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

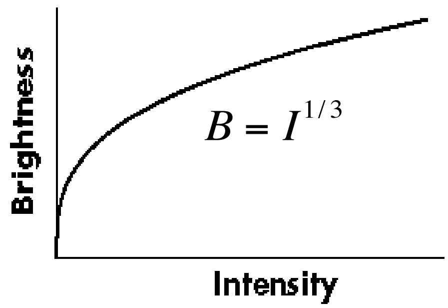
The relative radiance values of the marked pixels, clockwise from lower left: 1.0, 46.2, 1907.1, 15116.0, and 18.0.

Perception of Intensities

1. Sensation (S) vs. Intensity (I)

Steven's Law $S = I^p$

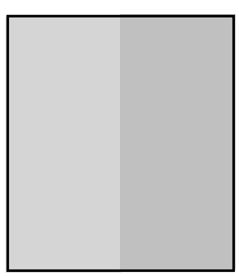
Sense	Exponent
Brightness	0.33
Smell	0.55
Loudness	0.60
Taste	0.80
Length	1.00
Heaviness	1.45



Perception of Intensities

2. Just-noticeable difference (JND)

Weber's Law



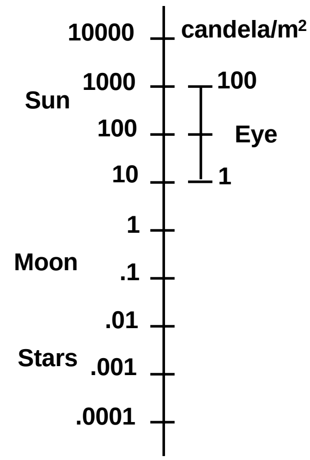
10%

$$JND = \frac{\Delta I}{I} \approx 0.01$$

Contrast

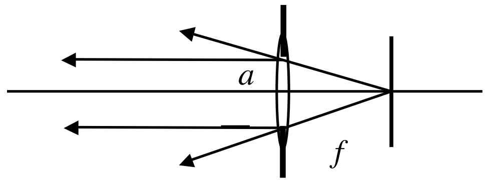
Contrast: Max:Min

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**



Exposure

Relative Aperture or F-Stop



$$a = \frac{f}{N}$$

F-Number and exposure:

