Consistent Tone Reproduction

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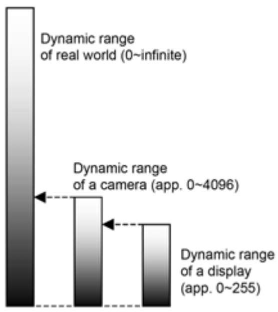
Introduction

Intro

- We introduce a tone-mapping algorithm for high dynamic range (HDR) images
- Our proposed method:
  1. *consistent* performances *without parameter tweaking*
  2. taking advantage of global adaptation as *efficiency*

Background

- Imagine that we acquired high dynamic range (HDR) radiance map (≈ real world radiance)
- Size of dynamic range (DR) : real world (HDR) > camera > display
- Huge difference of dynamic ranges between HDR and display
  → linear mapping into ordinary display: not suitable!



Tone-mapped HDR image

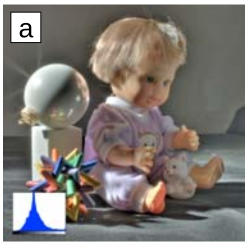
Related Work

- Local Adaptation Models*:
  - Compress only *high* freq. or gradients in HDR images considering spatial relationship with neighboring pixels
  - Pros: strong compression of dynamic range, …
  - Cons: computational cost - considerable (5sec~2min for 1M px), halo or banding artifacts,…
- Global Adaptation Models*:
  - Manipulate tone reproduction curve *non-linearly*
  - Pros: efficiency (≤3sec for 1M px), no artifacts,…
  - Cons: performance of compression is more often limited by *simplicity of algorithm*,
    e.g., too dark or too bright results

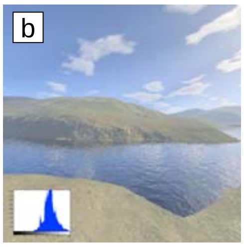
* References on paper

Problem Statement

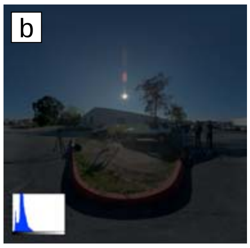
- However, sometimes…



Fattal et al. (SIG02)
Local adaptation
< halo artefact >



Drago et al. (EG03)
Global adaptation
< too bright, low contrast >



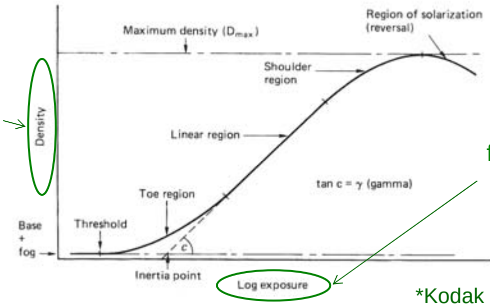
Reinhard&Devlin (TVCG05)
Global adaptation
< too dark, low contrast >

- *Manual parameter tweaking* has been necessary
  [a] to avoid *halo* → adjust the size of local kernel
  [b] to avoid *faulty tone reproduction* → globally adjust tone-reproduction curve

Our Approach

- Hence, we focus on:
  – Removing per-image intervention of users (*consistency*)
  – Using global adaption (*efficiency & no artifact)*
- Characteristic Curve Control:
  – Mimicking a tone reproduction curve of photographic film*: *sigmoidal shape in log-log domain*

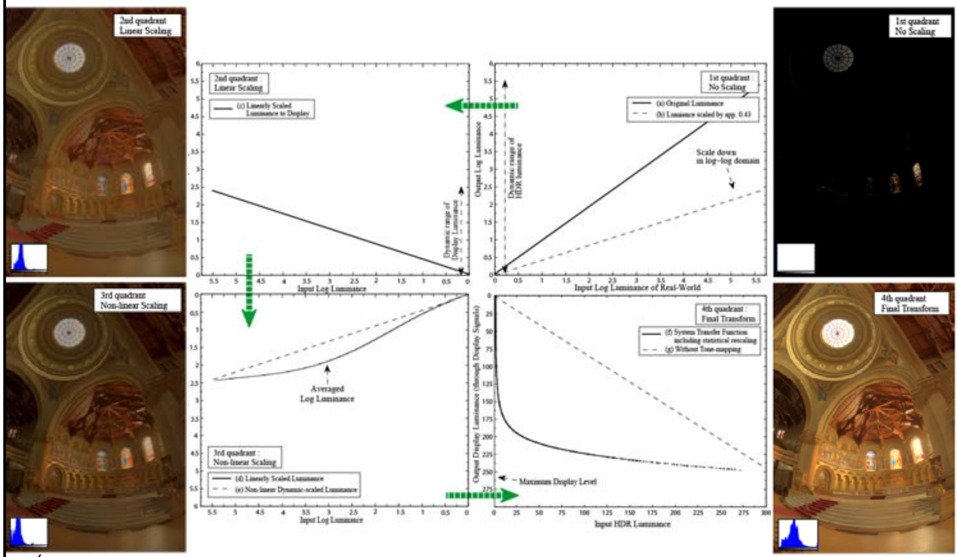
Log (Lumin. through film *surface*)
↓
Log (Tone-mapped Display Signals)



