Perception

vestibular - cutaneous tactile - visual - auditory
olfactory - proprioceptive

...a richly encoded representation of the relationship between the agent and the world.

Percept Inversion

"If sensory stimuli are produced in such and such a way by the world, then what must the world have been like to produce this stimulus"?

$$Stimulus = f(World) \qquad World = f^{-1}(S)$$

- the functions, $f()$, are only partially known,
- in general, the inverse of $f()$ is not well-conditioned

$$\Downarrow$$

knowledge and **experience** (richly associative sensor information) can fill in initially inaccessible detail

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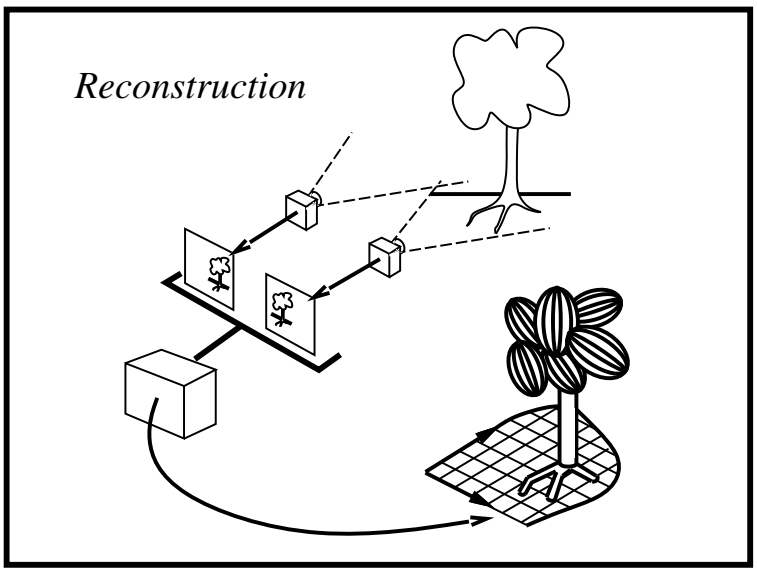
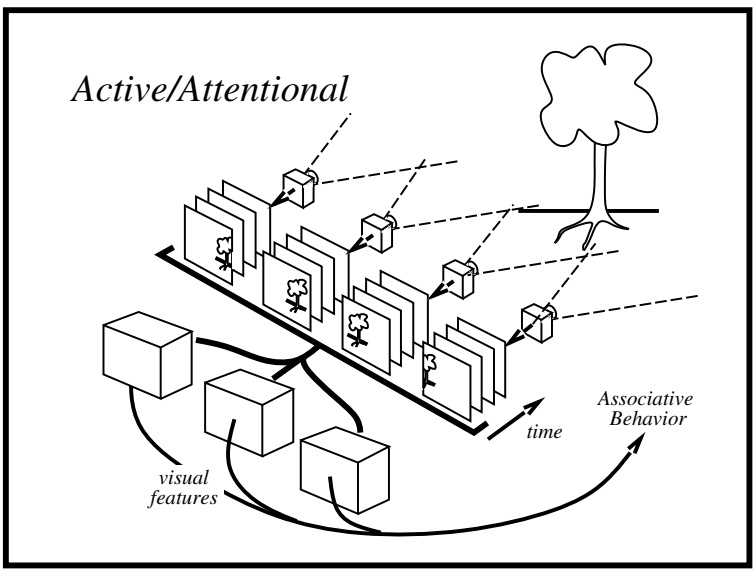
Embodied Perceptual Systems





adapted from material presented by Bob Bolles at the 1993 International Symposium on Intelligent Control

