Abstract: Previous work [Peli91] has demonstrated the value of using digital techniques to simulate the appearance of images to low vision observers. However unlike images, real scenes often have high dynamic ranges of intensities that can produce serious visual impairments in people with low vision. Existing simulation techniques do not account for these effects. In this work we present a new algorithm for simulating the appearance of high dynamic range scenes to normal and low vision observers. As input, the algorithm takes a stream of high dynamic range images captured by a digital camera or generated by a computer graphics system. The images are processed through a computational model of vision that accounts for the changes in glare, contrast and color sensitivity, visual acuity, and dark adaptation that occur under varying illumination conditions for normal and low vision observers. The output is a stream of low dynamic range images that simulate for a display observer what the scene looks like to the scene observer. To demonstrate the utility of the method we generate image sequences that simulate the dramatic differences in glare susceptibility and dark adaptation that are experienced by young and old observers in high dynamic range scenes.

Simulating low vision in high dynamic range scenes

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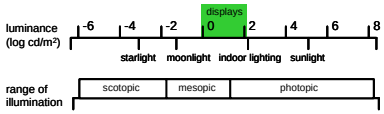
- **background:** the range of light we encounter in the environment is vast
  - absolute range: ~100,000,000:1 (sunlight to starlight)
  - dynamic range: >10,000:1 (highlights to shadows)



- vision functions over these ranges through adaptation
  - pupil, rods/cones, bleaching, neural gain controls
- but function is not equally good under all conditions
  - photopic: good contrast, trichromatic, high acuity
  - scotopic: poor contrast, achromatic, low acuity
  - time course of dark/light adaptation
  - light scattering/glare
- also visual function changes with aging/disease
  - increased glare
  - reduced contrast sensitivity
  - slowed time course of adaptation
- elderly and people with visual dysfunctions may have greater impairments under extreme lighting conditions

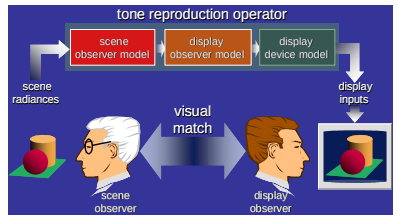
- **goal:** to produce images that are predictive simulations of visibility for different observers (young/old/impaired) under different lighting conditions (wide absolute/high dynamic ranges)

- **method:** image processing algorithm based on:
  - 1) physically accurate high dynamic range images
  - 2) visibility preserving tone reproduction operator
  - 3) model of visual adaptation/aging

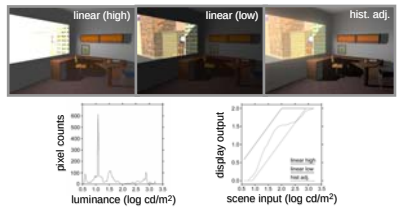
- **1) high dynamic range (HDR) imaging**

  - natural scenes can have large intensity ranges
  - can't be represented by standard image formats
  - method developed by Debevec89
  - process series of exposures
  - recover camera transfer function
  - stack exposures to produce "radiance maps"

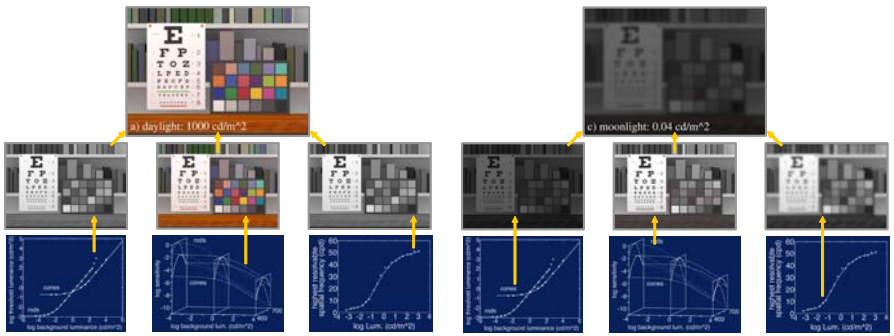
- **2) tone reproduction operator**
  - problem: display devices can't reproduce the large intensity ranges found in natural scenes
  - solution: tone reproduction operators
  - use visual models to map scene to display with the goal of reproducing appearance



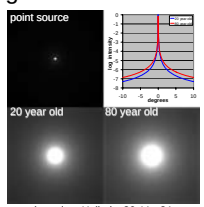
  - Ward97 tone reproduction operator
    - histogram adjustment method
    - visibility preserving



- **3) visual model**
  - based on Ferwerda96
  - accounts for changes in contrast/spectral sensitivity, acuity, glare, dark adaptation
  - varying illumination conditions (wide absolute/high dynamic ranges)
  - different observers (young/old)

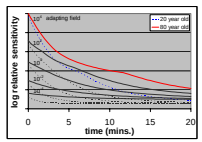


- glare:



  - based on Holladay26, Vos84

- dark adaptation:



  - based on Haig41, Jackson99

- **simulations:**
  - **20 vs. 80 year old, glare, hdr scene:**

  - **20 vs. 80 year old, dark adaptation:**

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