
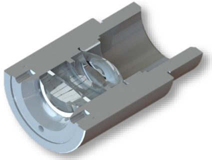



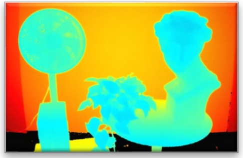


Computational Imaging

Lecture 06: High Dynamic Range Imaging and Tonemapping

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Today's Topic

- Common Image File Formats
  - Raster File Format
  - Vector File Format
- High Dynamic Range Imaging
- Tone Mapping
- Classical Methods
  - Night Sight "look"
  - Burst Alighment
- Finish Pipeline

Common Image File Formats

Raster File Formats

Made up of a set grid of dots called pixels

➢TIFF or Tagged Image File (.tif, .tiff)
Compression: Lossless - no compression. Very high-quality images.
Best For: High quality prints, professional publications, archival copies
Special Attributes: Can save transparencies

➢BMP or Bitmap Image File (.bmp)
Compression:None
Best For: High quality scans, archival copiess

➢Joint Photographic Experts Groups, JPEG (.jpg, .jpeg)
Compression: Lossy - some file information is compressed or lost
Best For: Web Images, Non-Professional Printing, E-Mail, Powerpoint
Special Attributes: Can choose amount of compression when saving in image editing programs like Adobe Photoshop or GIMP.

Raster File Formats

- GIF or Graphics Interchange Format (.gif)

Compression: Lossless - compression without loss of quality; 256 colors
Best For: Web Images
Special Attributes: Can be Animated, Can Save Transparency

- PNG or Portable Network Graphics (.png)

Compression: Lossless - compression without loss of quality; 16m colors
Best For: Web Images
Special Attributes: Save Transparency

- RAW Image Files (.raw, .cr2, .nef, .orf, .sr2, and more)

Compression: None
Best For: Photography
Special Attributes: Saves metadata, unprocessed, lots of information

- EXR or OpenEXR (.exr)

Compression: None; **Zip**(per scanline,16 scanline blocks); RLE; **PIZ**; PXR24. etc
Color Depth: 16/32bit floats; 32bit interger
Special Attributes:HDR, multi-channel

Vector File Formats

- EPS or Encapsulated PostScript (.gif)

Compression: None - uses vector information
Best For: Vector artwork, illustrations (Adobe Illustrator or CorelDRAW)
Special Attributes: Saves vector information

- PDF or Portable Document Format (.pdf)

Compression: None - uses vector information
Best For: Display/Print documents and graphics
Special Attributes: PDF is a near universal standard

- SVG or Scalable Vector Graphics (.svg)

Compression: Lossy - some file information is compressed or lost
Best For: Web
Special Attributes: Ban be edited, searched, indexed, scaled and compressed

High Dynamic Range Imaging

-4 stops

Credit: wikipedia

-2 stops

Credit: wikipedia

2 stops

Credit: wikipedia

2 stops

Credit: wikipedia

HDR contrast reduction (scaling)

Credit: wikipedia

HDR local tone mapping

Credit: wikipedia

High Dynamic Range Imaging (HDRI)

Problems:

- Sensors have a limited full well capacity, pixels saturate for higher electron count
- Non-zero noise floor and ADC quantization further reduce precision

Terminology:

- Dynamic range: ratio between brightest and darkest value
- Quantization (i.e., precision) within that range is equally important
  - →from 8 bits (256 values) to 32 bits floating point

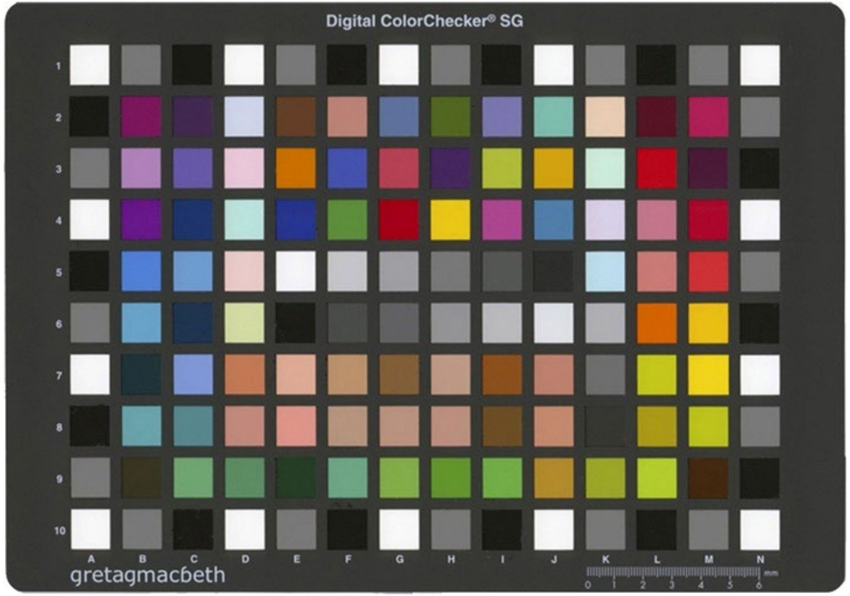
Credit: https://www.princetoninstruments.com/learn/camera-fundamentals/full-well-capacity-pixel-saturation

HDRI – Overview

- Estimate camera response curve
- Capture multiple low dynamic range (LDR) exposures
- Fuse LDR images into 32 bit HDR image
- Possibly convert to absolute radiance (global scaling)

HDRI – Estimating the Response Curve

- Not required when working with linear RAW images
- Easiest option: use calibration chart



HDRI – Estimating the Response Curve

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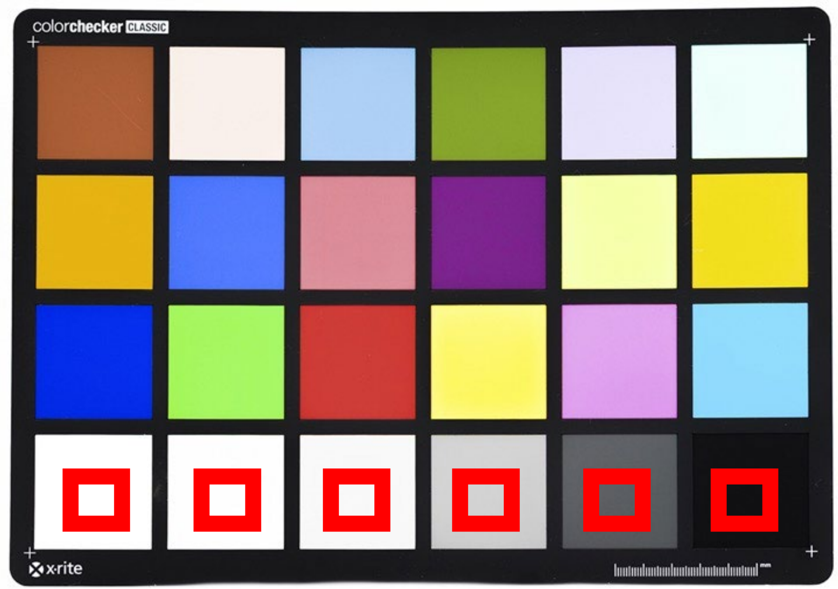
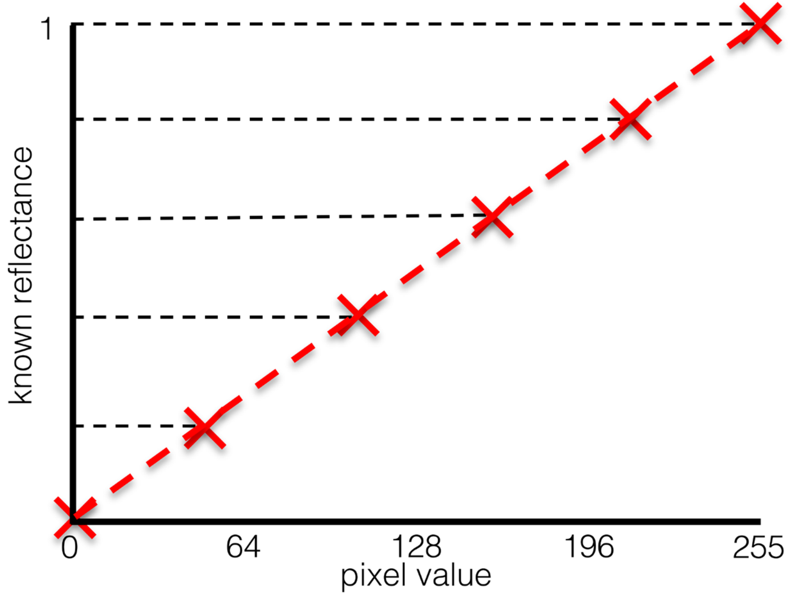
- Not required when working with linear RAW images
- Easiest option: use calibration chart



