Compressive sensing (Lecture #6)
Computational illumination (Lecture #7)

Sources: CMU 15-463

over-exposure
(non-linearity due
to sensor saturation)

number of photons

Sources: CMU 15-463

span of the light (weighted by human's eye sensitivity to different wavelengths)

Luminous intensity: Measure of the light that shines from the source in a given direction

Sources: CMU 15-463

and 3 x 10^{16} Hz)

Sources: CMU 15-463

$$\text{Luminous Intensity}(I) = \text{Luminance}(L) \times \text{Area}(A) \times \text{Solid Angle}(\Omega)$$

Sources: [CMU 15-463]

adaptation range of our eyes

adaptation range of our eyes

Sources: CMU 15-463

Sources: CMU 15-463

3. Inverse tonemapping: How do we show conventional images in HDR displays?

Sources: CMU 15-463

Sources: CMU 15-463

adaptation range of our eyes

Sources: CMU 15-463

adaptation range of our eyes

Sources: CMU 15-463

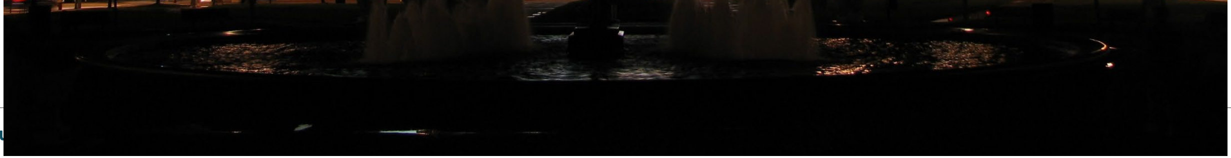
- Pros: Full control.
- Cons: Very slow, requires a lot of experience.

generic camera mode dial

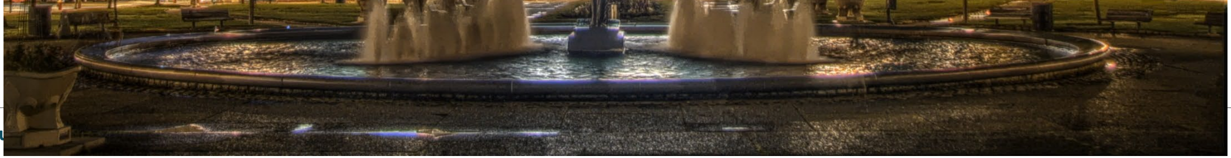
Sources: CMU 15-463

– Other methods for HDR imaging

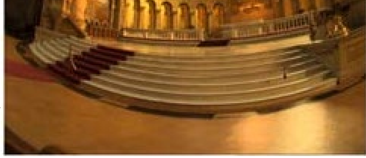
adaptation range of our eyes



Sources: CMU 15-463

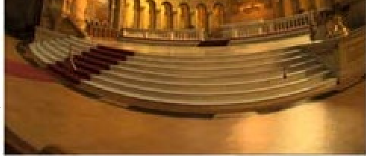


2. Merging: Combine them into a single HDR image



Sources: [CMU 15-463]

2. Merging: Combine them into a single HDR image



Sources: [CMU 15-463]

Sources: CMU 15-463

A brief note on ISO...

Sources: [CMU 15-463]

Sources: CMU 15-463

ISO 80 ISO 800 ISO 1600

Sources: [CMU 15-463]

Sources: CMU 15-463

4. Neutral density (ND) filters

Sources: CMU 15-463

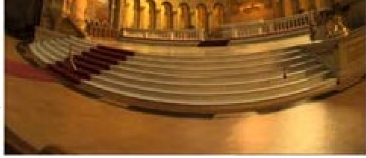
4. Neutral density (ND) filters

Sources: [CMU 15-463](CMU 15-463)

– Pros: works with strobe/flash
– Cons: not perfectly neutral (color shift), extra glass (interreflections, aberrations), need to touch camera (shake)

Sources: CMU 15-463

2. Merging: Combine them into a single HDR image



Sources: [CMU 15-463]

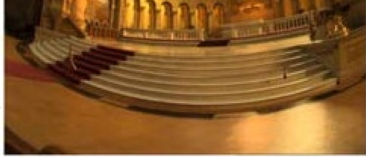
– Pros: works with strobe/flash
– Cons: not perfectly neutral (color shift), extra glass (interreflections, aberrations), need to touch camera (shake)

Sources: [CMU 15-463]

the metered exposure and +/- 2 stops around that.

