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"?

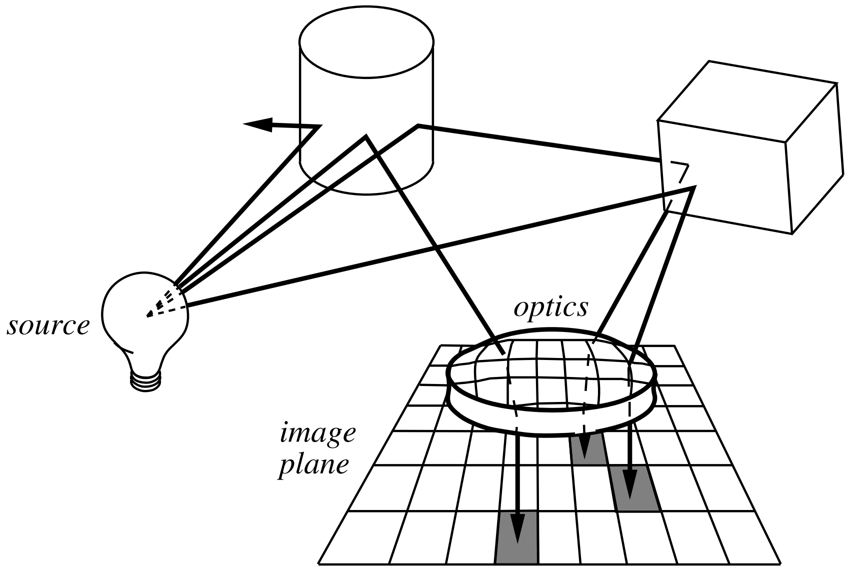
$$Stimulus = f(World) \qquad World = f^{-1}(S)$$

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

$$\Downarrow$$

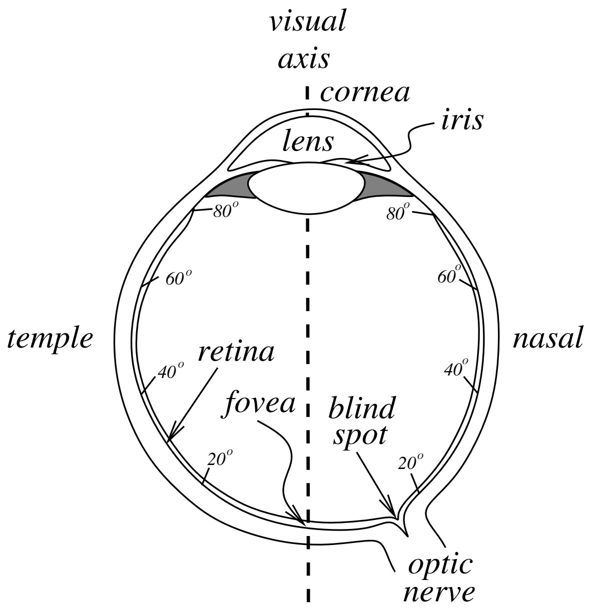
knowledge and **experience** (richly associative sensor information) can fill in initially inaccessible detail

Vision - Image Acquisition



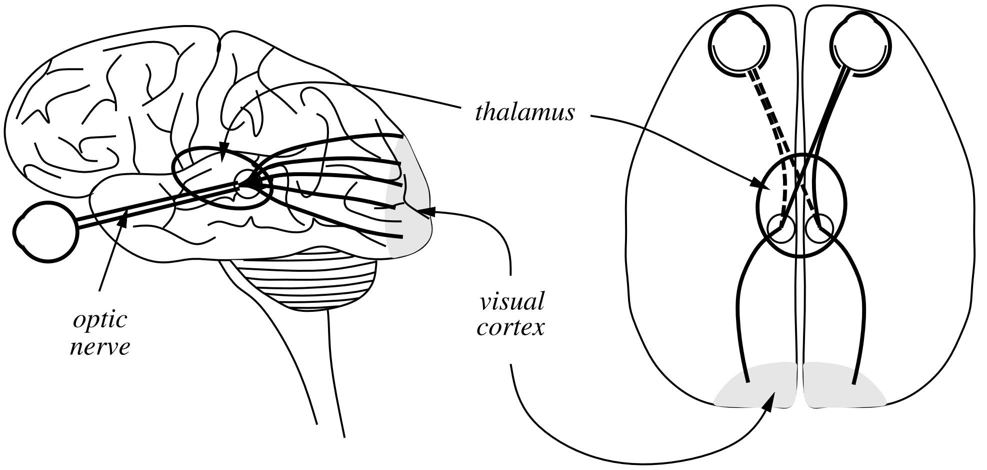
- Energy from a light source is radiated uniformly over 4π steradians.
- **irradiance** and consists of the sum of all incident radiation.
- **radiance** describes the energy leaving a surface and differs from the irradiance by energy transmitted into and absorbed.
- Reflection can be **diffuse** or **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.

