Georgia Institute of Technology

Computational Photography

Dr. Irfan Essa
Professor
School of Interactive Computing

Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.

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High Dynamic Range Photography (Part 1 of 2)

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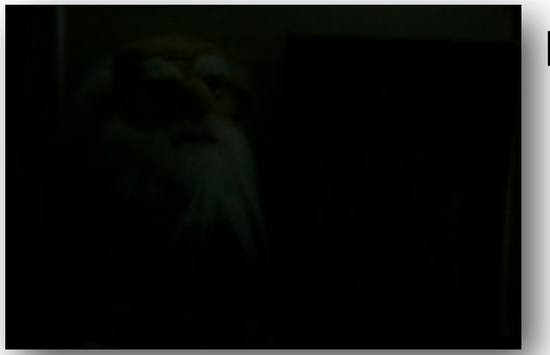
Importance and Characteristics of High Dynamic Range Images

Lesson Objectives

- ★ Explain in your own words the concept of Dynamic Range.
- ★ Identify one (1) reason why digital cameras do not encode Dynamic Range very well.
- ★ Identify correctly all of the components of the Image Acquisition Pipeline for Capturing Scene Radiance to Pixel Values.
- ★ Describe in your own words the linear and non-linear aspects inherent in the Image Acquisition Pipeline for Capturing Scene Radiance to Pixels Values.

Dynamic Range in Real World

http://commons.wikimedia.org/wiki/File:%22Sun%22.JPG



Inside, No Lights
Long Exposure

Dynamic Range in Real World

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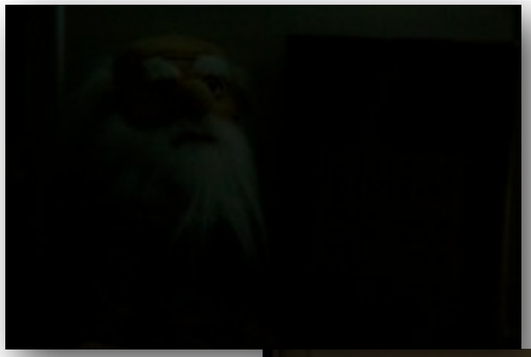

Inside, No Lights
Long Exposure

Inside, Incandescent
Light

Dynamic Range in Real World

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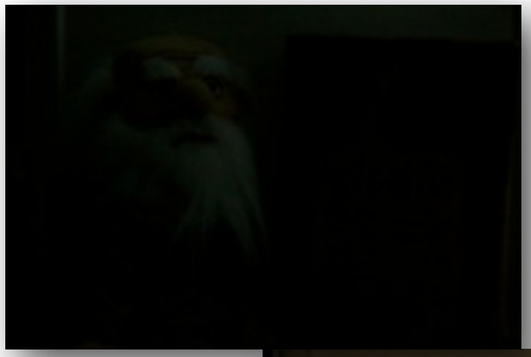

Inside, No Lights
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Inside, Near Window
(Natural Light)

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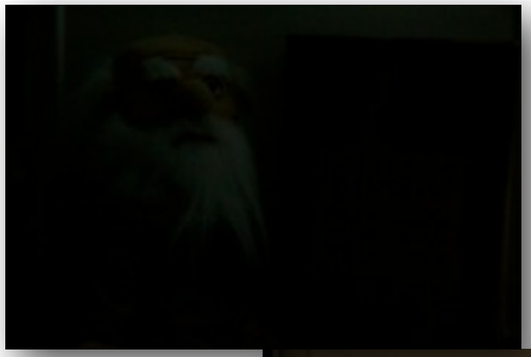

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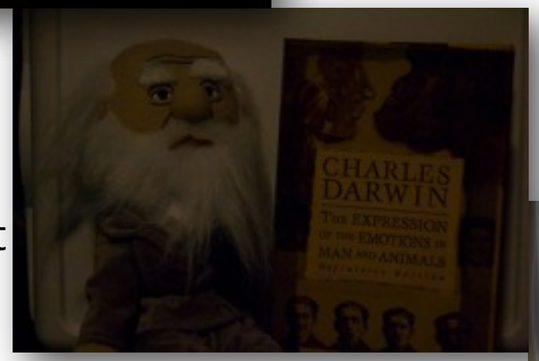

Inside, Incandescent
Light

Inside, Near Window
(Natural Light)

Outside, Under Shade

Dynamic Range in Real World

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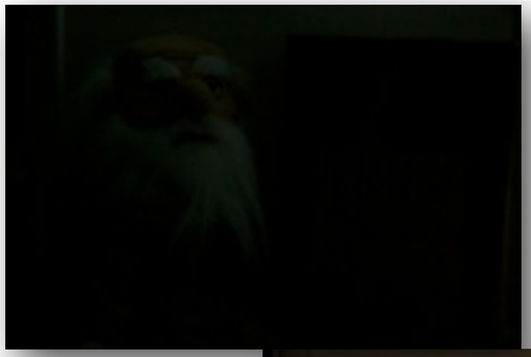
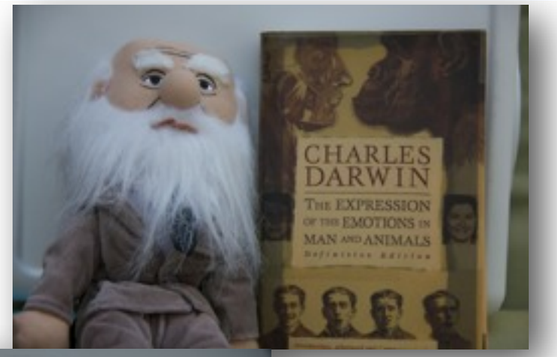


Inside, No Lights
Long Exposure

Outside, in the Sun



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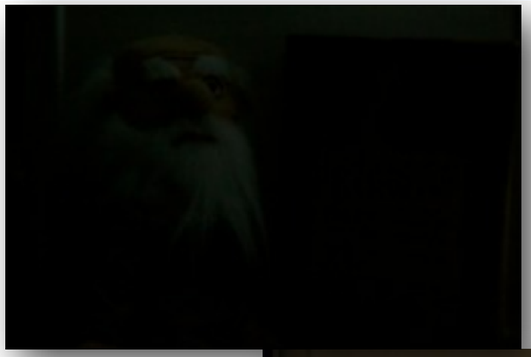

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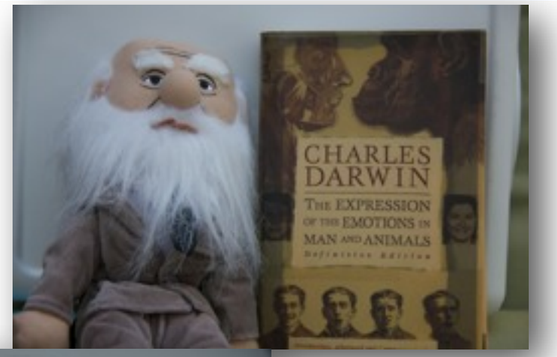

Into the Sun

Inside, Incandescent Light

Inside, Near Window
(Natural Light)

Outside, Under Shade

Dynamic Range in Real World

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Luminance (Definition): A photometric measure of the luminous intensity per unit area of light traveling in a given direction and is measured in candela per square meter (cd/m2).

Dynamic Range

http://en.wikipedia.org/wiki/Human_eye

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Luminance
(log cd/m^2)

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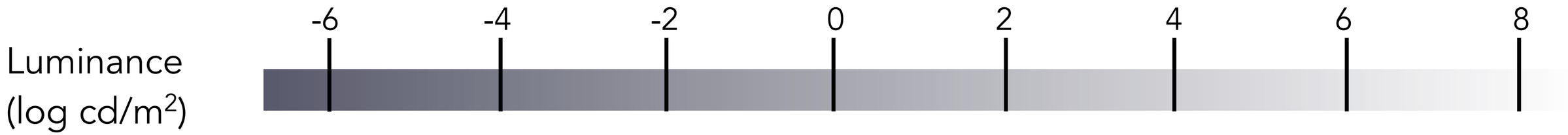

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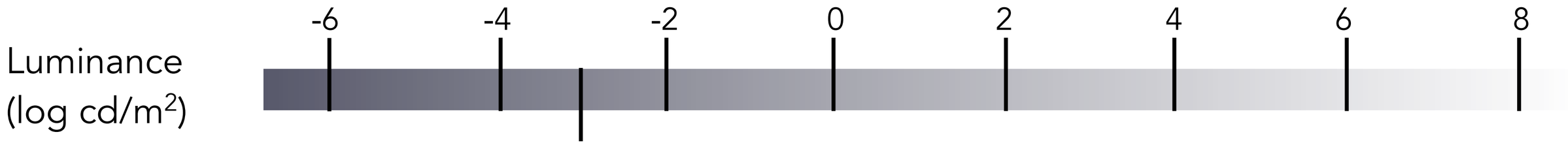

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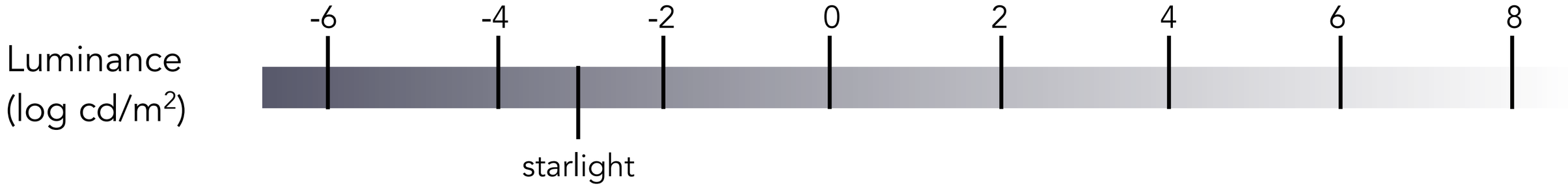

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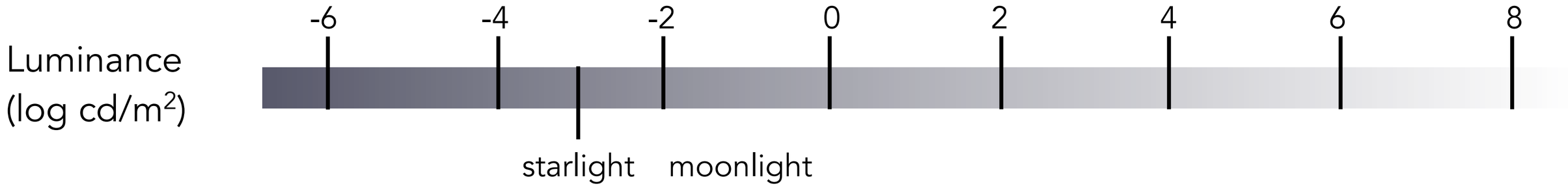