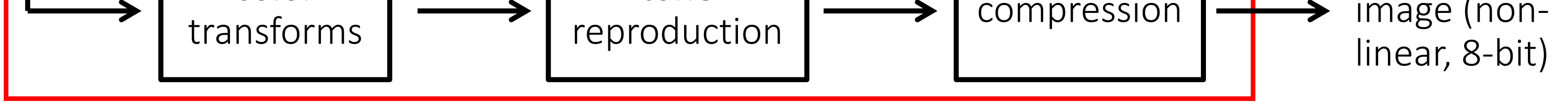
Sources: CMU 15-463

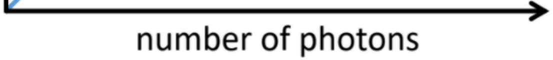
2. Merging: Combine them into a single HDR image

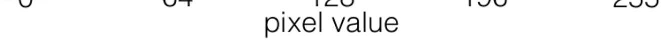


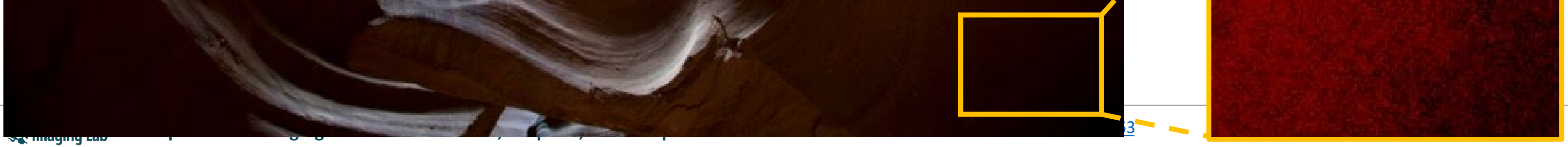
Sources: [CMU 15-463]


transforms
reproduction
compression
image (non-
linear, 8-bit)


transforms
reproduction
compression
image (non-
linear, 8-bit)


number of photons


pixel value

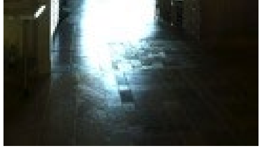
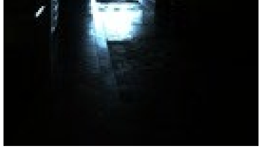
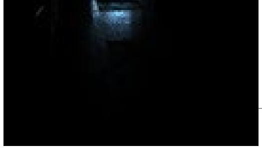


Sources: CMU 15-463

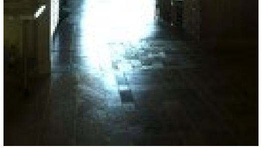
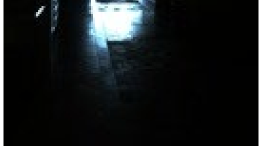
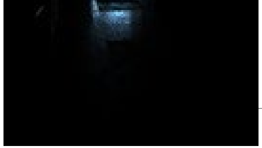
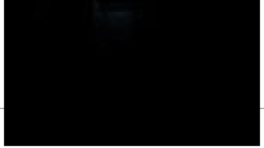
$$I_{linear}(x,y) = \text{clip}[\, t_i \cdot L(x,y) + \text{noise} \,]$$

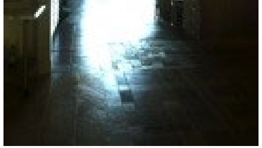
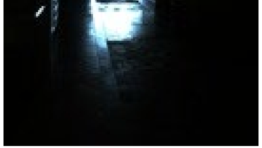
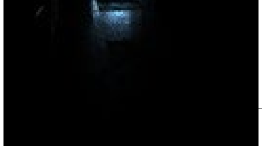
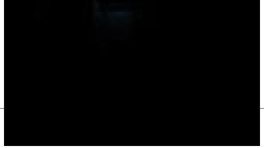
How can we merge these images into one?

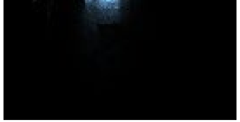
Sources: CMU 15-463

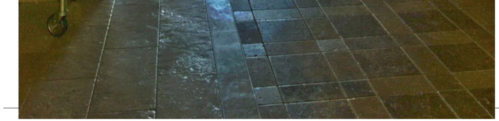











Sources: CMU 15-463

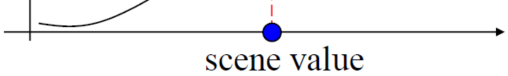
Sources: CMU 15-463

transforms

reproduction

linear, 8-bit)

Sources: CMU 15-463



Sources: CMU 15-463

Patches at bottom row have reflectance that increases linearly.