linear RAW



HDRI – Estimating the Response Curve

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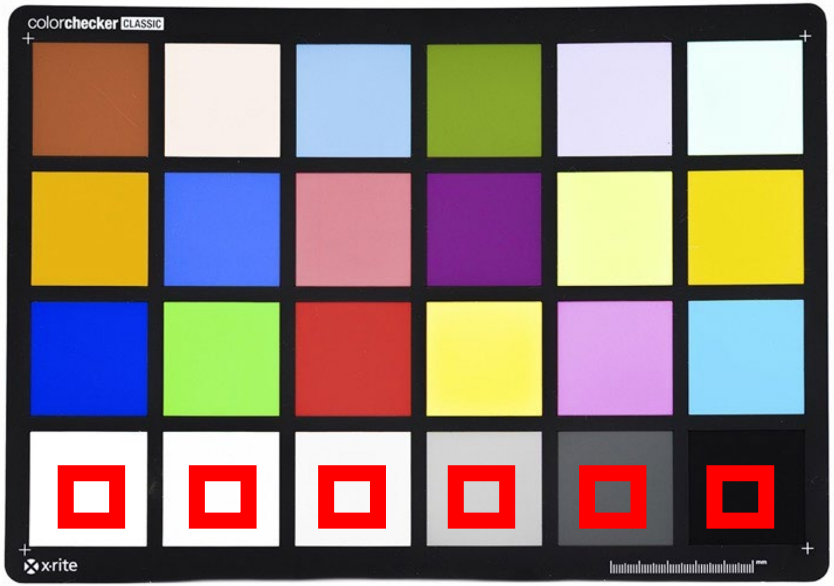
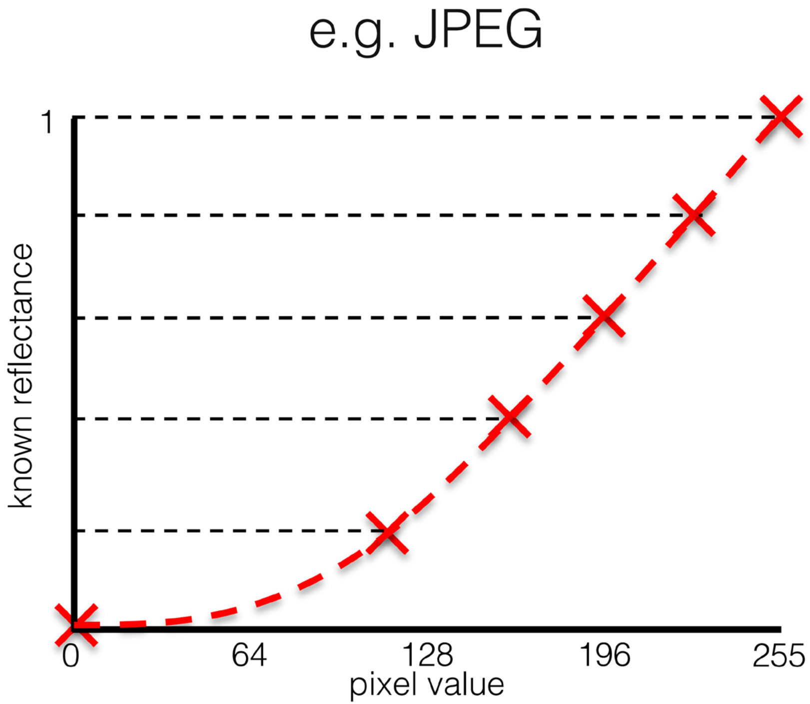


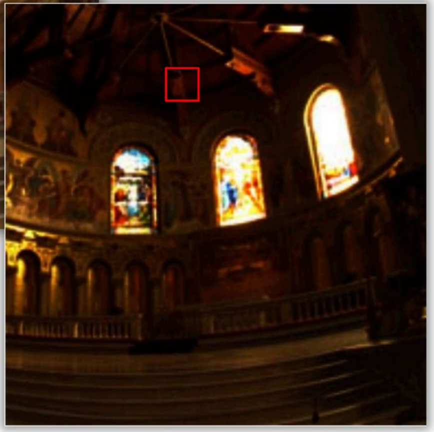


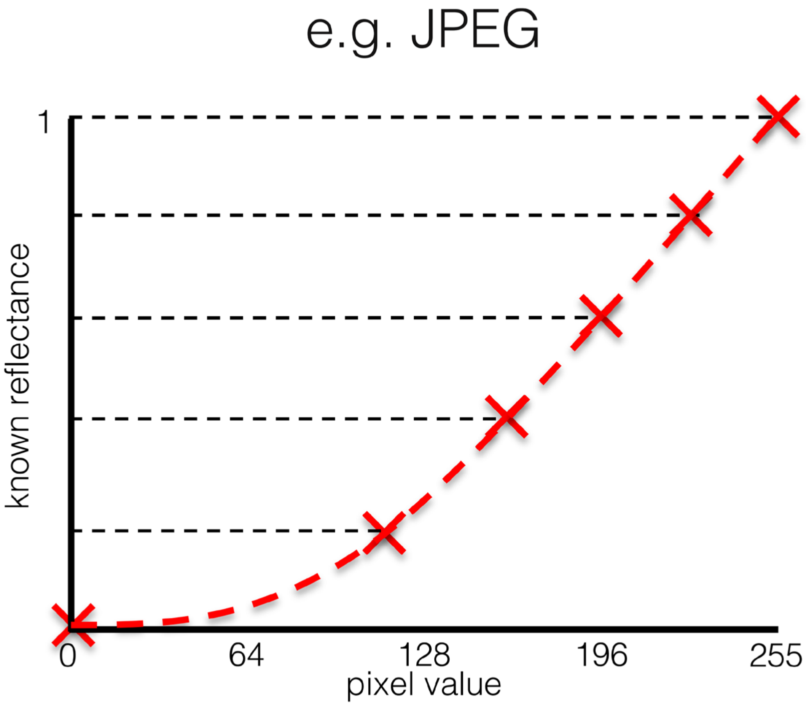
HDRI – Linearizing LDR Exposures

- Capture exposure, apply lookup table

I

$I_{lin} = f^{-1}(I)$





HDRI – Merging LDR Exposures

- Start with LDR image sequence I_i (only exposure time t_i changes)
- Individual exposure is: , $I_i = f\,(t_i X)$, f is camera response function

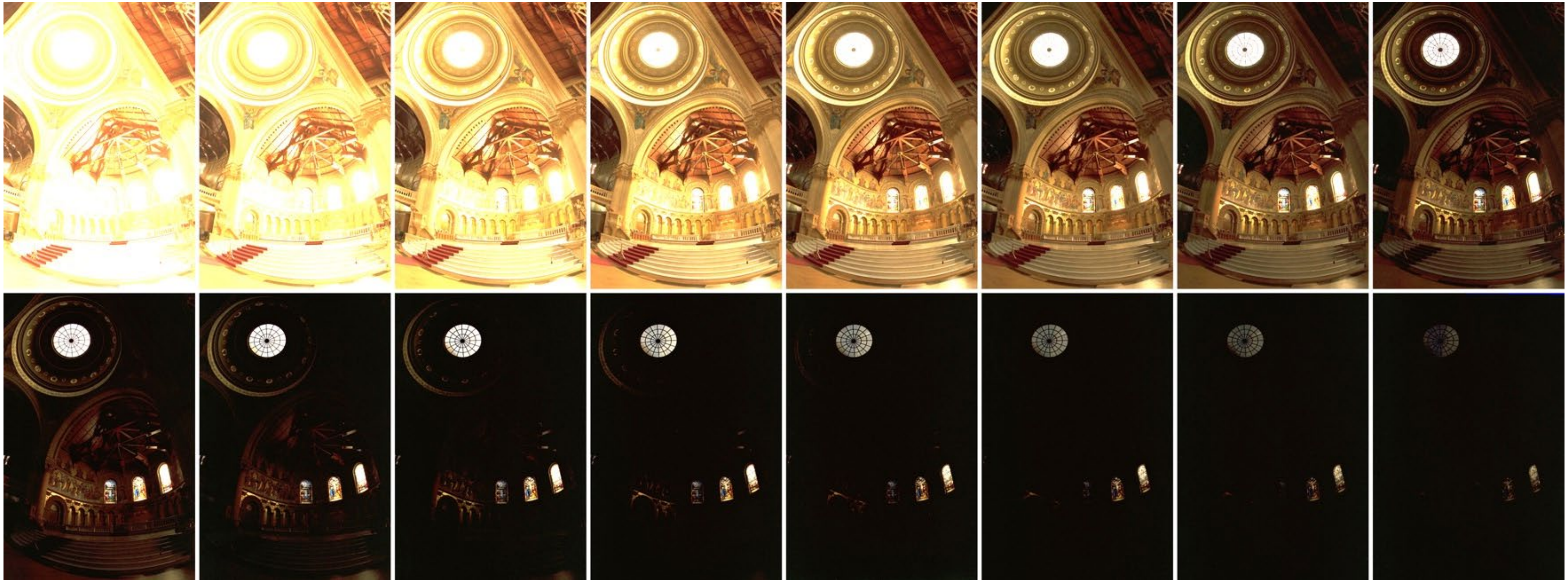


Image credit: Debevec & Malik, 1997

HDRI – Merging LDR Exposures

- Undo the camera response: $I_{lini} = f^{-1}(I_i)$
  - e.g., gamma function $f(I) = I^{1/\gamma} \longrightarrow f^{-1}(I) = I^{\gamma}$

