High Dynamic Range (HDR) Imaging

Based on slides by Rick Skarbez

Movie:
HDR Far Cry

Available online at:
http://farcry.filefront.com/file/Far_Cry_HDR_video;54636

Dynamic Range

- Computer monitors and digital cameras have limited dynamic range
  - 8 bits [0,255] to 12 bits [0,4095]
- The real world has MUCH greater dynamic range
  - The difference between sunlight and moonlight is on the order of 10000x
  - Some scenes can contain even a wider range

Capturing Greater Dynamic Range

- To capture this greater dynamic range with digital cameras, we can capture multiple <u>bracketed</u> images
  - <u>Bracketing</u> means taking multiple pictures of the same scene with different camera settings
    - *i.e.* different exposure times or aperture sizes
- To capture it with computer graphics, can just do lighting calculations with more bits

Stanford Chapel

Shortest Exposure

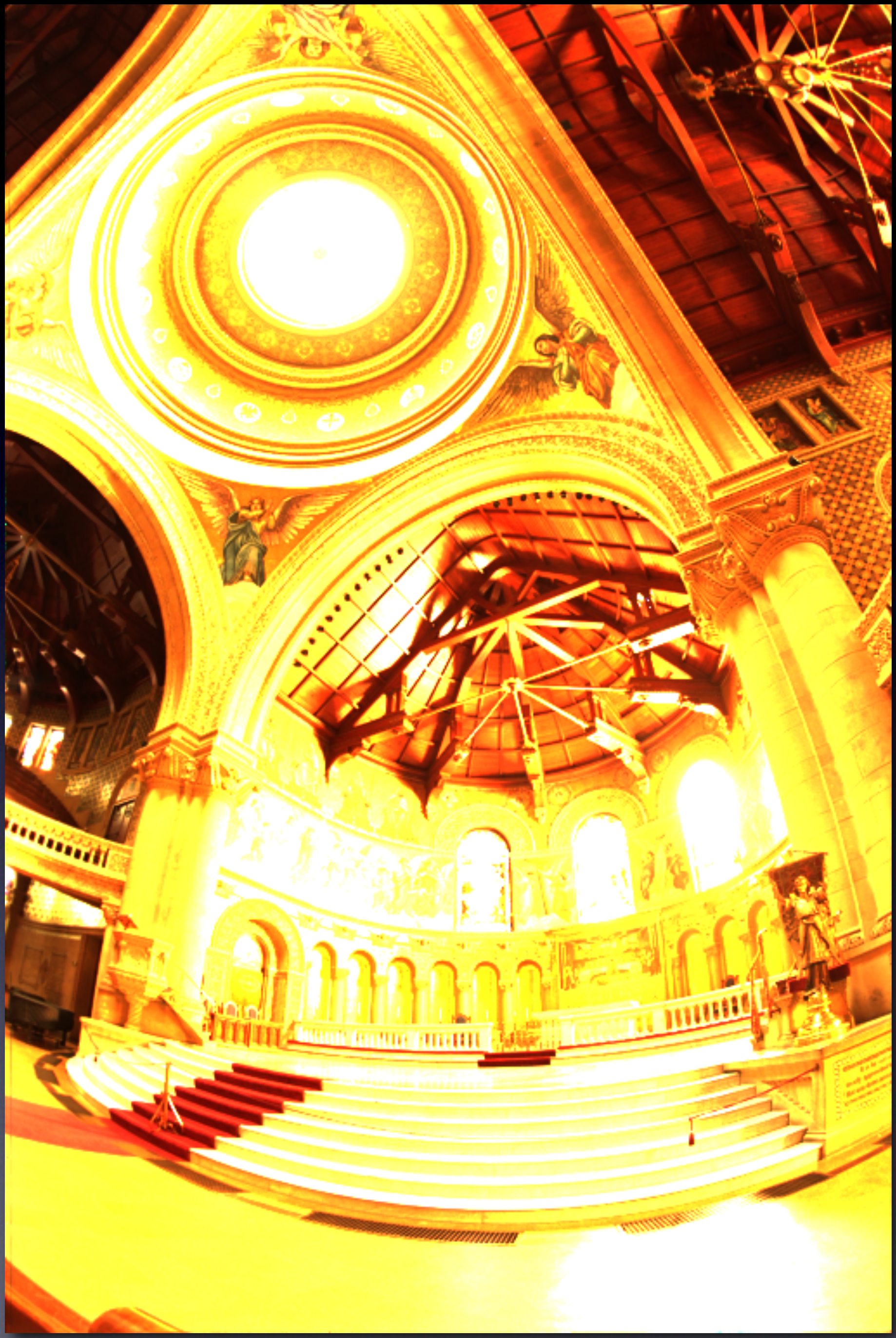