$$E = L\Omega = L\pi(\frac{r}{f})^2 = L\frac{\pi}{4}\frac{1}{N^2}$$

Fstops: 1.4 2 2.8 4.0 5.6 8 11 16 22 32 45 64

1 stop doubles exposure

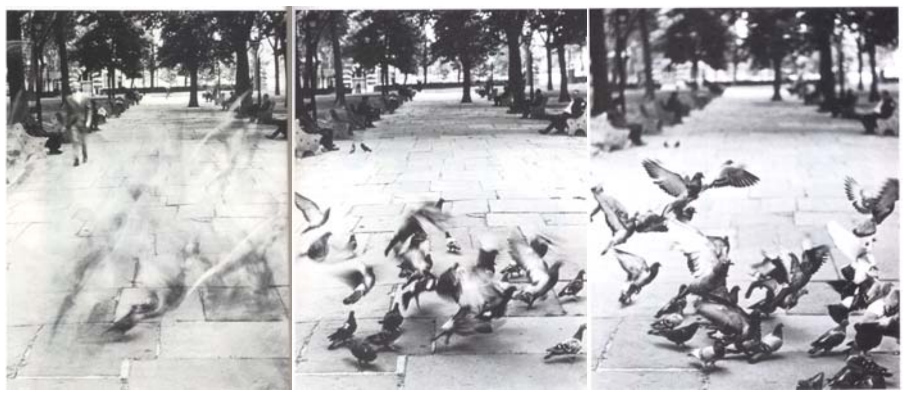
Camera Exposure

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



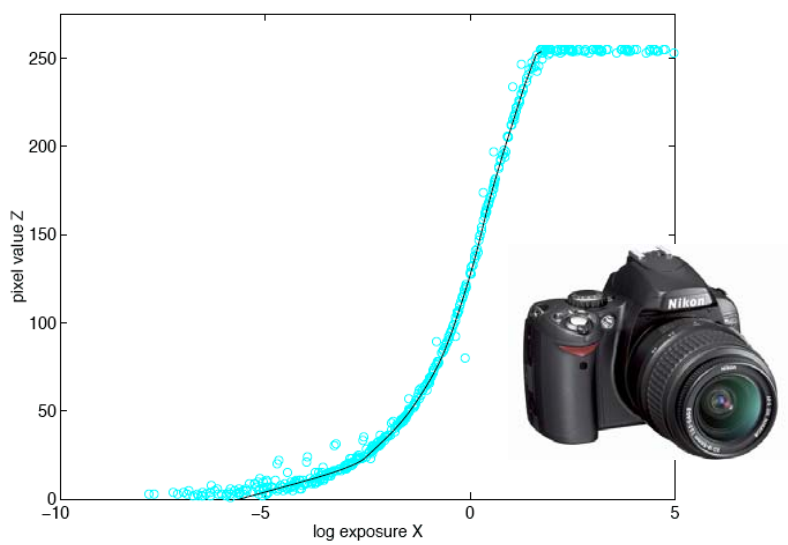
f/16
1/8s

f/4
1/125s

f/2
1/500s

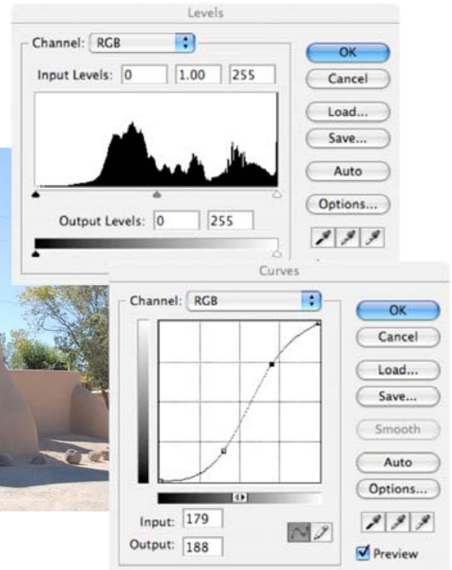
From London and Upton

Measured Response Curve



Correcting Exposure

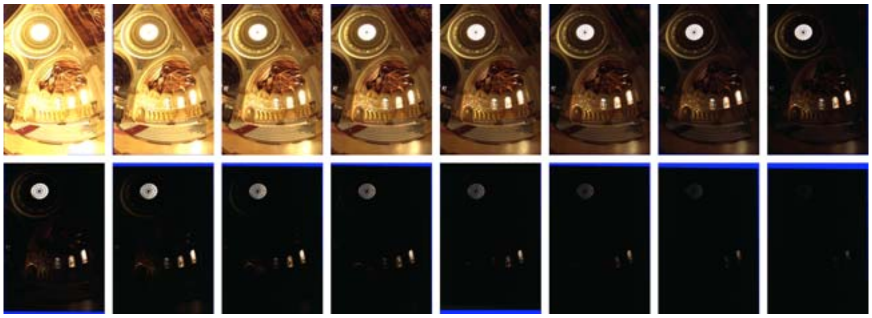
Rancho de Taos, Taos, NM
Pat Hanrahan



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**

$$\log E_i = R(V_i) - \log T_i$$

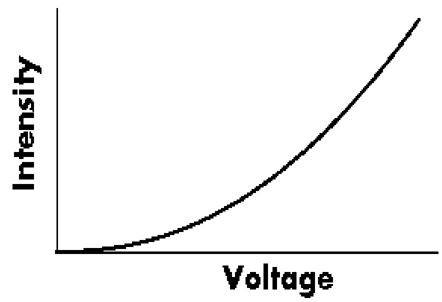
2. **Merge results**

$$\log E = \frac{\sum w(V_i) \log E_i}{\sum w(V_i)}$$

Single Floating Point HDR Image

Displays and Gamma

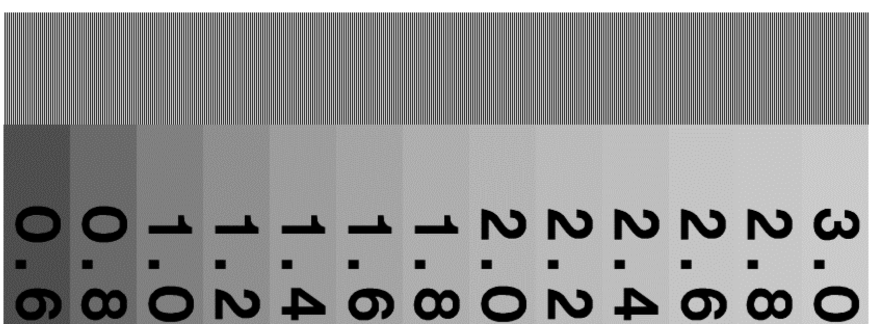
Gamma



$$I = g \cdot (V - V_b)^{\gamma}$$

