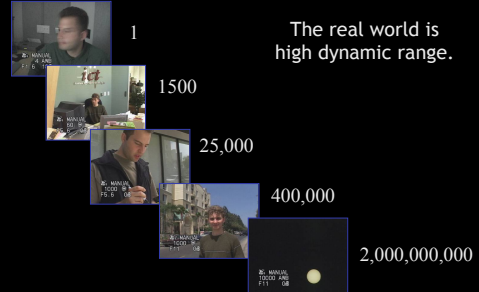


High Dynamic Range Imaging



COS 526, Fall 2014
With slides from Finkelstein, Debevec, Efros, Gunturk

Dynamic Range

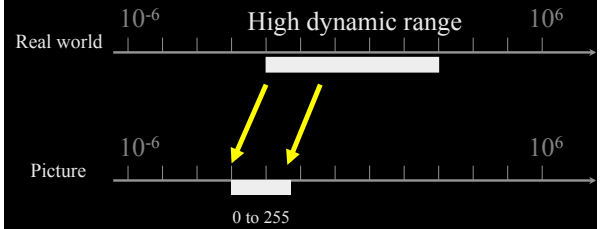


Problem

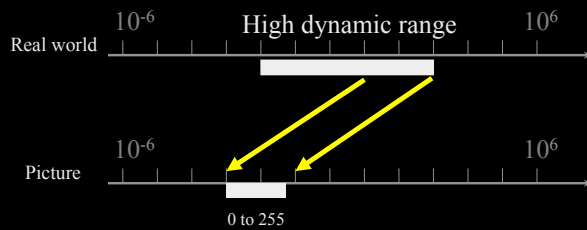
- Cameras cannot capture the full dynamic range of the world



Long Exposure



Short Exposure



Ways to Vary Exposure

- Shutter Speed (*)
- F/stop (aperture, iris)
- Neutral Density (ND) Filters



Varying Shutter Speed

Ranges: Canon D30: 30 to 1/4,000 sec.
Sony VX2000: 1/4 to 1/10,000 sec.

Pros:

- Directly varies the exposure
- Usually accurate and repeatable

Issues:

- Noise in long exposures

Varying Shutter Speed

- Note: shutter times usually obey a power series
 - 1/4, 1/8, 1/15, 1/30, 1/60, 1/125, 1/250, 1/500, 1/1000 sec
- Actually, each “stop” is usually a factor of 2:
 - 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512, 1/1024 sec

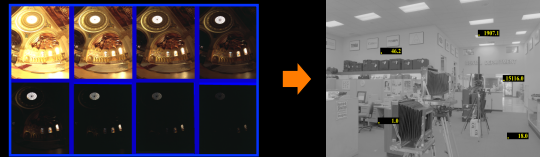


Varying Shutter Speed



High Dynamic Range Imaging

- Infer radiance of scene from multiple images with varying exposure (photometric calibration)

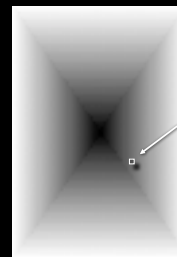


General Approach

- Build model of imaging system (radiance \rightarrow pixel values)
- Invert model (pixel values \rightarrow radiance)



