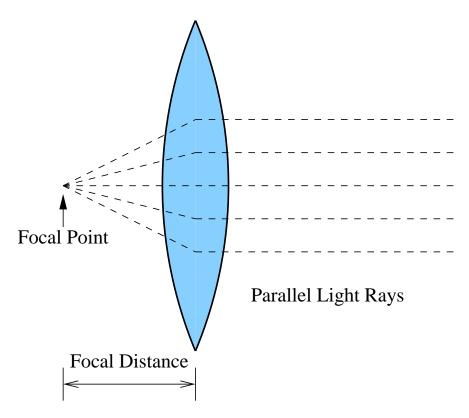
A Modern Digital Camera



- Single Lense Reflex (SLR) Camera
 - A mirror with a prism allows you to see through through the lense.
 - When photo is taken, mirror retracts to expose film and shutter in lense releases.
- Typical specifications (Nikon D200)
 - 23.6 mm×15.8 mm RGB charge coupled device (CCD) sensor
 - 10.2 Meg pixels (million pixels per photo)
 - 100 to 1600 ISO
 - Street price of $\approx $3,000$ with lense, flash, and digital media

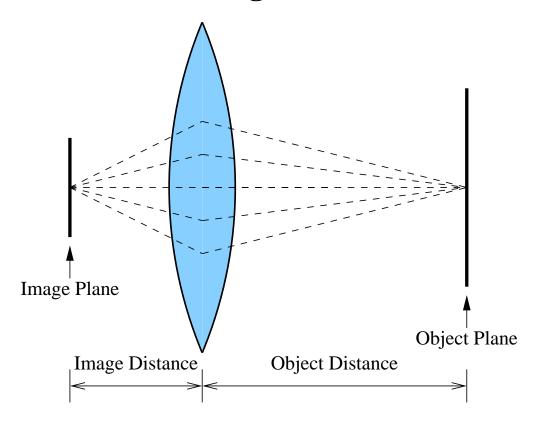
Lens: Focal Length



d_f - Focal length of lens

- Focuses incoming parallel rays of light to a point
- Based on a thin lens model

Lens: Image Formation



• Quantities:

 d_f - Focal length of lens

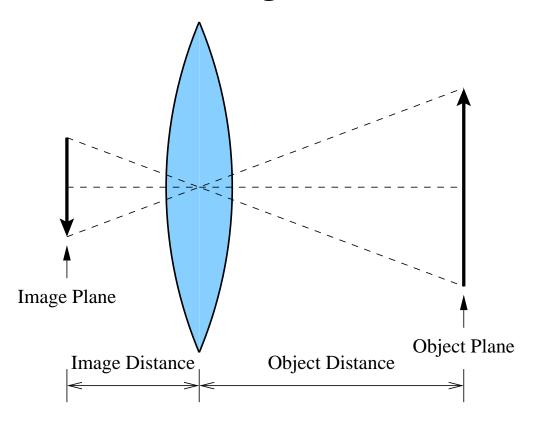
 d_o - Distance to object plane

 d_i - Distance to image plane

• Basic equation

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_f}$$

Lens: Magnification



• Quantities:

 d_o - Distance to object plane

 d_i - Distance to image plane

• Basic equation

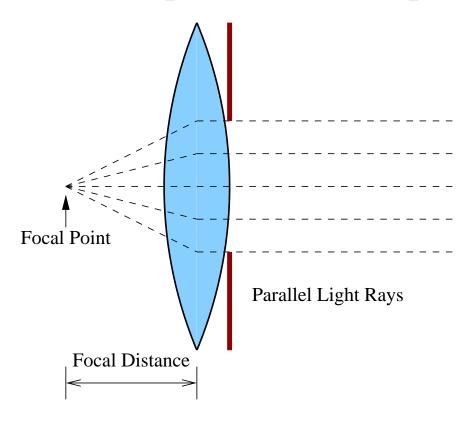
$$M = -\frac{d_i}{d_o}$$

- Negative sign indicates that image is inverted

Lens: Typical Imaging Scenerios

- Typical case for Photography
 - $-d_o >> d_f$
 - $-d_i \approx d_f$
 - But in addition $d_i > d_f$
 - -M << 1
- Typical case for microscopy
 - $-d_i >> d_f$
 - $-d_o \approx d_f$
 - But in addition $d_o > d_f$
 - -M >> 1

