Radiometric Calibration

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Radiometric Calibration

• Since color is important, we want to emit and capture the colors we expect

• Example Goal:
  “Given a desired color $x$, instruct the projector to illuminate the color $y$ such that what appears to the camera is $x$”

  ...Ideally $x=y$, but in practice this is not the case
Radiometric Calibration

- Coordinate the per-channel color intensities between multiple projectors

**Before light hits the image plane:**

- Scene → Scene Radiance $L$
- Lens → Image Irradiance $E$
- ~Linear Mapping

**After light hits the image plane:**

- Image Irradiance $E$ → Camera Electronics
- Measured Pixel Values $I$
- Non-linear Mapping

Can we go from measured pixel value, $I$, to scene radiance, $L$?
Grayscale Calibration

• Assuming n-bit channels, project $2^n$ “gray-level images” onto the scene and capture the appearance $2^n$ times
When extending to color, since color channels are not fully non-overlapping, the color mixture must be taken into account.
Color Calibration

• Assuming n-bit RGB channels, project $3 \times 2^n$ “single-color images” onto the scene and capture the appearance $3 \times 2^n$ times

\[
\begin{bmatrix}
R-R & G-R & B-R \\
R-G & G-G & B-G \\
R-B & G-B & B-B \\
\end{bmatrix} = C
\]
Color Calibration

• $\mathbf{C}$ is the color mixture matrix
• $\mathbf{x} = \text{projector color}, \mathbf{y} = \text{camera color}$, thus
  \[
  \mathbf{y} = \mathbf{C}\mathbf{x}
  \]
  \[
  \mathbf{x} = \mathbf{C}^{-1}\mathbf{y}
  \]
Additional Issues

• Linear vs. Nonlinear Response

Nayar et al., CAVE
Additional Issues

• Exposure settings
  At what aperture and shutter speed?
  ...behavior is not necessarily linear

  ...can fix the settings but that obtains a limited
  dynamic range

• Vignetting
Reducing Acquisition Time

- For 8-bit per channel, RGB, multiple exposures (e.g., 3), means $256 \times 3 \times 3 = 6912$ images

Acceleration schemes:

- e.g., total of 6 images

“Making One Object Look Like Another”
Grossberg et al., 2004

Does not handle “inter-reflections”...