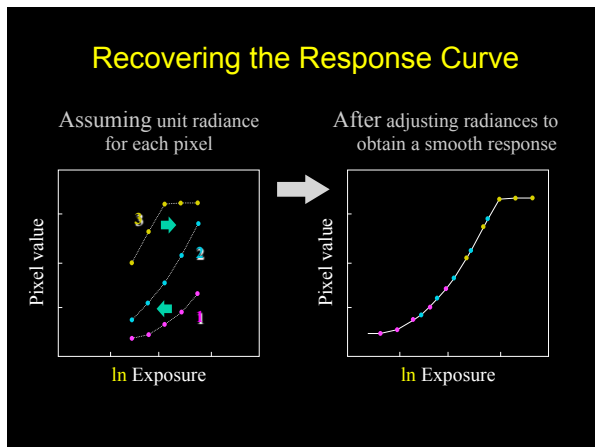
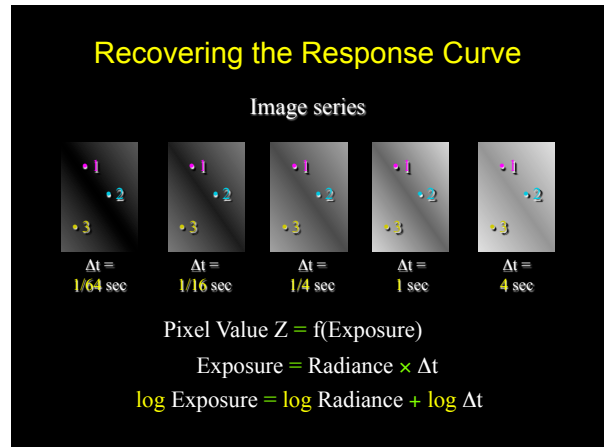
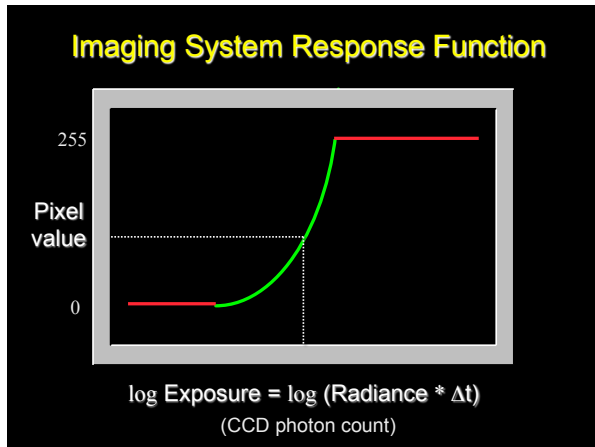
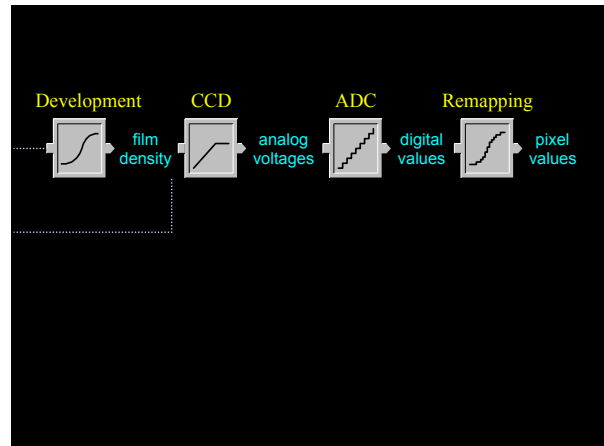
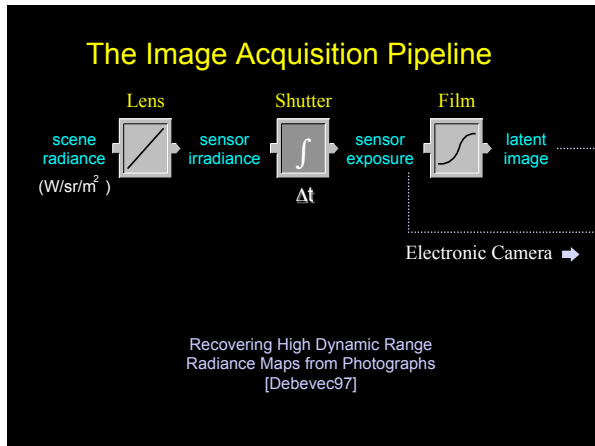
Imaging System?



pixel (312, 284) = 42

What does 42 mean?

Image



Recovering the Response Curve

- Let $g(z)$ be the *discrete* inverse response function
- For each pixel site i in each image j , want:

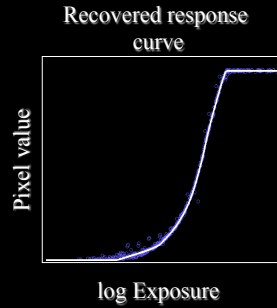
$$\ln \text{Radiance}_i + \ln \Delta t_j = g(Z_{ij})$$
- Solve the overdetermined linear system:

$$\sum_{j=1}^N \sum_{i=1}^P \left[\ln \text{Radiance}_i + \ln \Delta t_j - g(Z_{ij}) \right] + \lambda \sum_{z=Z_{\min}}^{Z_{\max}} g''(z)^2$$