Lens: Aperture and f-Stop



• Quantities:

A - Diameter of aperture

N - f-stop of lens

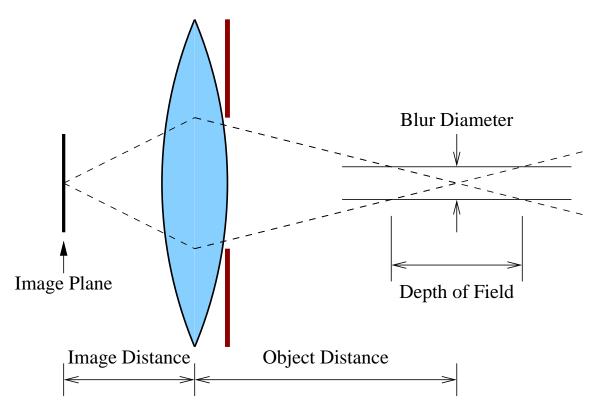
 d_f - Focal distance of lens

• Basic equation

$$N = \frac{d_f}{A}$$

- Large $N \Rightarrow$ small aperture \Rightarrow slow lens
- Small $N \Rightarrow$ large aperture \Rightarrow fast lens





• Quantities:

D - depth of field

 c_o - Blur diameter for object plane

N - f-stop of lens

 ${\cal M}$ - Magnification

• If object is far away, then

$$\frac{D}{c_o} = \frac{2N}{-M}$$

- Small aperture increases depth-of-field

Space Domain Models for Optical Imaging Systems

• Consider an imaging system with real world image f(x, y), focal plane image g(x, y), and magnification M. Then the behavior of the system may be modeled as:

$$g(x,y) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(\xi,\eta) h(x - M\xi, y - M\eta) d\xi d\eta$$
$$= \frac{1}{M^2} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f\left(\frac{\xi}{M}, \frac{\eta}{M}\right) h(x - \xi, y - \eta) d\xi d\eta$$

Define the function

$$\widetilde{f}(x,y) \stackrel{\triangle}{=} f\left(\frac{\xi}{M}, \frac{\eta}{M}\right)$$

• Then the imaging system act like a 2-D convolution.

$$g(x,y) = \frac{1}{M^2}h(x,y) * \tilde{f}(x,y)$$

Point Spread Functions for Optical Imaging Systems

• Definition: h(x, y) is known as the *point spread function* of the imaging system.

$$g(x,y) = \frac{1}{M^2}h(x,y) * \tilde{f}(x,y)$$

ullet Notice that when $f(x,y)=\delta(x,y)$

$$g(x,y) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \delta(\xi,\eta) h(x - M\xi, y - M\eta) d\xi d\eta$$
$$= h(x,y)$$

Transfer Functions for Optical Imaging Systems

• In the frequency domain,

$$G(u,v) = \tilde{F}(u,v) \frac{1}{M^2} H(u,v)$$

$$\begin{array}{ccc} g(x,y) & \overset{C \not S FT}{\Leftrightarrow} & G(u,v) \\ h(x,y) & \overset{C \not S FT}{\Leftrightarrow} & H(u,v) \\ \tilde{f}(x,y) & \overset{C \not S FT}{\Leftrightarrow} & \tilde{F}(u,v) \end{array}$$

• The Optical Transfer Function (OTF) is

$$\frac{H(u,v)}{H(0,0)}$$

• The *Modulation Transfer Function (MTF)* is

$$\left| \frac{H(u,v)}{H(0,0)} \right|$$