A Geometric Camera Model
Outline

1 The Pinhole Camera
2 The Projection Equations
3 Depth of Field
4 Distortion
The Pinhole Camera

- Pinhole
- Projection ray
- Image plane
- Optical axis
Putting the Image Plane in Front?
In Math, We Can

- **Camera reference system** \((X, Y, Z)\) is right-handed, \(Z\) toward scene
- Distance btw center of projection and principal point: *focal distance* \(f\)
- **Canonical image reference system** \((x, y)\) has origin at principal point
- **Pixel image reference system** \((\xi, \eta)\) has origin at top left of sensor
  - \(\xi = s_x x + \xi_0\) and \(\eta = s_y y + \eta_0\) (\(s_x, s_y\) in pixels/mm)
The Projection Equations

$$\frac{x}{u} = \frac{0}{v}$$

$$\begin{cases}
x = f \frac{x}{u} \\
y = f \frac{y}{u}
\end{cases}$$
Depth of Field

- Focal length: focal **distance** when an object at $\infty$ is in focus
- Focal length is a lens property
- Focal distance can be changed by rotating the focusing ring
- Nothing to do with **zoom**, which changes focal length
- Alas, $f$ is often used for either focal distance or focal length
Changing Depth of Field

- **Aperture**: diameter of the hole in front of the lens
- Measured in *stops*, or *f-numbers* $n = \frac{f}{a}$
  ($a$ is aperture diameter, $f$ is focal length)
- Area (light flux) is proportional to *square* of diameter
- Small aperture (big *f*-number) $\Rightarrow$ great depth of field
- A shallow depth of field is sometimes desirable
Distortion

pincushion

barrel

\[
\frac{1}{z} + \frac{1}{a} = f
\]