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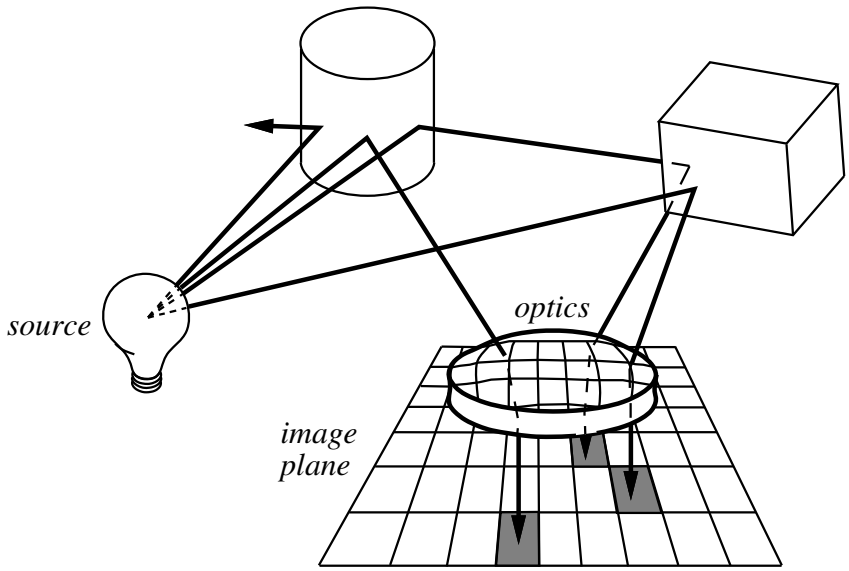
Vision - Image Acquisition



- Energy from a light source is radiated uniformly over 4π steradians.
- **irradiance** and consists of the sum of all incident radiation.
- **radiance** describes the energy leaving a surface and differs from the irradiance by energy transmitted into and absorbed.
- Reflection can be **diffuse** or **specular** depending on surface properties and wavelength.
- Reflected electromagnetic energy sources modulate the **spectral content**, **intensity**, and **polarization** of the incident light.
- the **radiant intensity function** is projected onto a 2D **image plane**, **sampled** spatially, and **digitized** 30 times each second.

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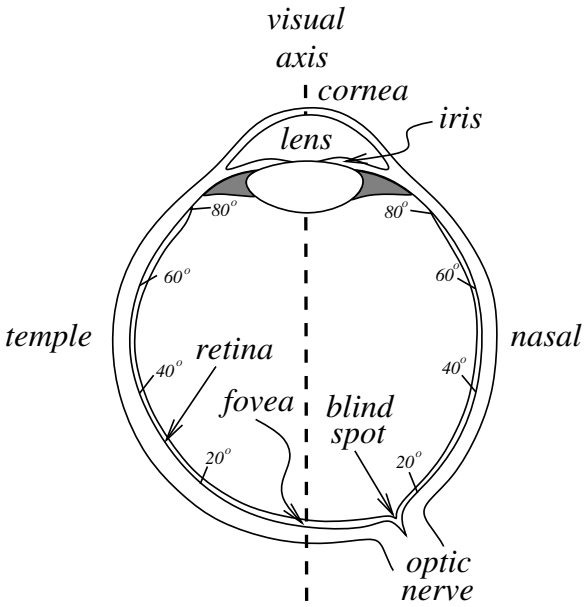
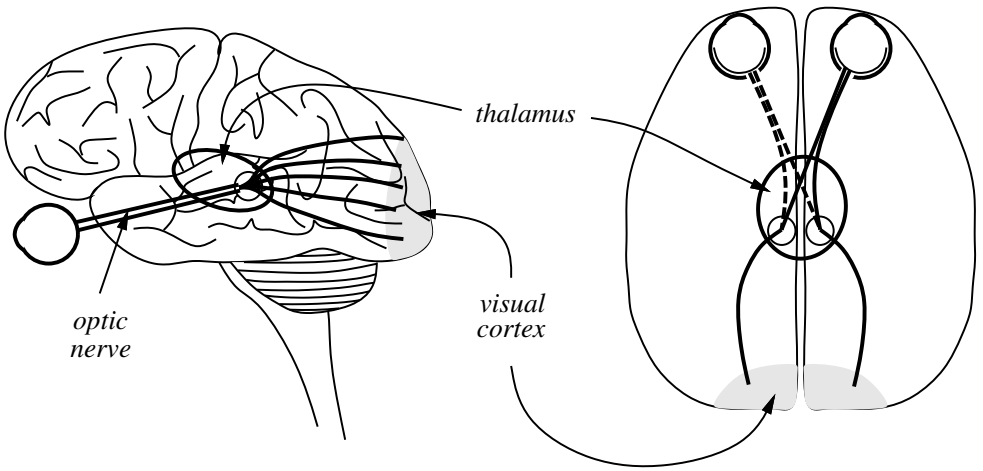
Human Eye



