Photographic Tone Reproduction for Digital Images

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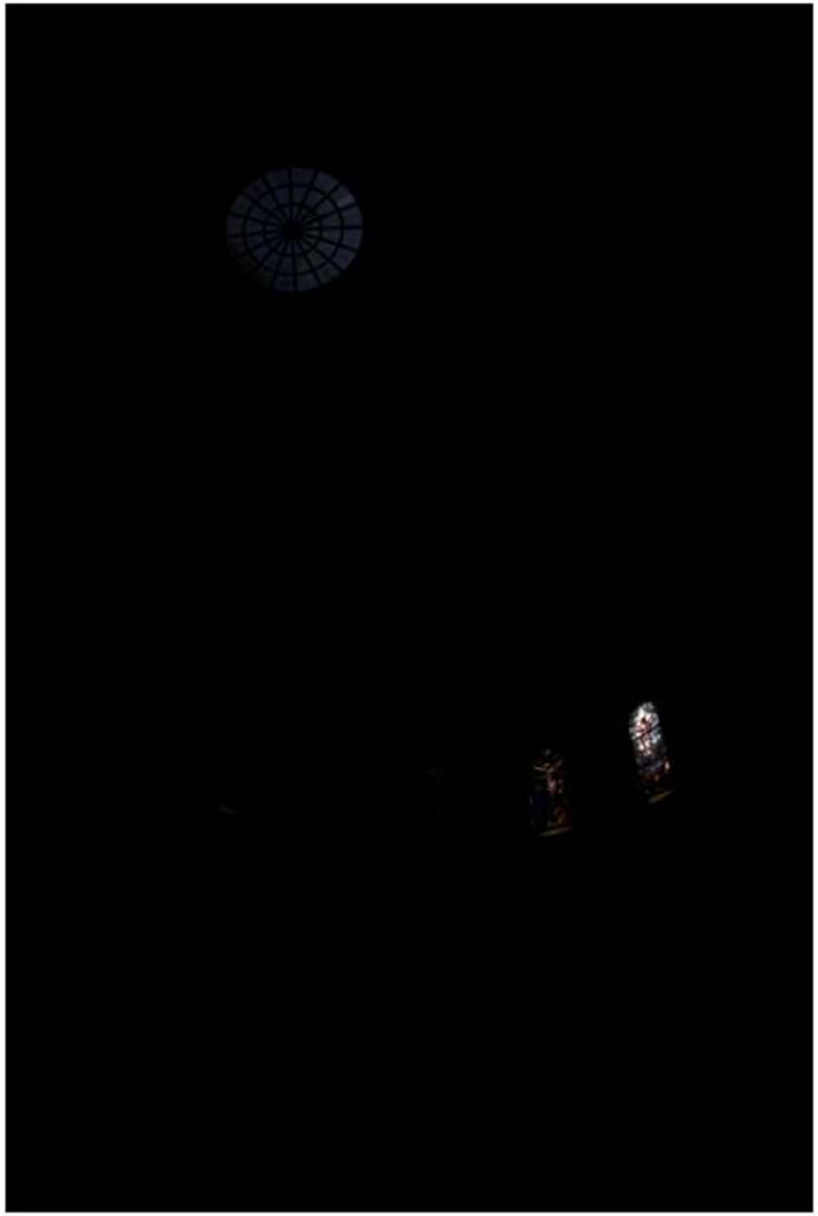
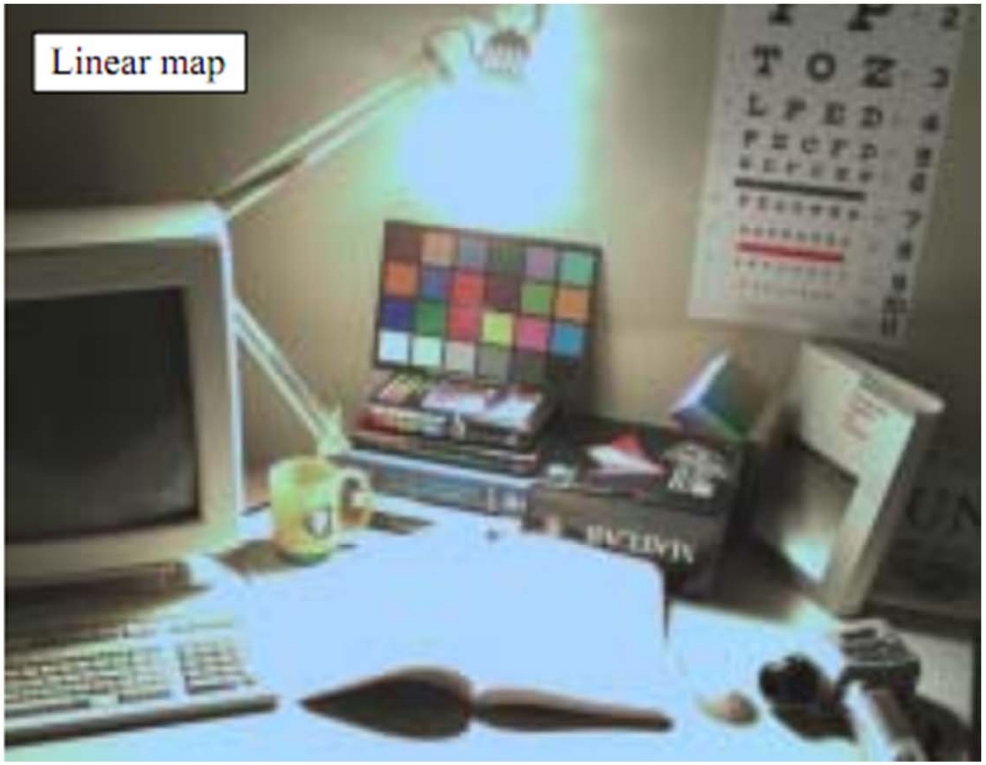
Tone Reproduction Problem