All HDR Data from http://debevec.org/

Stanford Chapel

Short Exposure

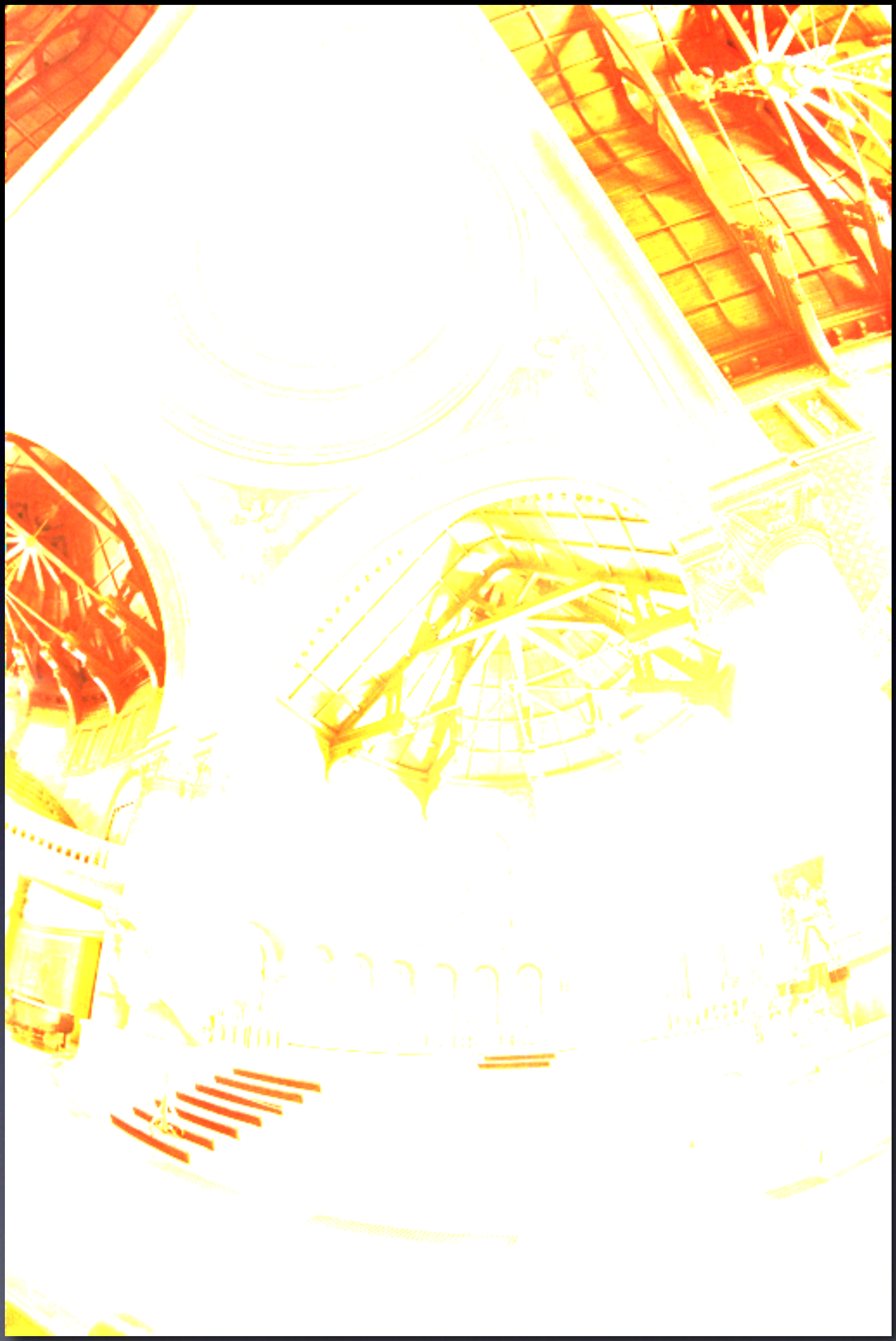
Stanford Chapel

Longer Exposure



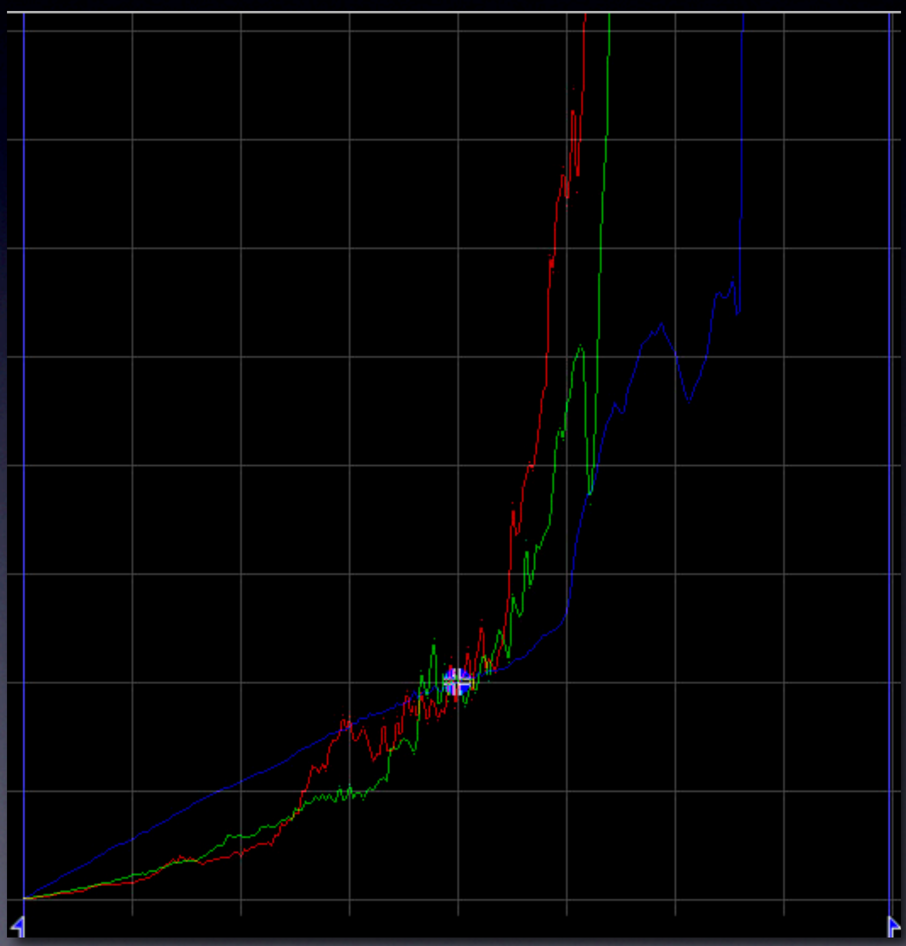
Stanford Chapel

Longest Exposure



HDR Image Generation

- Given the set of bracketed images, and knowledge of the exposure times
  - We can reconstruct the most likely underlying HDR signal
- The "response curve" shown here is native to the camera