The photosensitive **retina** consists of a total of about 100×10^6 receptors ($512 \times 512 = 0.25 \times 10^6$).
rods measure intensity
cones respond to red-green-blue bands of the visual spectrum.

Roughly 0.8×10^6 nerve fibers exit the eye via the **optic nerve**.



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Biological Variants

Herbivores - Side facing (monocular) vision systems yield almost wrap around field of view.

Carnivores - forward facing (stereo) system provides precision depth perception with a narrow field of view (< 180 degrees)

Cheetah - wide, eccentric foveal region spanning horizontal band for locating prey on the African plains.

Chamelion - turret eyes capable of both side- and forward-looking configurations

Nocturnal - variants with reflective back surface to catch stimulus that might otherwise slip through the receptive cells - small birds may sacrifice muscles for size.

Fishing - some fishing birds use polarizing lens

Rattlesnake - eyes oriented to side, but forward-looking stereo pit organs (no lens) that respond selectively to IR.

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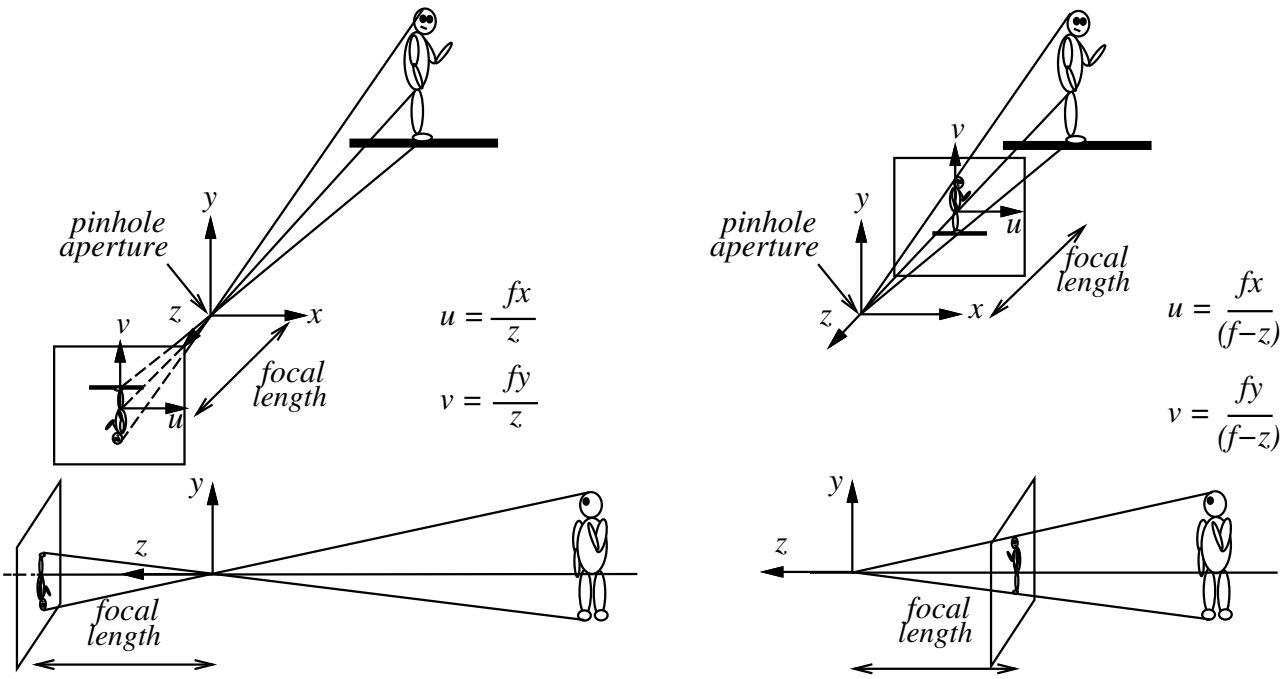
Pinhole Camera - Perspective Distortion



- **vanishing point** - point at which parallel lines in three space meet on the image plane due to perspective distortion.
- **orthographic projection** - as range goes to infinity, the geometric distortion due to variations in depth goes to zero.
- **shallow structure** - images of objects whose depth is small compared to their range are approximately orthographic.

