Radiance

**Outputs**
- Heating/cooling loads
- DGP profiles
- Illumination Profiles
- Ranked combination of states

**Implementation**
- Illuminance sensors
- Pyranometers
- Raspberry Pi
- HDR camera
- Temperature sensors
- EC glass

**Outputs**
- Optimal state
Simulation parameters

- 3 Different sky conditions
- 3 Zones with each 4 states i.e. 64 (4x4x4) combination of states per time step
- 4 View points/ sitting positions

All together a combination of 3 x 64 x 4 simulations for each time step over 365 days.
Running Simulations

- Convert Sketchup Model to Radiance Model using Groundhog
- Get the glass states from Optics
- Add the glass state to each zone as texture (Automate using a script)
- Define Sky condition, View Points and sensor locations for Daysim and Generate Annual Illuminance & DGP Profiles
- Generate Heating and Cooling loads using EnergyPlus
- Rank Combination of states per Sky Condition based on DGP, Illuminance Values & Heating/Cooling Loads
Implementation

Ranked combination of states for each time step, sky condition and viewpoint

<table>
<thead>
<tr>
<th>Rank</th>
<th>States Combination</th>
<th>DGP</th>
<th>Illuminance (lux)</th>
<th>Sensible Heating Rate <a href="Hourly">W</a></th>
<th>Sensible Cooling Rate <a href="Hourly">W</a></th>
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<tbody>
<tr>
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<td>0.26</td>
<td>1500</td>
<td>0</td>
<td>2020.8</td>
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<td>0</td>
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<td>0.56</td>
<td>5021</td>
<td>0</td>
<td>6440.8</td>
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</table>
Determining sky condition

A.Fakra* et al. has given some valuable analysis

Sky Ratio = $\frac{d_h}{G_h}$

- $d_h$ is Diffuse horizontal terrestrial-irradiance (W/m$^2$)
- $G_h$ is Global horizontal terrestrial-irradiance (W/m$^2$)

<table>
<thead>
<tr>
<th>sky ratio</th>
<th>sky type</th>
<th>success rate</th>
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<tbody>
<tr>
<td>SR $\geq$ 0.8</td>
<td>Overcast</td>
<td>81%</td>
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<tr>
<td>0.3 $&lt;$ SR $&lt;$ 0.8</td>
<td>Intermediate</td>
<td>60%</td>
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<tr>
<td>SR $\leq$ 0.3</td>
<td>Clear</td>
<td>98%</td>
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</table>

Visual and thermal comfort feedback

1. Completely uncomfortable
2. Uncomfortable
3. Slightly uncomfortable
4. Comfortable
5. Very Comfortable
Conclusion

• To avoid discomfort glare electrochromic glazing can be used.

• Dividing the EC-window in different zones allows for an optimum control.

• Choosing the right states depending on the season and on sky condition, can reduce the heating and cooling load significantly.

• Machine learning techniques will be used in combination with user feedback when sky conditions are difficult to predict.
### EC glass states

<table>
<thead>
<tr>
<th>SageGlass Type</th>
<th>$%T_{\text{vis}}$</th>
<th>$%T_{\text{sol}}$</th>
<th>SHGC</th>
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<tbody>
<tr>
<td>Clear state</td>
<td>60</td>
<td>33</td>
<td>0.41</td>
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<tr>
<td>Intermediate state 2</td>
<td>18</td>
<td>7</td>
<td>0.15</td>
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<tr>
<td>Intermediate state 1</td>
<td>6</td>
<td>2</td>
<td>0.10</td>
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<tr>
<td>Fully Tinted</td>
<td>1</td>
<td>0.4</td>
<td>0.09</td>
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