capturing non-visual (circadian) light through HDR photography

Radiance Workshop . Portland . 2017
University of Washington . Department of Architecture
Bo Jung . Mehlika Inanici
byj20 @ uw.edu
Outline

1. Background
   understanding non-visual (circadian) light

2. Methodology
   data collection
   post processing
   calibration
   melanopic units

3. Results

4. Discussion
   conclusions & future work
non-visual (circadian) light

\[ \text{Circa dies} \quad + \quad \text{Rhythm} \]

“About” “day”
non-visual (circadian) light
non-visual (circadian) light

Processing Optical Radiation

1. Visual system (photopic)
2. Non-Visual system (circadian)

non-visual (circadian) light
non-visual (circadian) light
non-visual (circadian) light

How is light affecting non-visual system?

photic history
  timing
  spectra
  intensity
  duration
Objective

What’s happening in the built environment?
Objective

circadian light measuring devices
Objective

HDR Photography

Photopic Light
- Calibrated with Luminance or Illuminance meters
- Photopic Luminance accuracy is evaluated and validated

Circadian Light
- What can be used to calibrate?
- The goal is to calibrate with an accessible / inexpensive device
Data collection

HDR Camera
EOS 5D | Sigma EX DG Fisheye8mm

Illuminance Color meter
Konica_Minolta_CL-200A

luminance meter
Konica_Minolta_LS-110
Data collection

full spectrum

CIE XYZ
Data collection - CCT* and Illuminance


collection period : 9 months
total no. data : 205
weather cond. : Seattle
Post Processing - calibration method 1

Vignetting + Cosine Correction

Illuminance Calibration (CIE Y)

Extract Pixel RGB value

dir-value -d -h -H -o image.hdr > data.txt

convert image RGB to XYZ

X = (0.4124 * R) + (0.3576 * G) + (0.1805 * B)
Y = (0.2127 * R) + (0.7151 * G) + (0.0722 * B)
Z = (0.0193 * R) + (0.1192 * G) + (0.9505 * B)

(sRGB) reference primaries

compare measured and captured XYZ values
Post Processing - calibration method 2

Vignetting + Cosine Correction

Illuminance Calibration (CIE Y)

Extract Pixel RGB value

```
pvalue -d -h -H -o image.hdr > data.txt
```

convert measured XYZ to RGB

\[
R = (3.2406 \times X) - (1.5372 \times Y) - (0.4986 \times Z) \\
G = -(0.9689 \times X) + (1.8758 \times Y) + (0.0415 \times Z) \\
B = (0.0557 \times X) - (0.2040 \times Y) + (1.0570 \times Z)
\]

(sRGB) reference primaries

compare measured and captured RGB values
Calibration

Regression line equation

original img data

\[
\begin{align*}
R &= 0.8743 \times R \\
R^2 &= 0.99721 \\
G &= 1.0022 \times R \\
R^2 &= 0.99995 \\
B &= 1.3308 \times R \\
R^2 &= 0.99922
\end{align*}
\]

calibrated img data

\[
\begin{align*}
R &= 1 \times R \\
R_{cal} &= 1.1438 \times R \\
G &= 1 \times G \\
G_{cal} &= 0.9978 \times G \\
B &= 1 \times B \\
B_{cal} &= 0.7514 \times B
\end{align*}
\]
Melanopic Units

Radiance  Photopic luminance  = 179 * ((0.2651 * R) + (0.6700 * G) + (0.0650 * B))
Melanopic Units

\[
\begin{align*}
\text{Radiance} & \quad \text{Photopic luminance} = 179 \times ((0.2651 \times R) + (0.6700 \times G) + (0.0650 \times B)) \\
\text{sRGB} & \quad \text{Photopic luminance} = 179 \times ((0.2127 \times R) + (0.7151 \times G) + (0.0722 \times B))
\end{align*}
\]
Melanopic Units

Radiance  
Melanopic luminance  
= 179 * ((0.0130 * R) + (0.3812 * G) + (0.6175 * B))
Melanopic Units

Radiance
Melanopic luminance = 179 * ((0.0130 * R) + (0.3812 * G) + (0.6175 * B))

sRGB
Melanopic luminance = 179 * ((0.0180 * R) + (0.4024 * G) + (0.5950 * B))
Melanopic Units

photopic
179 * ((0.2127 * R) + (0.7151 * G) + (0.0722 * B))

melanopic
179 * ((0.0180 * R) + (0.4024 * G) + (0.5950 * B))
Melanopic Units

226 photopic lux (D65)
250 Equivalent Melanopic Lux

@ 75% or more workstations on vertical plane with at least 4 hour exposure daily on annual basis