Different values correspond to patches of increasing reflected irradiance.

Sources: CMU 15-463

All points on (the white part of) the target have the same reflectance.

Different values correspond to images taken under increasing camera exposure.

Sources: [CMU 15-463]

Same scene irradiance, different camera exposure

Sources: CMU 15-463

$$I_{non\text{-}linear}(x,y) = f[\ I_{linear}(x,y)\ ]$$

Sources: [CMU 15-463]

$I_{non\text{-}linear}(x,y) = f[\, I_{linear}(x,y) \,]$

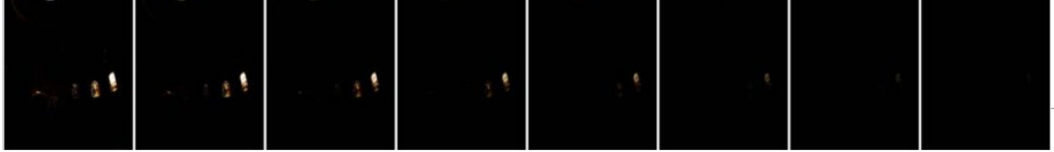
If we undo the non-linearity, we are back to I_{linear} as before...

f^{-1}

Sources: [CMU 15-463](CMU 15-463)

$I_{non\text{-}linear}(x,y) = f[\ I_{linear}(x,y)\ ]$ $I_{est}(x,y) = f^{-1}[\ I_{non\text{-}linear}(x,y)\ ]$

Sources: CMU 15-463



Same steps as in the RAW case.

Sources: CMU 15-463

Sources: CMU 15-463

HDR image (relative radiance) | spotmeter (absolute radiance at one point) | absolute radiance map

Sources: [CMU 15-463]

HDR image (relative radiance)

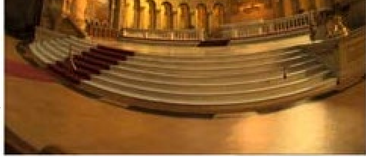
spotmeter (absolute radiance at one point)

absolute radiance map

Sources: CMU 15-463

Sources: CMU 15-463

2. Merging: Combine them into a single HDR image



Sources: [CMU 15-463]

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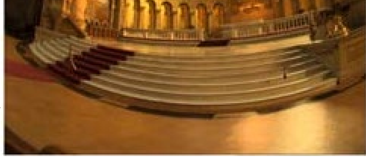
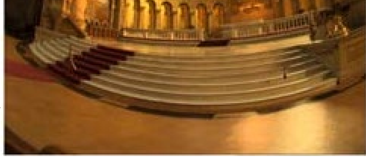


Sources: [CMU 15-463]

2. Merging: Combine them into a single HDR image



Sources: [CMU 15-463](CMU 15-463)

Sources: CMU 15-463

- Hybrid approaches (e.g., based on compressive sensing) & DL-based approaches

Sources: CMU 15-463

Sources: [CMU 15-463]

Sources: CMU 15-463

(a) Input images with corresponding weight maps (b) Fused result

Mertens, Tom, Jan Kautz, and Frank Van Reeth. "Exposure Fusion." *Computer Graphics and Applications, Pacific Conference on*. IEEE Computer Society, 2007.

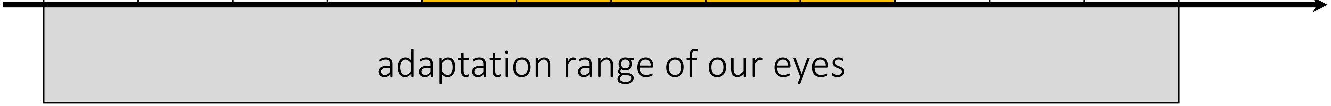
[Mertens 2007] http://ntp-0.cs.ucl.ac.uk/staff/j.kautz/publications/exposure_fusion.pdf

Serrano, Ana, Felix Heide, Diego Gutierrez, Gordon Wetzstein, and Belen Masia. "Convolutional sparse coding for high dynamic range imaging." In *Computer Graphics Forum*, 2016.