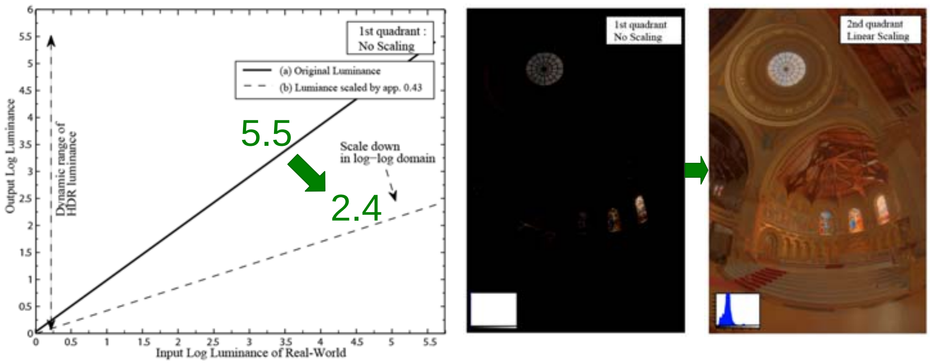
Log (Lumin. from *light source*)
↓
Log (HDR radiance map)

*Kodak Ektacolor Negative Film

3-Steps Algorithm (Jones Quadrant Diagram)



1st Quadrant → 2nd Quadrant

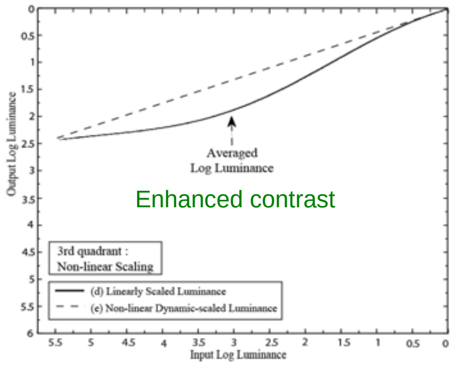


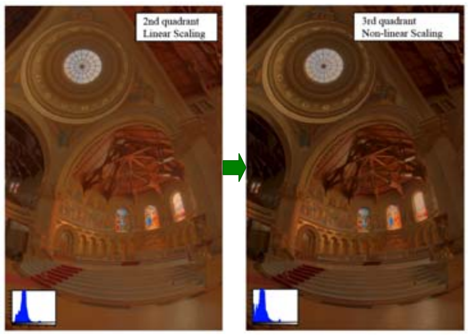
- DR reproduction: HDR Radiance → LDR Display
- Dynamic Range Compression (on Y in CIEXYZ):
  - Explicit linear-compression in logarithmic domain by k_1:

$$k_1 = \frac{\log L_{d_{\max}} - \log L_{d_{\min}}}{\log L_{s_{\max}} - \log L_{s_{\min}}}$$

e.g., Display DR: 2.4 (8-bits signals),
HDR DR: 5.5, *k1* = 0.43

2^{nd} Quadrant → 3^{rd} Quadrant





- Linear compression: not enough for plausibility
- Thus, add Gaussian-weighting to scalar k_1
- A new factor k_2 is non-linearly scaled version of k_1 in log-log domain

Continued…

2^{nd} Quadrant → 3^{rd} Quadrant (detail)