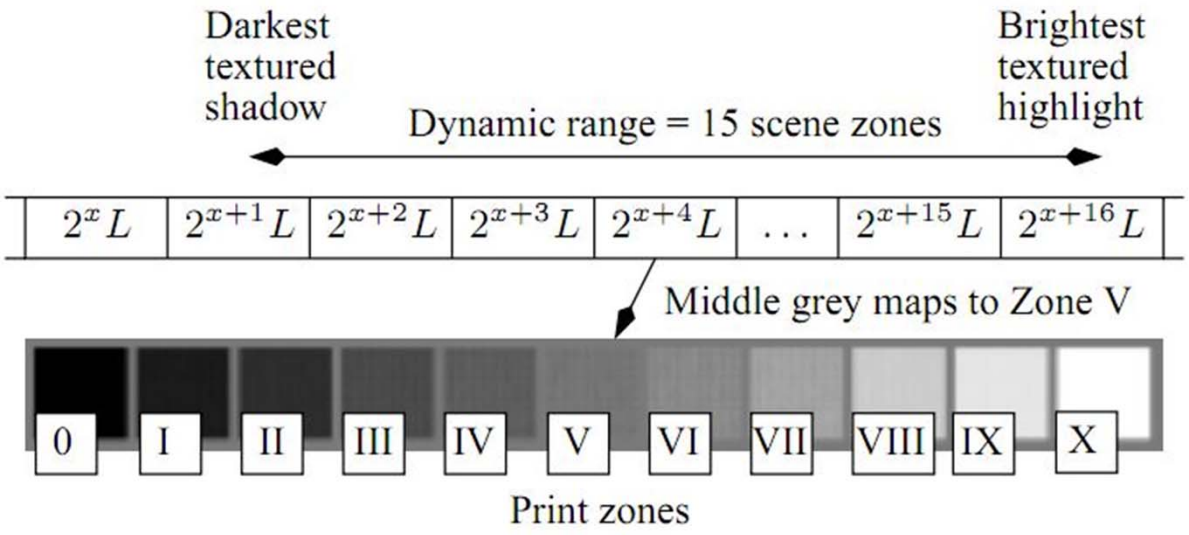
How should we map measured/simulated scene luminances to display luminances and produce a satisfactory image?