HDR Image Generation

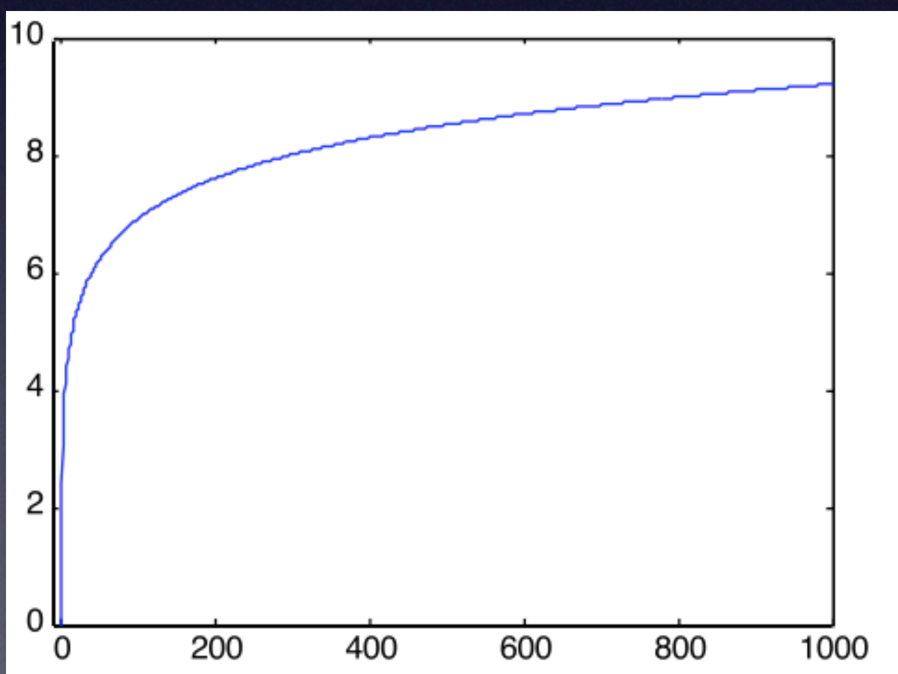
- From here on out, the discussion assumes that we already have the underlying HDR image
  - Downloaded from the internet, or
  - Constructed from bracketed images by some other software package, or
  - Generated by a computer graphics application

HDR Image Generation

- We have a problem here
  - Does anyone see it?
    - These images have too much dynamic range to be drawn on our display!
- The process of fixing this is called tone mapping

What Can We Do?

Solution #1:
Log Mapping



Log Mapping

- Log mapping is a two-step process
  - Take the log of the signal
  - Scale the new signal to use the entire 0-255 range
- Note that if you switch the order, you get a different result
  - Log is non-linear
- Note also that you cannot have any 0 values in your signal
  - $\log(0) = \infty$

How can we do better?

- Retinex theory
  - Edwin Land, 1971
  - Basically, states that the human visual system is really bad at detecting absolute differences, and really good at detecting relative differences
    - Gradual changes in luminance aren't noticed
    - Sharp changes are

What Can We Do?