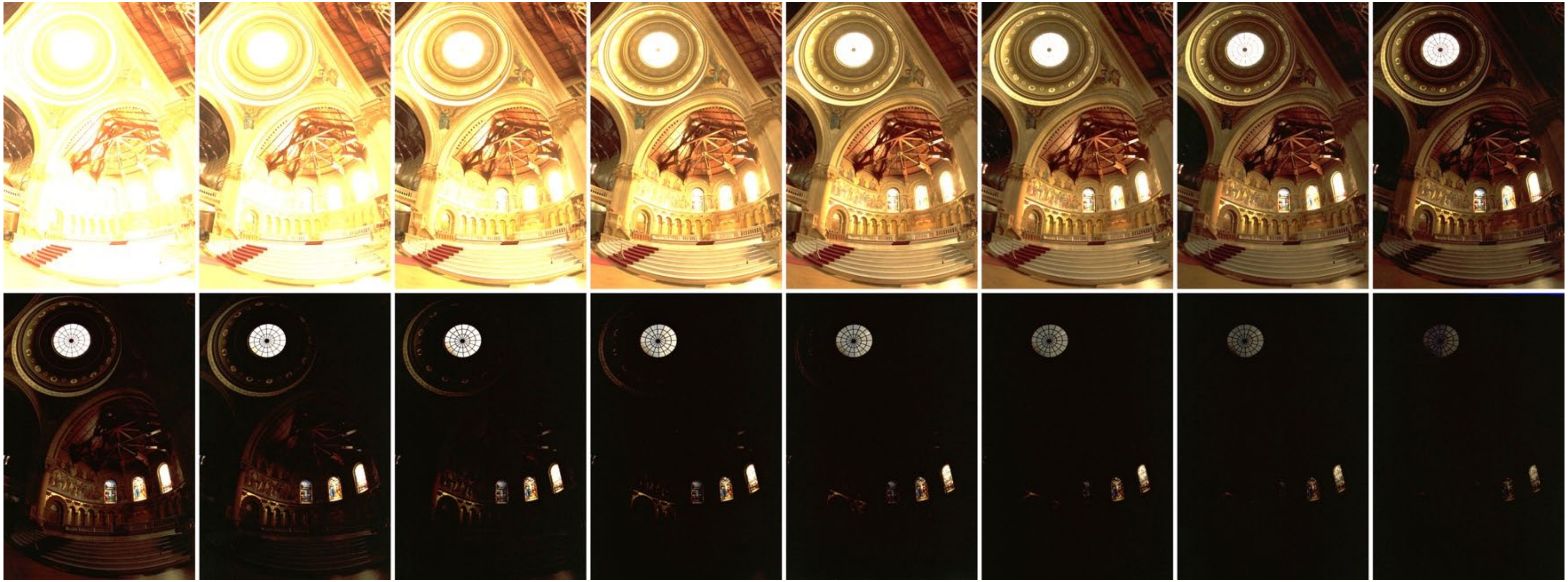


Image credit: Debevec & Malik, 1997

HDRI – Merging LDR Exposures

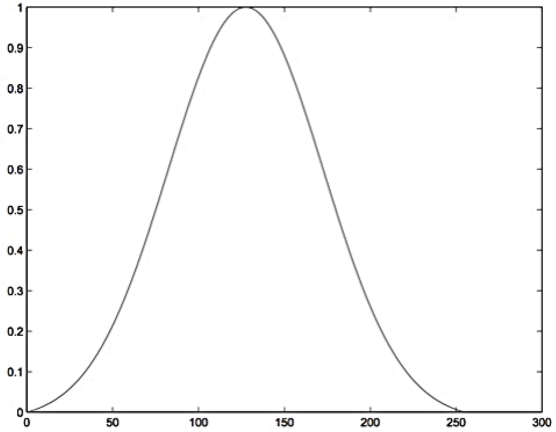
- Compute a weight (confidence) that a pixel is well-exposed

  → (close to) saturated pixel = not confident,

  → pixel in center of dynamic range = confident!

$$w_{ij} = exp(-4\frac{(I_{lin_{ij}} - 0.5)^2}{0.5^2})$$

or mean pixel value,
e.g. 127.5 if I in [0, 255]



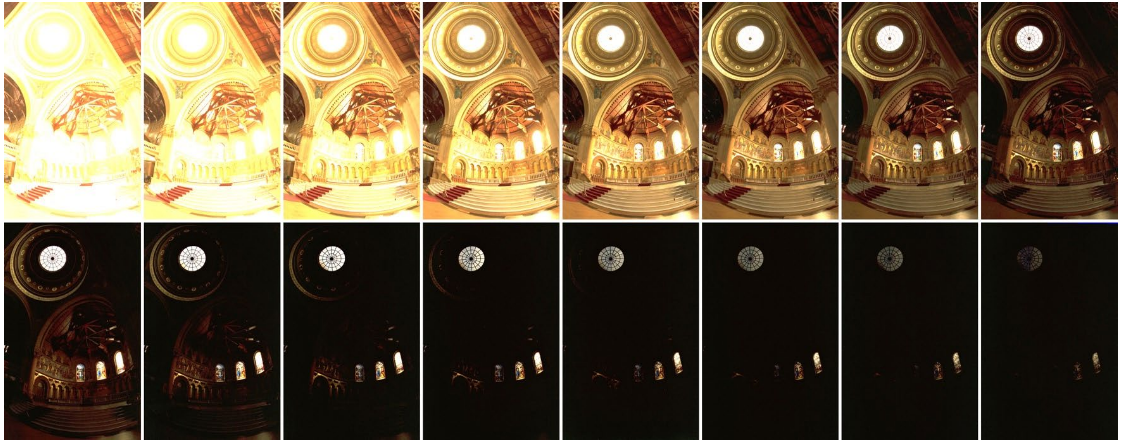


Image credit: Debevec & Malik, 1997

HDRI – Merging LDR Exposures

- Compute per-color-channel-per-LDR-pixel weights

$$w_{ij} = exp(-4\frac{(I_{lin_{ij}} - 0.5)^2}{0.5^2})$$

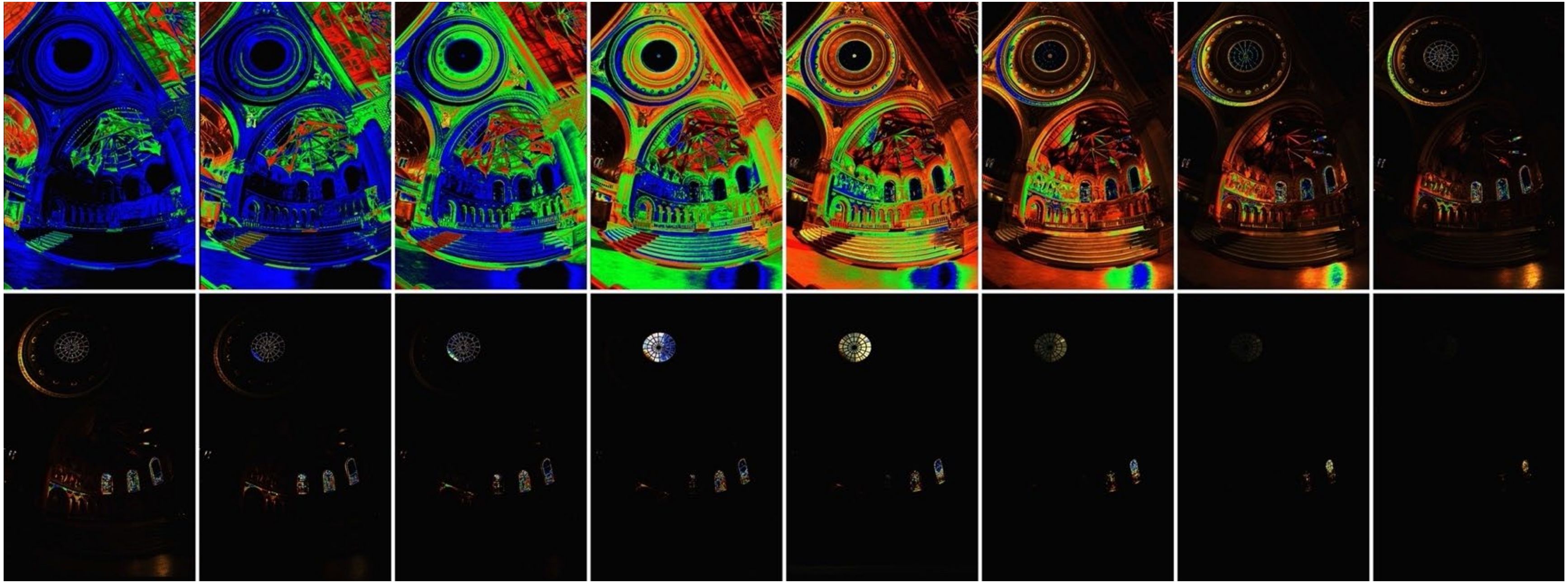


Image credit: Debevec & Malik, 1997

HDRI – Merging LDR Exposures

- Define least-squares objective function in log-space

  → perceptually linear:

$$\underset{X}{\text{minimize}} \quad O = \sum_i w_i \left(\log\left(I_{lin_i}\right) - \log\left(t_i X\right) \right)^2$$

- Equate gradient to zero:

