Optics for ~~Dummies~~

Ron Parr
CPS 1/296

Optics for Roboticists

Ron Parr
CPS 1/296

Basic Pinhole Camera

- Make a tiny hole a piece of paper
- Place a screen in a darkened area behind paper
- See picture on board

- Result: Flipped (top/bottom, right/left) reproduction of scene in miniature

Pinhole Camera Equations

- Idealize pinhole as a point
- All rays producing image must pass through this point
- Assume:
  - Pinhole is origin
  - image plane is distance z' from pinhole
  - Subect is in a plane with offset distance z from pinhole
- Reasoning from similar triangles:

$$\frac{x'}{x} = \frac{y'}{y} = \frac{z'}{z}$$

Magnification

- Determine scale from ratio of z' to z

$$x' = z'\frac{x}{z} = -mx$$

$$y' = z'\frac{y}{z} = -my$$

$$m = -\frac{z'}{z}$$

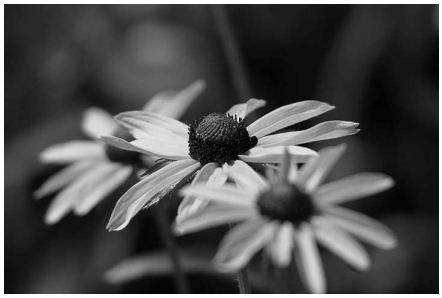
- Note that z' and z have opposite signs

Why Aren't all Cameras Pinhole Cameras?

http://www.camerahacker.com/EOS_Pin-Hole_Lens/index.shtml

- Inefficient use of light
- No flexibility in size/design
- Deep (infinite) depth of field
  (both a pro and con)

Depth of Field Example I



Depth of Field

- Range of depths that are acceptably sharp
- Depends upon viewing conditions
- Powerful tool for photographers
- Mostly an annoyance for roboticists
- Can be used to get depth from focus in some cases

http://www.ri.cmu.edu/projects/project_365.html

Depth of Field Example II

Perspective

- Why do parallel lines seem to "meet at infinity"???

$$x' = z'\frac{x}{z} = -mx$$

$$y' = z'\frac{y}{z} = -my$$

$$m = -\frac{z'}{z}$$

- What is constant?
- What changes?

Thin Lenses

- Simplified model of lenses
- Ignores thickness of lens – properties derived from shape of material surface (typically assumed to be arcs) only
- An actual camera "lens" is composed of multiple individual lenses called "elements"
- OK approximation

Thin Lens Equations

- Lens collects rays from a point at depth z
  - Contrast with pinhole
  - See example on board
- Focuses these rays on a point at depth z'

$$\frac{1}{z'} - \frac{1}{z} = \frac{1}{f}$$

- f is the focal length of the lens (can be derived from curvature and index of refraction of material)

How Does a Camera Focus?

- Move the lens (most common), or…
- Move the image(r) plane

Determining Focal Length Experimentally

- Focus camera at "infinity"
- Measure distance from lens to image
- What is the focal length of a pinhole camera?

Focal Length and Magnification

- Similar triangles idea still applies
- Combine: $$\frac{1}{z'} - \frac{1}{z} = \frac{1}{f}$$
- With $$x' = z'\frac{x}{z} = -mx$$ $$y' = z'\frac{y}{z} = -my$$ $$m = -\frac{z'}{z}$$