Solution #2:
Low Frequency Attenuation

- Reduce Low Frequencies
  - i.e. gradual changes
- Keep High Frequencies

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Low Frequency Mask

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Low Frequency Attenuation

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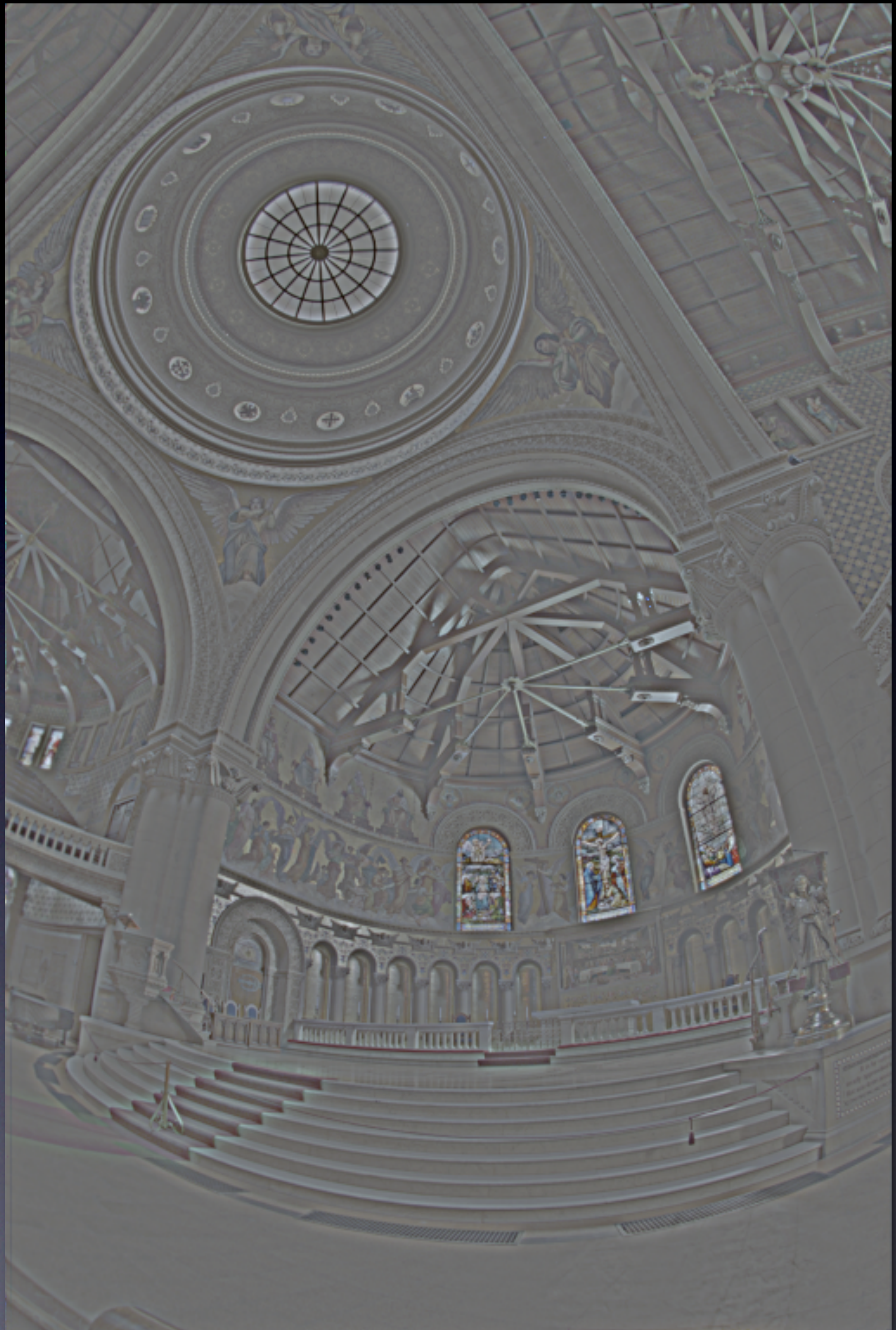
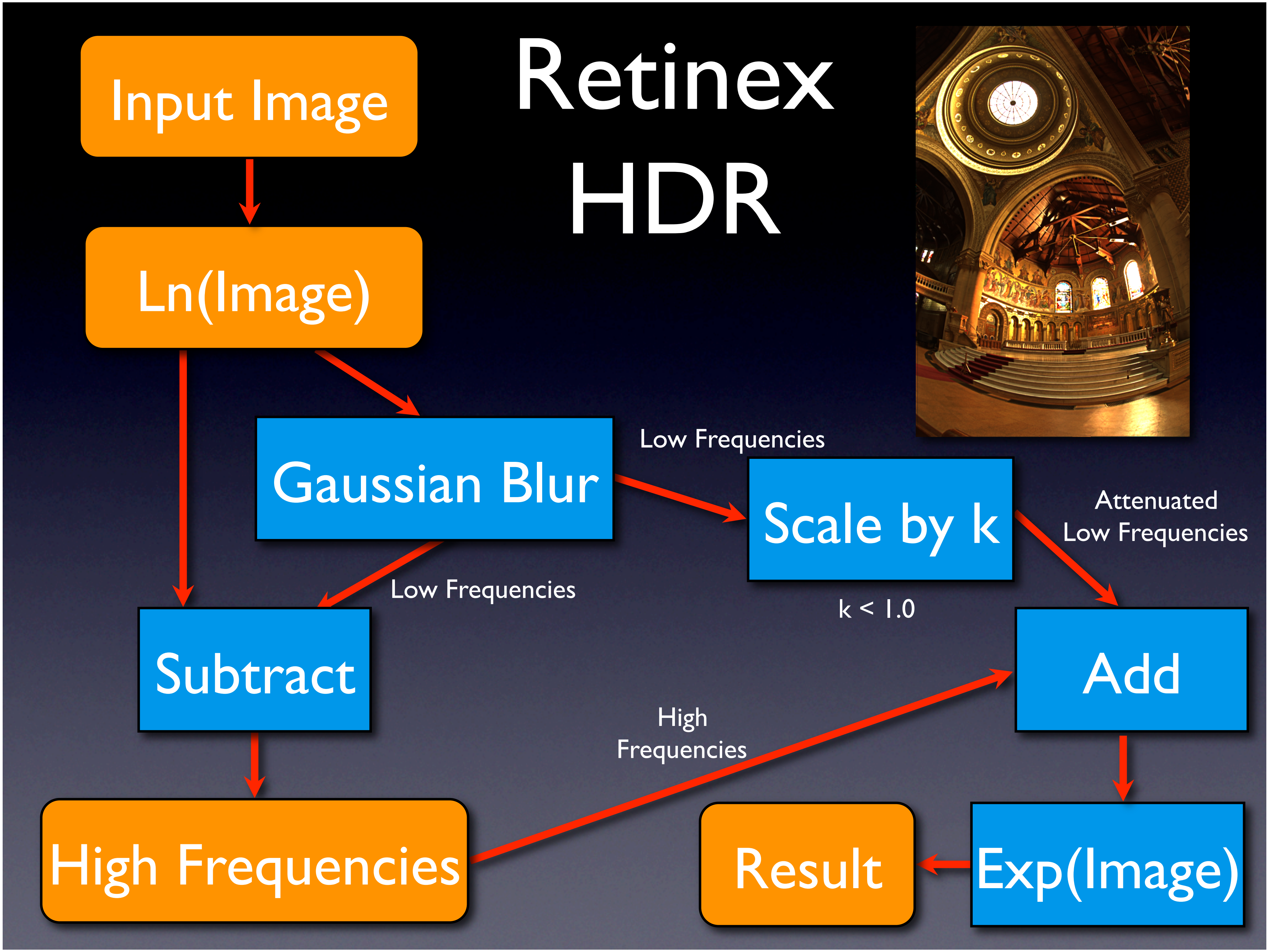
High Frequency Mask