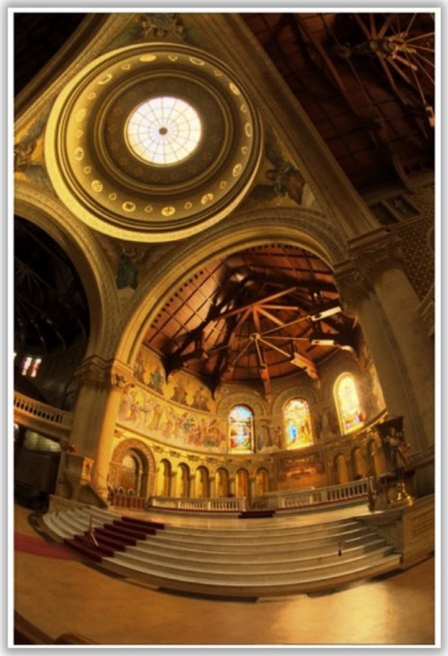
$$\frac{\partial O}{\partial \log(X)} = -2 \sum_i w_i \left(\log\left(I_{lin_i}\right) - \log\left(t_i\right) - \log(X) \right) = 0$$

- Gives:

$$\boxed{\hat{X} = \exp\left(\frac{\sum_i w_i \left(\log\left(I_{lin_i}\right) - \log\left(t_i\right) \right)}{\sum_i w_i} \right)}$$

HDRI – Relative v Absolute Radiance

- LDR to HDR only gives relative radiance
- Scale by reference radiance to get absolute!



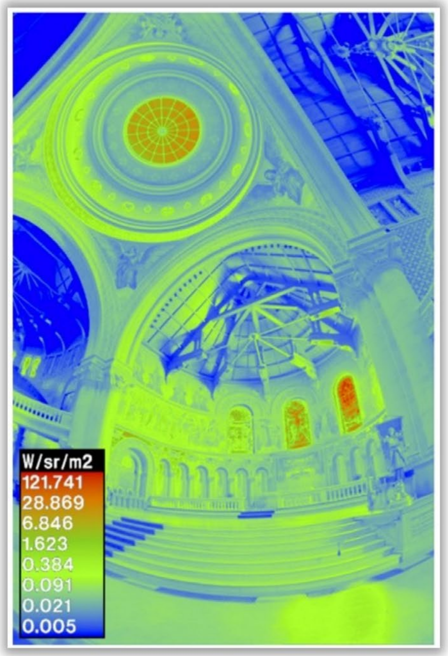


Image credit: Debevec & Malik, 1997

Tone Mapping

HDRI – Tone Mapping

- Problem: how to display a 32 bit HDR image on an 8 bit LDR display?

- Solution: tone mapping, i.e., “scale” into luminance range of display (or 0-255), while preserving high-contrast image details