Linear map

Key Ideas

- Zone
- Middle-grey
- Dynamic range
- Key
- Dodging-and-burning




VI
III
IV
VII
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IX
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VII
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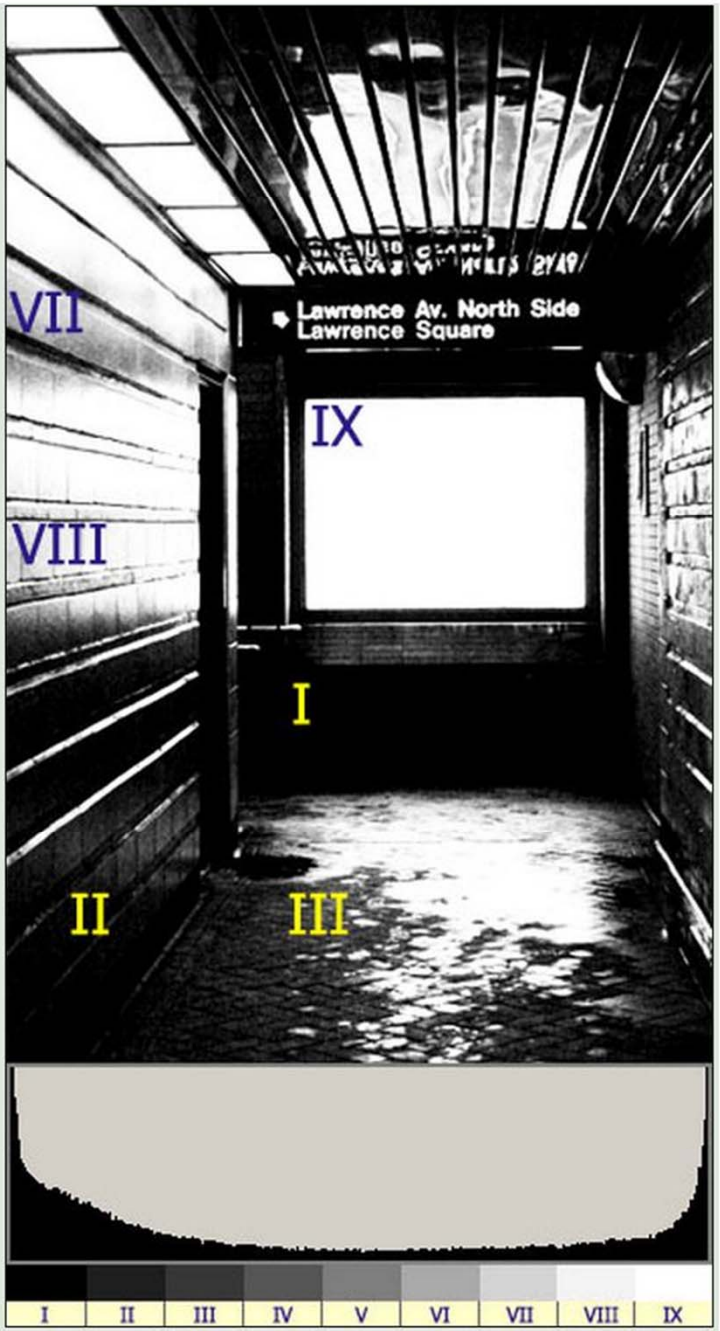
IX


Lawrence Av. North Side
Lawrence Square
VII
IX
VIII
I
II
III
I
II
III
IV
V
VI
VII
VIII
IX

Algorithm

- Apply luminance mapping
- If necessary, apply automatic dodging-and-burning

Initial Luminance Mapping

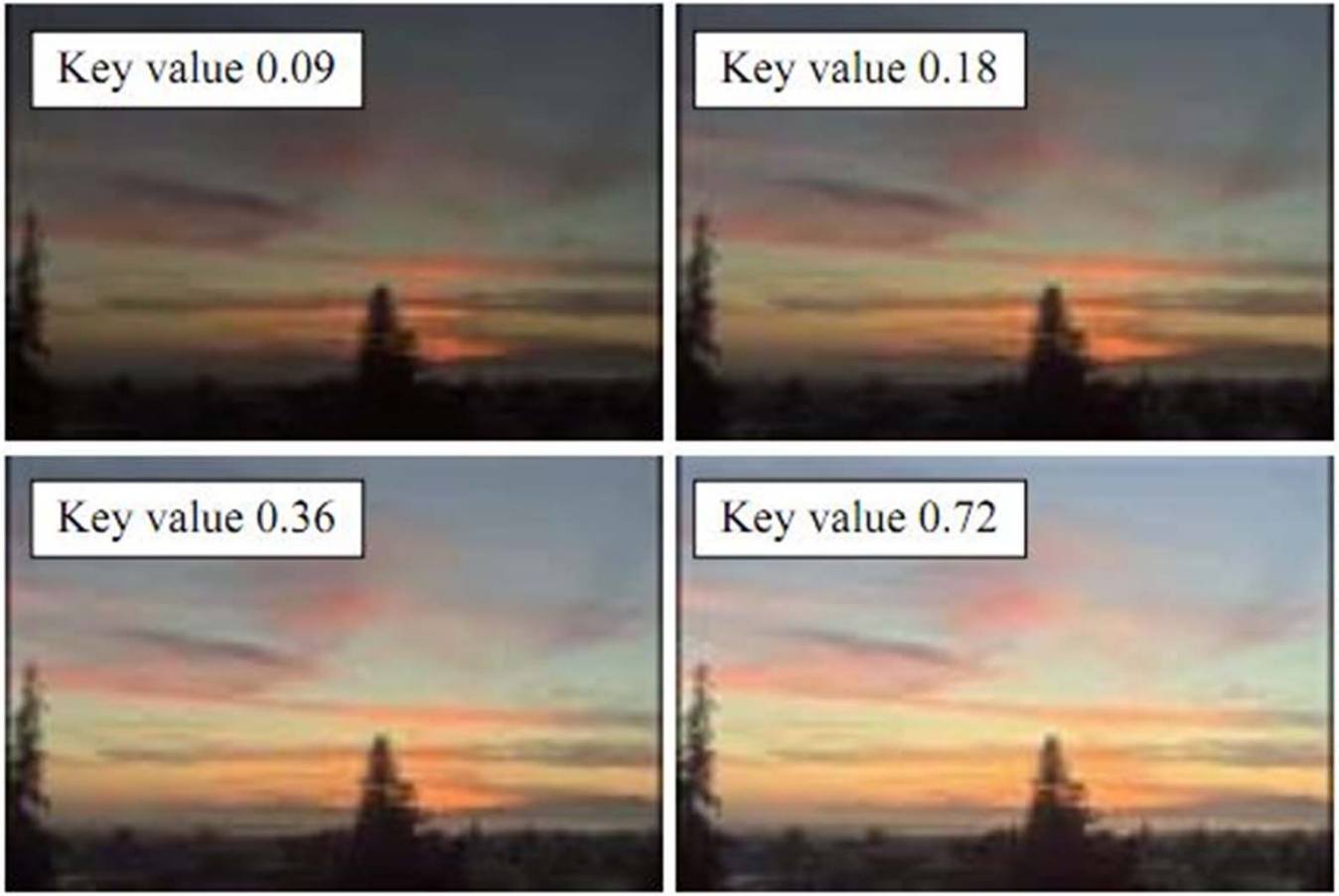
$$\bar{L}_w = \frac{1}{N} \exp\left(\sum_{x,y} \log\left(\delta + L_w(x,y)\right) \right)$$