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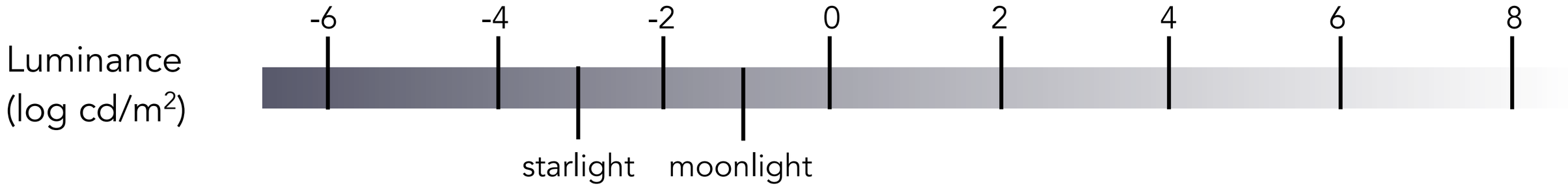

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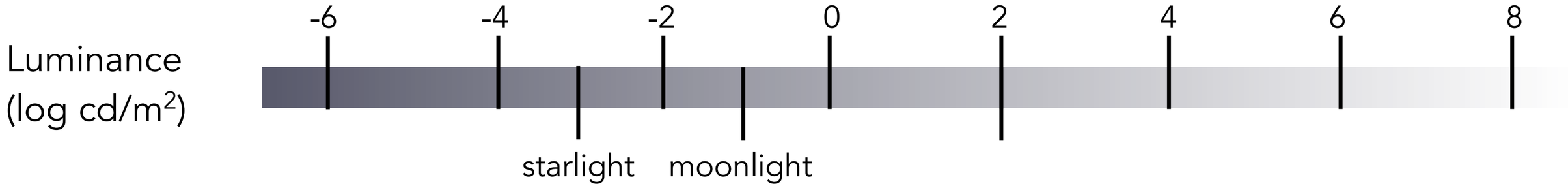

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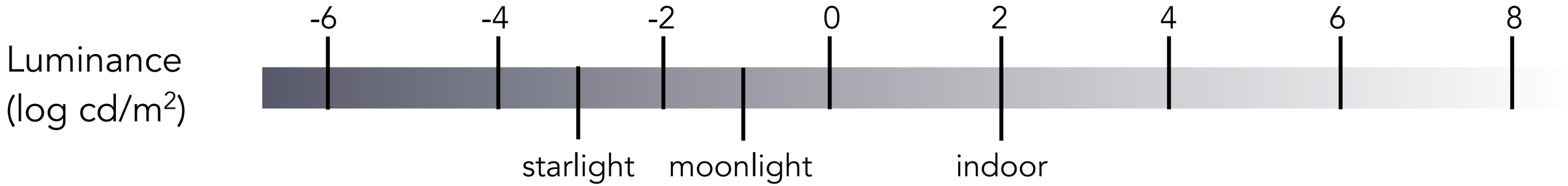

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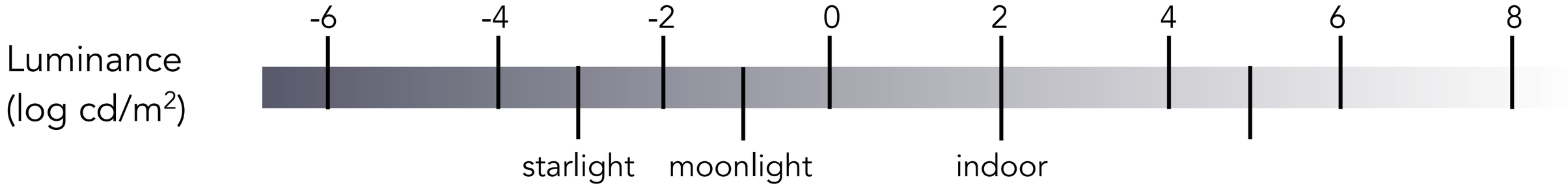

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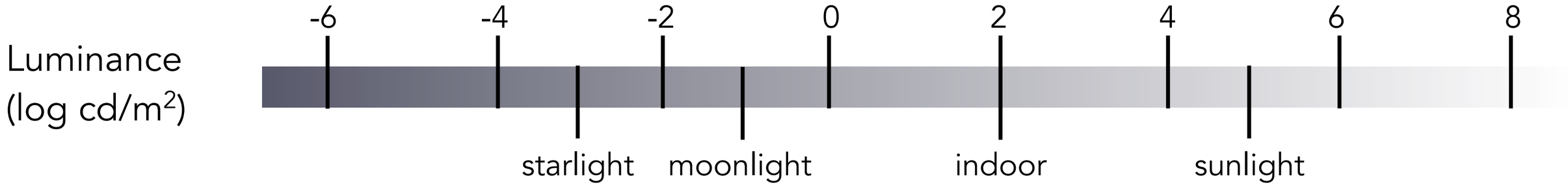

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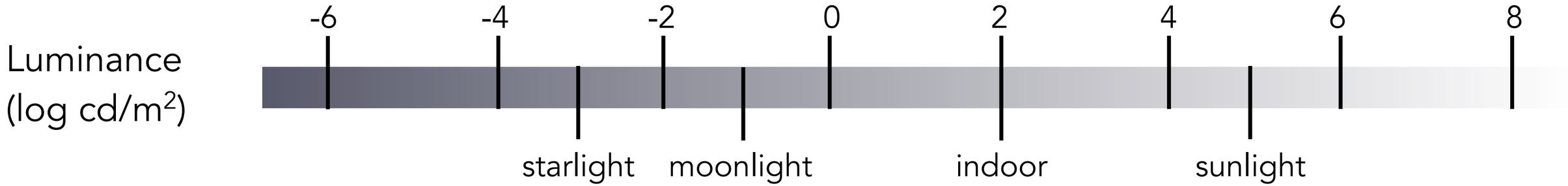

- Human Static Contrast Ratio: 100:1 (10^2:1) ➔ about 6.5 f-stops

Dynamic Range

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5

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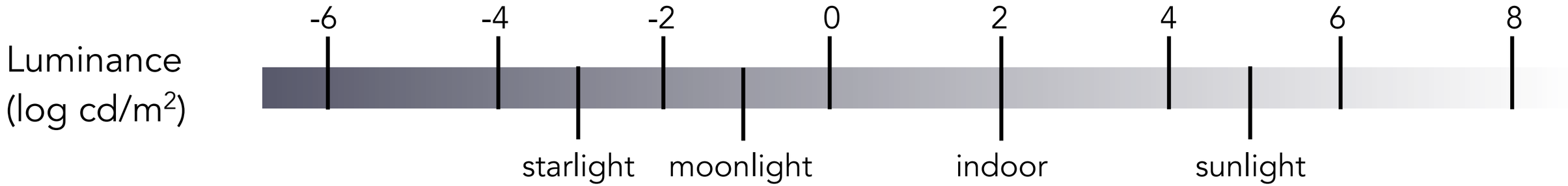

- Human Static Contrast Ratio: 100:1 (10^2:1) ➔ about 6.5 f-stops
- Human Dynamic Contrast Ration: 1,000,000:1 (10^6:1) ➔ about 20 f-stops

Dynamic Range

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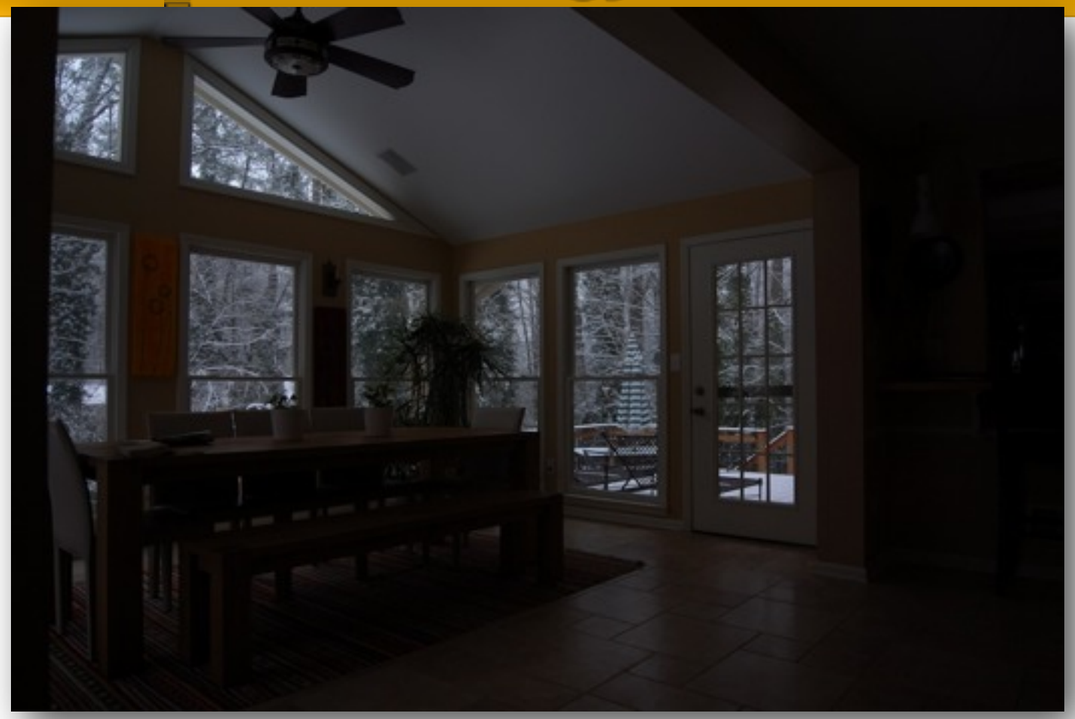
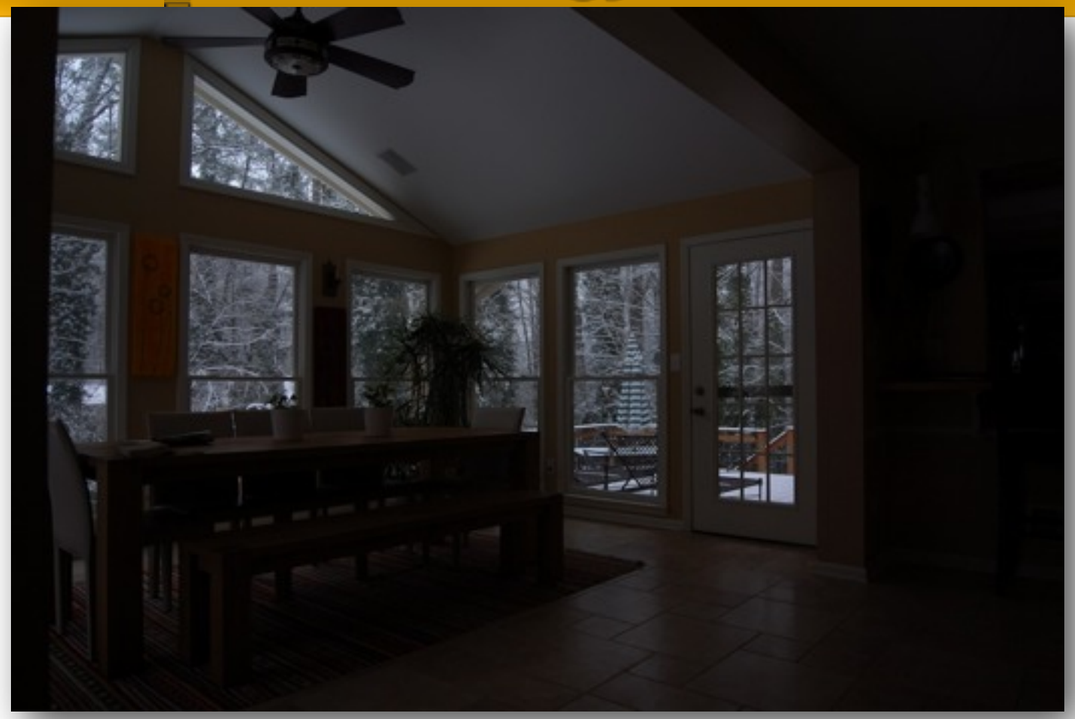