Saturation

- Sun overexposed
- Foreground too dark

Credit: Durand and Dorsey, 2002

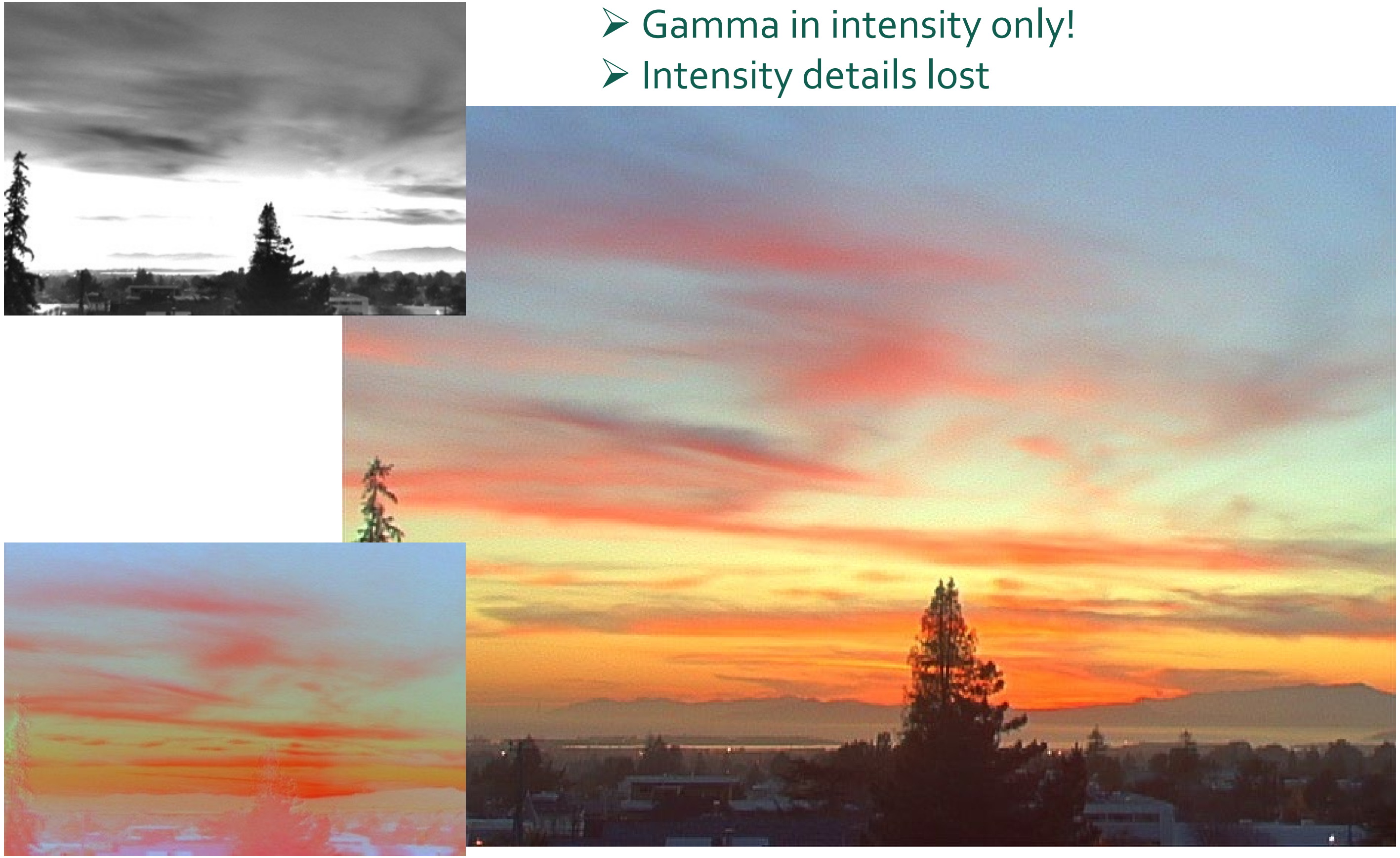
Tone Mapping w/ Simple Gamma

- Gamma correction: $I = I^{\gamma}$
- Colors are washed out

Credit: Durand and Dorsey, 2002

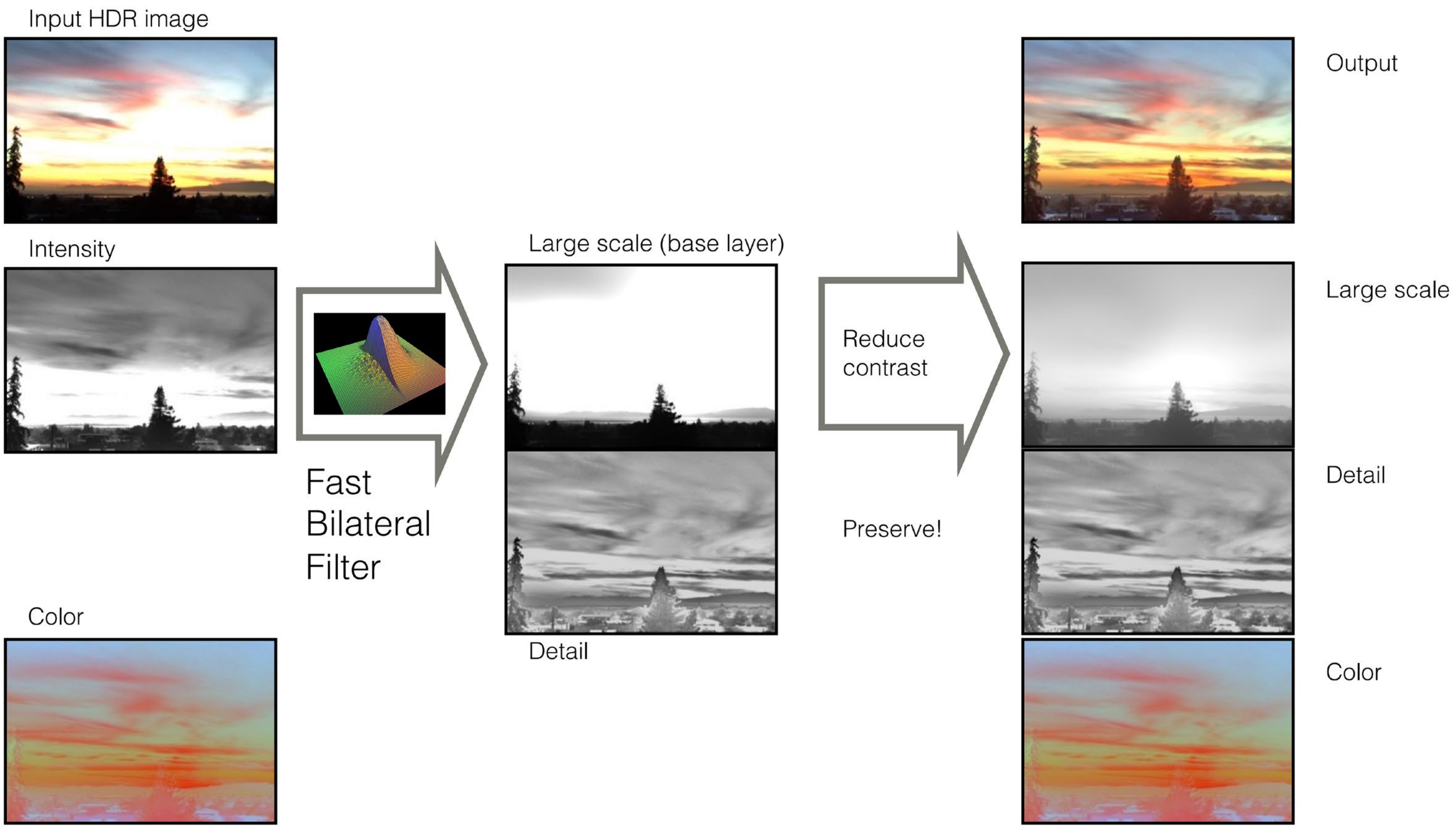
Tone Mapping w/ Simple Gamma

- Gamma in intensity only!
- Intensity details lost



Credit: Durand and Dorsey, 2002

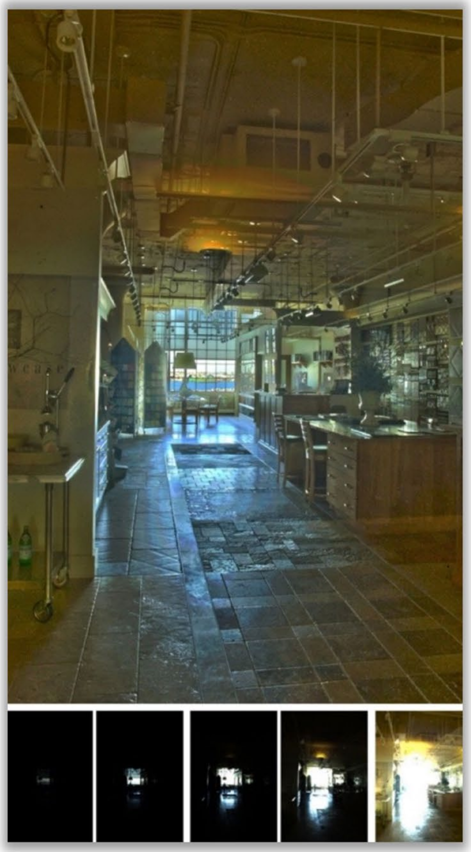
Tone Mapping w/ Bilateral Filter



Credit: Durand and Dorsey, 2002

Tone Mapping w/ Bilateral Filter





Credit: Durand and Dorsey, 2002

Tone Mapping w/ Local Laplacian Filters

- Many many more and more complicated tone mapping algorithms out there (too many to discuss here)
- Local Laplacian Filters is one of the state-of-the-art approaches

(a) input HDR image tone-mapped with a simple gamma curve (details are compressed)

(b) our pyramid-based tone mapping, set to preserve details without increasing them

(c) our pyramid-based tone mapping, set to strongly enhance the contrast of details

Credit: Paris et al., 2011

Classical Methods

Night Sight “Look”

- Too bright: turns night time into day and can create overexposed halos. May also over-brighten noise.
- Too dark: hides shadow detail.

→Carefully tuned a tone curve that suppresses noise in the darks, reveals details in the shadows, exposes the midtones well, and preserves highlights.

Different tone curves applied to the same evening scene

Too bright (looks likedaytime)

Too dark (details are not visible)

Night Sight "Look"

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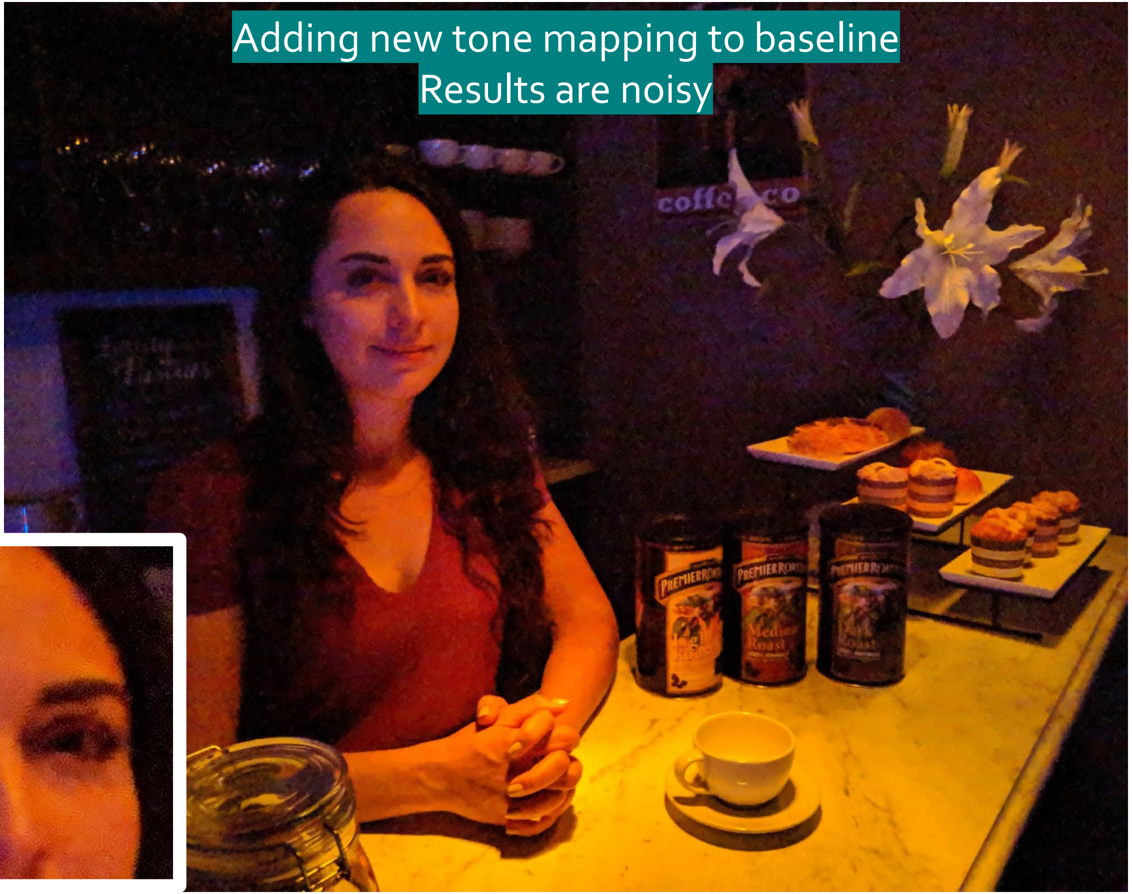
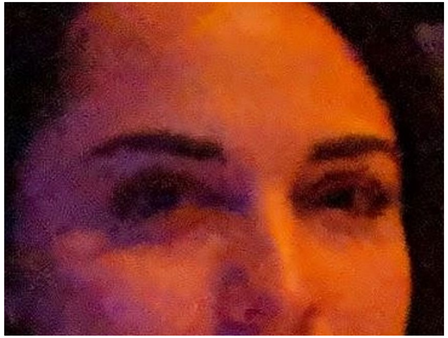
Baseline system(HDR+, Hasinoff et al, 2016)
13 frames,exposure time: 1/15 s

Night Sight “Look”





Credit: Google

Night Sight “Look”

