Natural Light in Design
Using simulation tools to explore realistic daylight-responsive solutions

Dynamic Daylight Performance Metrics
Christoph Reinhart, Ph.D.
## Overview – Dynamic Daylight Performance Metrics

**Tuesday, Jan 24* 2006**

<table>
<thead>
<tr>
<th>Time Slot</th>
<th>Content</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon 9:30</td>
<td>Welcome, class introduction, design project (teams formed next morning)</td>
<td>MA, all</td>
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<tr>
<td>Mon 10:00</td>
<td>- General introduction to daylighting (benefits, history, some case studies)</td>
<td>MA</td>
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<tr>
<td>Mon 10:30</td>
<td>- Introduction to Building Simulation (why simulations for architects, tools used in this course)</td>
<td>CR</td>
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<td>Mon 11:00</td>
<td>coffee break</td>
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<tr>
<td>Mon 11:15</td>
<td>- Photometry (definition, measurement, typical values, DF definition (MA)</td>
<td>MA, CR, all</td>
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<td>- Static Daylighting Metrics (context of LEED, selected results from NRC survey, DF &amp; Solar Shading) (CR)</td>
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<td>- Daylight factor calculations: protractor method, LEED spreadsheet method, sky models CIE and Perez (MA)</td>
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<td>- Daylight factor simulation: design sky, split flux method in Ecotect (CR)</td>
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<td>▪ Hands-on exercise: DF calculation in Ecotect (split flux) (CR)</td>
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<td>▪ Hands-on exercise: solar shading module in Ecotect (CR)</td>
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<td>- Intro to Radiance (CR)</td>
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<td>▪ Hands-on exercise: Radiance visualizations (CR)</td>
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<td>▪ Hands-on exercise: DF calculation in Ecotect (Radiance) (CR)</td>
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<td>Mon 13:00</td>
<td>lunch (on your own)</td>
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<td>Mon 14:00</td>
<td>- Climate Data (kind of data and measurement, weather files, E+ weather data directory) (MA)</td>
<td>MA, CR, all</td>
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<td>▪ Hands-on exercise: weather tool in Ecotect (CR)</td>
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<td>▪ Overview on visual comfort (glare, contrast, requirements, health) (MA)</td>
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<td>- Dynamic Metrics &amp; related tools (CR)</td>
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<td>Mon 15:45</td>
<td>coffee break</td>
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<td>Mon 16:00</td>
<td>▪ Hands-on exercise: Daysim exercise from tutorial interrupted by discussions on:</td>
<td>all</td>
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<td>- Short time steps dynamics</td>
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<td>- Daylight Coefficients</td>
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<td>- User Behavior Model</td>
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<td>- Daylight Autonomy Results</td>
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<td>Mon 17:00</td>
<td>▪ Hands-on exercise: students to repeat at DF, Solar Shading &amp; DA analysis on their own</td>
<td>all</td>
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<td>Mon 17:30</td>
<td>end of first day</td>
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Daylight Factor Use in Design

- Argument:
  - overcast sky as a worst case scenario
  - venetian blinds (even if closed) still admit sufficient DL

- view to the outside
Could it be better?
What about:

- local climate data (Vancouver vs. Regina)
- building use (occupancy patterns, lighting requirements)
- movable shading devices (venetian blinds)
Dynamic Daylight Simulations (DDS)

- As opposed to static DL simulations that only consider one sky condition at a time, dynamic daylight simulations generate annual time series of interior illuminances and/or luminances.
Daylight Performance Metrics

- DDS result in thousands of data points for each sensor.

- The task at hand is to reduce the data without diminishing its value for building design.

- Points for discussion:
  - time base (daylit hours vs. occupied hours)
  - lighting requirements (UDI, daylight autonomy, annual light exposure,…)
  - movable shading devices
Time Base

- Daylit Hours of the year:
  - building form directly related to building site

- Occupied hours of the year:
  - daylight needs “witnesses”
  - sensitive to building use
  - self scaling: spans the whole range from 0% to 100%
  - occupancy profiles for different building zones available from ASHARE etc.

Current trend towards occupied hours of the year.
Lighting Requirements I

- **Daylight Autonomy (DA):** percentage of working hours when a minimum work plane illuminance is maintained by daylight alone.

- **Useful Daylight Illuminances (UDI):** divides working hours into three bins:
  - % < 100lux (insufficient daylight)
  - % between 100lx and 2000x (useful daylight)
  - % > 2000 lux (too much DL => visual/thermal discomfort)

- **CHPS criteria:**
  - continuous DA >40% 1 credit
  - continuous DA >60% 2 credits
  - continuous DA >80% 3 credits

  for 60% of work plane and DA_{max}<1%
Lighting Requirements II

- Annual Light Exposure: established upper threshold for artwork – already established used used for museums (CIE TC3-22 ‘Museum lighting and protection against radiation damage’)
Lighting Requirements III

- Light and Health: possible future lighting recommendations for building occupants (light intensity and spectrum)
Movable Shading Devices

Venetian blinds should be treated as the reference case.

Venetian blinds are arguably more suitable than light shelves in predominantly cloudy climates.

USER BEHAVIOUR ?!

- blinds always up
- blinds always down, slats at 45°
- blinds always fully closed
Monitoring User Behavior

Lighting Research & Technology
Reinhart, Voss 2003
Monitoring Blind Usage

- video surveillance camera
- receiver 2414.5 MHz
- Blind setting
- EIB system
- data acquisition
Monitoring Setup in the Offices

Illuminance
Temperature

HOBO data logger

occupancy
Switch-On Probability (I)

Jim Love, University of Calgary
User Behavior Model

Lightswitch 2002

- annual occupancy profiles
- annual illuminance profiles

Lightswitch Algorithm (stochastic)

el. lighting/blinds profile

Solar Energy
Reinhart, 2004
DDS Programs

- ADELİNE (http://www.ibp.fhg.de/wt/adeline/)
- Daysim (www.daysim.com)
- ESP-r (http://www.esru.strath.ac.uk/Programs/ESP-r.htm)
- Lightswitch Wizard (www.buildwiz.com)
- SPOT (http://www.archenergy.com/SPOT/)