Photographic Tone Reproduction for Digital Images

Paper by: Erik Reinhard, Michael Stark, Peter Shirley, and James Ferwerda
Tone Reproduction Problem

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

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

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

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

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

\[ L_d(x, y) = \frac{L(x, y)}{1 + L(x, y)} \quad \text{or} \quad L_d(x, y) = \frac{L(x, y) \left(1 + \frac{L(x, y)}{L^2_{\text{white}}} \right)}{1 + L(x, y)} \]
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: \[ |V(x, y, s_m)| < \epsilon \]
Global vs. Local operator

Global

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

or

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

Local

\[ L_d(x, y) = \frac{L(x, y)}{1 + V_1(x, y, s_m(x, y))} \]
Results
Discussion

Questions?
Question 1

What is problematic in the algorithm?
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?

\[
L_d(x, y) = \frac{L(x, y)}{1 + V_1(x, y, s_m(x, y))}
\]  \quad (9)

\[
V_i(x, y, s) = L(x, y) \otimes R_i(x, y, s).
\]  \quad (6)

\[
R_i(x, y, s) = \frac{1}{\pi(\alpha_is)^2} \exp \left( -\frac{x^2 + y^2}{(\alpha_is)^2} \right).
\]  \quad (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 $a$

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