What Can We Do?

Solution #2:
Low Frequency Attenuation

- Reduce Low Frequencies
  - i.e. gradual changes
- Keep High Frequencies

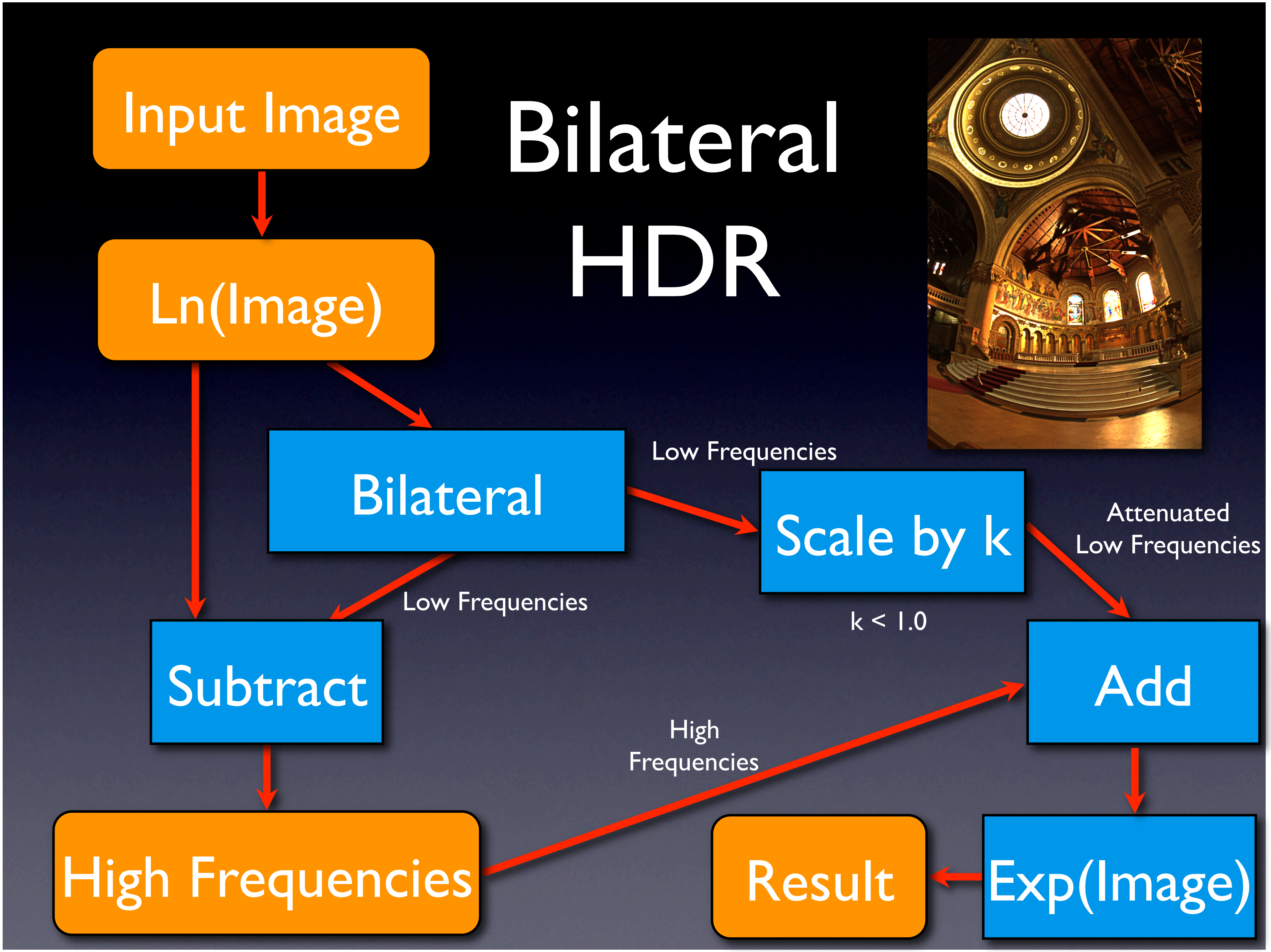

Retinex
HDR
Input Image
Ln(Image)
Gaussian Blur
Low Frequencies
Scale by k
Attenuated
Low Frequencies
Low Frequencies
k < 1.0
Subtract
Add
High
Frequencies
High Frequencies
Result
Exp(Image)

How can we do even better?

- Maybe Gaussian filters aren’t the best tool
  - Blur across edges, obscuring high frequency detail
- Can use an edge-preserving filter
  - I won’t go into the math
  - Basically, the filter can recognize when it encounters an edge, and not blur across it