Limited Dynamic Range of Current Cameras



Short Exposure: Snow and Outside Visible

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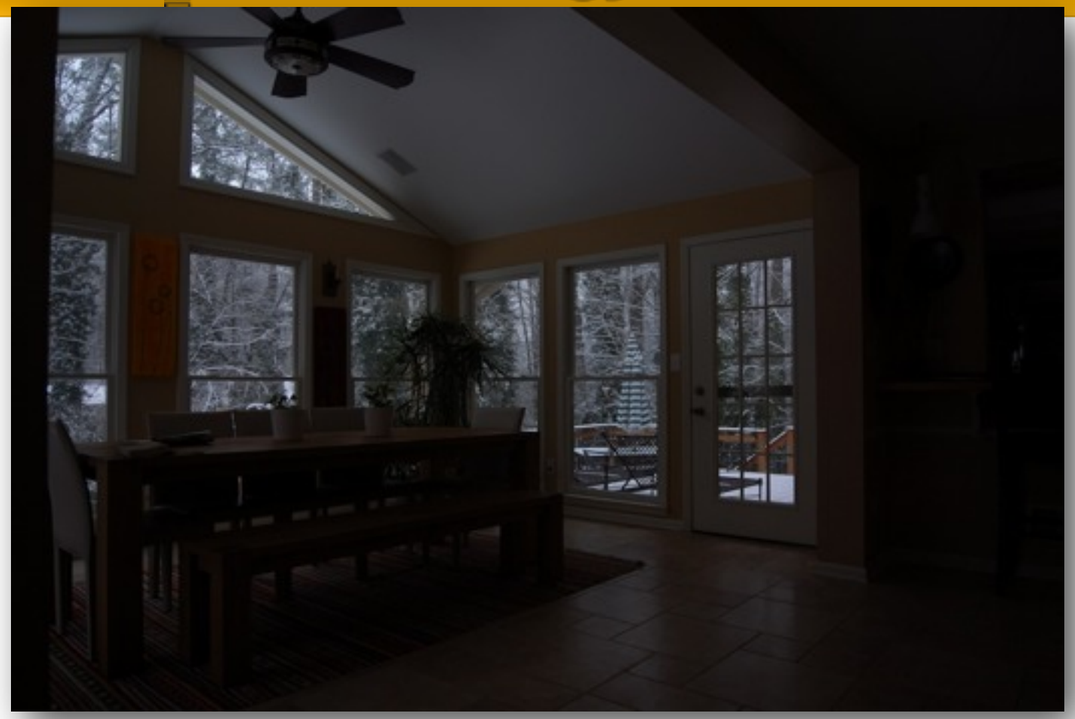

Short Exposure: Snow and Outside Visible

Long Exposure: Inside Visible

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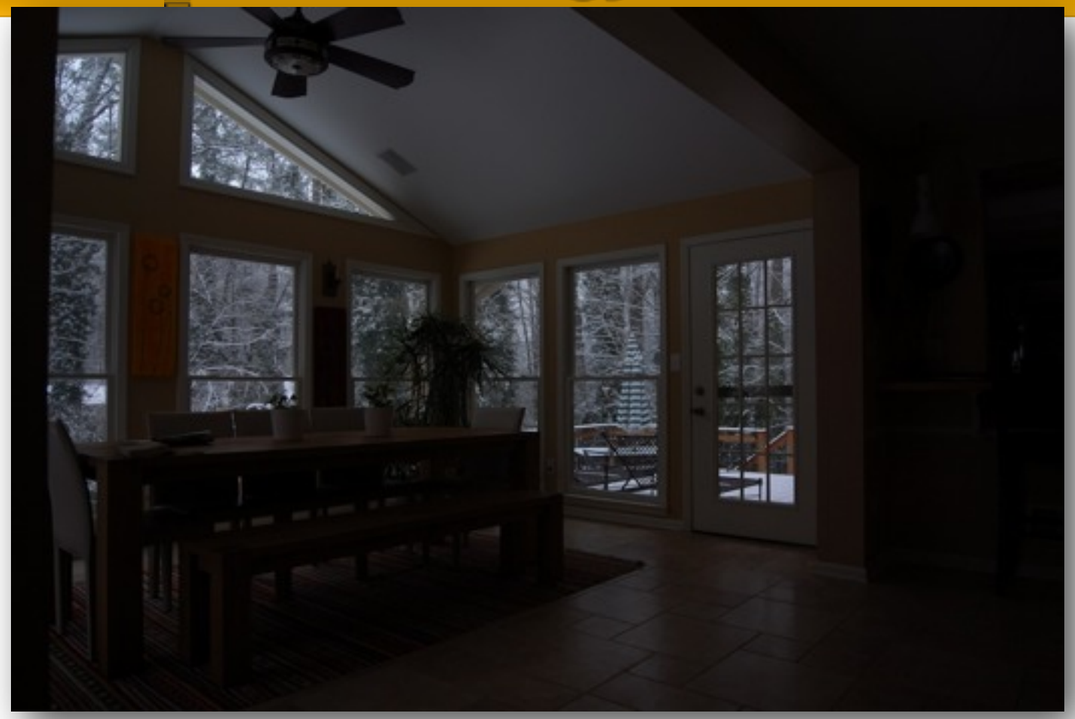
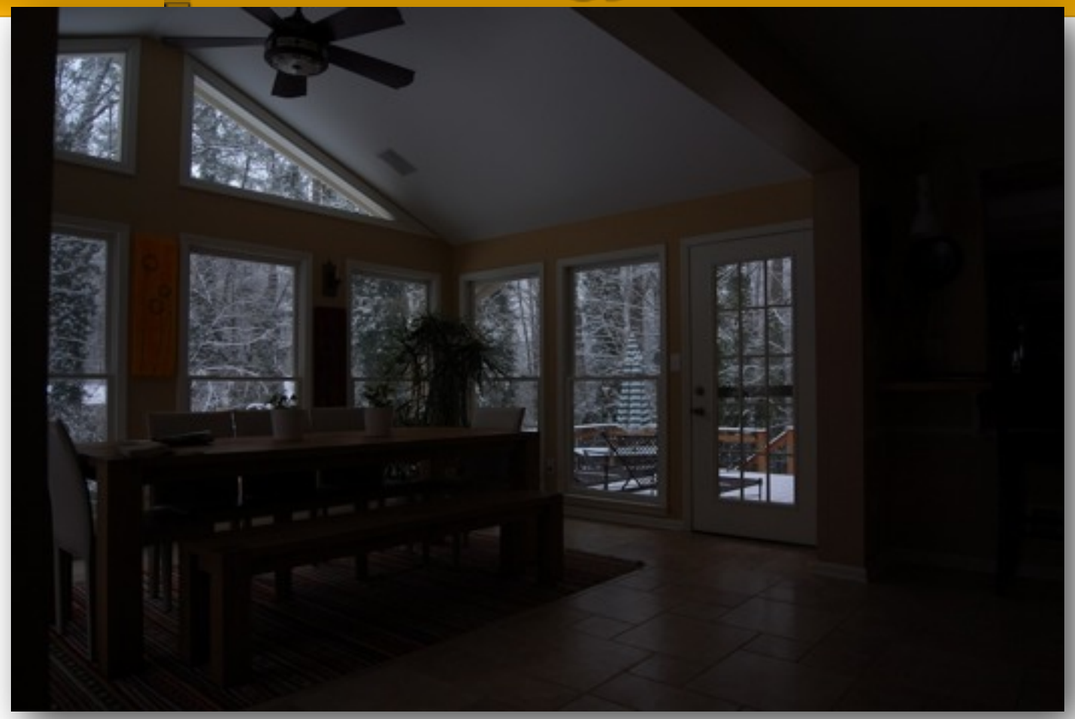


Short Exposure: Snow and Outside Visible

Long Exposure: Inside Visible

- Need about 5-10 million values to store all brightnesses around us.

