Optics redux
CS 178, Spring 2009

Marc Levoy
Computer Science Department
Stanford University

A few extra notes on tradeoffs between camera parameters, on macro lenses, and on zoom lenses, added 4/14/09
Tradeoffs affecting brightness

Legend:
- Camera Setting(s)
- Photographic Effect
- Changing one setting
- Changing two settings

Diagram showing the relationships and tradeoffs between
- Aperture & ISO
- Exposure Time
- Motion Blur
- Depth of Field
- Brightness
Tradeoffs affecting depth of field

\[ \text{DOF} \approx \frac{2CNU^2}{f^2} \]
\[ D_{\text{TOT}} \approx \frac{2NCU^2}{f^2} \]

\begin{itemize}
  \item \( N = f/4.1 \)
  \item \( C = 2.5\mu \)
  \item \( U = 5.9\text{m (19')} \)
  \item \( f = 73\text{mm (equiv to 362mm)} \)
  \item \( D_{\text{TOT}} = 132\text{mm} \)
  \item 1 pixel on this video projector
    \[ C = 2.5\mu \times \frac{2816}{1024} \text{ pixels} \]
    \[ D_{\text{EFF}} = 363\text{mm} \]
\end{itemize}
\* $N = f/16$
\* $C = 6.4\mu$
\* $U = \sim 9$mm
\* $f = 65$mm

(use $N' = (1+MT)N$ at short conjugates ($MT=5$ here))

$D_{TOT} = 0.02$mm! (20\mu)
Sidelight: macro lenses

\[ \frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f} \]

Q. How can the Casio EX-F1 at 73mm and the Canon MP-E 65mm macro, which have similar \( f \)'s, have such different focusing distances?

A. Because they are built to allow different \( s_i \)

- this changes \( s_o \), which changes magnification \( M_T \) \( \Delta \equiv -s_i / s_o \)
- macro lenses are well corrected for aberrations at short \( s_o \)
Extension tube:
converts a normal lens to a macro lens

✦ toilet paper tube, black construction paper, masking tape
✦ camera hack by Katie Dektar  (CS 178, 2009)
Lens combinations: telephoto

- telephoto (a) reduces the back focal distance B.F. relative to $f$
  - for long focal length lenses, to reduce their physical size
- reversed telephoto (b) increases B.F. relative to $f$
  - for wide-angle lenses, to ensure room for the reflex mirror
Lens combinations: telephoto

- Canon 500mm telephoto
- Canon 1200mm telephoto
- 500mm non-telephoto

(wikipedia)
Lens combinations:

✦ called **optically compensated zoom**, because the in-focus plane stays (more or less) stationary as you zoom

✦ to change focus, you move both lenses together

Canon FD 24-35mm f/3.5 L manual focus lens

(Flash demo)

http://graphics.stanford.edu/courses/cs178-09/applets/zoom.swf