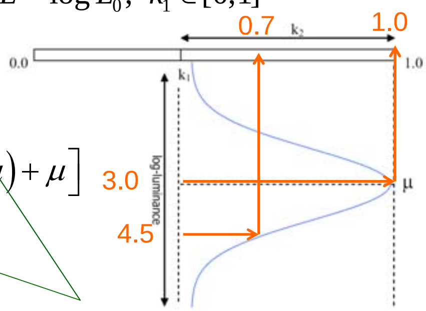
- Gaussian scale factor k_2: between k_1 and 1.0
  → depends on the intensity of log-luminance
  → it has its peak at the *average log-luminance* μ

$$k_2(L) = (1-k_1)w(L) + k_1, \quad \text{where } L = \log L_0,\ k_1 \in [0,1]$$

$$w(x) = \exp\left(-\frac{1}{2}\frac{(x-\mu)^2}{\sigma^2}\right), \ \sigma = \frac{d_0}{c_1},$$

$$L_1(x,y) = \exp\left[c_2 k_2 \left(\log L_0(x,y) - \mu\right) + \mu\right]$$

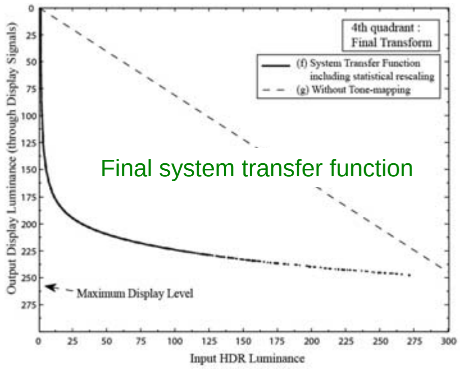
where d_0 is original dynamic range;
μ is averaged log-luminance

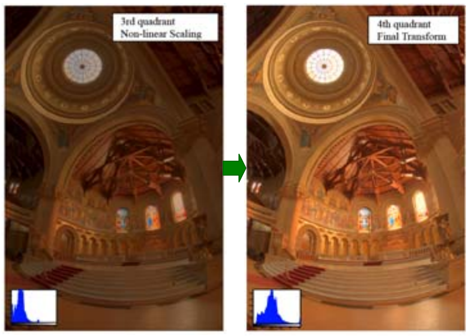


Parameters
(will be discussed later)

3rd Quadrant → 4th Quadrant

Intro > Related Work > Our Approach



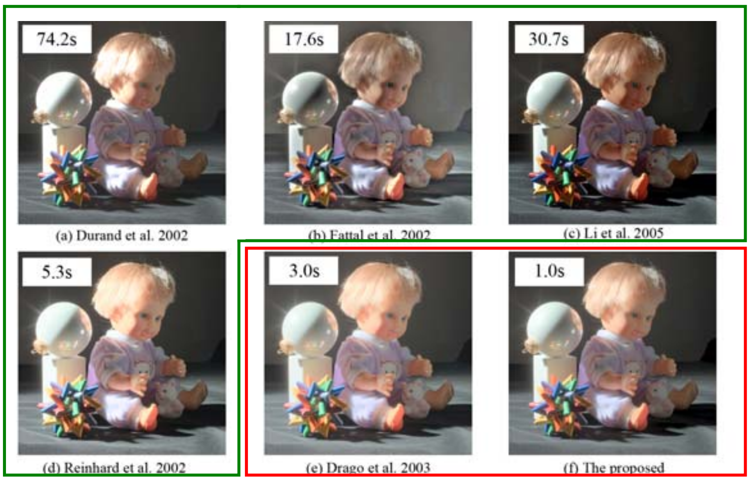


- Inverse Display Characterization:
  - 1~99% Signals in *cumulative probability* → Display DAC
  - Inverse transform into sRGB color space: XYZ→RGB
  - *1/γ* gamma correction (γ≈2.2, sRGB display devices)

Results – Efficiency

Intro > Related Work > Our Approach > Results

Local



Global

- Taking advantage of global approach (efficiency)
- Less than *1.0* sec (*922x901* ≈ *1M*) on P4 (*2.0GHz*)