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

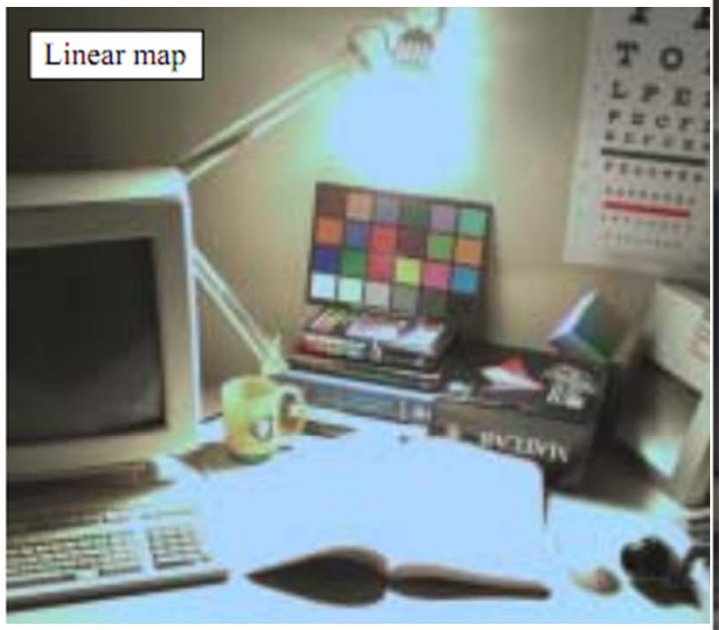
$$L_d(x,y) = \frac{L(x,y)}{1 + L(x,y)}$$

or

$$L_d(x,y) = \frac{L(x,y)\left(1 + \frac{L(x,y)}{L_{\text{white}}^2}\right)}{1 + L(x,y)}$$