Limited Dynamic Range of Current Cameras

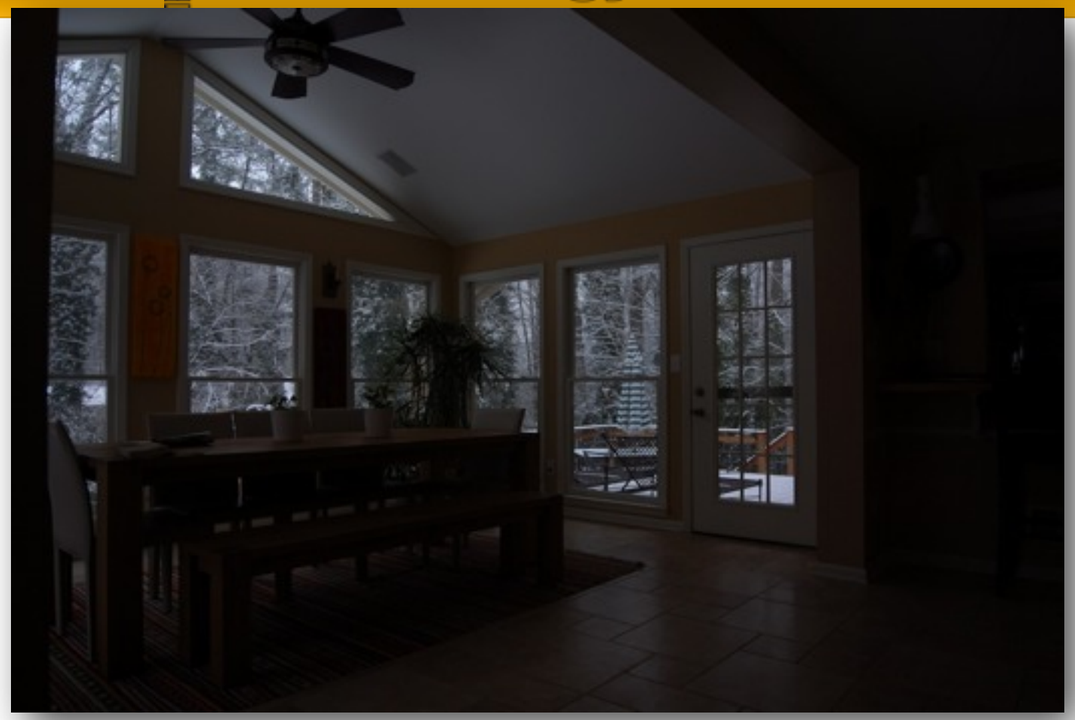


Short Exposure: Snow and Outside Visible

Long Exposure: Inside Visible

- Need about 5-10 million values to store all brightnesses around us.
- 8-bit cameras provide only 256 values!!

Limited Dynamic Range of Current Cameras



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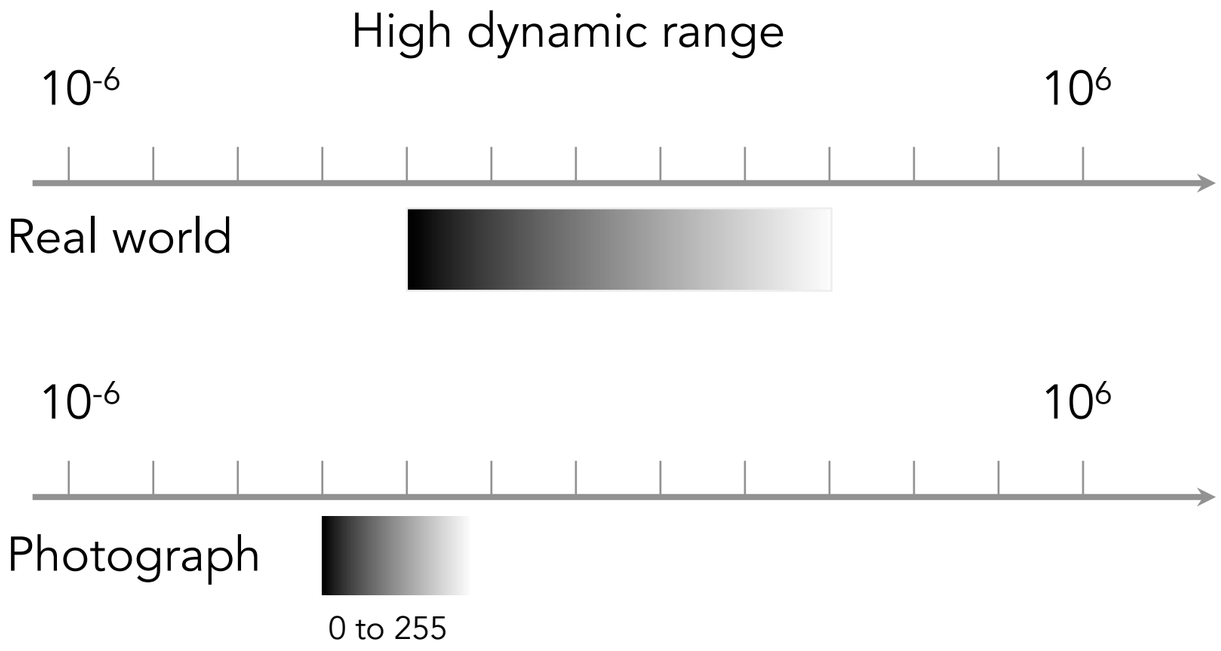

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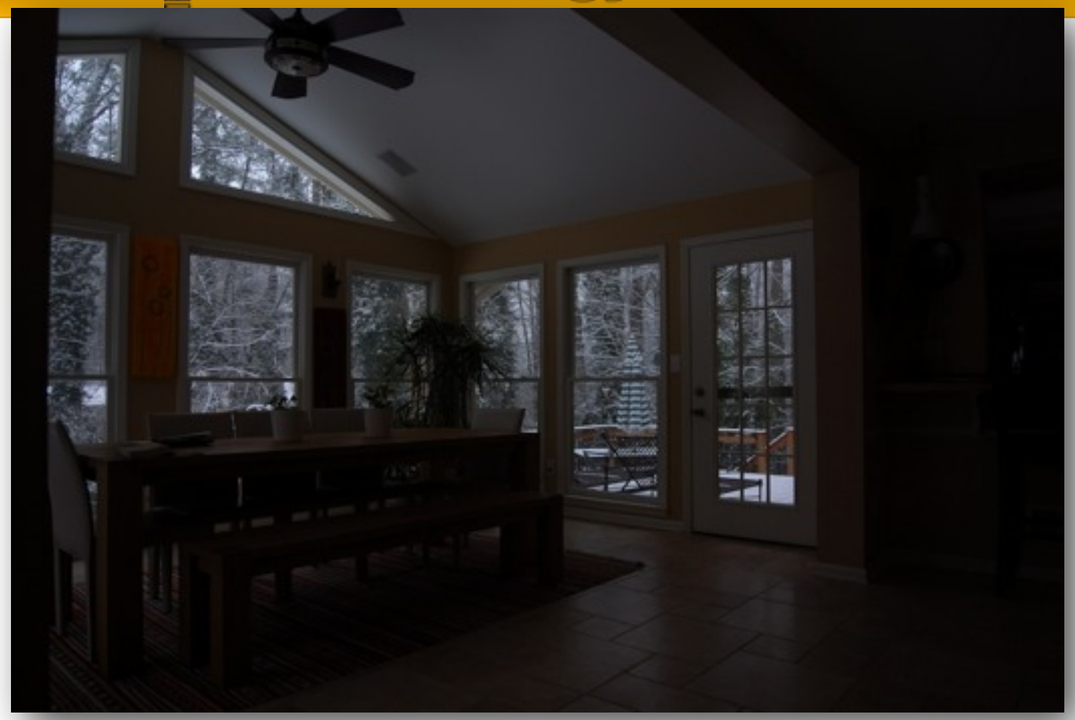

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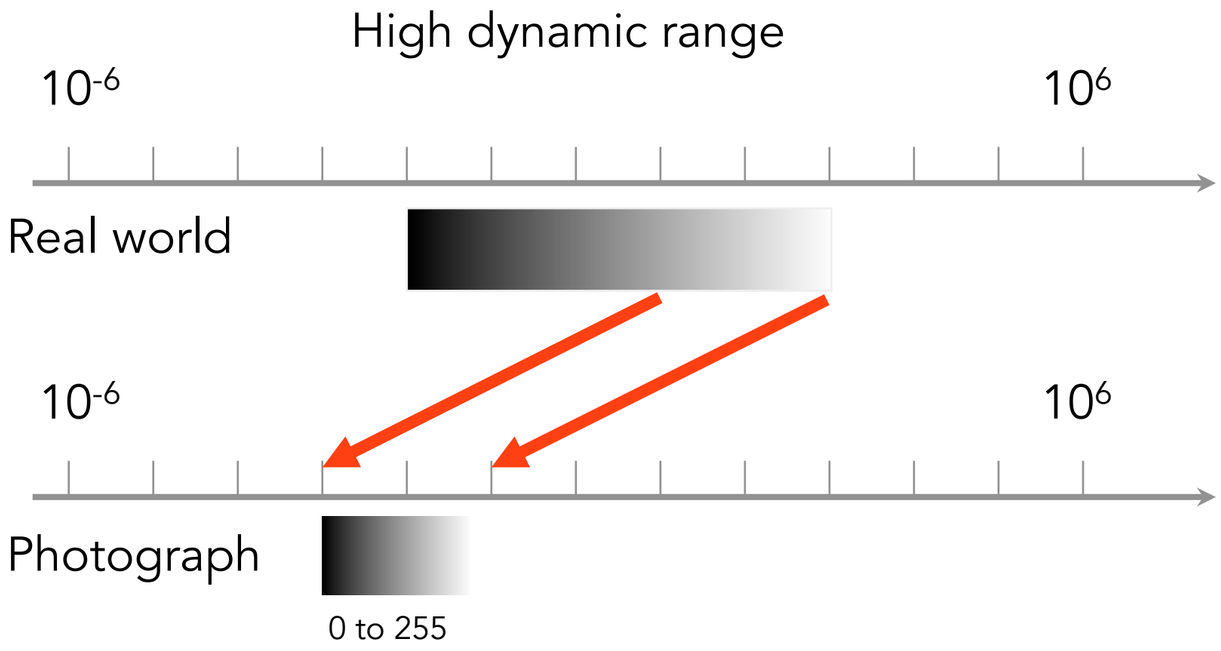