[Serrano 2016] http://webdiis.unizar.es/~bmasia/pubs/eg2016/project_page_CSCHDR.html

Sources: CMU 15-463

Sources: CMU 15-463



Sources: [CMU 15-463]

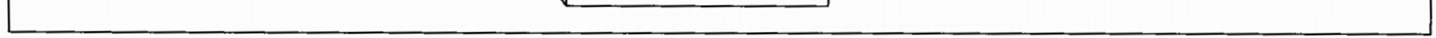
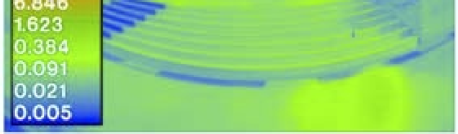
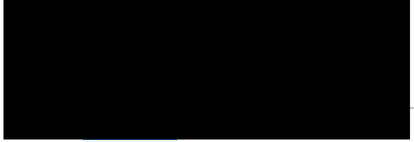
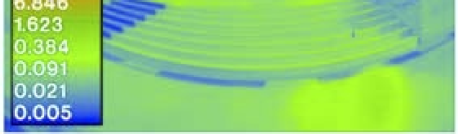


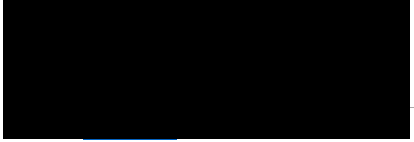
Figure 1. The tone reproduction problem: What operator will cause a close match between real-world and display brightness sensations?

a set of output values to approximate the appearance of an HDR image in a medium that has low dynamic range.


1.623
0.384
0.091
0.021
0.005




1.623
0.384
0.091
0.021
0.005



- Perceptually motivated, as it approximates our eye's response curve.

Sources: [CMU 15-463]

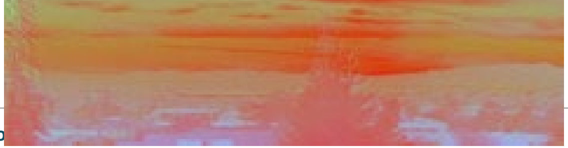
 

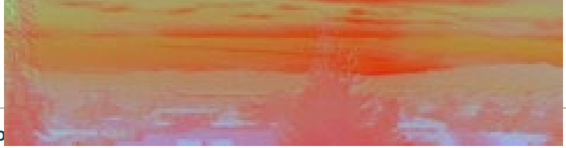
Sources: CMU 15-463



Sources: CMU 15-463

Sources: [CMU 15-463]





Sources: [CMU 15-463]

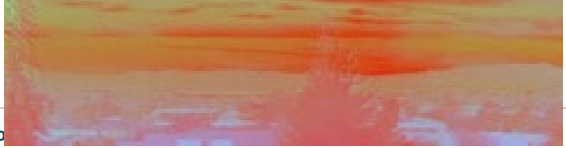
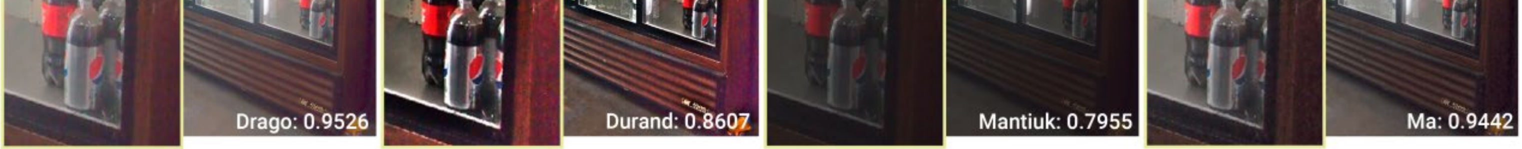


image has more contrast, which is often critical in contrast-deprived HDR images. This method also allows changing the tonal curve to better suit the image.

Sources: [CMU 15-463]


Drago: 0.9526
Durand: 0.8607
Mantiuk: 0.7955
Ma: 0.9442

- We know how to display HDR images (tonemapping)

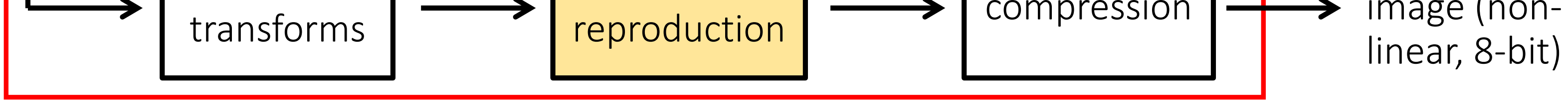
Sources: [CMU 15-463](CMU 15-463)

