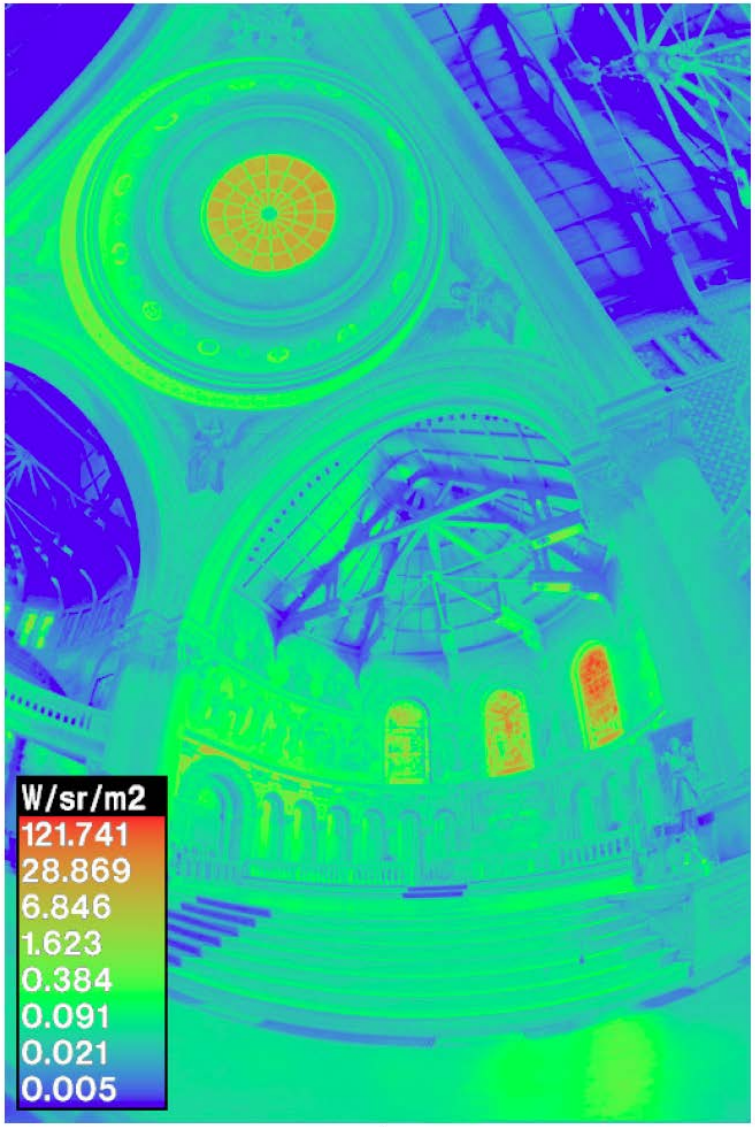
Tone Reproduction

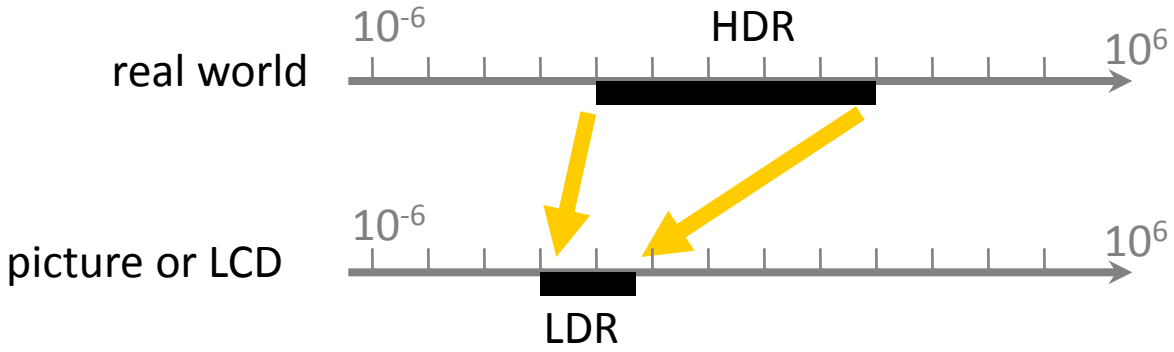
Reconstructed Radiance Map



How to Display a Radiance Map

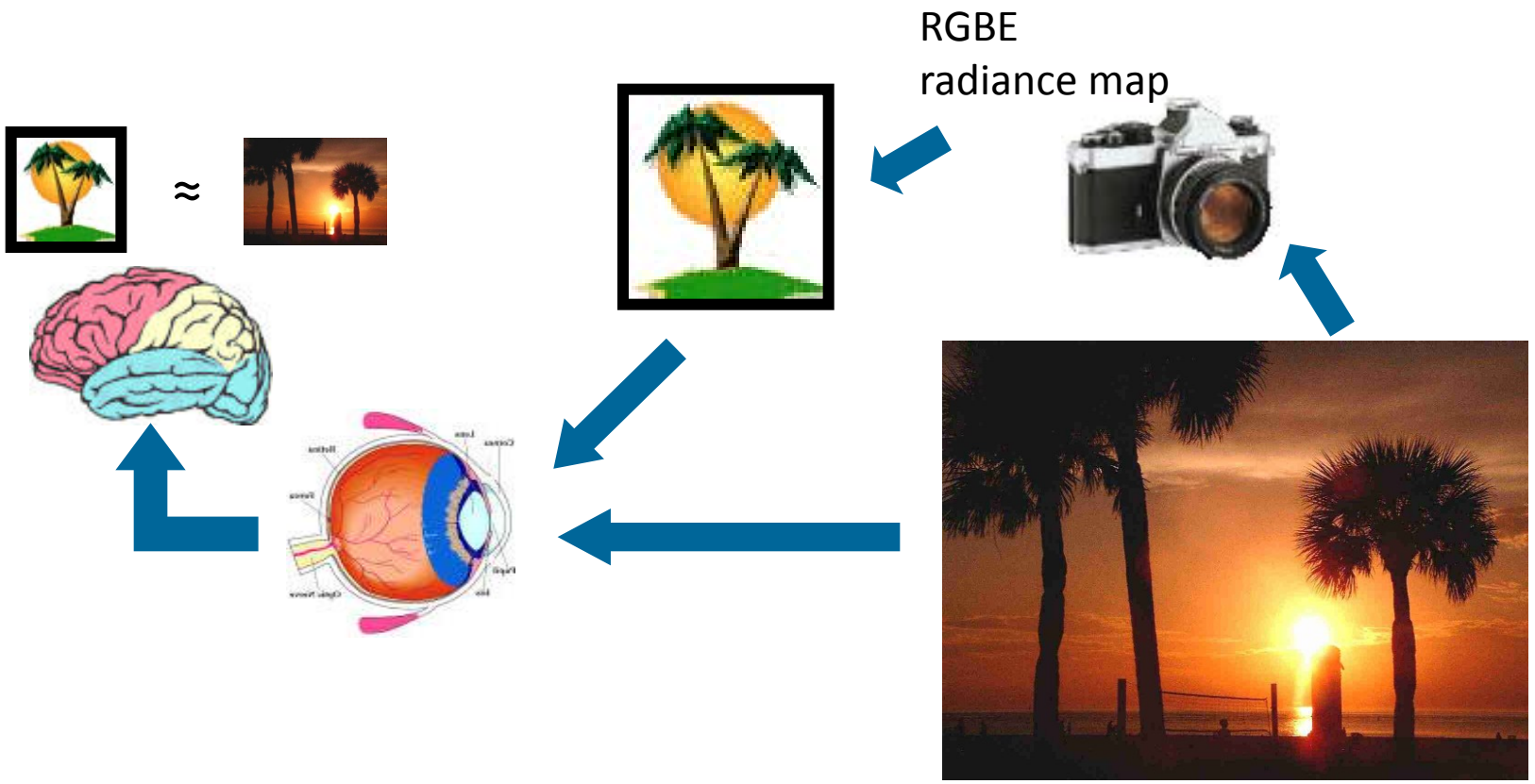
- Human eyes perceive higher dynamic ranges than those reproduced on LCD or photo paper

- Tone reproduction problem
  - How do we map perceived scene luminance to display luminance and produce a satisfactory image?