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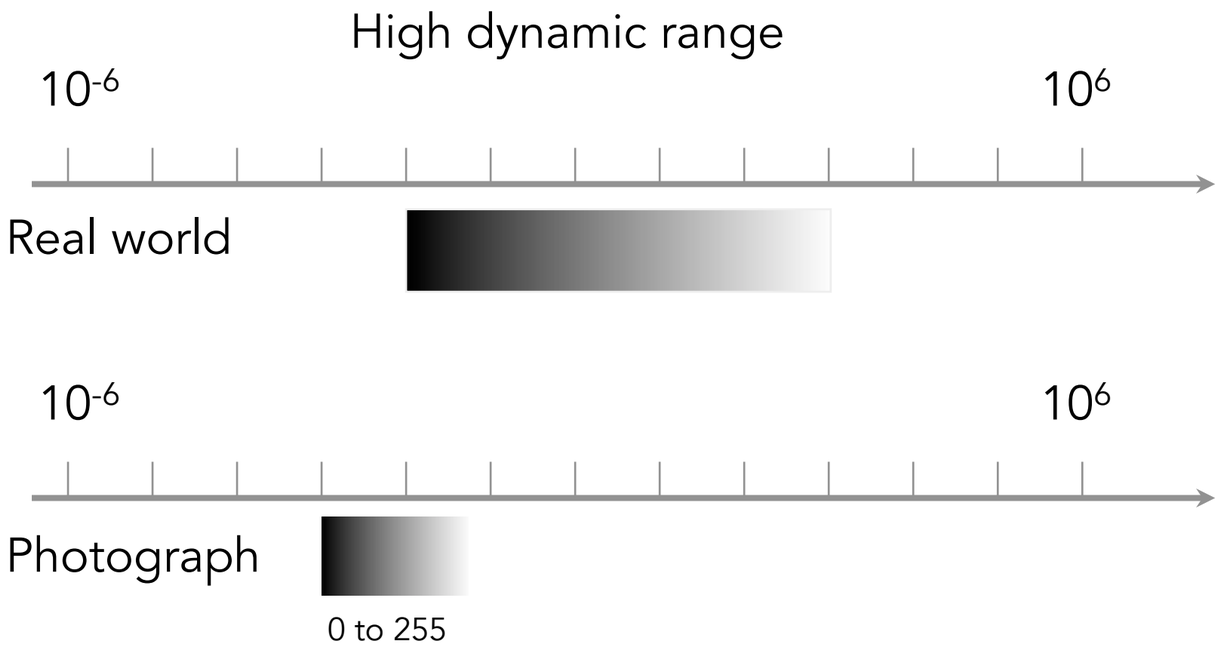

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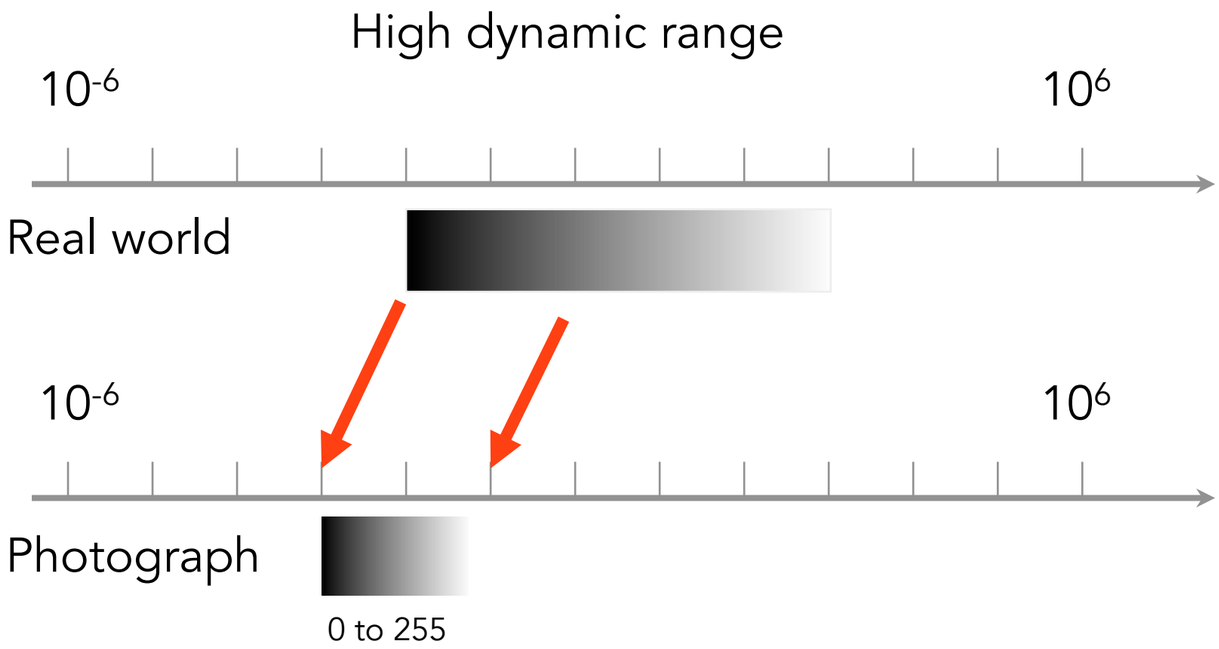

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Limited Dynamic Range of Current Camera

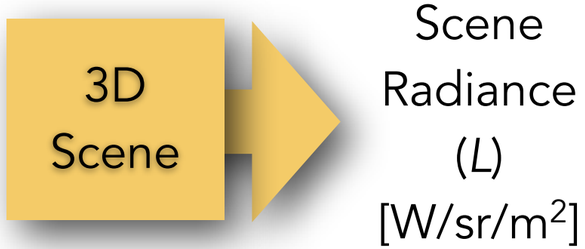
Relationship between Image and Scene Brightness

The Image Acquisition Pipeline

Relationship between Image and Scene Brightness

The Image Acquisition Pipeline

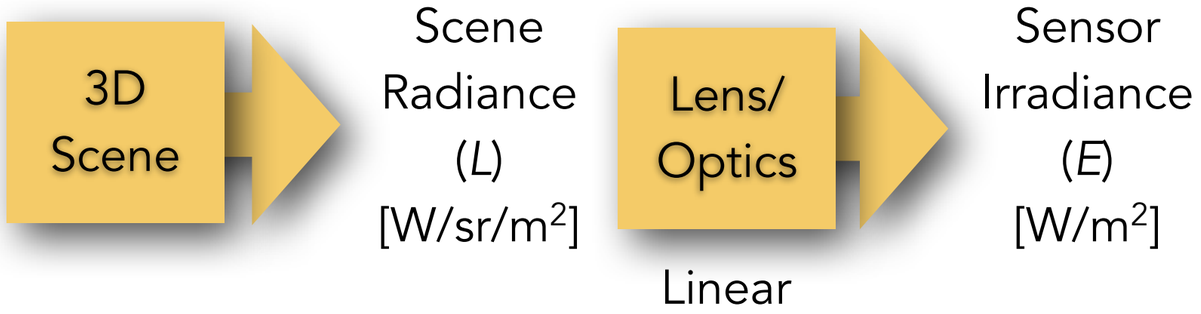
★ Scene Radiance



Relationship between Image and Scene Brightness

The Image Acquisition Pipeline

- ★ Scene Radiance
- ★ Sensor Irradiance



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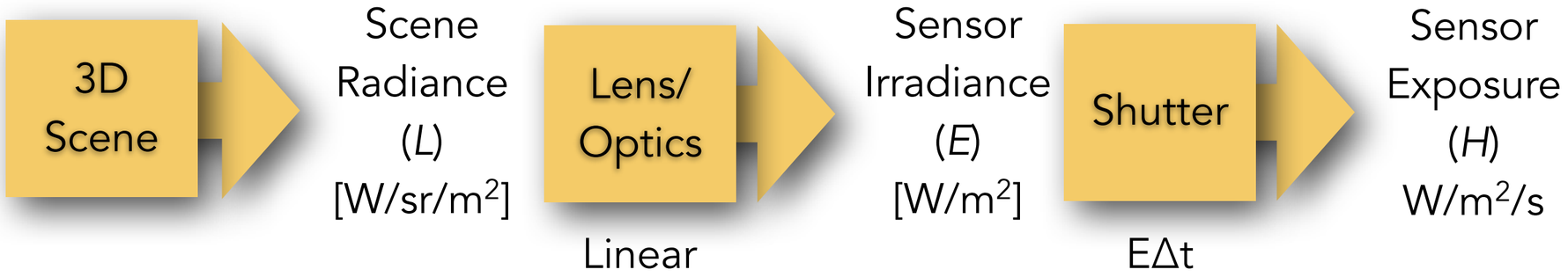

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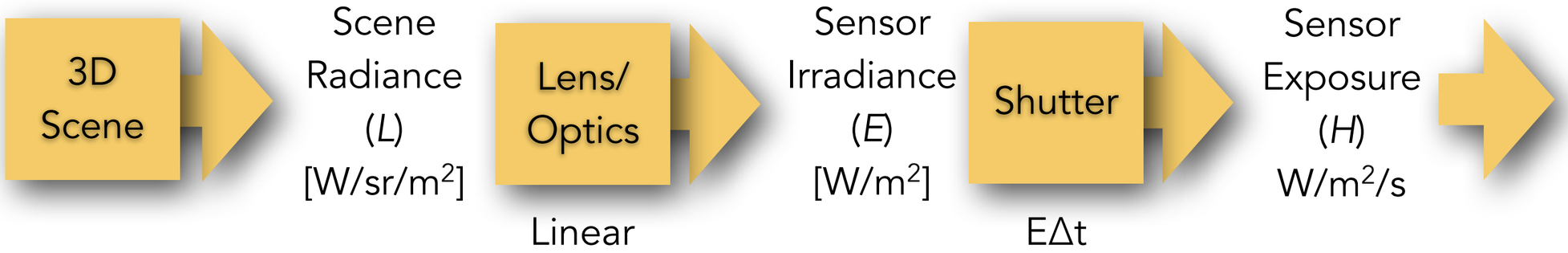

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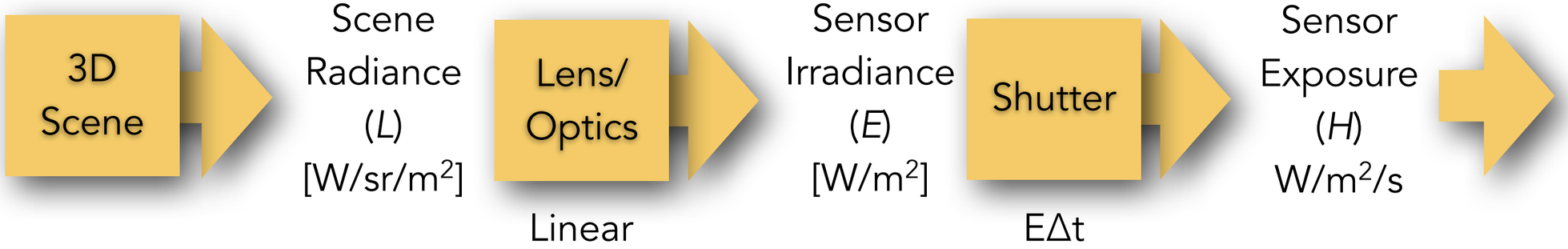