Radiance map courtesy of Paul Debevec



Radiance map courtesy of Cornell Program of Computer Graphics

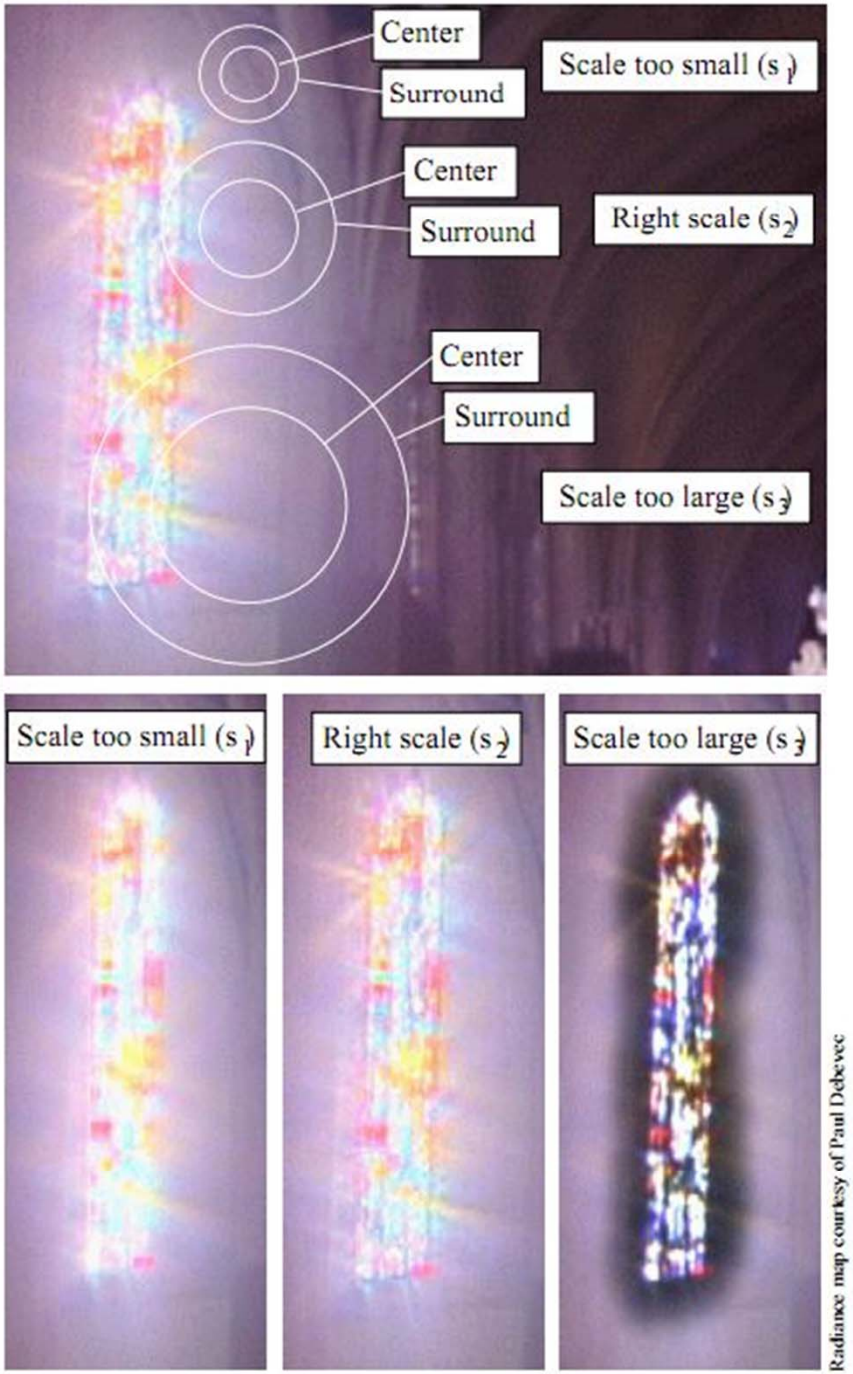
Automatic Dodging-and-burning

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

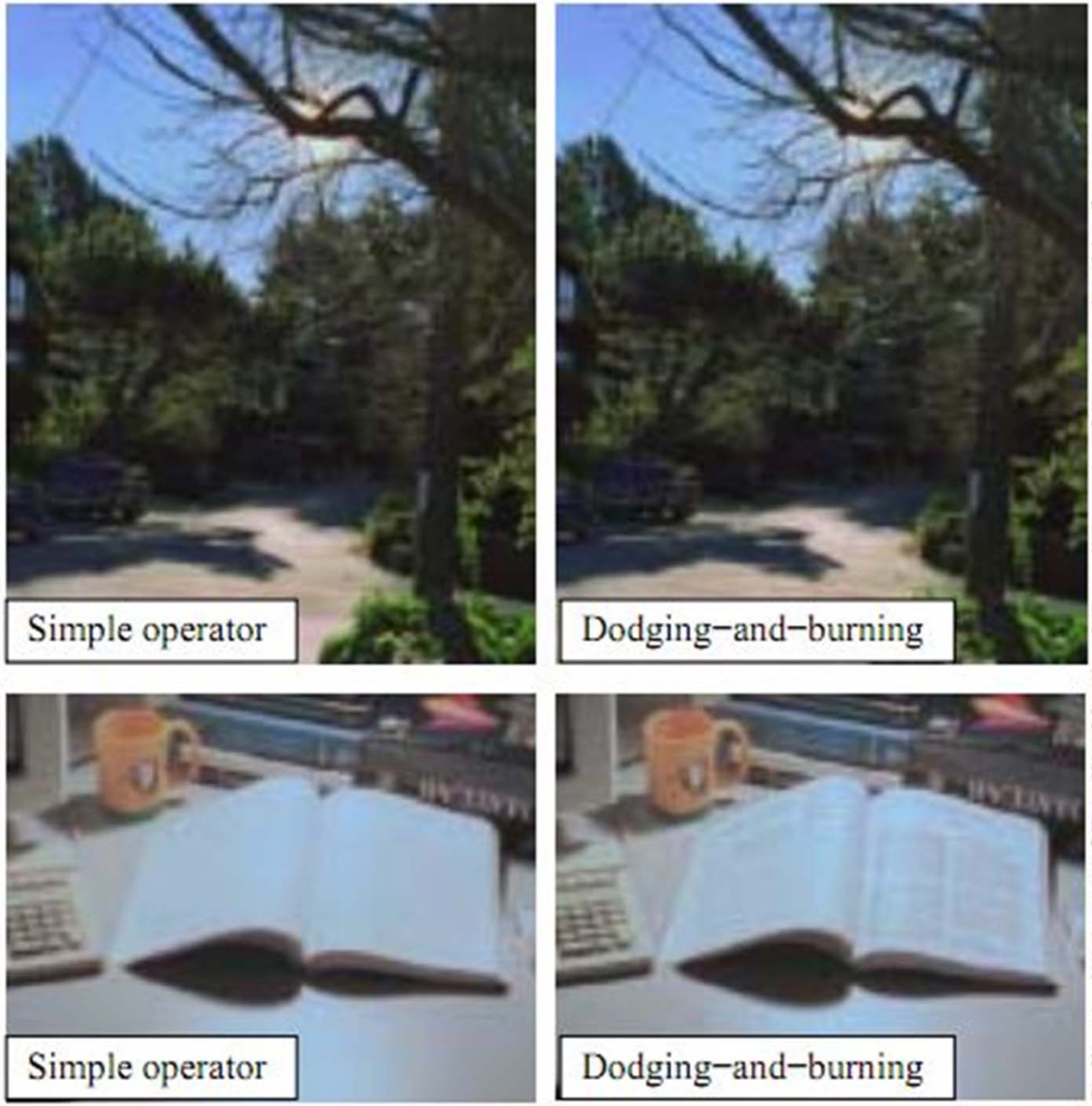
$$V_i(x, y, s) = L(x, y) \otimes R_i(x, y, s).$$

$$V(x, y, s) = \frac{V_1(x, y, s) - V_2(x, y, s)}{2^{\phi} a / s^2 + V_1(x, y, s)}$$

Seek first scale sm where: $|V(x, y, s_m)| < \epsilon$



Radiance map courtesy of Paul Debevec

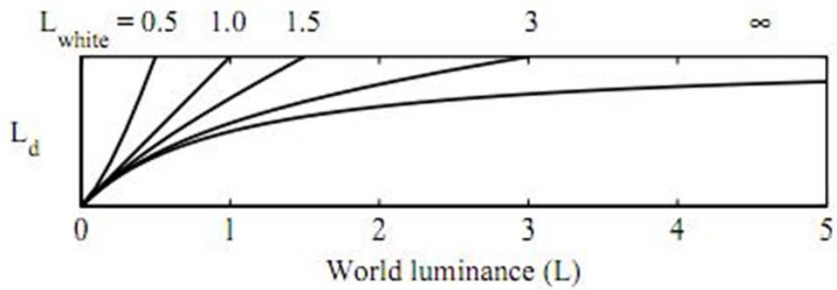


Radiance map courtesy of Greg Ward (top) and Cornell Program of Computer Graphics (bottom)

