Thin lens model (camera)

\[ E(x,y) = L(\theta) \frac{\pi (A')^2}{f^2} \]

Camera f-number (f-stop)

\[ N = \frac{f}{A} \]

\[ N = 1.4, 2, 2.8, 4, 5.6, 8, 11 \]

\[ N = \sqrt{2}, \sqrt{4}, \sqrt{9}, \sqrt{16}, \sqrt{32}, \sqrt{64}, \sqrt{128} \]

Change \( f \) with \( A \) fixed

Two ways to change \( N \)

Change \( A \) with \( f \) fixed

Exposure

\[ E(x,y) \times t = \text{light energy} \]

Shutter Speed (\( \frac{1}{t} \))

Typical \( t \)

... 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512, ...

Typical shutter speed \( \frac{1}{t} \) (on camera display)

... 2, 4, 8, 15, 30, 60, 125, 250, 500, ...
Exposure

\[ E(x,y,t) = \frac{L(x,y)}{N^2} \left( \frac{A}{e^2} \right)^4 \cdot t \]

- Increase \( N \) (by decreasing \( A \)) \( \Rightarrow \) \( E(x,y,t) \) fixed
- Decrease \( t \) (increase \( t \)) \( \Rightarrow \) \( E(x,y,t) \) fixed
- Increase \( N \) (by increasing \( t \)) \( \Rightarrow \) \( E(x,y,t) \) increased
- Decrease \( t \) (increase \( t \)) \( \Rightarrow \) \( E(x,y,t) \) size change (more complicated)

Camera Response (Time Invariant)

\[ T \left( E(x,y,t) \right) \rightarrow \{ 0, 1, \ldots, 255 \} \]

- Under exposure
- 0
- 255
- \( \log \) exposure = \( \log E + \log t \)

Dynamic Range

- 255
- 0
- \( \log \) exposure = \( \log E + \log t \)

High Dynamic Range Imaging

- Given: \( T \left( E(x,y,t) \right) \rightarrow \{ 0, 1, \ldots, 255 \} \)
- Image intensities \( I_t(x,y) \)
- For many shutter speeds \( \frac{1}{t} \)

Compute

\[ E(x,y,t) = T^{-1} \left( I_t(x,y) \right) \]

For each \((x,y)\) use an image such that \( 0 \leq I(x,y) \leq 255 \)
Color

Radiance
}

irradiance

\( L(x, \vec{t}, \lambda) \)

\( E(x, \lambda) \)

BRDF

\( \rho(x, \text{in}, \text{out}, \lambda) \)

Image irradiance

\( E(x, y, \lambda) \)

Pixel (Bayer pattern)

\( E_{\text{RGB}}(x, y) = \int C_{\text{RGB}}(\lambda) E(x, y, \lambda) \, d\lambda \)

3 intensities per pixel