Dynamic daylight simulations for façade optimization (and some other applications)

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Background

Daylight
Depends on exterior conditions

Proportion of Daylight blocked by building’s envelope
Depends on building’s geometry orientation and construction

Usable daylight
\[ U = T - B - G \]

Proportion of Daylighting that needs to be blocked to avoid glare
Depends on occupant’s behavior

Electrical lighting

Design Illuminance \( (E_d) \)
Relevant factors

**Considered**
- Climate
- Facade geometry
- Occupant’s response to glare
- Resulting illuminance on work plane

**Not considered**
- Furniture location
- Lighting control strategies
- Sensor placement
- Type of luminaire / type of blinds
- Diffusing window panes
- … etc.
Assessment of glare conditions
Assessment of glare conditions

Survey answers compared to calculated glare (% dissatisfied vs. glare index)

- % of discomfort answers compared to calculated glare index (DGI)
  - R² = 0.226702689199795
  - % discomfort > dgi.o @0
  - DGI

- % need close blinds compared to calculated glare index (DGI)
  - R² = 0.468877365143391
  - % blinds[glare] > dgi.o @0
  - DGI

- % of discomfort answers compared to calculated glare index (DGP)
  - R² = 0.538320640256362
  - % discomfort > dgp.s @0
  - DGP

- % need close blinds compared to calculated glare index (DGP)
  - R² = 0.890085608221169
  - % blinds[glare] > dgp.s @0
  - DGP
Assessment of glare conditions

Survey answers compared to calculated glare (% of answers for closing blinds)

BL - LOGVIL  |  AIC=85.06  coeff=-10.9276  2.9246

Log_{10} (Vertical Illuminance)

% of answers to close blinds
Optimization by a *simple* genetic algorithm

1. Obtain a new generation (10 individuals)
2. Produce new individuals by mutation, crossover, etc.
3. Generate Radiance geometry
4. Calculate the Fitness of each
5. Select best 10

Character encoding

Dynamic simulation
Model definition

1-window width
2-sill height
3-window height
4-ext lightshelf depth
5-int lightshelf depth
6-lightshelf height
7-overhang depth
8-low sunshade depth
9-high sunshade depth
10-Nr. Shades / window
11-Nr. Windows
12-window sill depth
13-wall reflectance
14-ext lightshelf reflec.
15-int lightshelf reflec.
16-window sill reflec.
17-sunshade reflectance
18-window size factor
19-shading size factor
20-window transmission
21-reflective Lightshelf (Y/N)
1 Determine sky conditions from weather data

2 Calculate discomfort of users from glare probability index

3 Determine the position of blinds (open - closed) proportionally to discomfort

4 Calculate daylight illuminance on work plane considering the position of blinds \( 0 \leq U_{ho} \leq E_d \)

5 Calculate Fitness with data from all hours

\[
F = \frac{U_a}{500lx} = \frac{\sum_{h}^{H} \sum_{o}^{O} U_{ho}}{H \cdot O \cdot 500lx}
\]
Sky contribution (Tregenza model)

rtcontrib with sky subdivisions adapted for vertical openings
“Real” time step calculation

0 Determine contributions with blinds open and closed  
   (vertical at eye level and horizontal on work plane for each observer)

1 Calculate vertical illuminance at eye level for each observer  
   => calculate discomfort glare and closing probability

2 Determine which set of contributions to use for illuminance  
   calculations => calculate average illuminance on work plane

3 Add average illuminance to annual total

4 Calculate Fitness with data from all hours
Typical evolution

[Graph showing typical evolution with generations and fitness levels]

- Average Fitness all individuals
- Average Fitness best seven individuals
- Fitness Best individual
Typical evolution

F:0.652252500118461
G - 000

F:0.682540308855077
G - 040

F:0.706570714292173
G - 080

F:0.730509884568645
G - 120

F:0.746261257140445
G - 160

F:0.757922512202524
G - 200

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Genetic algorithm and other optimization methods

Advantages:
- Can consider the simultaneous variation of several parameters
- Increase the relevance of the cases studied
- Complements parametric studies

Disadvantages:
- Requires large number of simulations
- Different cases may require different optimization methods

Possible improvements:
- Larger population size
- Statistical analysis of climate data to improve the significance of the days that are simulated
- Selective fitness:
  - define separate fitness for different times of the year (e.g. summer / winter) and increase the probability of breeding between complementary individuals
- Extend the model to include other factors (e.g. thermal performance)
Translucent materials in a museum environment - Background
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Translucent materials in a museum environment
Approximation of parameters for “trans” material
Approximation of parameters for “trans” material
Translucent materials in a museum environment
Translucent materials in a museum environment

Sample 2: SEPAR AR 24-50
Sample 3: Baminol "Blanc Venus" Ref 04011
Sample 4: Cérclage Lucell 0588a

Sample 5: Fugati Fugalux - opac
Sample 6: Fugati Fugalite (opac) 730 multi
Sample 7: SEPAR AS 02-70 P