Tone Reproduction

- How to reproduce visual impression



A Simple Approach to Displaying HDR Images

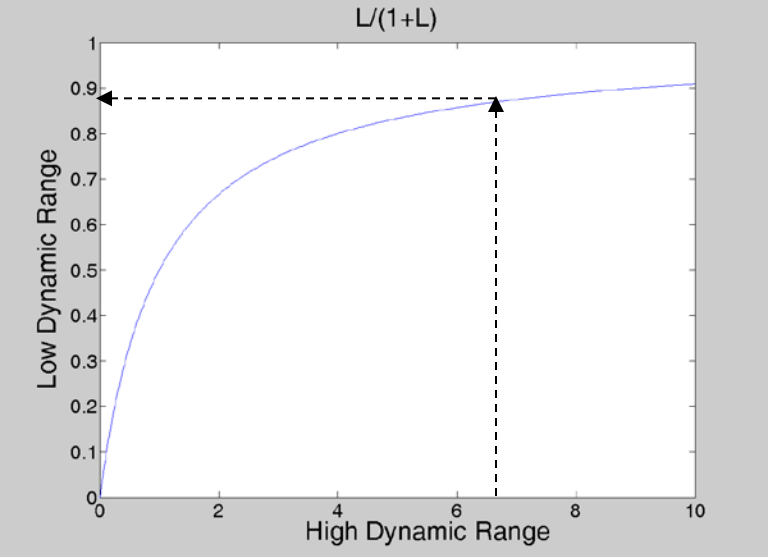
- Radiance map RGB → Luminance

$$L(x,y) = 0.2126\,R(x,y) + 0.7152\,G(x,y) + 0.0722\,B(x,y)$$

- *Global Tone Mapping*

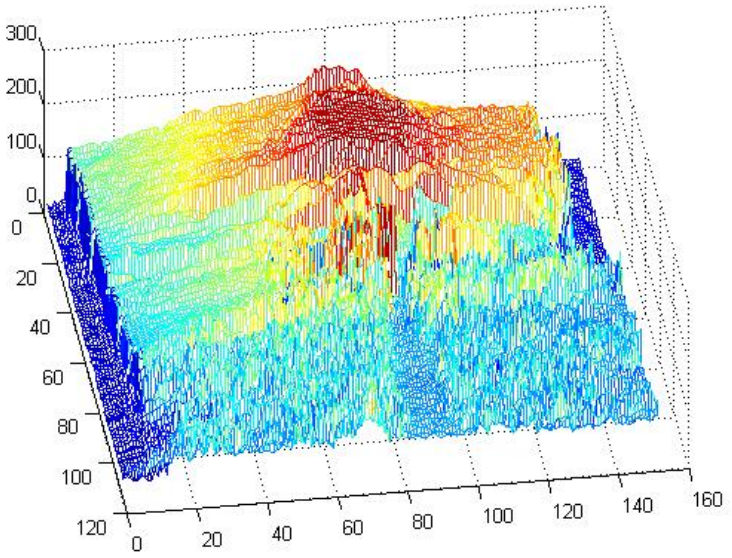
$$L' = \varphi(L) = L/(1+L)$$

$$\varphi(x) = \frac{x}{1+x}$$

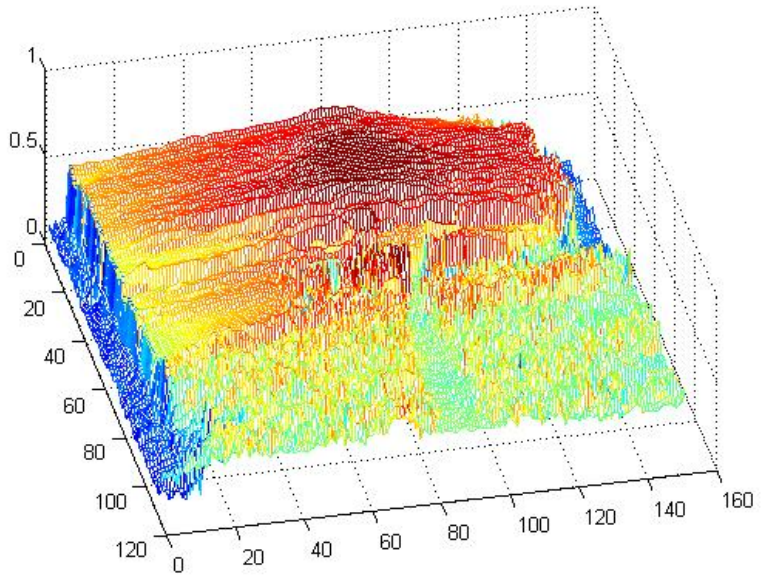


- Outputs range from 0 to 1
- Details in brighter area are lost

$$L' = \varphi(L) = L/(1+L)$$

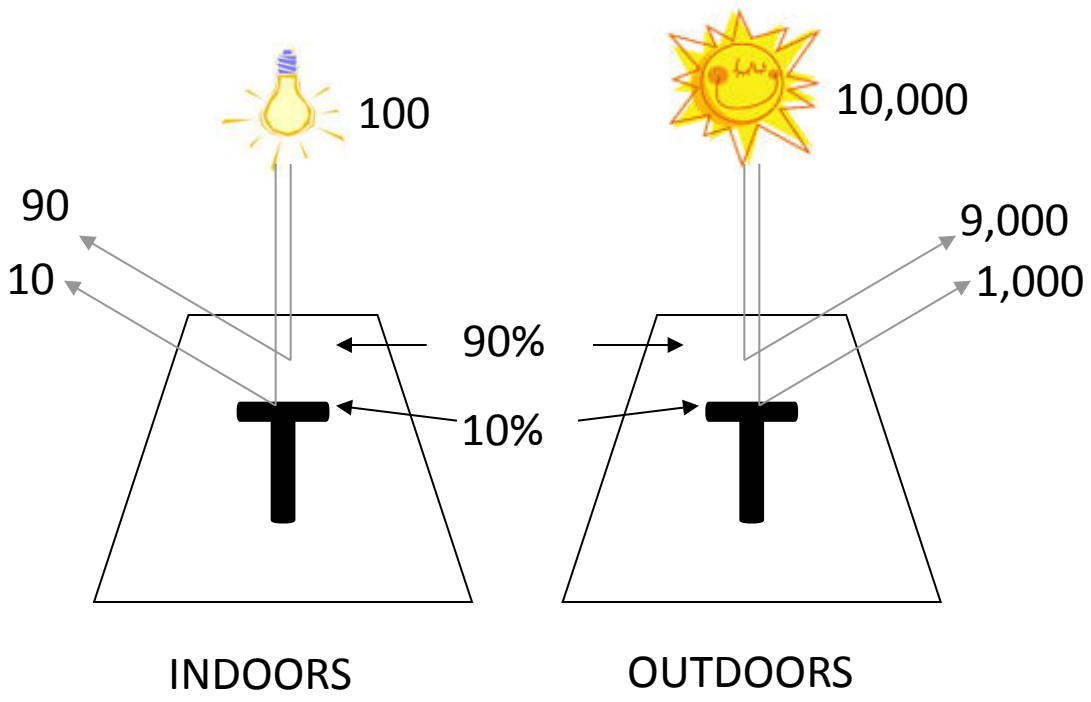


you might lose the details after applying direct compression



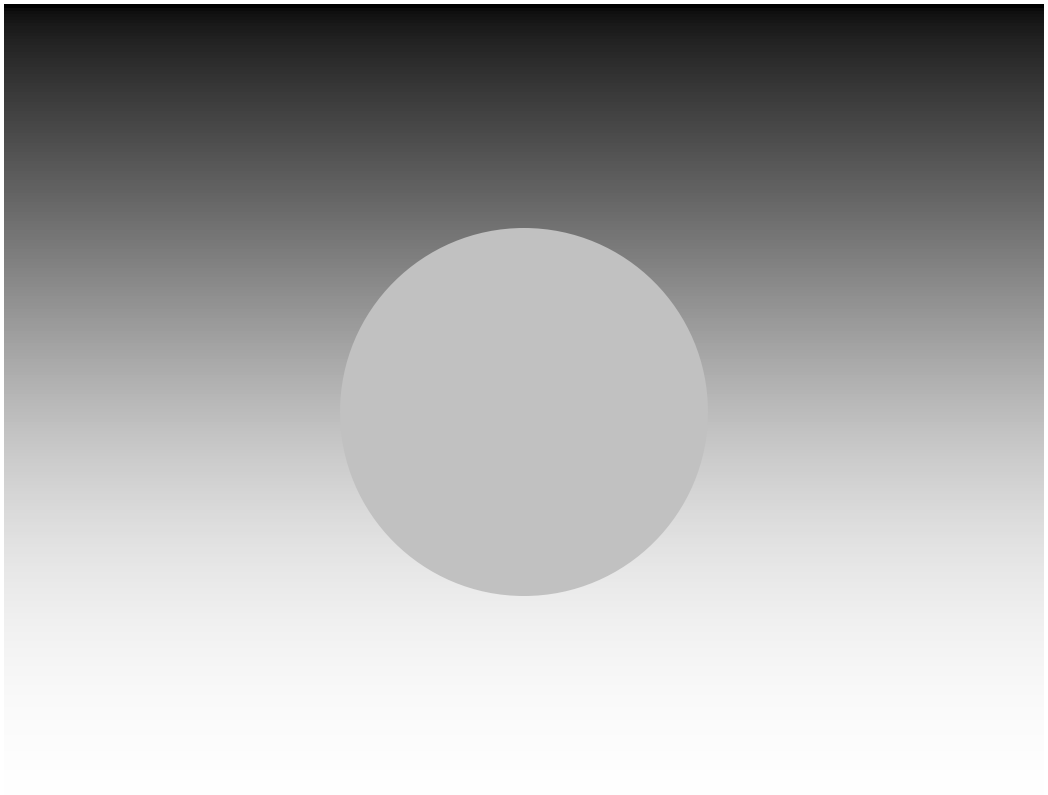
Lightness Constancy