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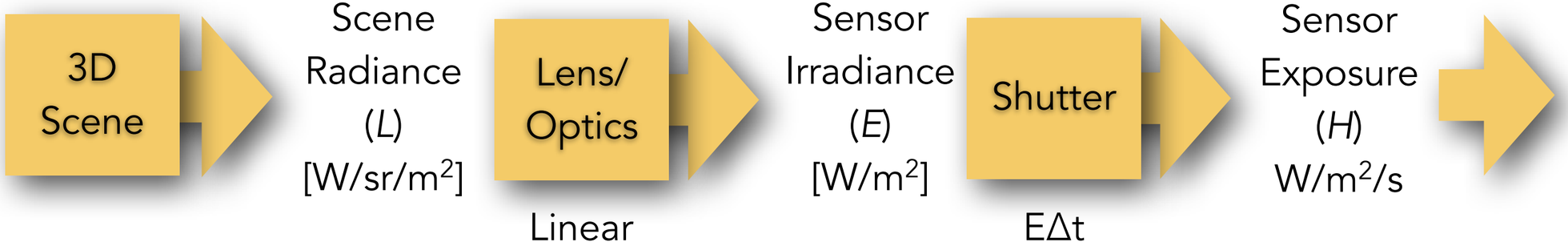

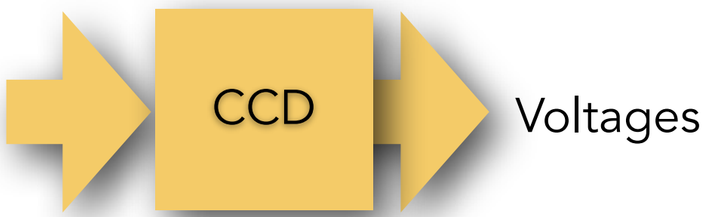

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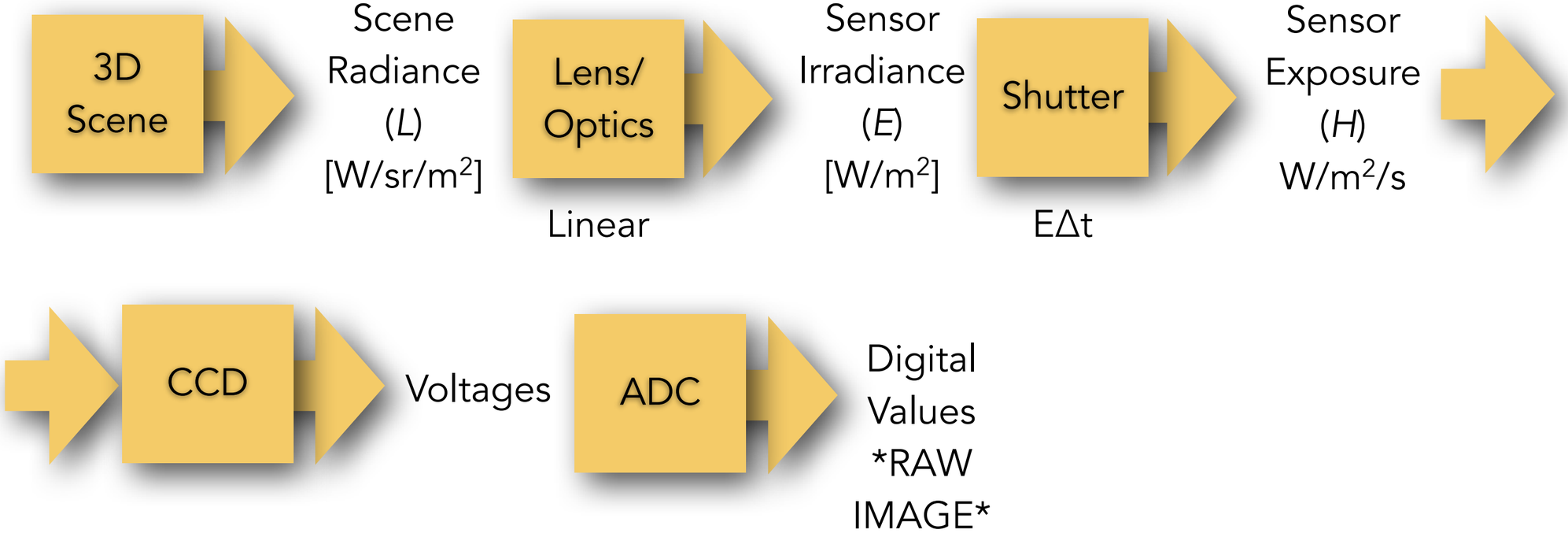

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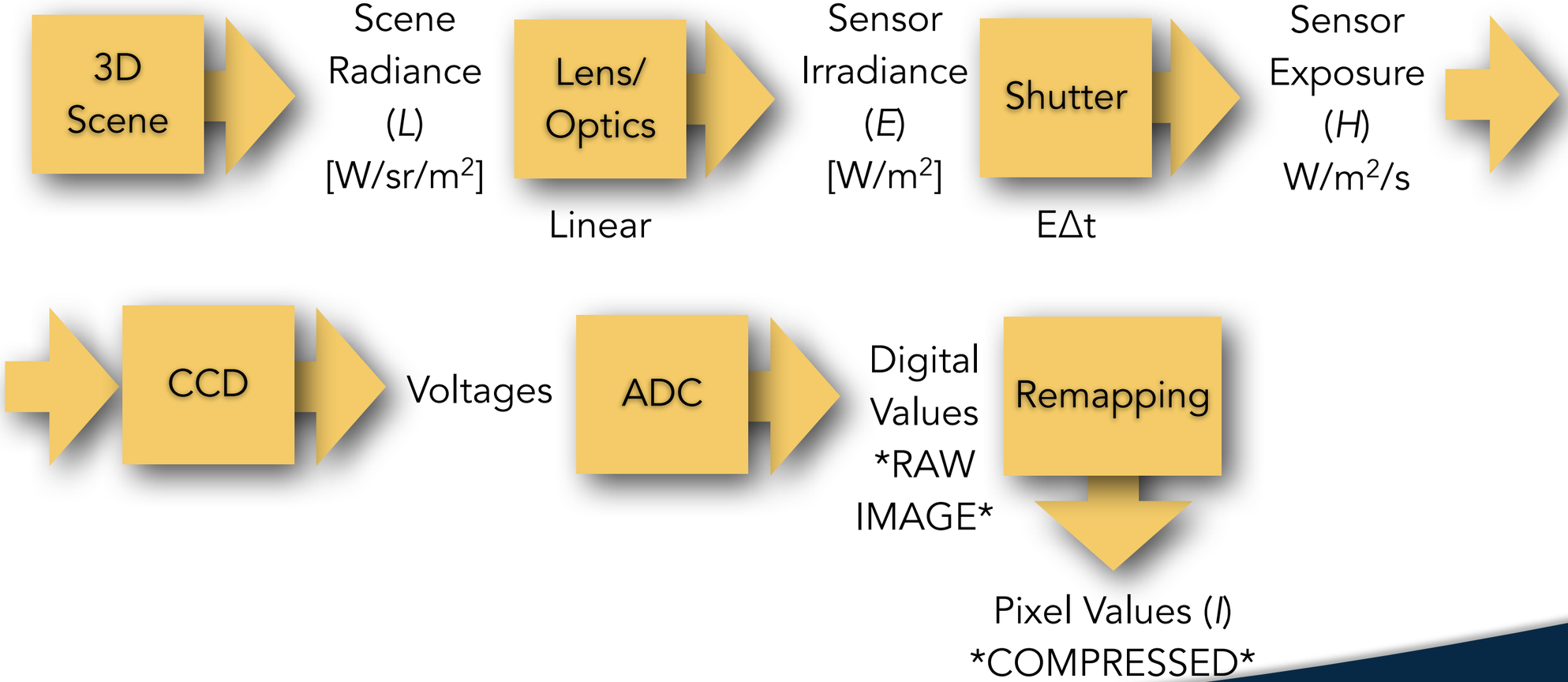

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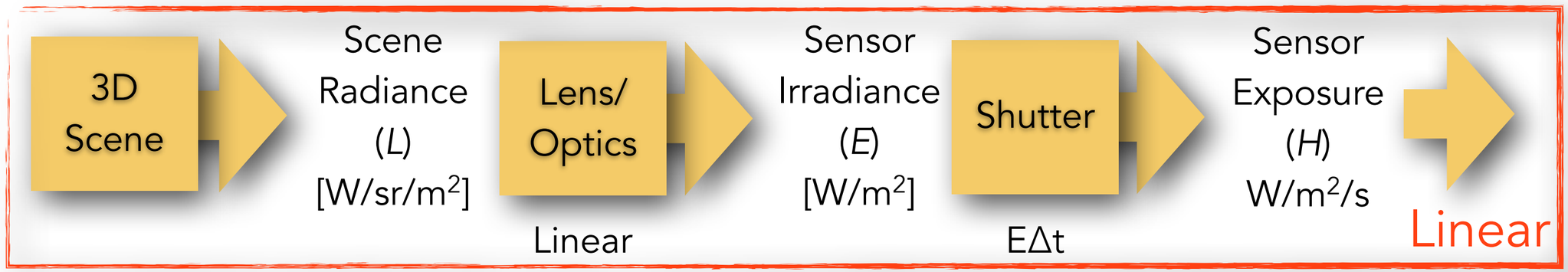