Human Eye

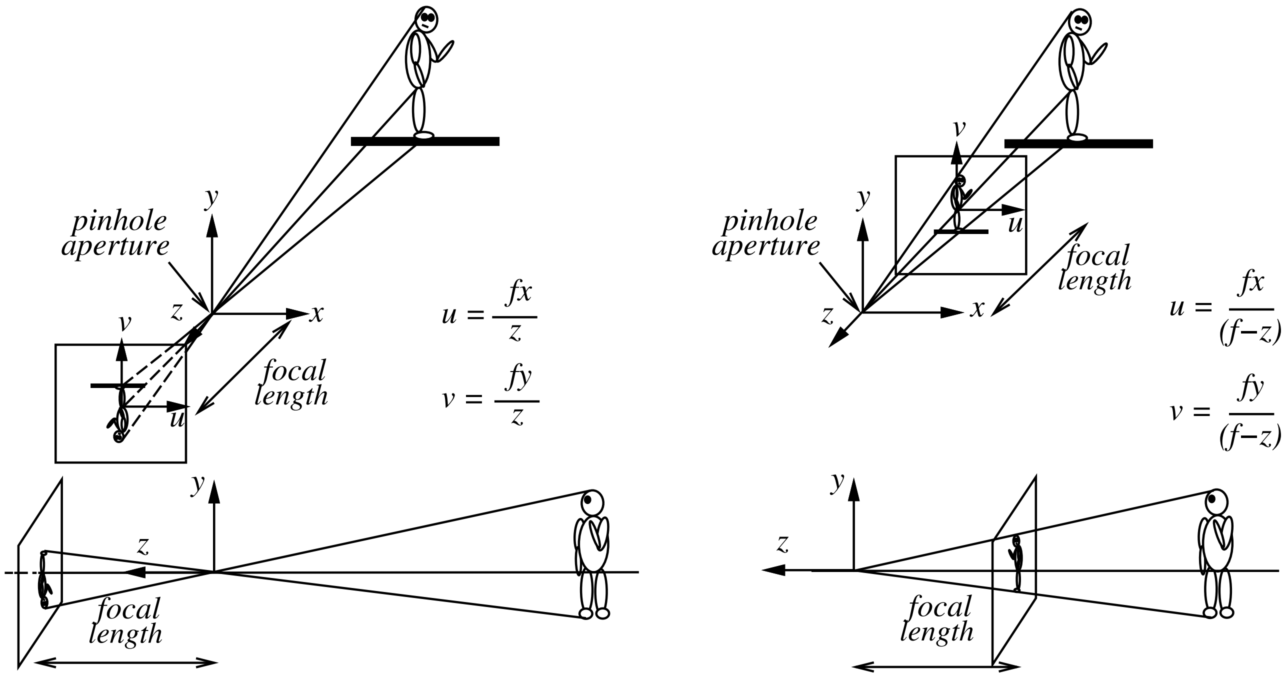


The photosensitive **retina** consists of a total of about 100×10^6 receptors ($512 \times 512 = 0.25 \times 10^6$).
rods measure intensity
cones respond to red-green-blue bands of the visual spectrum.

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

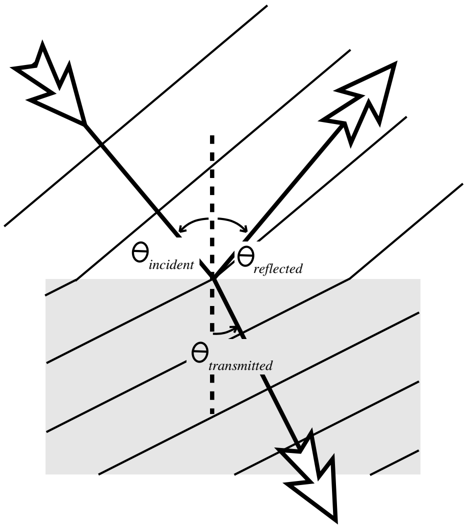


Pinhole Camera - Perspective Distortion



- **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.

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.

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

Optics - Gaussian Lens Formula

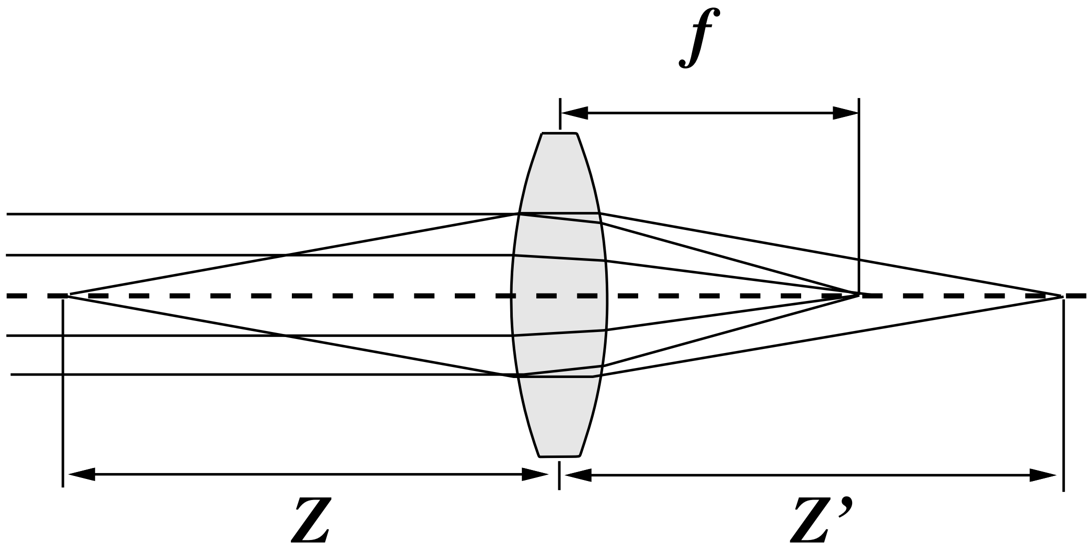
$$\frac{1}{Z} + \frac{1}{Z'} = \frac{1}{f}$$