- Illumination and reflectance



Local Adaptation Effect

- Change the shading of background

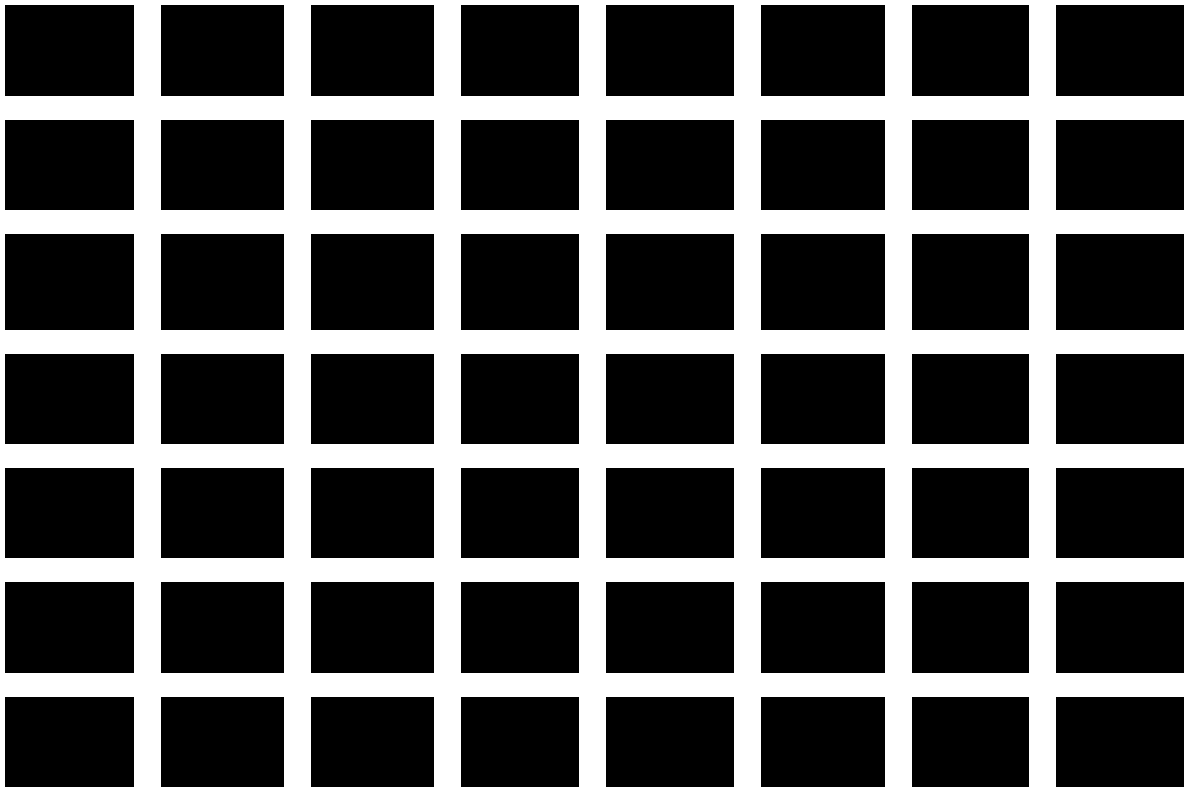


Local Adaptation Effect

- Lightness contrast

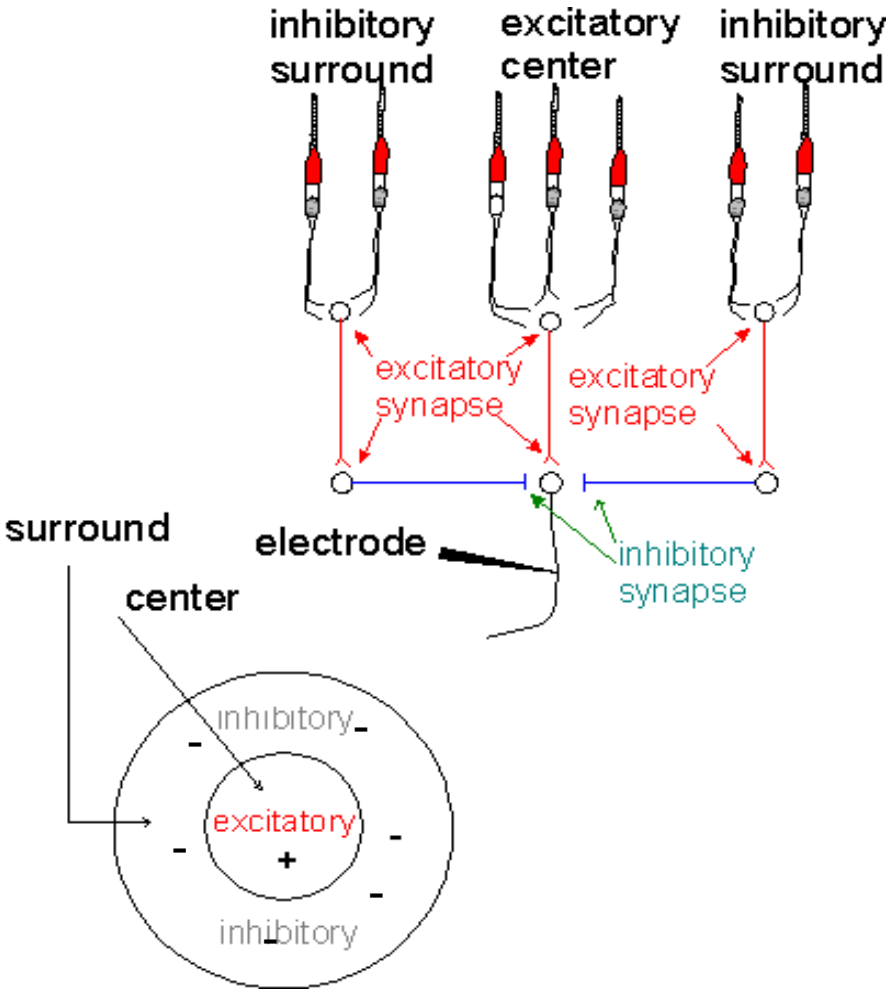
Center-Surround Mechanism

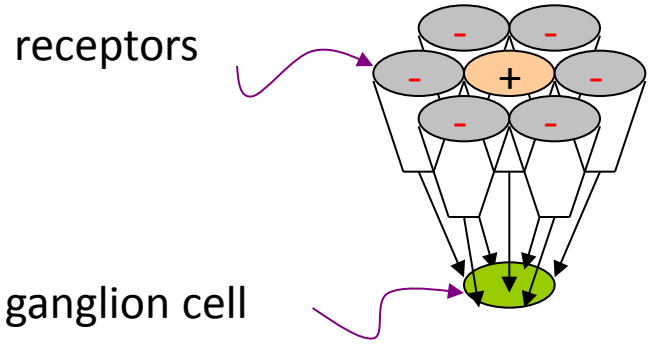
- Hermann grid illusion



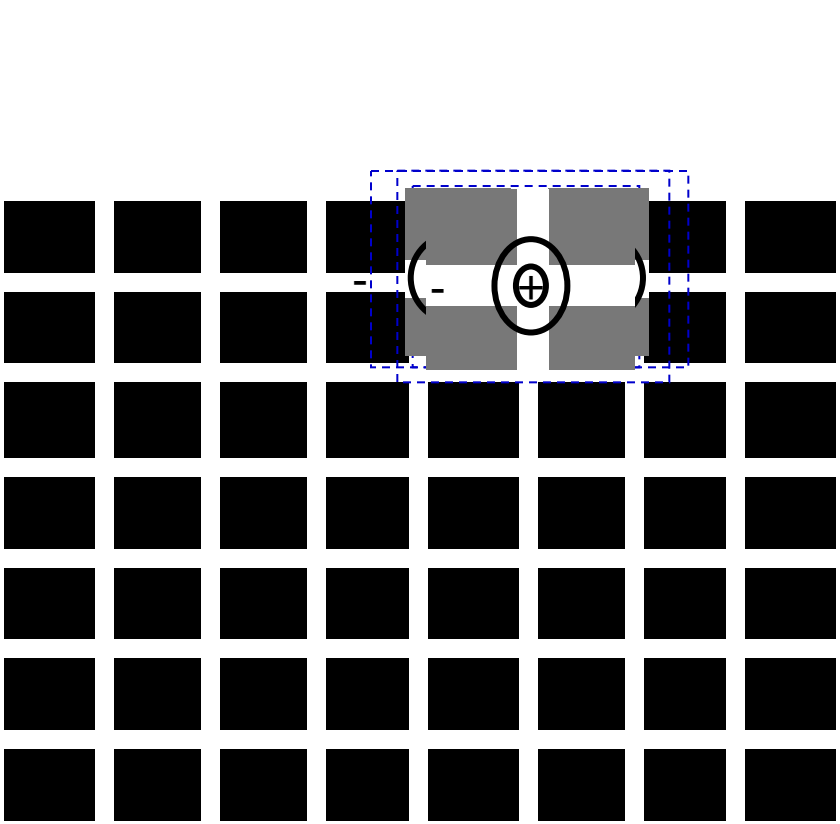
Center-Surround Organization

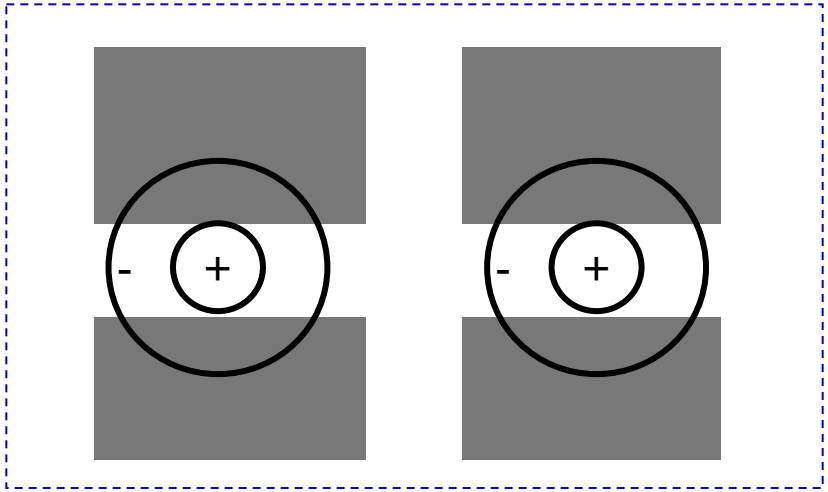
- Stephen Kuffler (1953) -- Discover that small spots of light activate the retinal ganglion cells better than large spots of light

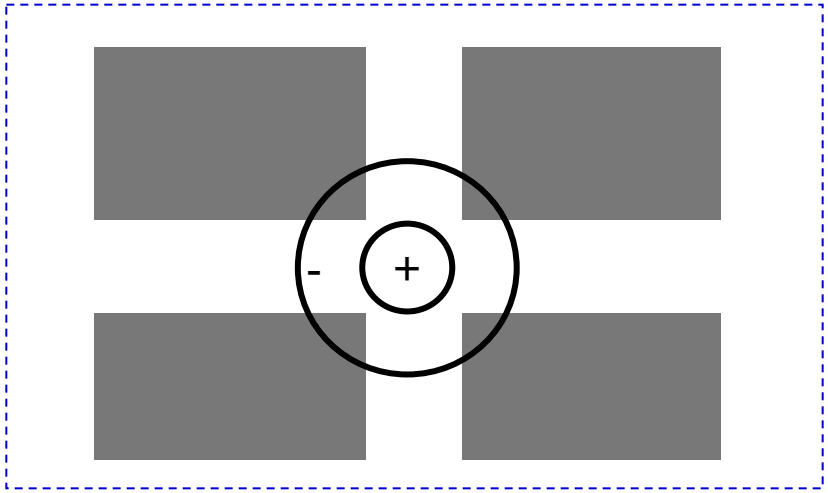




Hermann Grid Illusion - Revisit



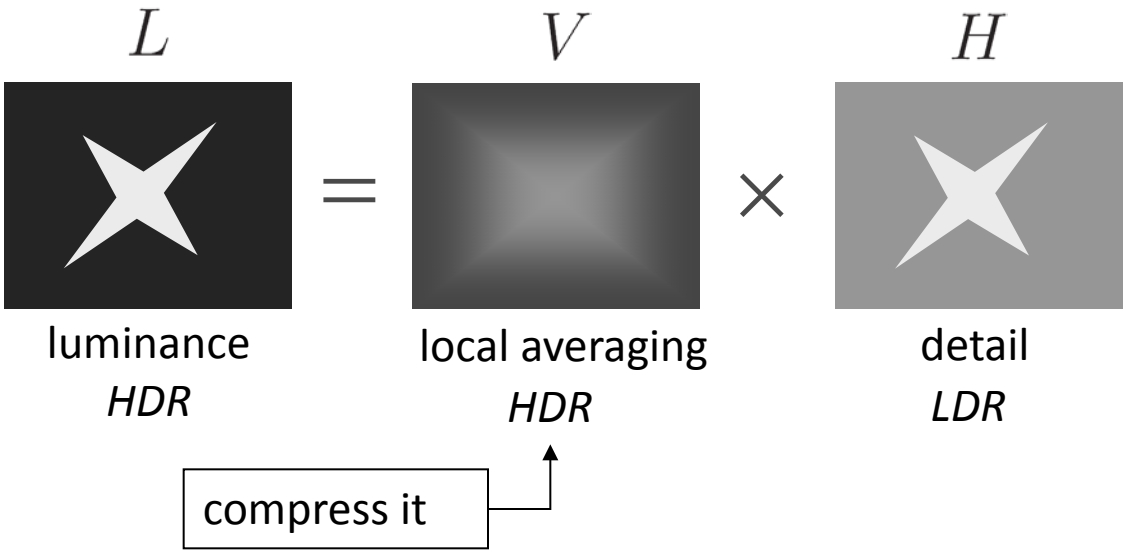




Spatial Varying Tone Mapping