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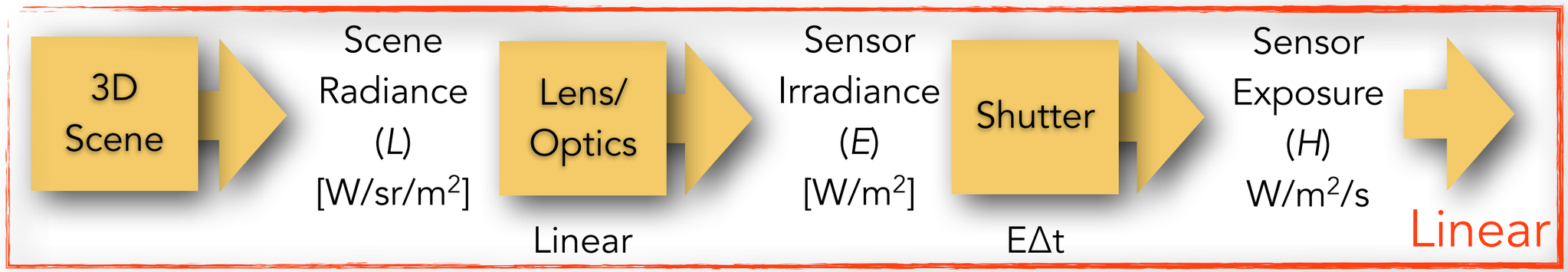
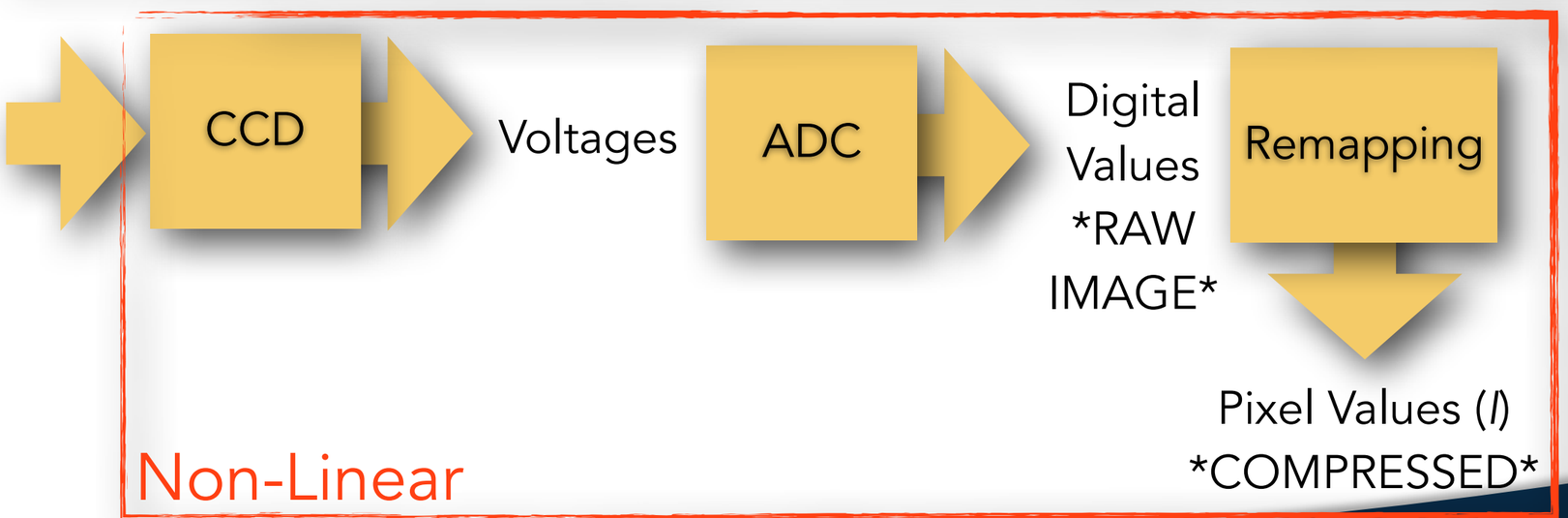
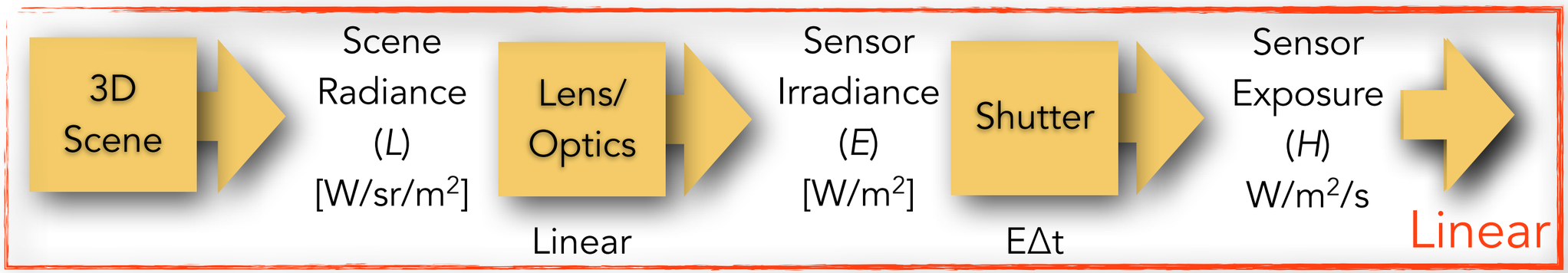
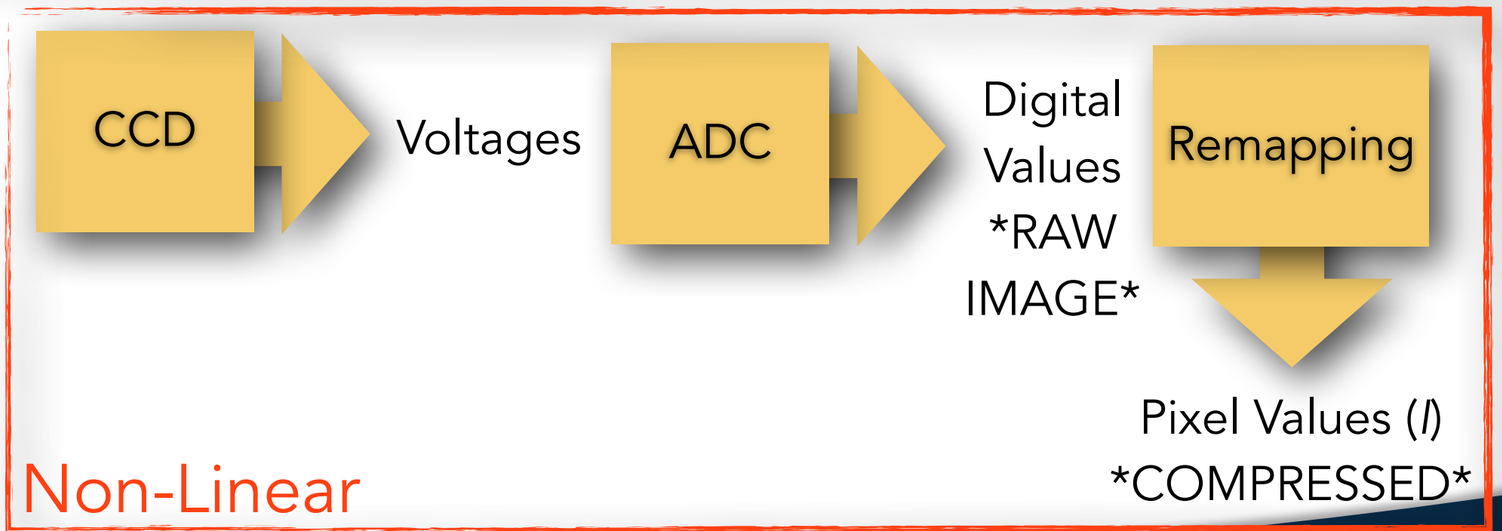




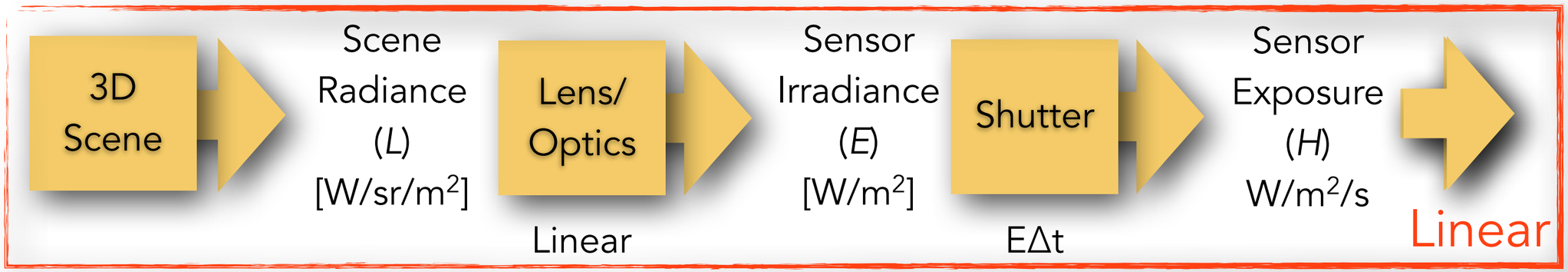
Relationship between Image and Scene Brightness