Comparison to Other Methods*

The Proposed

Drago et al. EG03

Reinhard & Devlin TVCG05

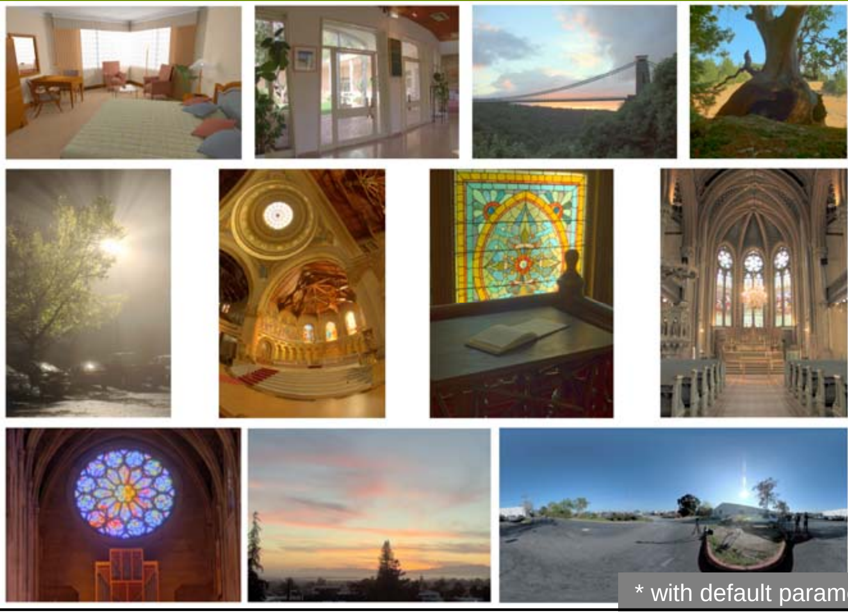
* with their default parameters

Results – Consistency (Thumbnails)*

* with default parameters

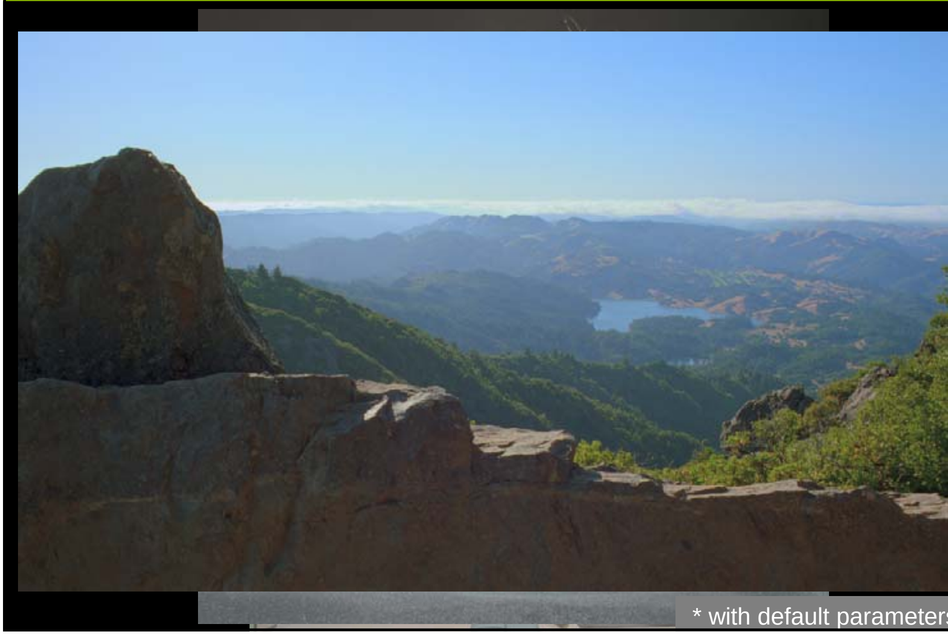
Results – Consistency (Thumbnails)*

Intro > Related Work > Our Approach > Results



* with default parameters

Results – Consistency (Close-up)*



* with default parameters

Discussion – Influence of Parameter c_1

$\therefore c_1 \approx 3.0$

- Adjustment of the shape of Gaussian fall-off: within image's DR (width of its characteristic curve)
- Influences: *level of compression* and *detail*

Discussion – Influence of Parameter c_2

for higher DR devices (e.g., Apple Cinema HD Display)

For lower DR devices (General sRGB displays)

$\therefore c_2 \approx 0.5$

- Actual DR of display ≤ Ideal DR (signal range)
  - Ideal DR of display: 2.4 (same as signal range, 8-bits)
  - Measured Display DR: ≤ 2.0 (e.g. Apple Cinema HD, 80%)
- Can be decided by the dynamic range of target

Discussion – Default Parameters

- In summary, our choice of default parameters was:
  - $C_1 = 3.0$
  - $C_2 = 0.5$
- Same parameters produce consistent results across all images
- Sufficient to choose parameters **once** according to your preference and a target condition

Conclusions

- The proposed method achieves *consistent* and *plausible* results with *a fixed set of parameters* for a large variety of images
  → Consistent tone-mapping
- Takes advantage of global adaptation approaches
  → Efficiency and no artifacts
- It will be beneficial for applications that *cannot afford parameter tweaking*,
  → such as *HDR preview*, *HDR thumbnails, HDR video,…* or other solutions for displaying HDR images

Thank you very much!

Images courtesy of Martin Cadik, Cornell University, Paul Debevec, Yuanzhen Li, Dani Lischinski, Industrial Light & Magic, Karol Myszkowski, Jack Tumblin, and Greg Ward