Lightning

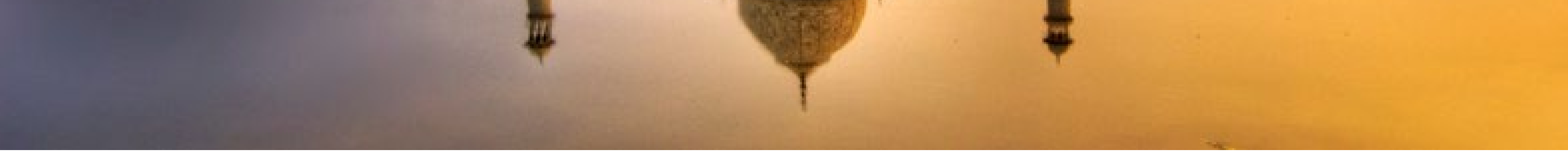
combination of 1-3, depending on the imaging scenario.

In consumer photography, HDR photography includes step 4 (tonemapping).

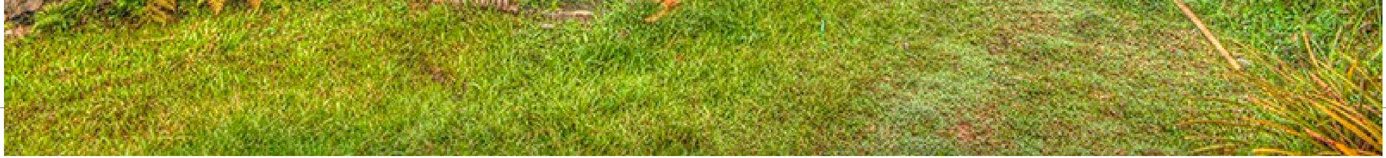
Sources: [CMU 15-463]

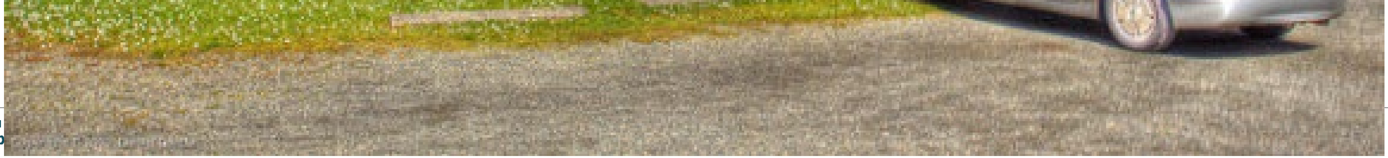

transforms
reproduction
compression
image (non-linear, 8-bit)

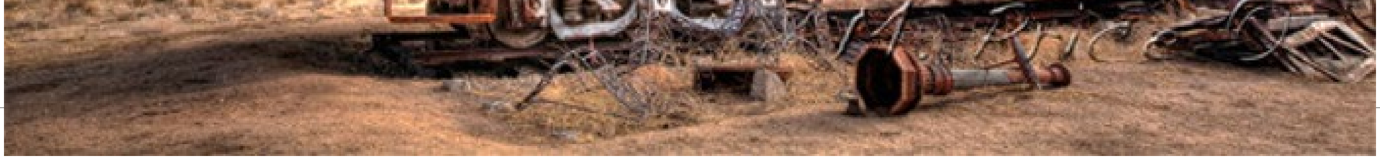
Sources: CMU 15-463



Sources: CMU 15-463







Sources: CMU 15-463

SIGGRAPH and SIGGRAPH Asia conferences.

the demosaicked RGB (or YUV) frames produced by hardware Image Signal Processors (ISPs) common on mobile platforms. This gives us more bits per pixel and allows us to circumvent the ISP's unwanted tone mapping and spatial denoising. Third, we use a novel FFT-based alignment algorithm and a hybrid 2D/3D Wiener filter to denoise and merge the frames in a burst. Our implementation is built atop Android's Camera2 API, which provides per-frame camera control and access to raw imagery, and is written in the Halide domain-specific language (DSL). It runs in 4 seconds on device (for a 12 Mpix image), requires no user intervention, and ships on several mass-produced cell phones.

SA '16 Technical Papers, December 05 - 08, 2016, Macao
ISBN: 978-1-4503-4514-9/16/12
DOI: http://dx.doi.org/10.1145/2980179.2980254

Sources: [CMU 15-463]

- Levoy, "Extreme imaging using cell phones," http://graphics.stanford.edu/talks/seeinthedark-public-15sep16.key.pdf
  A set of slides by Marc Levoy on the challenges of HDR imaging and modern approaches for addressing them.

Sources: CMU 15-463