Global vs. Local operator

Global

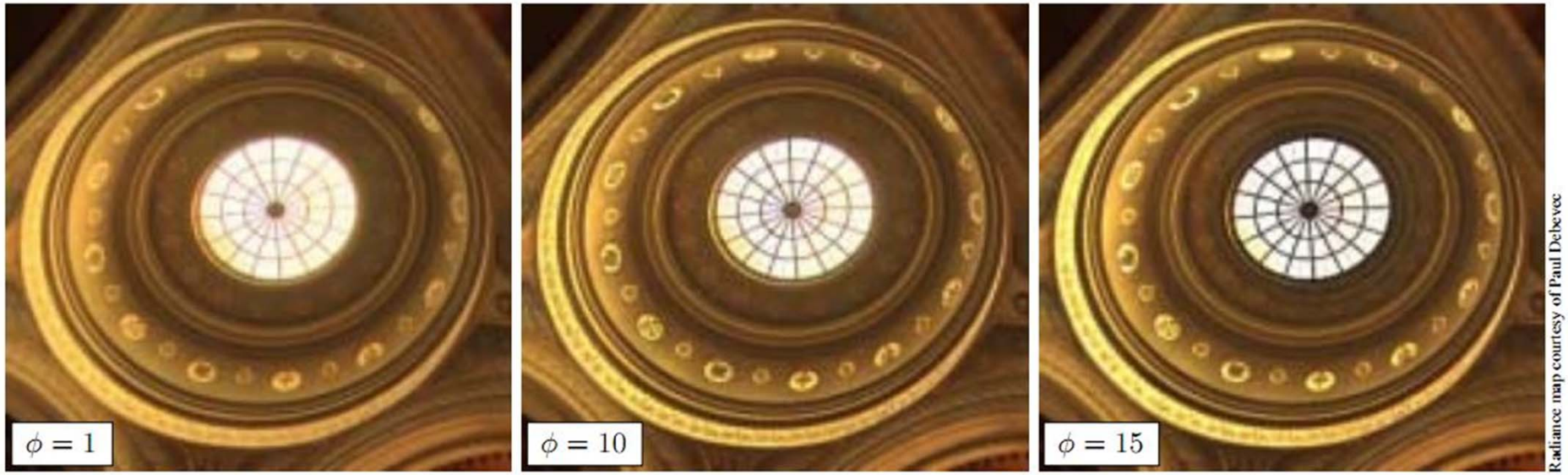
$$L_d(x,y) = \frac{L(x,y)}{1+L(x,y)} \quad \text{or} \quad L_d(x,y) = \frac{L(x,y)\left(1+\frac{L(x,y)}{L_{\text{white}}^2}\right)}{1+L(x,y)}$$