- Adopt the concept of local adaptation — Chiu et al., 1993
- Construct a local adaptation luminance

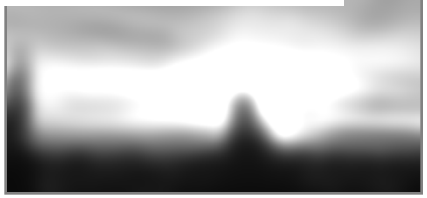
- Gaussian smoothing $L = V \times H$



Chiu et al. 1993

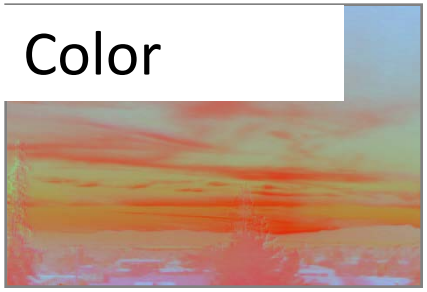
- Reduce contrast of low-frequencies
- Keep high frequencies

Low-freq.



High-freq.

Color



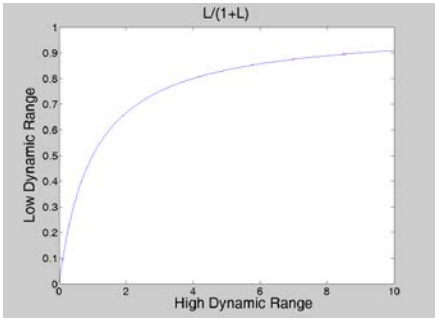
Reduce low frequency

How Does It Work?

- Local tone mapping function

$$L = H \times V$$

$$\varphi(x) = \frac{x}{1+x}$$



compress it by the global mapping function

$$L' = H \times V'$$

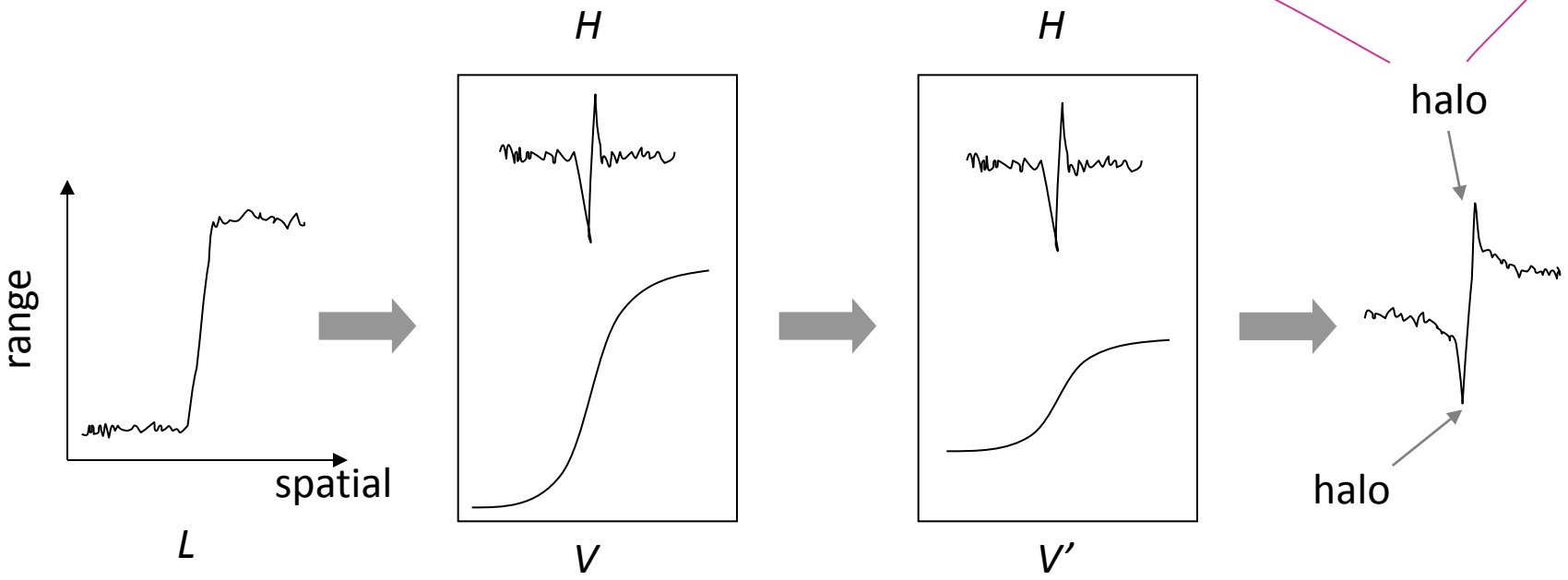
$$= (\frac{L}{V}) \times (\frac{V}{1+V}) = \boxed{\frac{L}{1+V}}$$