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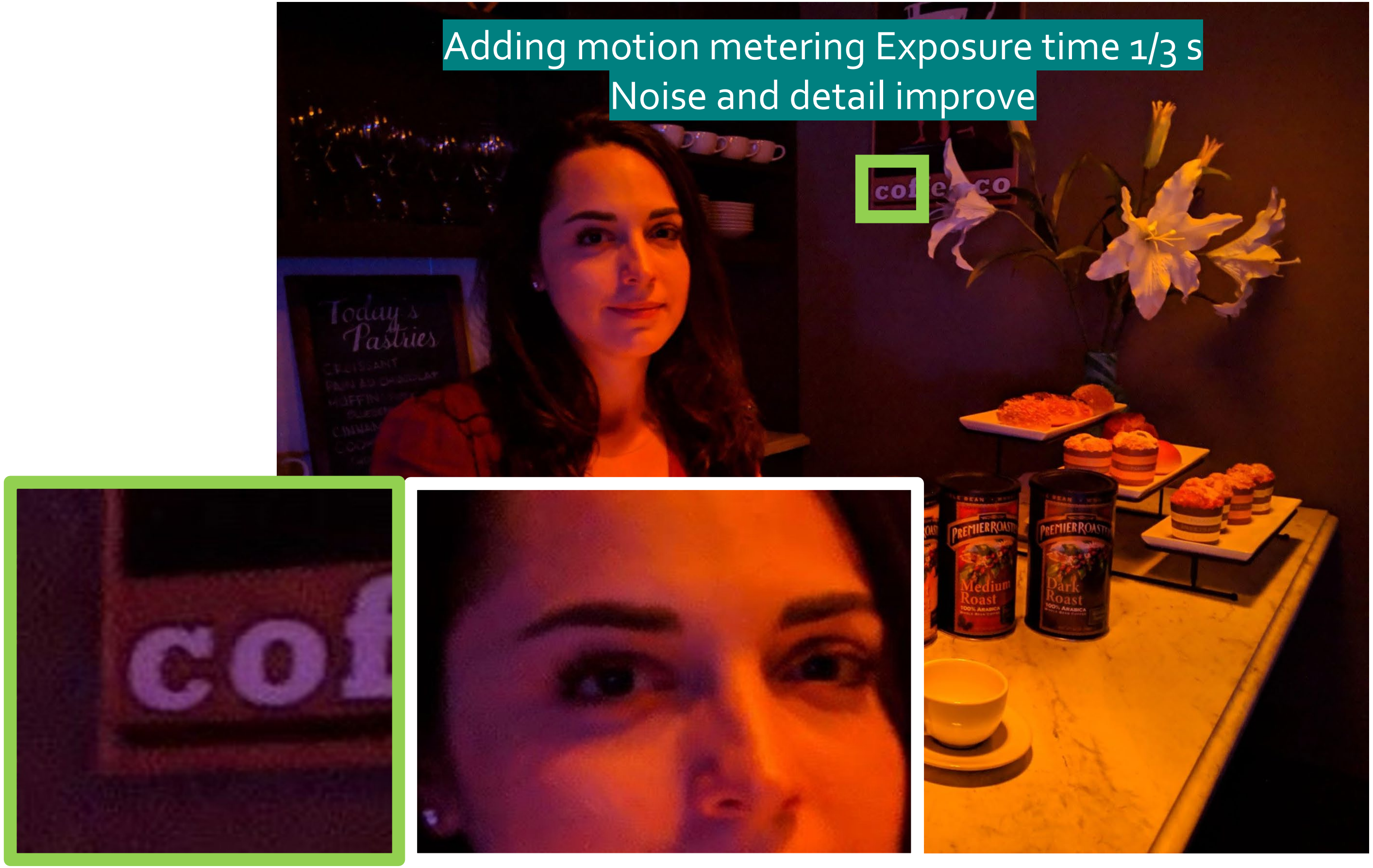
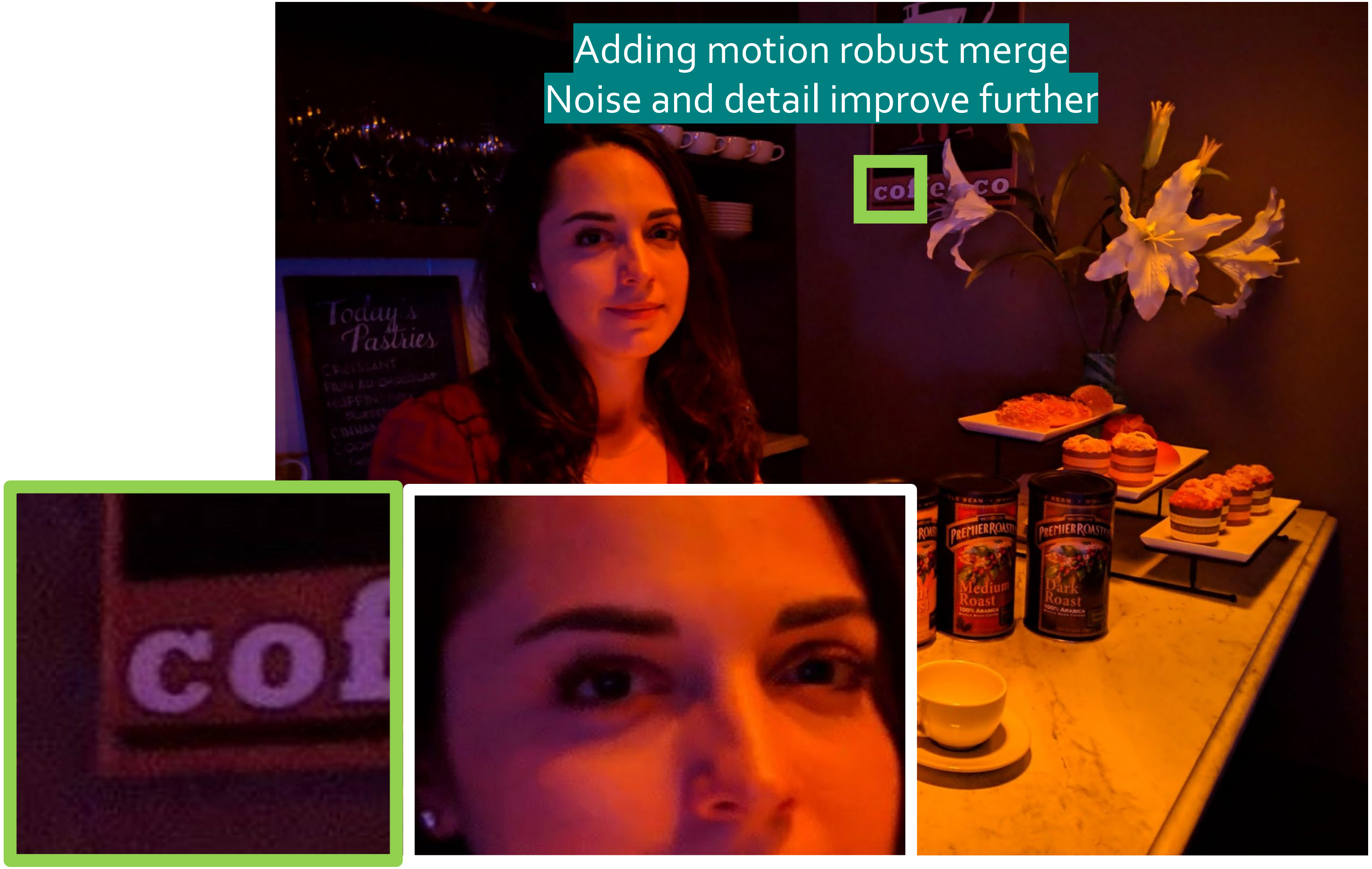


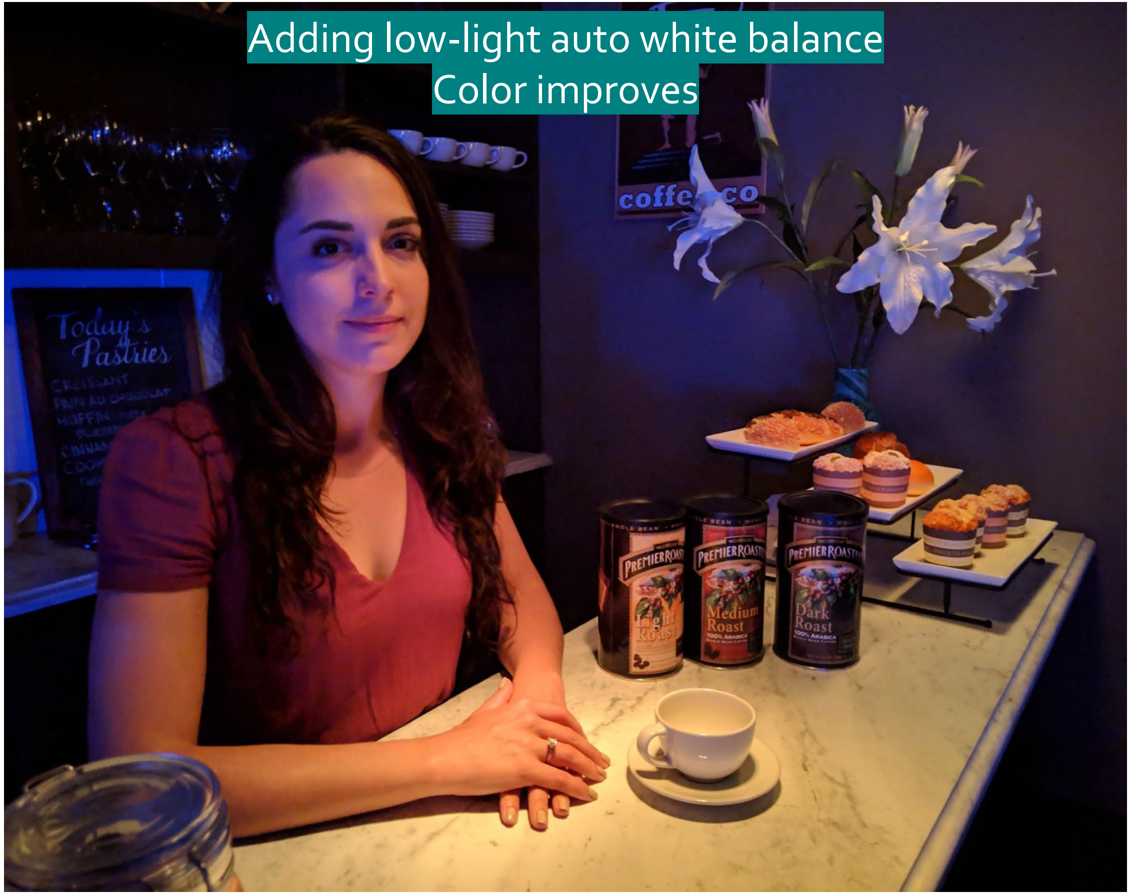
Credit: Google

Night Sight “Look”