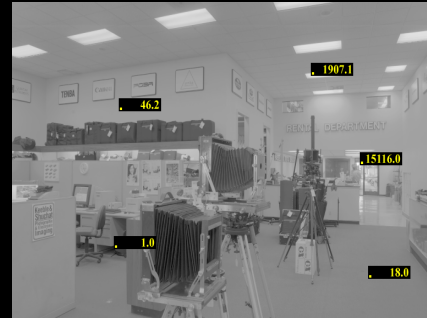
fitting term
smoothness term

Results: Digital Camera

Kodak DCS460
1/30 to 30 sec

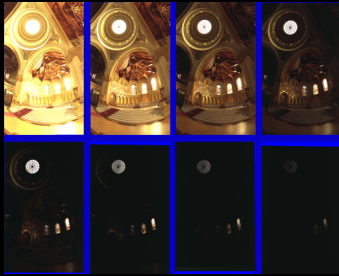


Reconstructed radiance map

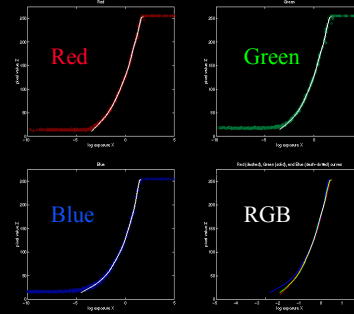


Results: Color Film

- Kodak Gold ASA 100, PhotoCD

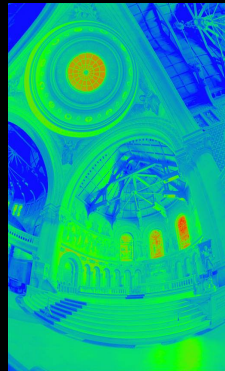


Recovered Response Curves



The Radiance Map

W/sr/m²
121.741
28.869
6.846
1.623
0.384
0.091
0.021
0.005



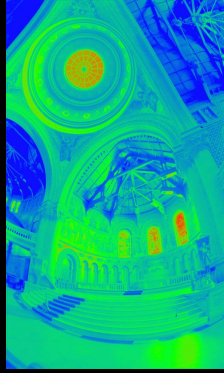
The Radiance Map



Linearly scaled to display device

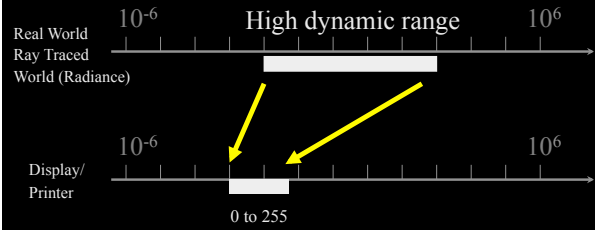
Now What?

W/sr/m²
 121.741
 28.869
 6.846
 1.623
 0.384
 0.091
 0.021
 0.005



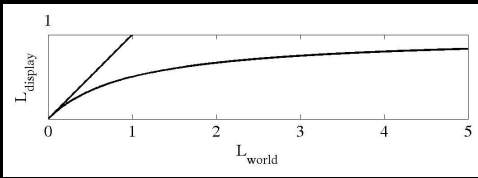
Tone Mapping

For displaying HDR images:



Reinhart et al

$$L_{display} = \frac{L_{world}}{1 + L_{world}}$$



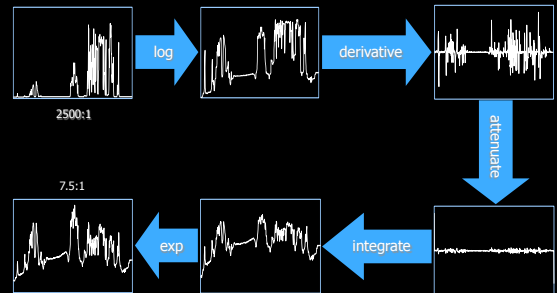
Reinhart et al Results



Reinhart Operator

Darkest 0.1% scaled to display device

Fattal et al (in 1D)



Informal comparison



Gradient-space
[Fattal et al.]

Bilateral
[Durand et al.]

Photographic
[Reinhard et al.]

Durand & Dorsey

Informal comparison



Gradient-space
[Fattal et al.]

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Informal comparison



Gradient-space
[Fattal et al.]

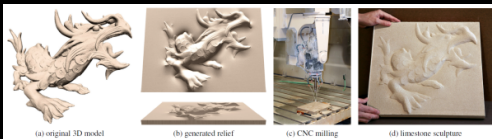
Bilateral
[Durand et al.]

Photographic
[Reinhard et al.]

HDR Tone Mapping Example



Similar idea: "tone mapping" for height fields:



Digital Bas-Relief from 3D Scenes
[SIGGRAPH 2007]

Tim Weyrich, Jia Deng, Connelly Barnes,
Szymon Rusinkiewicz, Adam Finkelstein