spatial varying

local mapping function

Halos

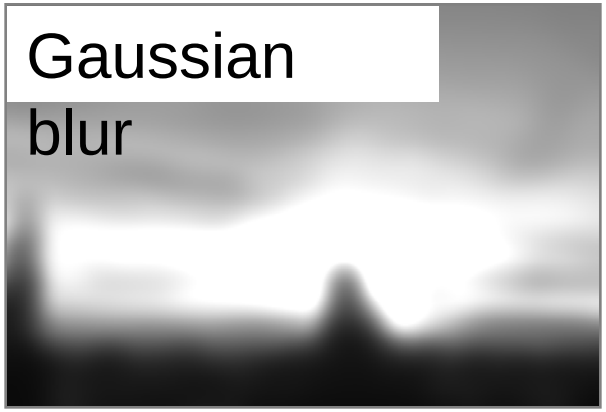
- Inverse contrasts/gradients



Preventing Halos

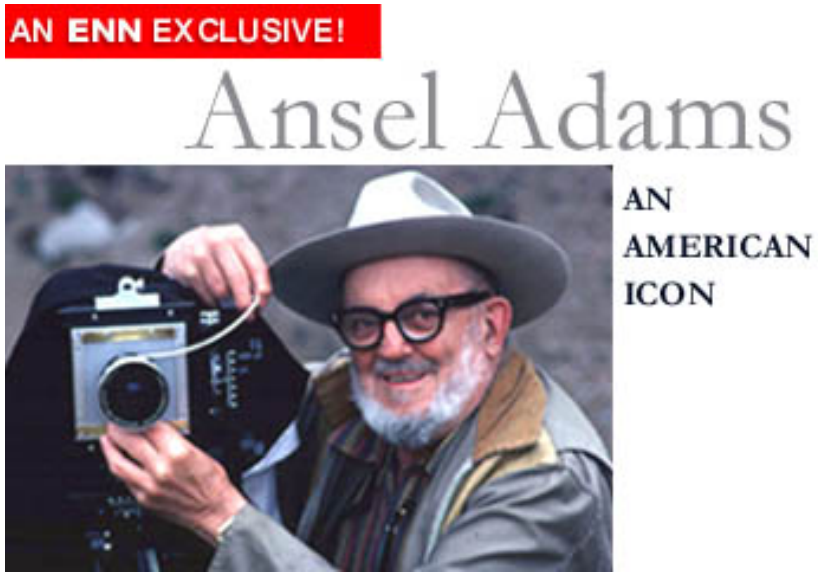
- Need to construct a more appropriate local adaptation luminance V

- Local averaging without blurring edges
  - Multi-scale center-surround



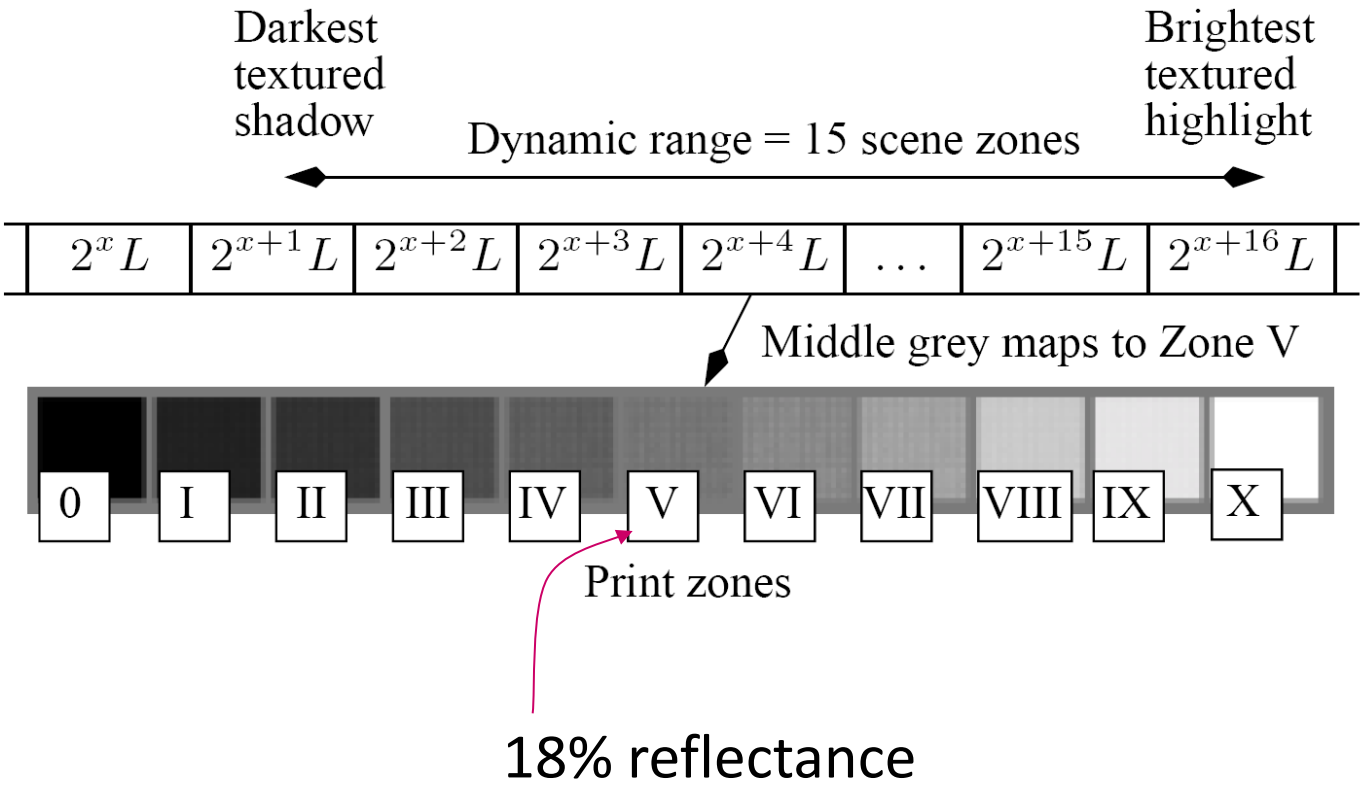
Photographic Tone Reproduction

- Inspired by



- Reinhard *et al.*, 2002

Mapping from Scene Zones to Print Zones



Initial Luminance Mapping

- Log-average luminance
  - An approximation to the key of the scene

$$\bar{L}_w = \exp\left(\frac{1}{N}\sum_{x,y}\log\left(\delta + L_w(x,y)\right)\right)$$

