Exposure and Tone Mapping

Topics

Perception of light intensities
Camera exposure
Exposure correction - ‘levels and curves’
Creating a high dynamic range (HDR) image
Displays and gamma
HDR and tone reproduction
Perception

Real World = High Dynamic Range

The relative radiance values of the marked pixels, clockwise from lower left: 1.0, 46.2, 1907.1, 15116.0, and 18.0.
Perception of Intensities

1. Sensation (S) vs. Intensity (I)
   Steven’s Law \( S = I^p \)

<table>
<thead>
<tr>
<th>Sense</th>
<th>Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brightness</td>
<td>0.33</td>
</tr>
<tr>
<td>Smell</td>
<td>0.55</td>
</tr>
<tr>
<td>Loudness</td>
<td>0.60</td>
</tr>
<tr>
<td>Taste</td>
<td>0.80</td>
</tr>
<tr>
<td>Length</td>
<td>1.00</td>
</tr>
<tr>
<td>Heaviness</td>
<td>1.45</td>
</tr>
</tbody>
</table>

\[ B = I^{1/3} \]

2. Just-noticeable difference (JND)
   Weber’s Law

\[ JND = \frac{\Delta I}{I} \approx 0.01 \]
Contrast

Contrast: Max:Min

1. World:
   - Possible: 100,000,000,000:1
   - Typical: 100,000:1

2. People: 100:1

3. Media:
   - Printed page: 10:1
   - Displays: 80:1 (400:1)
   - Typical viewing conditions: 5:1

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Exposure
Relative Aperture or F-Stop

F-Number and exposure:

\[ E = L \Omega = L \pi \left( \frac{r}{f} \right)^2 = L \frac{\pi}{4} \frac{1}{N^2} \]

F-stops: 1.4 2 2.8 4.0 5.6 8 11 16 22 32 45 64

1 stop doubles exposure

Camera Exposure

\[ H = E \times T \]

Exposure overdetermined

- **Aperture:** f-stop - 1 stop doubles H
  - Decreases depth of field
- **Shutter:** Doubling the open time doubles H
  - Increases motion blur
Aperture vs Shutter

From London and Upton

f/16  
1/8s

f/4   
1/125s

f/2   
1/500s

Measured Response Curve
Correcting Exposure

Rancho de Taos, Taos, NM
Pat Hanrahan

Demonstration

Creating High Dynamic Range Images
Multiple Exposures

Sixteen photographs of the Stanford Memorial Church taken at 1-stop increments from 30s to 1/1000s.

From Debevec and Malik, High dynamic range photographs.

Algorithm

1. Estimate exposure for each image

\[ \log E_i = R(V_i) - \log T_i \]

2. Merge results

\[ \log E = \frac{\sum w(V_i) \log E_i}{\sum w(V_i)} \]
Single Floating Point HDR Image

Displays and Gamma
Gamma

\[ I = g \cdot (V - V_b)^\gamma \]

Monitor: \( \gamma = 2.5 \)

Estimating Gamma

Demonstration
Monitor + Perception = Linear

Amazing coincidence!

Perceptual vs. Intensity Space

Perceptual Space
  + good distribution of values
    ■ more perceivable intensities and saturated colors
  + optimal compression
    ■ bits used more effectively
    ■ less sensitivity to noise

Intensity Space
  - bad distribution of values
    ■ fewer perceivable intensities and colors
  + Easier to simulate physical effects
    ■ blending, dithering, antialiasing, lighting, ...
HDR and Tone Reproduction

Tone Mapping Techniques

1. Linear map (min -> 0, max -> 255)

2. Remap through the response/gamma curve
   Demonstrate openexr plugin for Photoshop

3. Log L
   1. \( L = L / \text{Lave} \) (Lave = average value)
   2. \( C = L / (1 + L) \)

4. Fancy techniques!
   See Chapter 22, Shirley
Tone Reproduction Algorithms

Linear map  
Logarithmic map

Adaptive histogram  
With glare, contrast, blur
World's First High Dynamic Range Display - DR37-P

BrightSide introduces the DR37-P, a spectacular breakthrough in display technology. The DR37-P uses an array of individually modulated LED backlights to provide 10 times the brightness and 100 times the contrast of existing televisions and computer monitors. BrightSide's Extreme Dynamic Range display delivers more vibrant images and allows you to see your data in vivid detail.

- Extreme Dynamic Range
- Over 3000 cd/m² Brightness
- 0.001 cd/m² 2 Black Level
- Contrast Ratio > 200,000:1
- High Definition 1920x1080
- 37” Screen
- 16 bits per color
- IML ED - Individually Modulated Array of LED backlights

Brightside Display Technology

HDR Image  LED array  LCD with correction  Output image