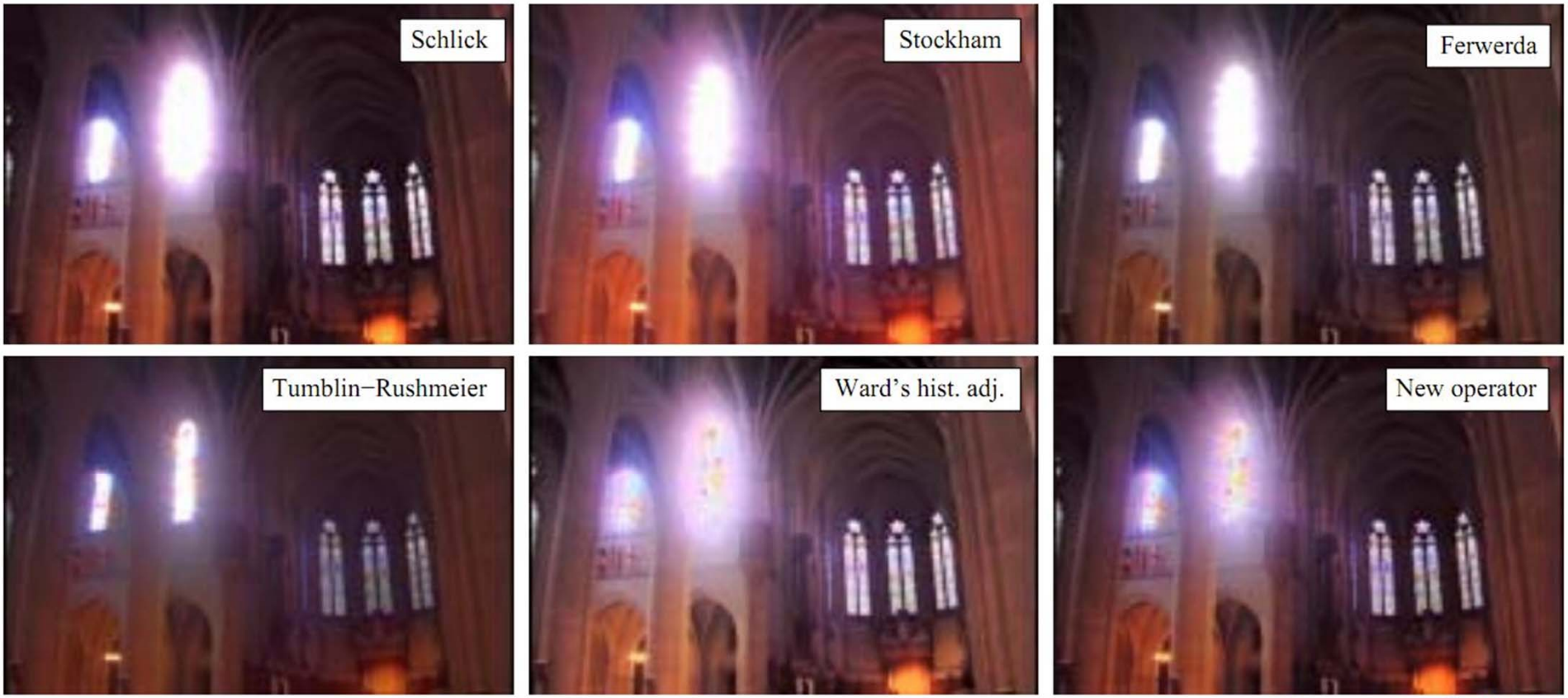
Local

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

Results



Radiance map courtesy of Paul Debevec



Radiance map courtesy of Paul Debevec

Rendering by Peter Shirley

Discussion

Questions?

Question 1

What is problematic in the algorithm?

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What is problematic in the algorithm?

- Set parameters
  - “Sharpening” Phi
  - Scale alpha_1, alpha_2
  - Threshold epsilon
  - Scale s
  - Key value a
- “Magic”

$$V(x,y,s) = \frac{V_1(x,y,s) - V_2(x,y,s)}{2^{\phi} a/s^2 + V_1(x,y,s)}$$

Question 2

Why does equation 9 increase local contrast?

$$L_d(x,y) = \frac{L(x,y)}{1 + V_1(x,y,s_m(x,y))} \tag{9}$$

$$V_i(x,y,s) = L(x,y) \otimes R_i(x,y,s). \tag{6}$$

$$R_i(x,y,s) = \frac{1}{\pi(\alpha_i s)^2} \exp\left(-\frac{x^2+y^2}{(\alpha_i s)^2}\right). \tag{5}$$

Question 3

What do we change in the algorithm to obtain images like this?

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Make histogram peak in high/low tone area

→ key value a

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

Question 4

Why can we obtain luminance like this?

$$L = 0.27R + 0.67G + 0.06B$$

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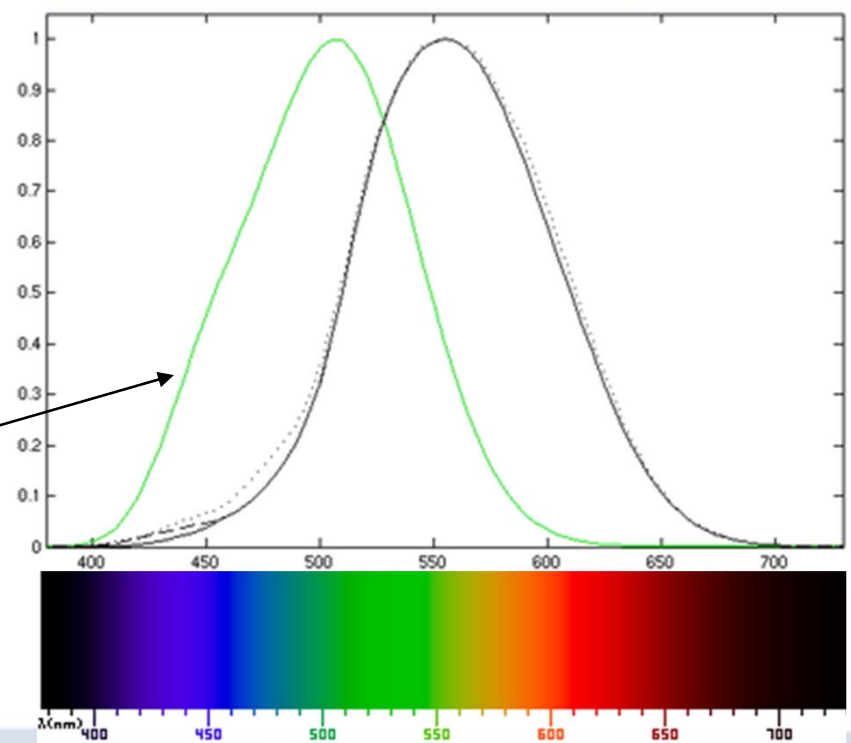
→ Luminosity function (see Wikipedia)

→ Scotopic vs. photopic vision

Scotopic, sensitivity of the eye is mediated by rods



Question 5

Why is it called dodging & burning?

Why does burning darken the image?

Why does dodging lighten it?

Question 5

Darkroom

→ prints are made from negatives

→ negative process: more light → darker