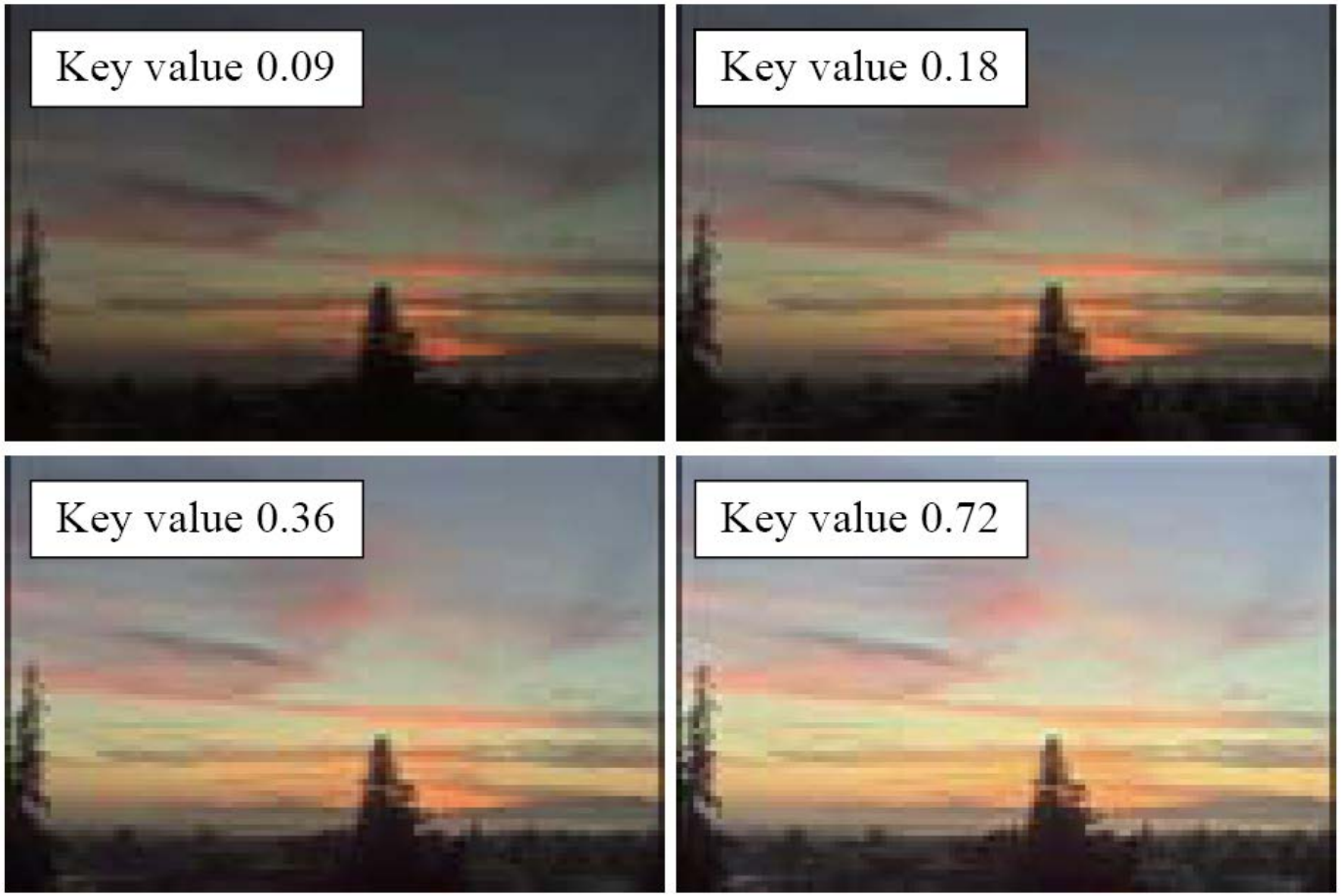
number of pixels

world luminance

- Scaled luminance

$$L(x,y) = \frac{a}{\bar{L}_w} L_w(x,y)$$

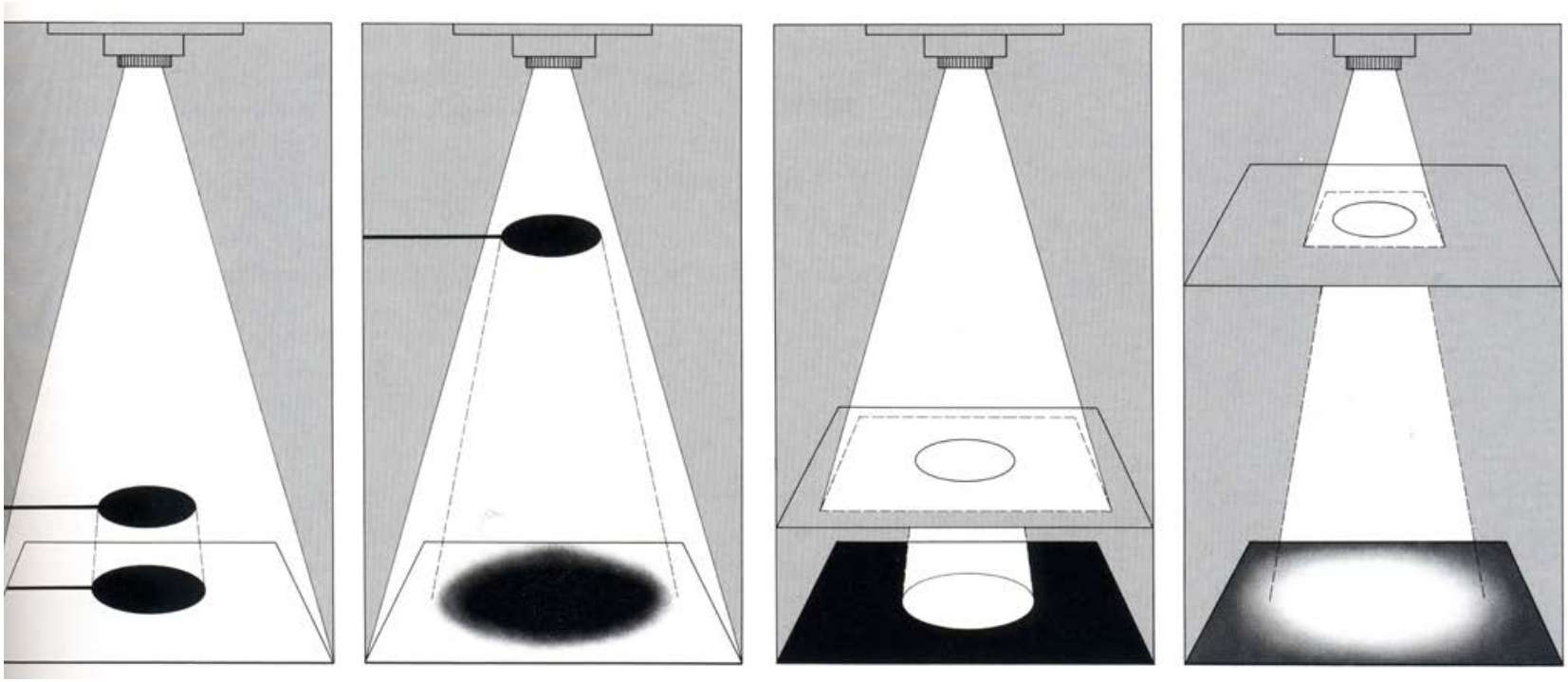
"key value" a = 0.18


Key value 0.09
Key value 0.18
Key value 0.36
Key value 0.72

Dodging and Burning

- During the print
- Hide part of the print during exposure
  - Makes it brighter

