Rendering High-Dynamic-Range (HDR) Images

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Problem Statement

- Dynamic range – Ratio between the maximum and minimum values.
- Human vision – Ranges from bright sunlight to dim starlight
  - Ranges from 10,000:1 in a single view
- Typical CRT monitor – about 100:1

How can a HDR image be scaled to fit a CRT display?

Range of luminance:

100,000,000:1 in the natural world

10,000:1 that the eye can accommodate in a single view

100:1 that a typical CRT monitor can display
HDR Images

(a) Linear mapping of the luminance values that underexposes the view of the interior.

(b) Linear mapping of the luminance values that overexpose the view through the window.

(c) A false color image showing the luminance values for a window office. Red color represents higher luminance values; blue color represents lower luminance values.

(d) The luminance mapped to preserve the visibility of both indoor and outdoor features using the histogram adjustment algorithm.

Figure 2 Synthetic HDR images simulated by computer using radiosity and Monte Carlo path tracing techniques in terms of luminance values of the real-world scene. [3]
Image Enhancement

- Correct an distorted image
- The goal is to maximize visibility or contrast

HDR Image Rendering

- An undistorted HDR image
- Simulate visibility accurately

Figure 1: Comparison of dark and bright image before and after histogram equalization. The equalizer brings both images to nearly identical brightness. ([www.cis.rit.edu/class/sima732](http://www.cis.rit.edu/class/sima732))
iCAM

- A next generation of image color-appearance model, iCAM.

- The flexibility module design of the iCAM framework make it possible for aboard applications.
  - Imaging difference and quality predictions
  - Rendering HDR images

**Procedures**
- Chromatic & Luminance Adaptation
- Local Contrast & Surround Effect
- IPT Transform
- Inverse Model
- Display the Images
Fast Bilateral Filtering

Flowchart
- Separate image into achromatic and chromatic channels
- Decomposed achromatic channel into base layer and detail layer
- The base layer is generated using an edge-preserving filter called bilateral filter
- Generate the output image

Fast bilateral filtering for rendering HDR images can reduce contrast while preserving details.

The method is fast and requires no initial parameters.
Photographic Tone Reproduction

The Zone System

- Zone
- Middle-key
- Key
- Dodging-and-burning

Figure 6 Mapping from scene zones to printer zones. Scene zones at either extreme will map to pure black (zone 0) and white (zone X) if the dynamic range of the scene is eleven zones or more.®

(a) A normal-key map
(b) A high-key map

Figure 7 A normal key map for a high-key scene results in an unsatisfactory image; a high key map solves the problem.®
Photographic Tone Reproduction (Cont.)

![Images showing different scale factors and results](image)

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

- \( L_d(x, y) \) – Display Luminance
- \( V_1(x, y, s_m(x, y)) \) – Surround Luminance
- \( s_m(x, y) \) – Scalar
- \( L(x, y) \) – Pixel Luminance

**Dodging** – Decrease the display luminance and increase contrast at that pixel

\[ L < V_1 \]

**Burning** – Reduces the display luminance a little bit

\[ L > V_1 \]

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Figure 8 Results of different scale factor. If scalars are too small, detail information is lost, while if scalars are too large, the artifact – dark rings surround luminance object will be produced.
A new histogram adjustment technique is based on the population of local adaptation luminance in a scene. This technique accounts for human contrast sensitivity, glare, color sensitivity and spatial acuity.

- Human contrast sensitivity – Don’t see equally well at all light levels
- Glare – caused by bright sources in the visual periphery, which scatter light in the lens of eye, obscuring fovea vision.
- Color sensitivity – reduced in dark environment
- Visual acuity – impaired in dark environment
Conclusions

- The HDR images are images that have a large contrast ratio, spanning at least about three orders of magnitude. Tone reproduction is necessary to display these images on a low-dynamic-range display device.

- Two types of tone reproduction operators:
  - Spatially uniform (single-scale or global) – Histogram Adjustment
  - Spatially varying (multi-scale or local) – iCAM, Fast Bilateral Filtering, and photographic tone reproduction

- The four algorithms are chosen based on previous work in MCSL.
Reference