Image: WELL Building Standard
architectural context

1 5 14 36 109 326 973 3000 cd/m²
weather

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Photopic</th>
<th>Circadian</th>
<th>CCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>APR 15</td>
<td>1:31 pm</td>
<td>2615 lx</td>
<td>2822 lx</td>
<td>7423 K</td>
</tr>
<tr>
<td>APR 15</td>
<td>4:32 pm</td>
<td>1766 lx</td>
<td>2029 lx</td>
<td>9162 K</td>
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<tr>
<td>MAY 4</td>
<td>1:22 pm</td>
<td>2498 lx</td>
<td>2727 lx</td>
<td>7159 K</td>
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<tr>
<td>MAY 4</td>
<td>4:29 pm</td>
<td>158 lx</td>
<td>151 lx</td>
<td>5979 K</td>
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</table>
Building depth

<table>
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<tr>
<th>Time</th>
<th>Photopic</th>
<th>Circadian</th>
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<tbody>
<tr>
<td>Aug 13 1:27 pm</td>
<td>2753 lx</td>
<td>2582 lx</td>
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<tr>
<td>CCT</td>
<td>5793 K</td>
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<tr>
<td>Aug 13 1:34 pm</td>
<td>932 lx</td>
<td>849 lx</td>
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<tr>
<td>CCT</td>
<td>5579 K</td>
<td></td>
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<tr>
<td>Aug 13 1:37 pm</td>
<td>483 lx</td>
<td>440 lx</td>
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<tr>
<td>CCT</td>
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<tr>
<td>Aug 13 1:43 pm</td>
<td>77 lx</td>
<td>65 lx</td>
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<td>CCT</td>
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night exposure

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<tbody>
<tr>
<td>3628 K</td>
<td>94 lx</td>
<td>60 lx</td>
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<tr>
<td>3142 K</td>
<td>315 lx</td>
<td>171 lx</td>
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<tr>
<td>11301 K</td>
<td>113 lx</td>
<td>150 lx</td>
</tr>
<tr>
<td>2859 K</td>
<td>61 lx</td>
<td>30 lx</td>
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example day

<table>
<thead>
<tr>
<th>Time</th>
<th>8:00</th>
<th>9:00</th>
<th>10:00</th>
<th>11:00</th>
<th>12:00</th>
<th>13:00</th>
<th>14:00</th>
<th>15:00</th>
<th>16:00</th>
<th>17:00</th>
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<tbody>
<tr>
<td>Temp</td>
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<td>5367 K</td>
<td>5361 K</td>
<td>5634 K</td>
<td>5467 K</td>
<td>5807 K</td>
<td>4038 K</td>
<td>3835 K</td>
<td>3746 K</td>
<td>6584 K</td>
<td>4854 K</td>
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<tr>
<td>1 cd/m²</td>
<td>77</td>
<td>3393</td>
<td>6215</td>
<td>5651</td>
<td>3884</td>
<td>8103</td>
<td>426</td>
<td>359</td>
<td>309</td>
<td>319</td>
<td>58</td>
</tr>
<tr>
<td>67</td>
<td>3050</td>
<td>5622</td>
<td>5356</td>
<td>3629</td>
<td>7634</td>
<td>327</td>
<td>255</td>
<td>212</td>
<td>327</td>
<td>46</td>
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### example day

<table>
<thead>
<tr>
<th>Time</th>
<th>Temperature</th>
<th>Light Intensity</th>
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<tbody>
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<td>8:00</td>
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<td>7677</td>
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<td>9:00</td>
<td>3157 K</td>
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<tr>
<td>10:00</td>
<td>3233</td>
<td>111</td>
</tr>
<tr>
<td>11:00</td>
<td>3157 K</td>
<td>135</td>
</tr>
<tr>
<td>12:00</td>
<td>3157 K</td>
<td>135</td>
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<tr>
<td>13:00</td>
<td>5807 K</td>
<td>8103</td>
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<tr>
<td>14:00</td>
<td>3275</td>
<td>12</td>
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<td>15:00</td>
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<td>16:00</td>
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<td>12</td>
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<tr>
<td>17:00</td>
<td>3275</td>
<td>12</td>
</tr>
<tr>
<td>18:00</td>
<td>4854 K</td>
<td>58</td>
</tr>
</tbody>
</table>

*FEB 25*

**Light Intensity Scale:**
- 1 cd/m²
- 5 cd/m²
- 14 cd/m²
- 36 cd/m²
- 109 cd/m²
- 326 cd/m²
- 973 cd/m²
- 3000 cd/m²
CCT, photopic and melanopic illuminance

- Photopic > Melanopic
- Photopic < Melanopic
conclusions & future work

conclusions
- demonstrate utilisation of HDR
- provides rich data for the design and guidelines development of circadian friendly settings

Future Work
- further accuracy testing will be done with spectrophotometer
- further studies needed to test colour calibration in other cameras
- more biological studies are required to develop time and duration guidelines
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