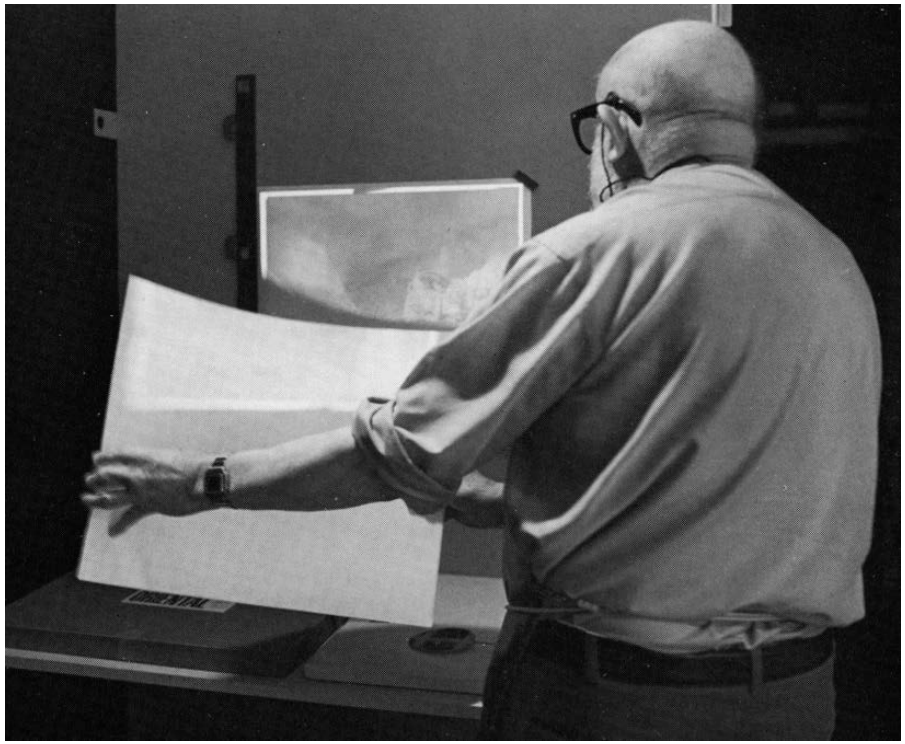
Photoshop tools

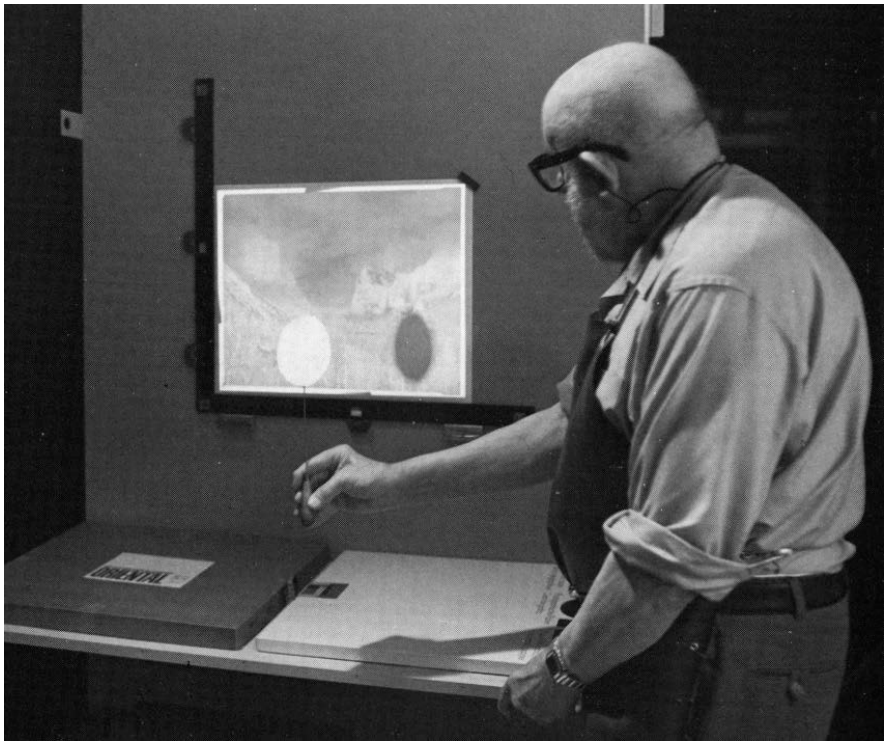



Ansel Adams
The Print

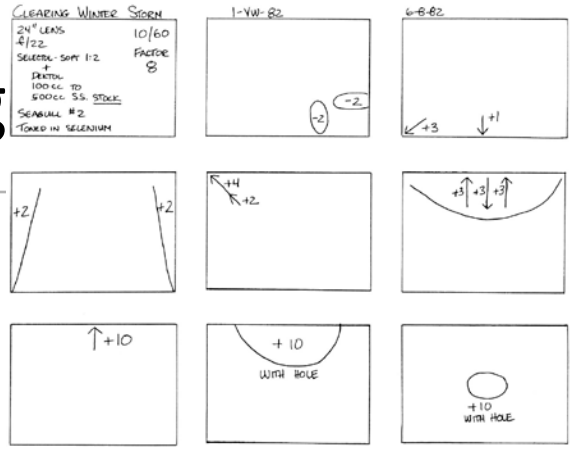
Ansel Adams
The Print

Dodging and Burning





Dodging and Burning



- Must be done for every single print

straight print

dodging and burning

Ansel Adams
The Print

Straight Print

Ansel Adams
The Print

Dodging and Burning

Automatic Dodging-and-Burning

- Circular symmetric Gaussian

$$R_i(x, y, s) = \frac{1}{\pi(\alpha_i s)^2} \exp\left(-\frac{x^2 + y^2}{(\alpha_i s)^2}\right)$$

- Convolution

$$V_i(x, y, s) = L(x, y) \otimes R_i(x, y, s)$$

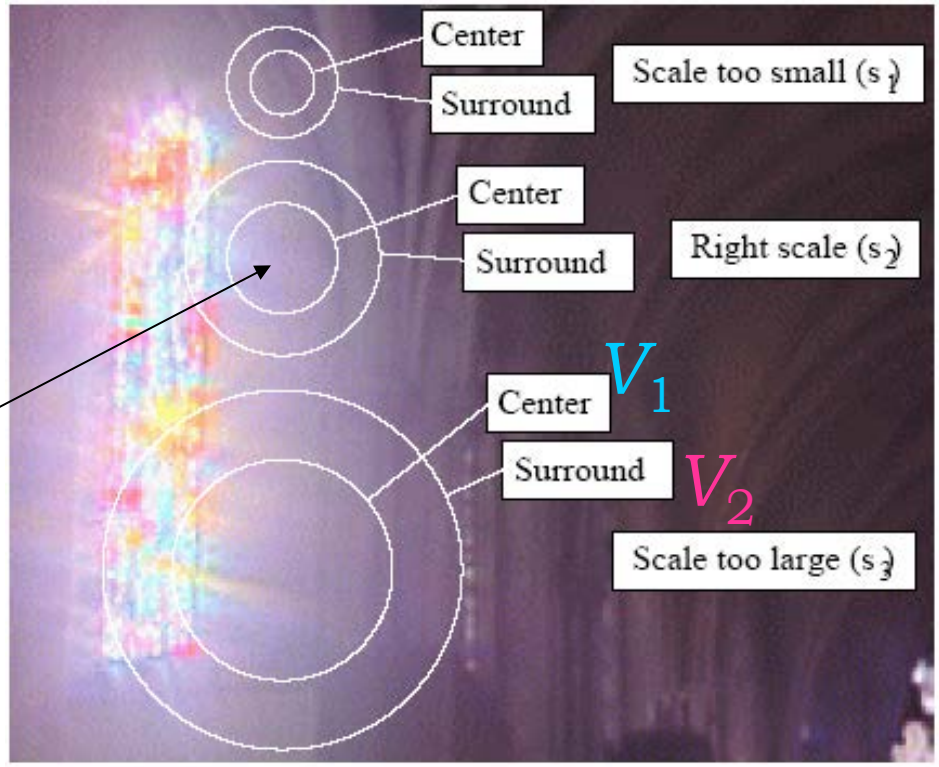
Center-Surround Scheme

gradually increase *s* until

$$\left| \frac{V_1(x,y,s) - V_2(x,y,s)}{2^{\phi} a/s^2 + V_1(x,y,s)} \right| > \epsilon$$