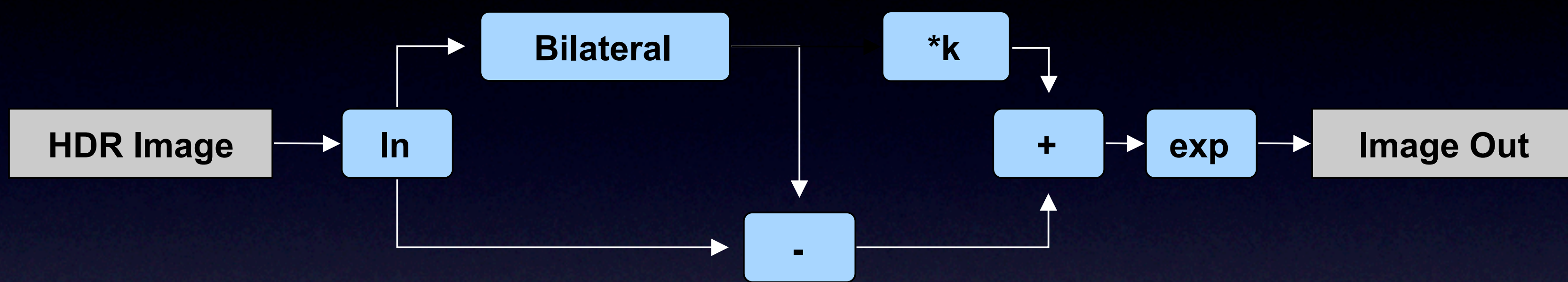
Bilateral Filter Example

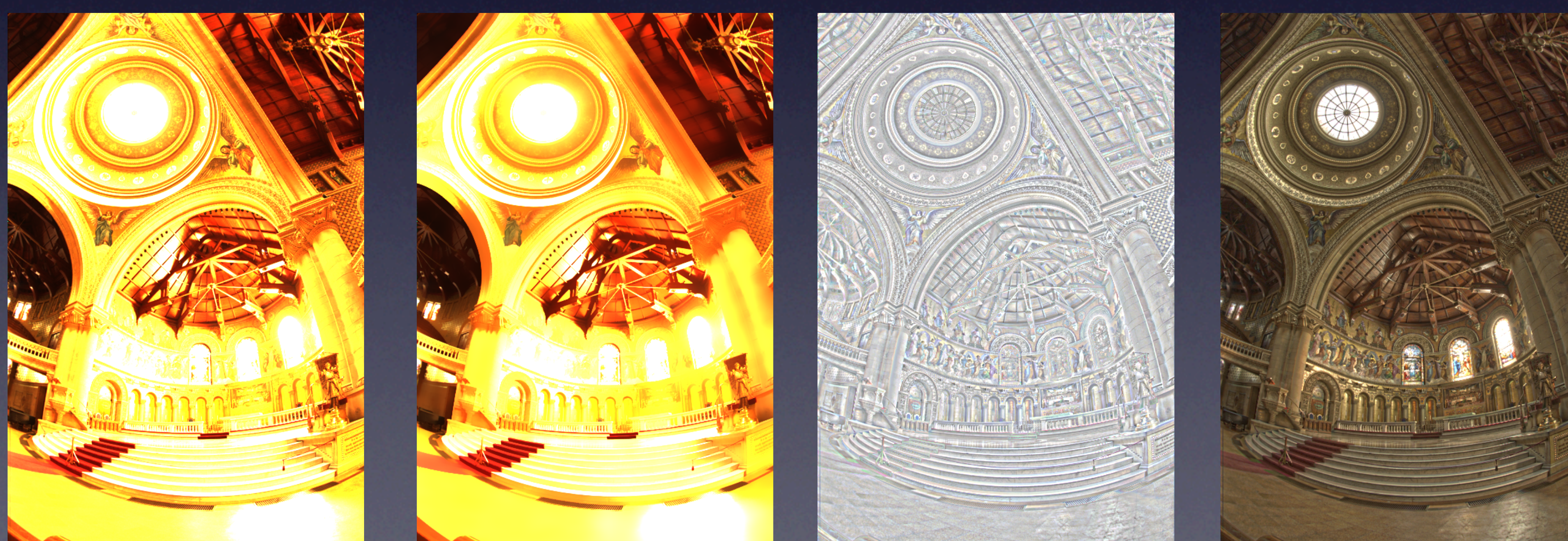
Original Gaussian Bilateral


Bilateral HDR
Input Image
Ln(Image)
Bilateral
Low Frequencies
Scale by k
k < 1.0
Attenuated Low Frequencies
Low Frequencies
Subtract
Add
High Frequencies
High Frequencies
Result
Exp(Image)

Bilateral Filter HDR

Durand & Dorsey, SIGGRAPH 02





What Can We Do?

Solution #3:
Bilateral Tone Mapping

Durand & Dorsey 02

HDR Results

Global Compression | Local Tone Mapping | Local Tone Mapping

Log Mapping

Retinex Tone Mapping

Bilateral Tone Mapping

Sample HDR Images

Image from Wikipedia Commons

Sample HDR Images

Image from Wikipedia Commons

Sample HDR Images

Image from Wikipedia Commons