Credit: Google

Night Sight "Look"



Credit: Google

Side by Side Comparison

HDR+, Hasinoff et al 2016

Night Sight "Look"

Credit: Google

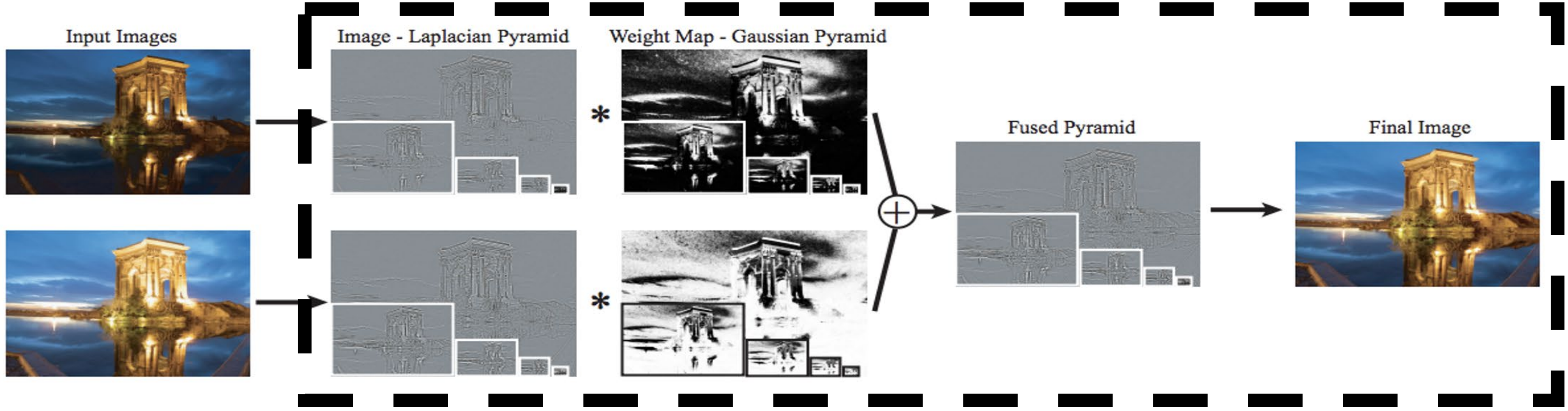
Side by Side Comparison

HDR+, Hasinoff et al 2016

Night Sight "Look"

Credit: Google

Classical Local Tonemapping

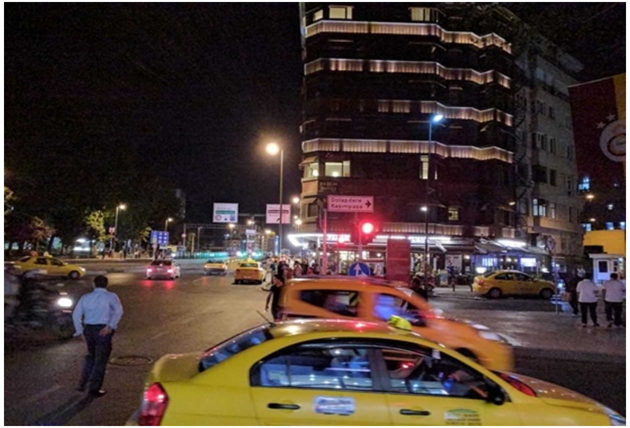


- Synthetic exposures from AE
    - Single merged input image
    - Digital gains
- Automatically set tuning parameters

Credits: pyramid blending for HDR tonemapping
[Mertens et al., 2007]
[Paris et al. 2011]
[Aubry et al. 2014]

Burst Alignment

input burst



reference frame input burst

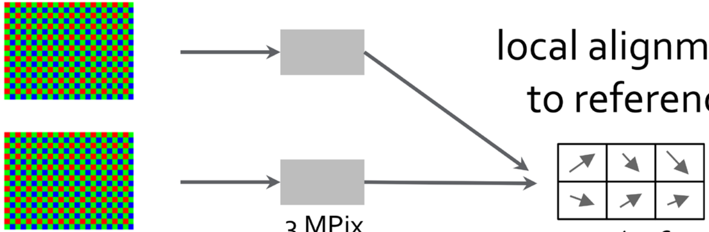
raw

R+Gr+Gb+B

reference frame

alternate frame

local alignment to reference

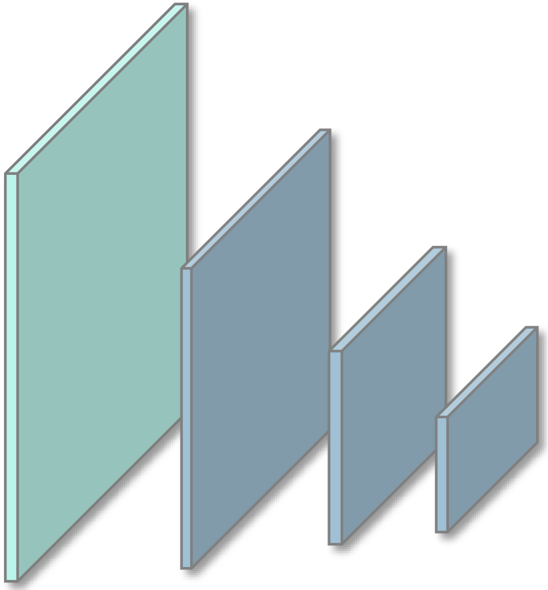


12 MPix

3 MPix

120x90 (or 60x45)

Coarse to Fine Alignment



metric	search range	subpixel?
L2	9x9	yes
L1	3x3	no

- ➢ 4 pyramid levels
- ➢ Upsample with multiple hypotheses [Tao et al., 2012]

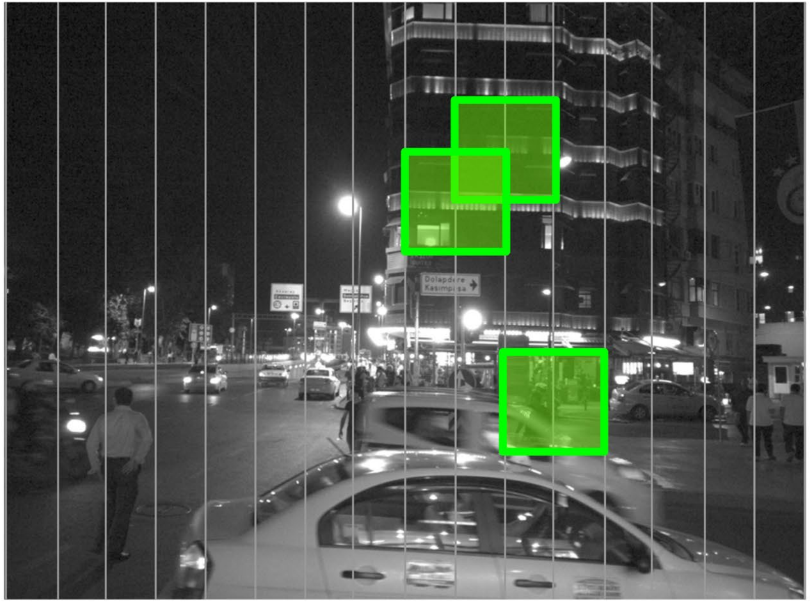
Example Alignment

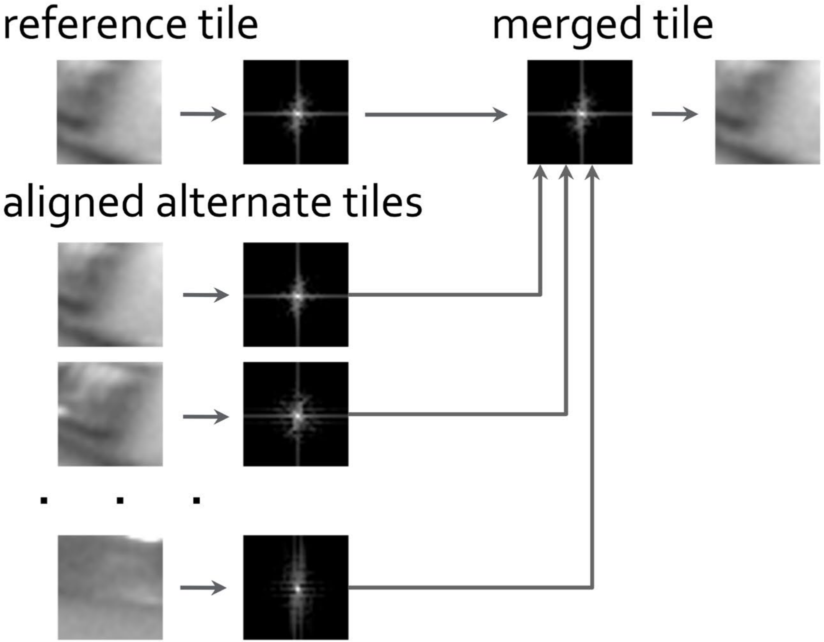
Reference frame

Aligned to reference

Tiled Fourier-based Merge

- Divide into 16x16 or 32x32 tiles
- 50% overlap - every pixel covered by 4 tiles
- Merge in Fourier domain