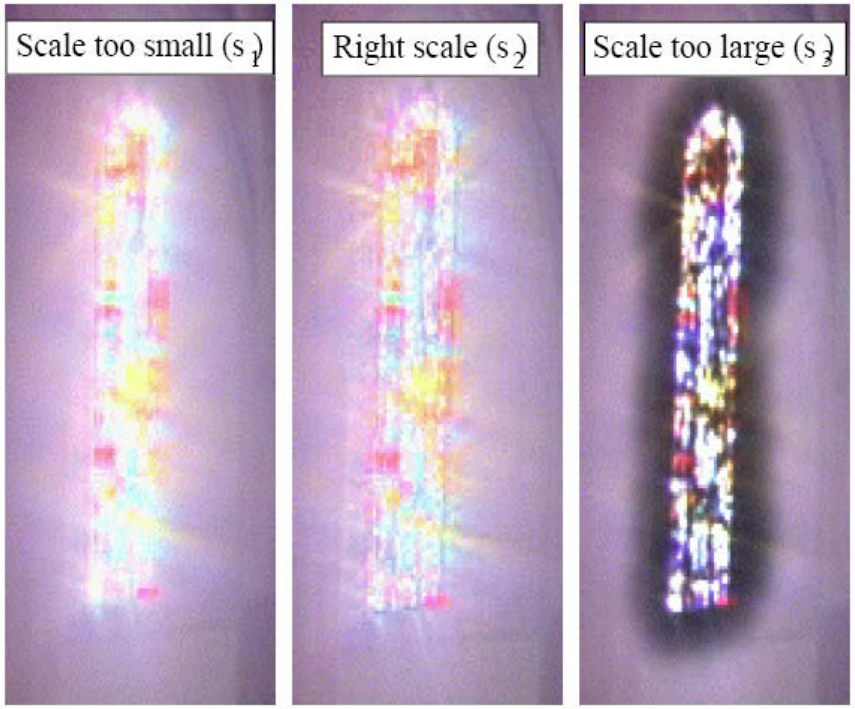
local averaging

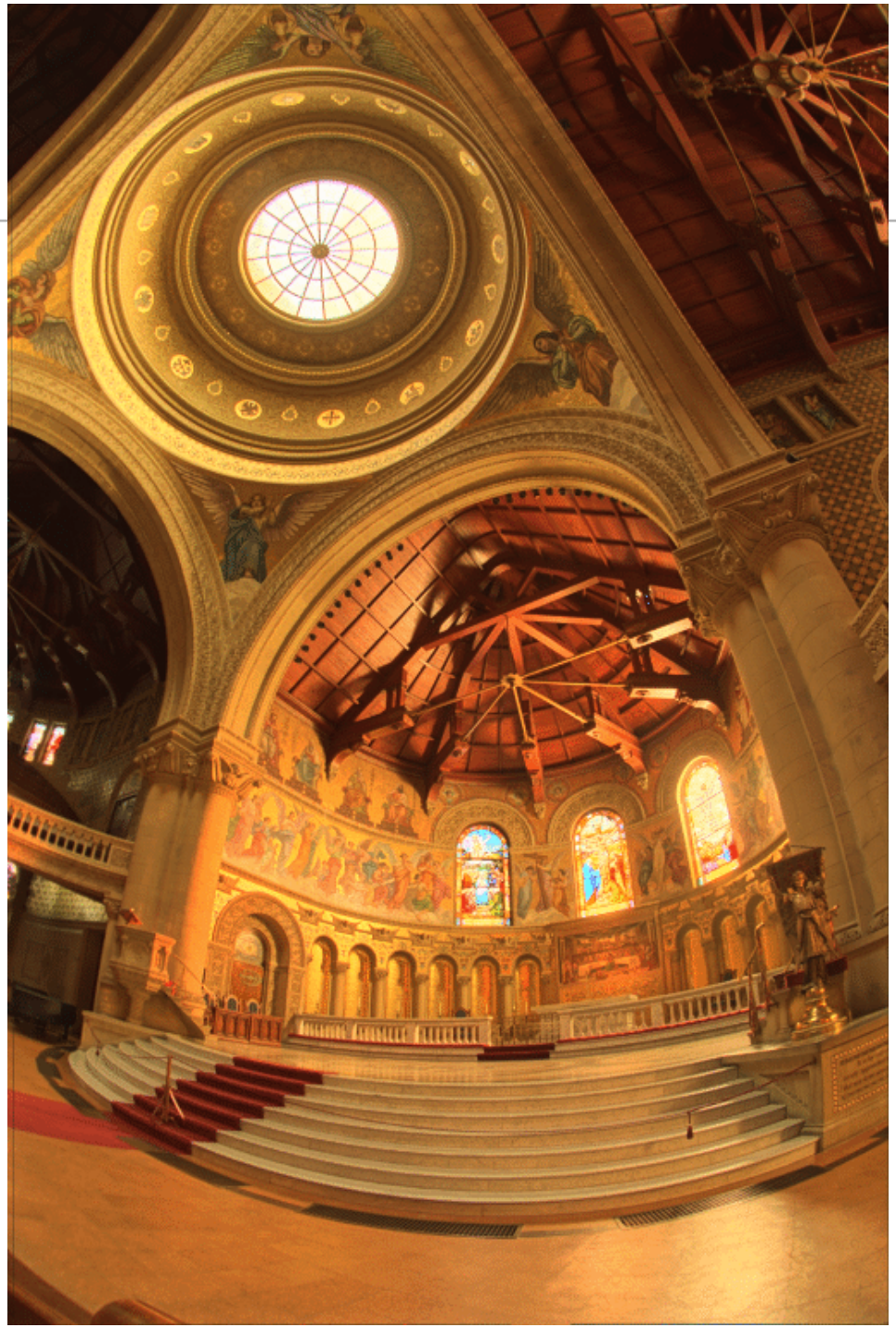
$$V_i(x,y,s) = L(x,y) \otimes R_i(x,y,s)$$



Preventing Halos

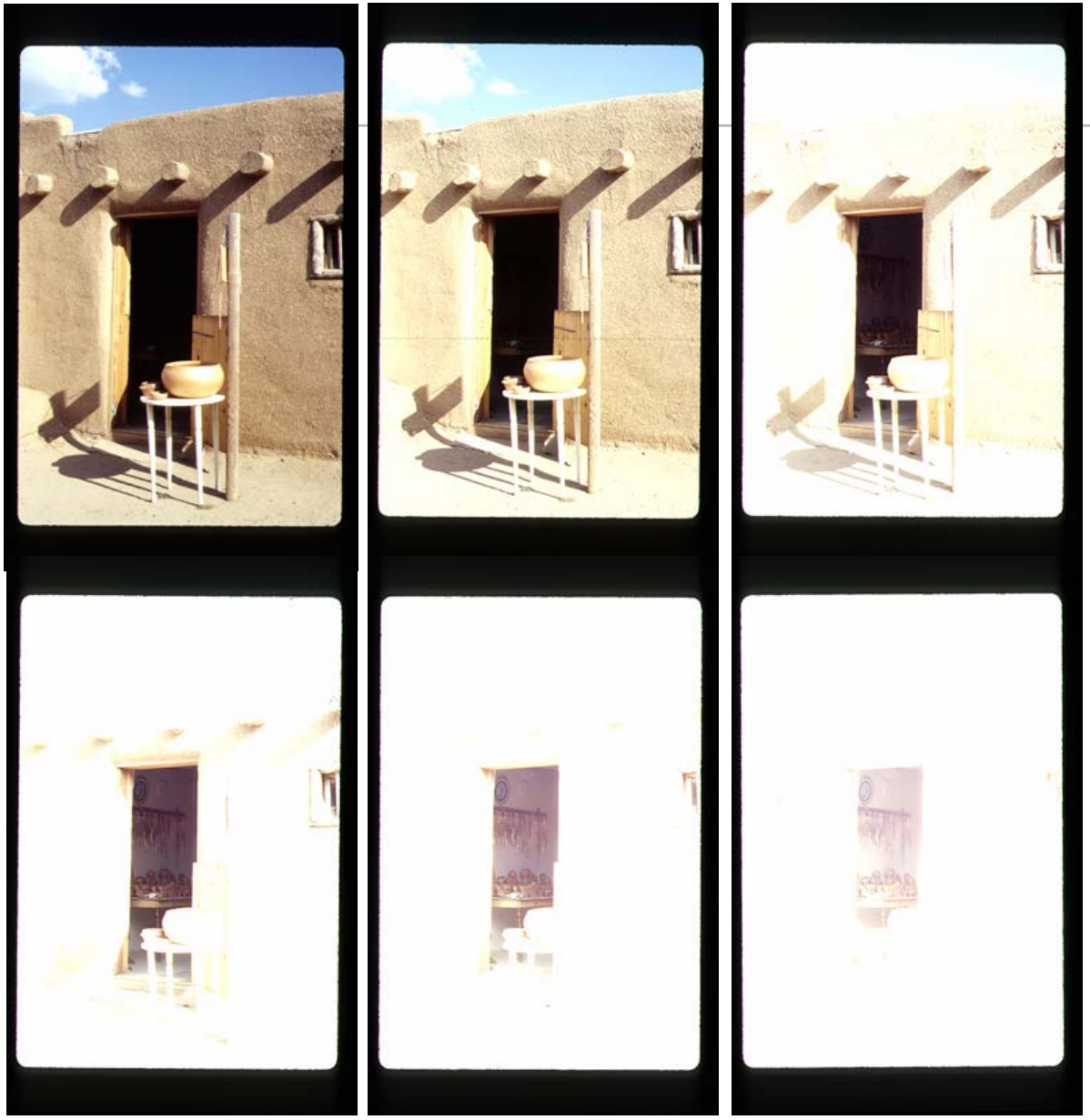
$$L_d(x,y) = \frac{L(x,y)}{1 + V_1(x,y,s_m(x,y))}$$





1

- Take some grayscale or color photos of the same scene under different exposures.



"number of images" – 1

```
numExposureRatios 5
exposureRatio     0 5.0e-001
exposureRatio     1 5.0e-001
exposureRatio     2 5.0e-001
exposureRatio     3 5.0e-001
exposureRatio     4 5.0e-001
```

$$(\text{exposure ratio})_{1,2} = (\text{exposure})_1 / (\text{exposure})_2$$

$$(\text{exposure}) = \left(\frac{1}{(\text{F - number})} \right)^2 \cdot (\text{shutter speed})$$

2

- (a) Use, or modify if necessary, the MATLAB code provided in the paper of [Debevec & Malik] to recover the HDR radiance map from the photos.

- (b) You may also use MATLAB function 'makehdr' to create an HDR radiance map from images.
  - Use MATLAB functions ' hdrwrite' and 'hdrread' to write and read HDR files

3

- Compare the results obtained by the methods of [Debevec&Malik] and Matlab 'makehdr'
  - (a) Display the HDR randiance maps using MATLAB function 'tonemap‘
  - (b) Display the randiance maps using 'HeatMap' in false color:

```
L_w = 0.2126*MyRadMap(:,:,1)+0.7152*MyRadMap(:,:,2)+0.0722*MyRadMap(:,:,3);
L_w_bar = exp(mean(log(L_w(:) + delta))); %%% delta is a small number
L = (0.18/L_w_bar)*L_w;
%%% 0.18 is the middle-grey key value;
%%% You may set the value to 0.09, 0.36, 0.54, 0.72.

HeatMap(L, 'colormap', 'jet', 'symmetric', 'false')
```

Note

- 1. To ensure a sufficiently over-determined system, you need
  `number of sample points > 255/(number of images -1)`
- 2. After solving the linear system for **`g()`** on sample points, you need to apply **`g()`** to every pixel in those differently exposed images to get the final radiance map.
- 3. You are encouraged to do some experiments. For example,
  i) try different kinds of weighting functions;
  ii) try different sampling schemes;
  iii) try different ways of processing color channels;
  iv) try to recover the response function using different numbers of images;
  v) try to reduce noise;
- vi) try patch-based HDR reconstruction
  http://cvc.ucsb.edu/graphics/Papers/Sen2012_PatchHDR/