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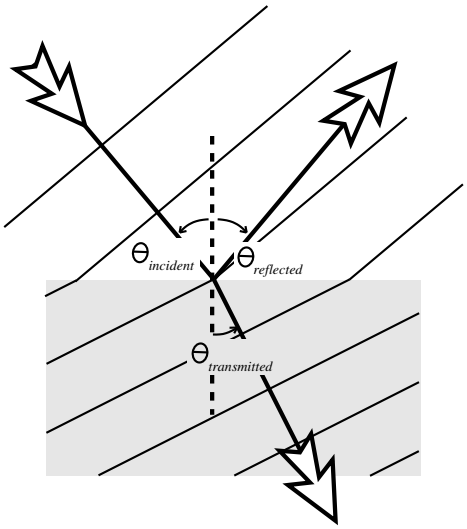
Optics - Snell's Law



Index of Refraction — the ratio of the speed of light in a vacuum to that in the optical material.

$$n = \frac{c}{v} = \sqrt{\frac{\epsilon\mu}{\epsilon_0\mu_0}}$$

where

μ – magnetic permeability, and

ϵ – electric permittivity.

$$\frac{sin(\theta_{incident})}{sin(\theta_{transmitted})} = \frac{n_t}{n_i},$$

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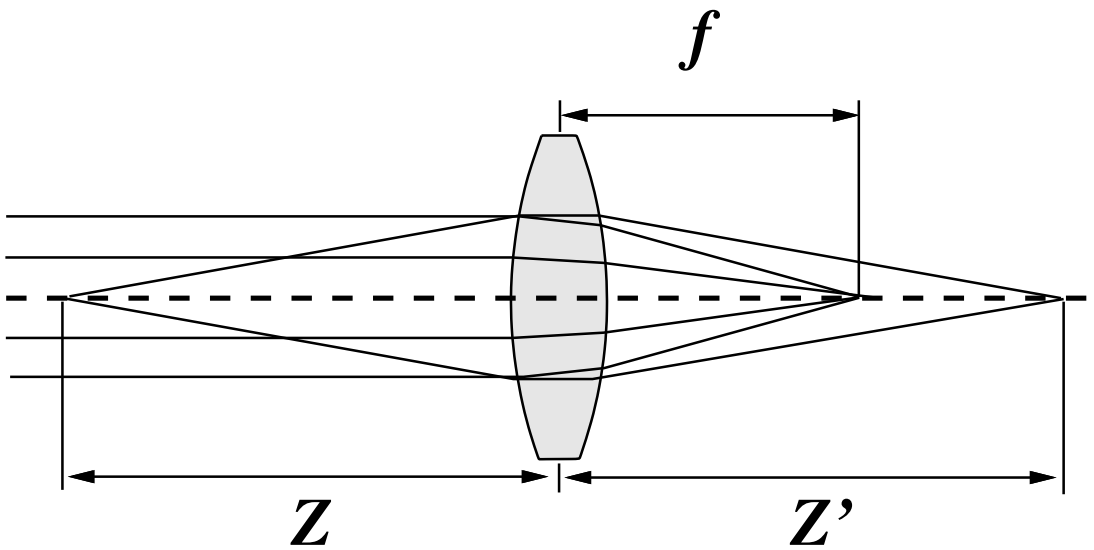
Optics - Gaussian Lens Formula

$$\frac{1}{Z} + \frac{1}{Z'} = \frac{1}{f}$$

where:

- Z – distance from the lens to the object
- Z' – distance from the lens to place where the image is formed
- f – focal length of the lens



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