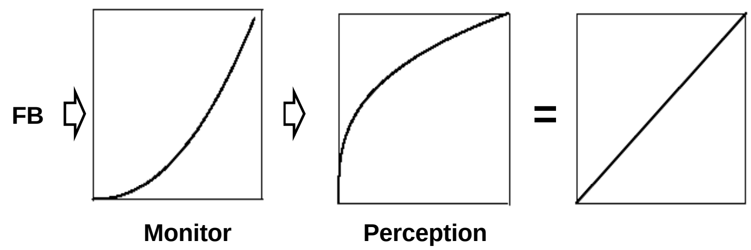
Monitor: γ=2.5

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

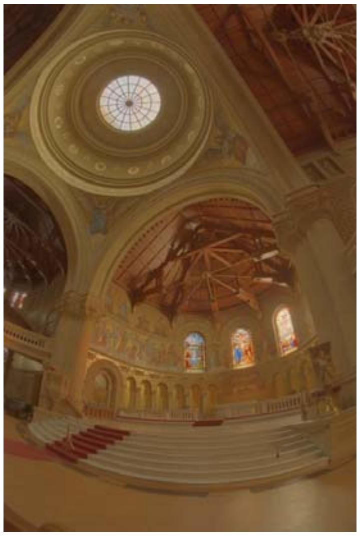
1. Linear map (min -> 0, max -> 255)

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

3. Log L
   1. L = L/Lave (Lave = average value)
   2. C = L / (1 + L)

4. Fancy techniques!
   See Chapter 22, Shirley

Tone Reproduction Algorithms



Linear map

Logarithmic map

Tone Reproduction Algorithms

Adaptive histogram

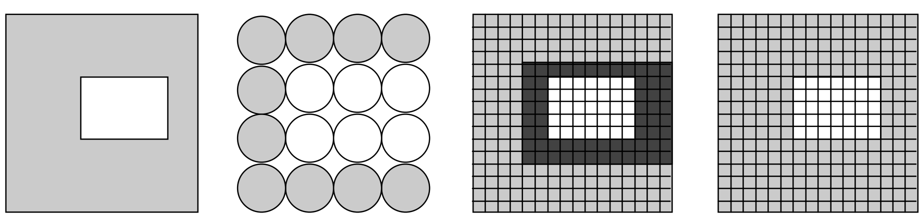
With glare, contrast, blur

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/m 2 Brightness
- 0.015 cd/m 2 Black Level
- Contrast Ratio > 200,000:1
- High Definition 1920x1080
- 37" Screen
- 16 bits per color
- IMLED – Individually Modulated Array of LED backlights

Brightside Display Technology



HDR Image | LED array | LCD with correction | Output image