Robust Per-frequency Merge

- Reference frame

$$T_0$$

- Aligned average

$$\frac{1}{N}\sum T_i$$

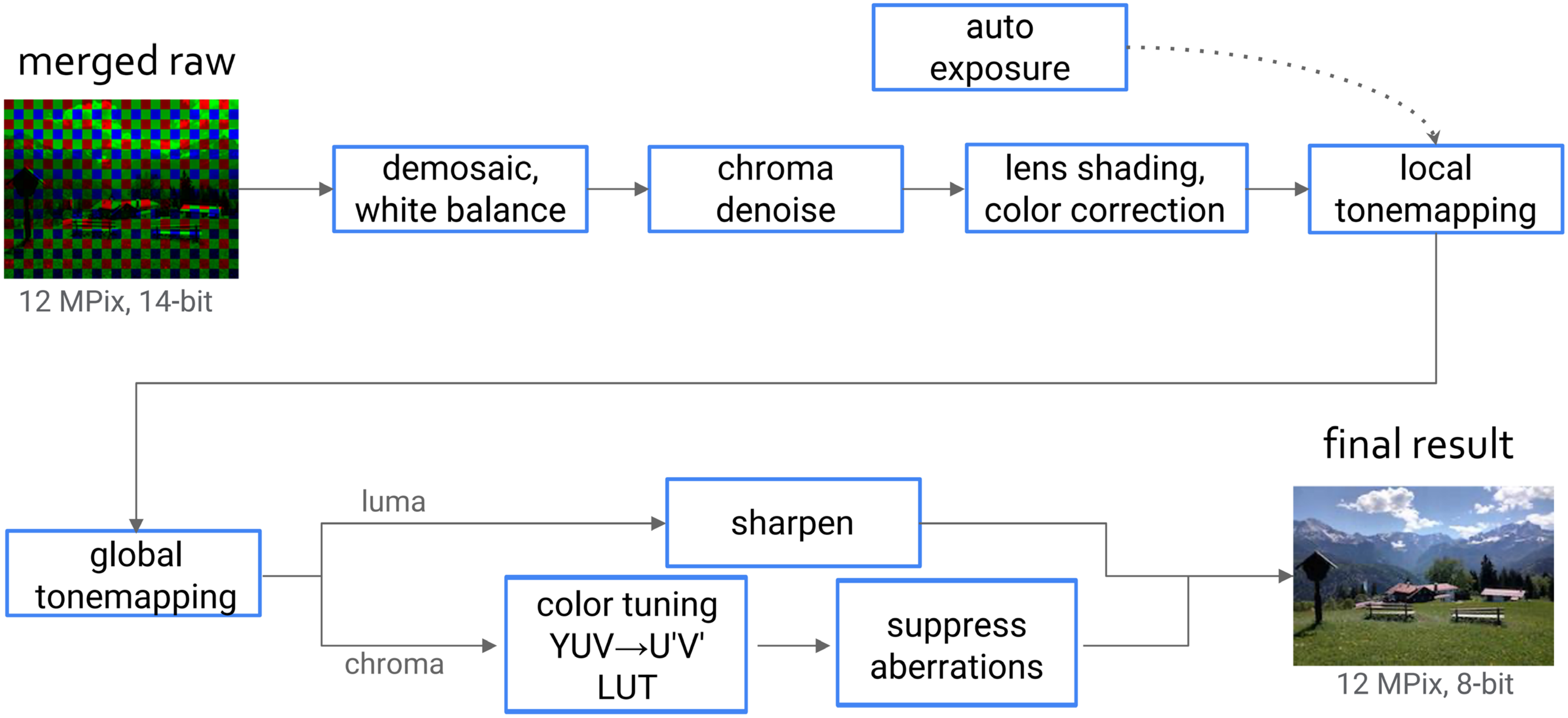
- Robust pairwise merge

$$\frac{1}{N}\sum(1-A_i)\,T_i + A_i\,T_0$$

$$A_i = \frac{||T_0 - T_i||^2}{||T_0 - T_i||^2 + k\sigma^2} \in [0, 1]$$

Finish Pipeline

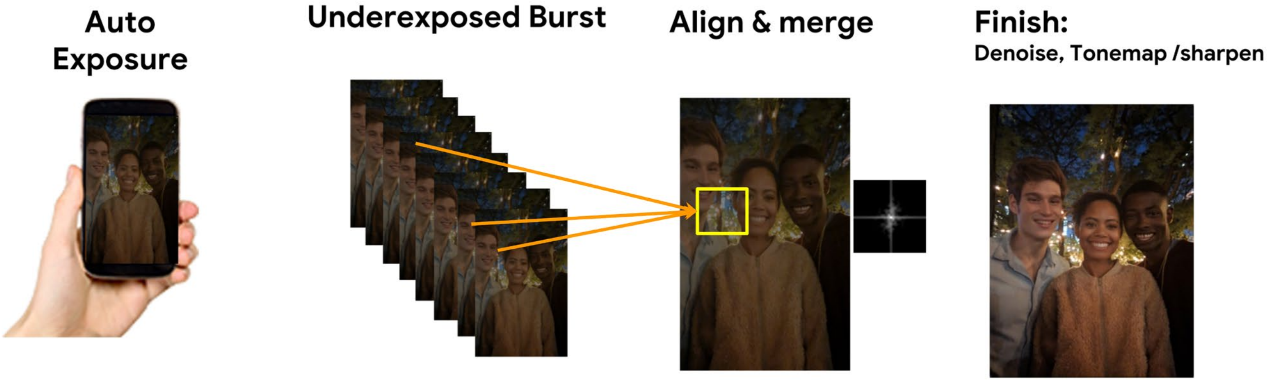
Finish Pipeline



Credit: Google

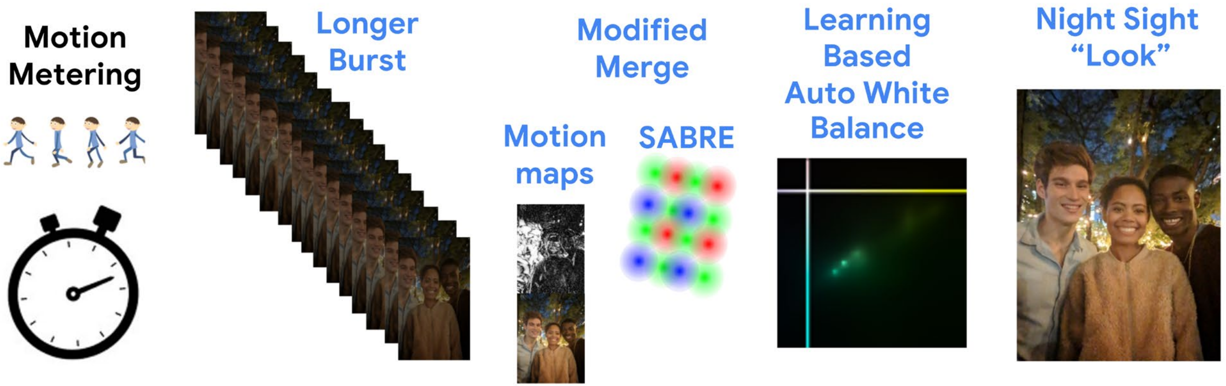
Finish Pipeline

HDR+



Burst photography for high dynamic range and low-light imaging on mobile cameras,
Samuel W. Hasinoff, Dillon Sharlet, Ryan Geiss, Andrew Adams, Jonathan T. Barron, Florian Kainz, Jiawen Chen, Marc Levoy , SIGGRAPH Asia 2016

Night Sight



Credit: Google

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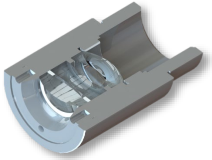



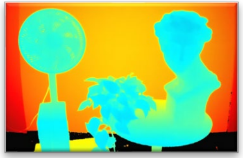
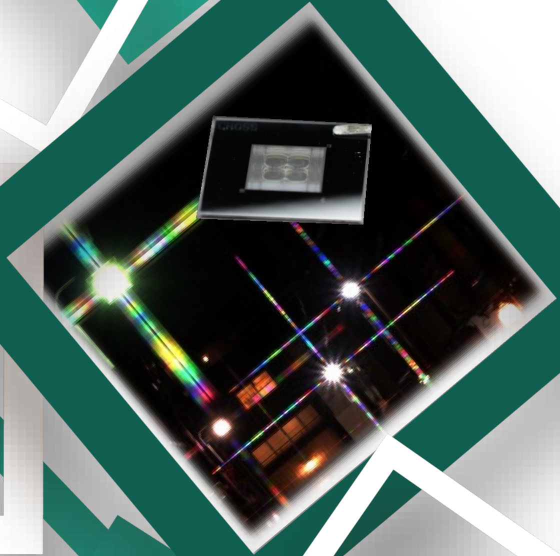

Thank You!

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