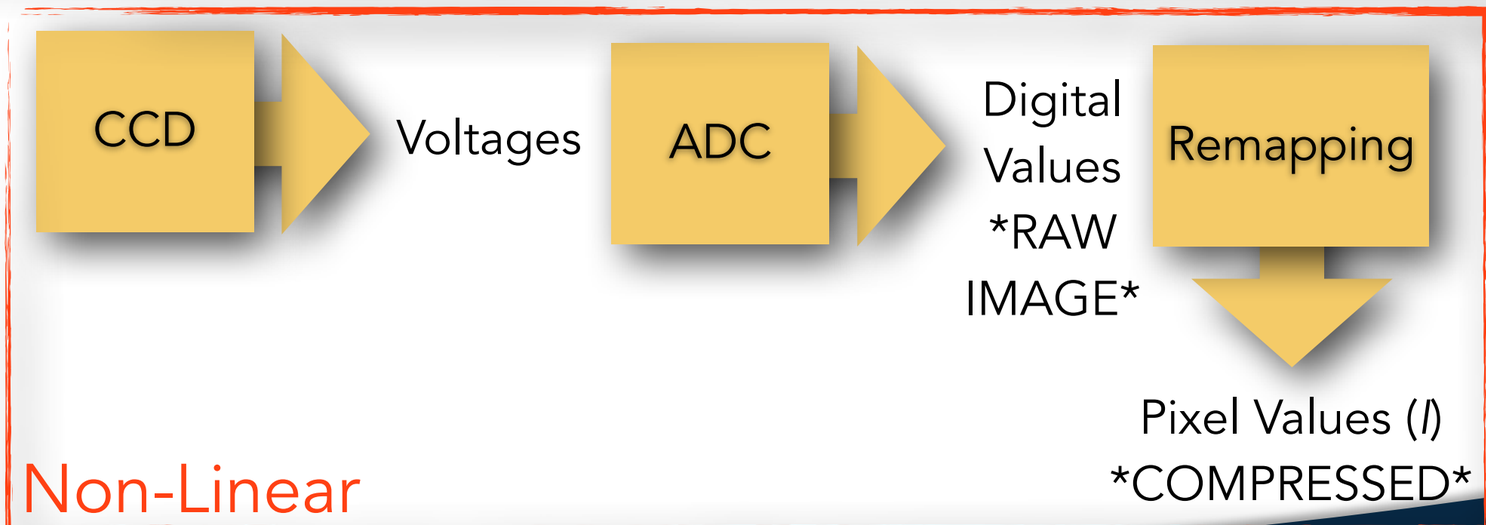




Relationship between Image and Scene Brightness

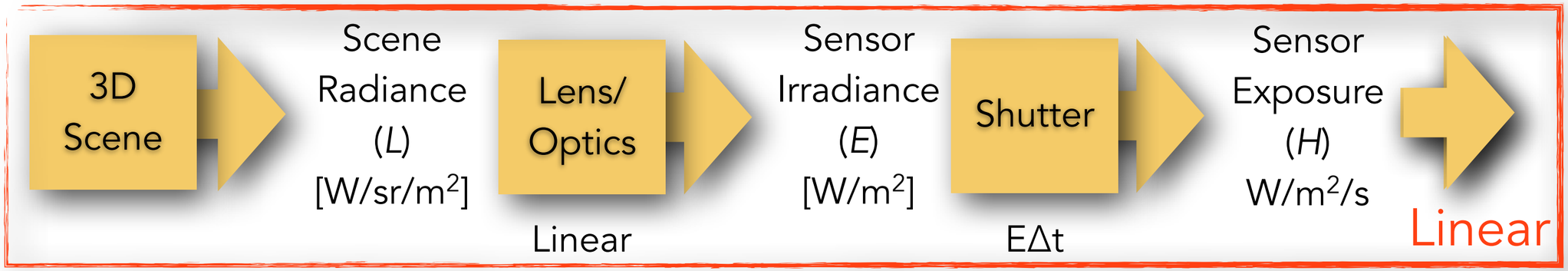
$g: L \rightarrow E \rightarrow H \rightarrow I$

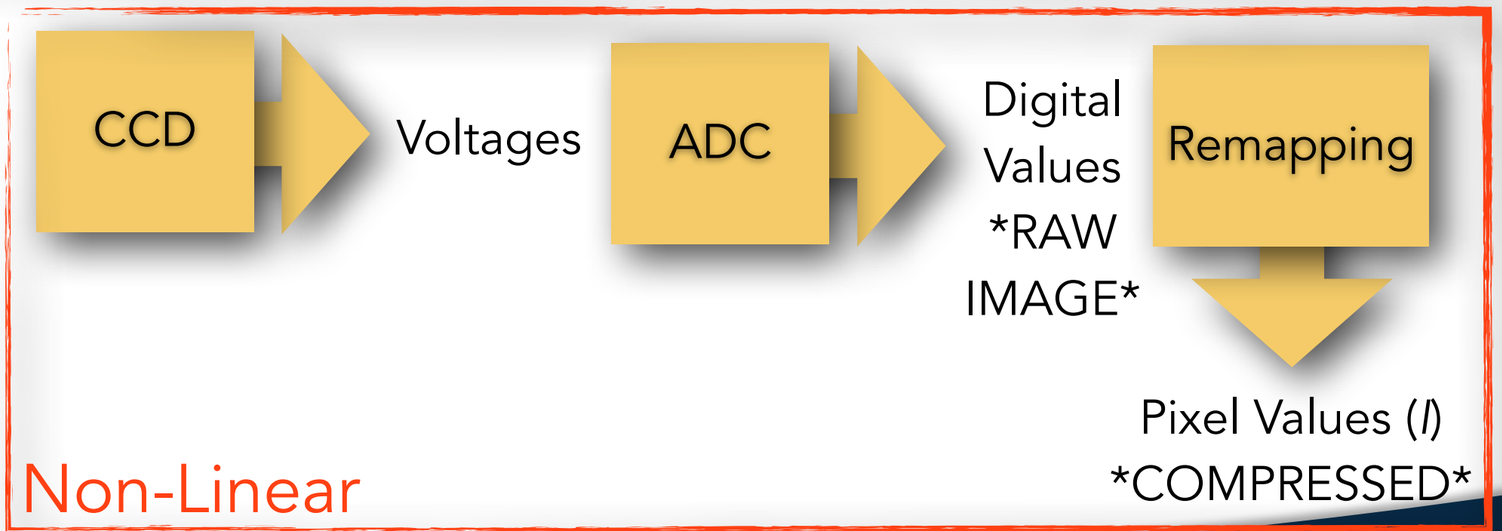




Relationship between Image and Scene Brightness

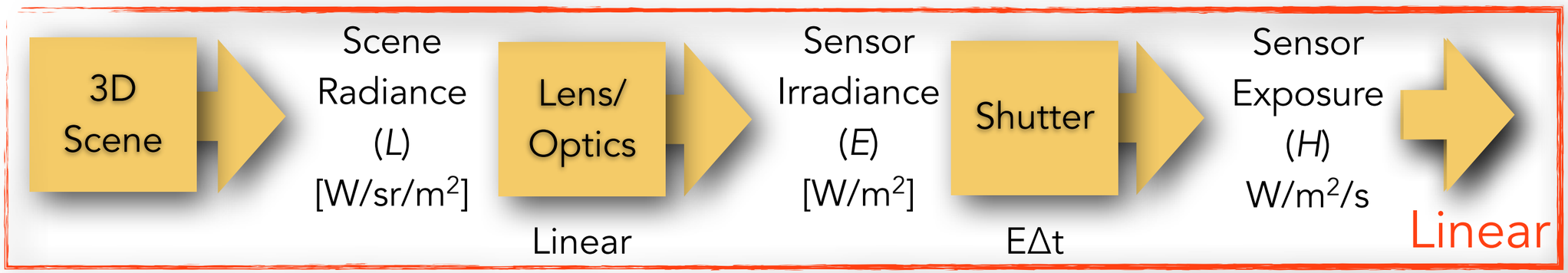
$g: L \rightarrow E \rightarrow H \rightarrow I$ ⟷

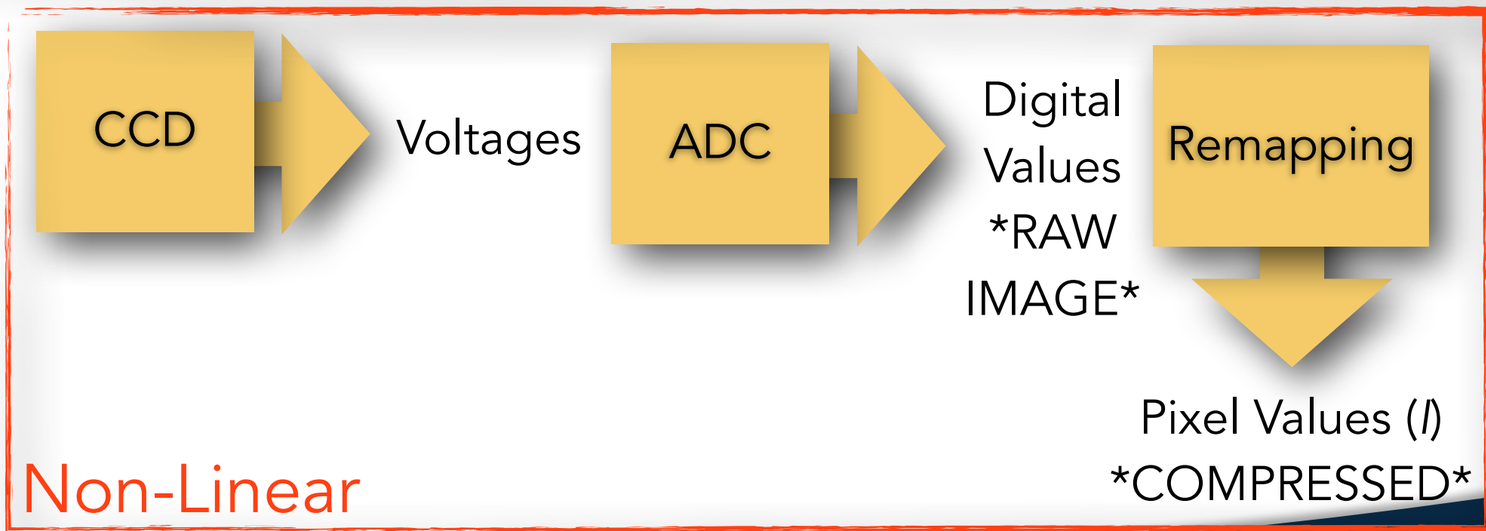




Relationship between Image and Scene Brightness

$g: L \rightarrow E \rightarrow H \rightarrow I \quad \Leftrightarrow \quad g^{-1}: I \rightarrow E \rightarrow H \rightarrow L$





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Summary

- ★ Discussed issues of Dynamic Range.
- ★ Discussed why digital cameras do no encode it very well.
- ★ Presented the Image Acquisition Pipeline for Capturing Scene Radiance to Pixel Values.
- ★ Discussed the linear and non-linear aspects of the Image Acquisition Pipeline for Capturing Scene Radiance to Pixel Values.

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Further Information

- Grossberg and Nayar (2003), “Determining the Camera Response from Images: What is Knowable?," IEEE Transactions on Pattern Analysis and Machine Intelligence, [PDF]
- Debevec and Malik (1997). “Recovering High Dynamic Range Radiance Maps from Photographs.” In SIGGRAPH 1997 [PDF]
- Ward (2001), “High Dynamic Range Imaging,” Proceedings of the Ninth Color Imaging Conference, November 2001. [PDF]
- Durand and Dorsey (2002), “Fast Bilateral Filtering for the Display of High-Dynamic-Range Images” In SIGGRAPH 2002. [PDF]
- Reinhard, Stark, Shirley and Ferwerda (2002), “Photographic Tone Reproduction for Digital Images”, In SIGGRAPH 2002. [Website]
- Banterle, Artusi, Debattista, and Chalmers (2011) Advanced High Dynamic Range Imaging CRC Press. (with Matlab Code)
- Many Software suites on the Internet.
- Also, look for “Exposure Fusion”

commons.wikimedia.org/

Next Class

- ★ HDR Continued
  - Computing the relationship between Scene Radiance and Pixel Values
  - Display HDR Images

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Credits

- ★ Softwares used
  - Matlab by Mathwork's Inc.
- ★ For more information, see
  - Richard Szeliski (2010) Computer Vision: Algorithms and Applications, Springer.
- ★ Some concepts in slides motivated by similar slides by J. Hays.
- ★ Some images retrieved from
  - http://commons.wikimedia.org/.
  - List will be available on website.
  - Photographs by Irfan Essa

www.flickr.com/photos/neneonline/231886965/

Georgia Institute of Technology

Computational Photography

Dr. Irfan Essa
Professor
School of Interactive Computing

Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.