where:

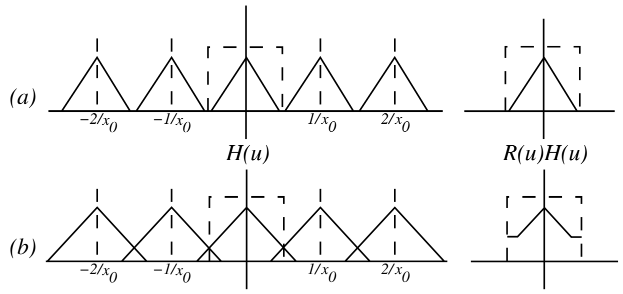
Z – distance from the lens to the object

Z' – distance from the lens to place where the image is formed

f – focal length of the lens



Aliasing (cont.)



$R(u)$ is a frequency domain bandpass filter

$$R(u) = \begin{array}{l} 1 \;\; if \;\; |u| < 1/(2x_0), \\ 0 \;\; otherwise \end{array}$$

Aliasing: When replicated spectra interfere, the crosstalk introduces energy at relatively high frequencies changing the appearance of the reconstructed image.

The Sampling Theorem: *if the image contains no frequency components greater than one half the sampling frequency, then the continuous image is faithfully represented in the sampled image.*

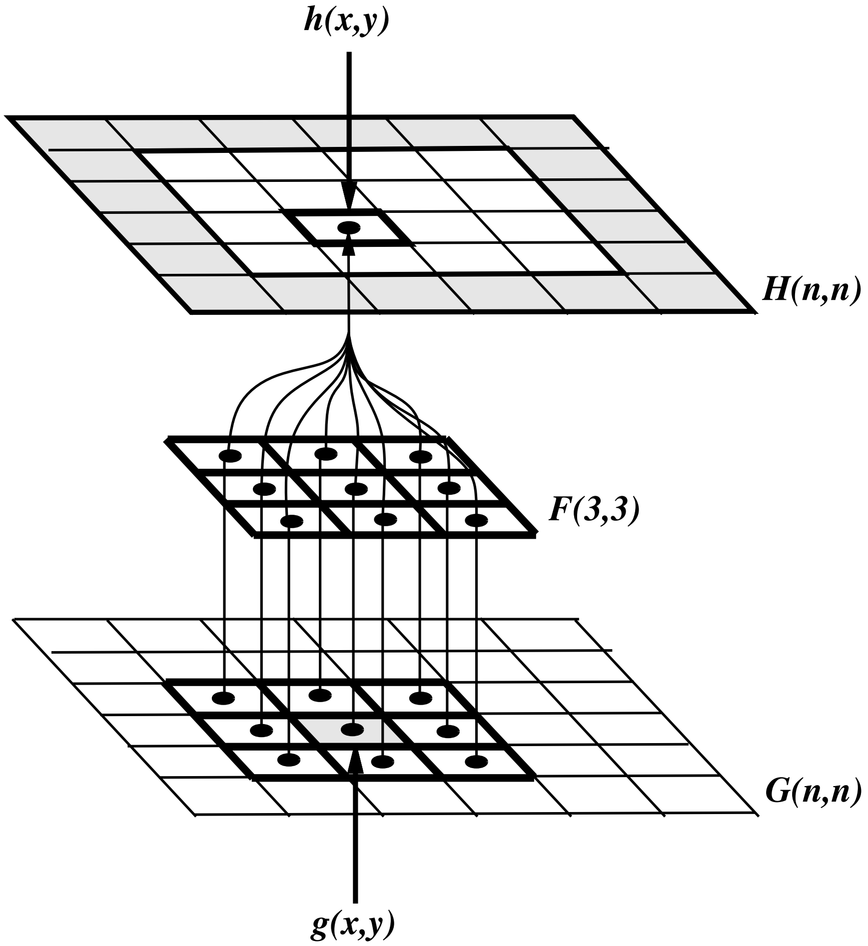
Early Processing - Convolution

The convolution of two functions $f(x)$ and $g(x)$:

$$f(x,y) * g(x,y) = h(x,y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(u,v)g(x-u,y-v)dudv$$

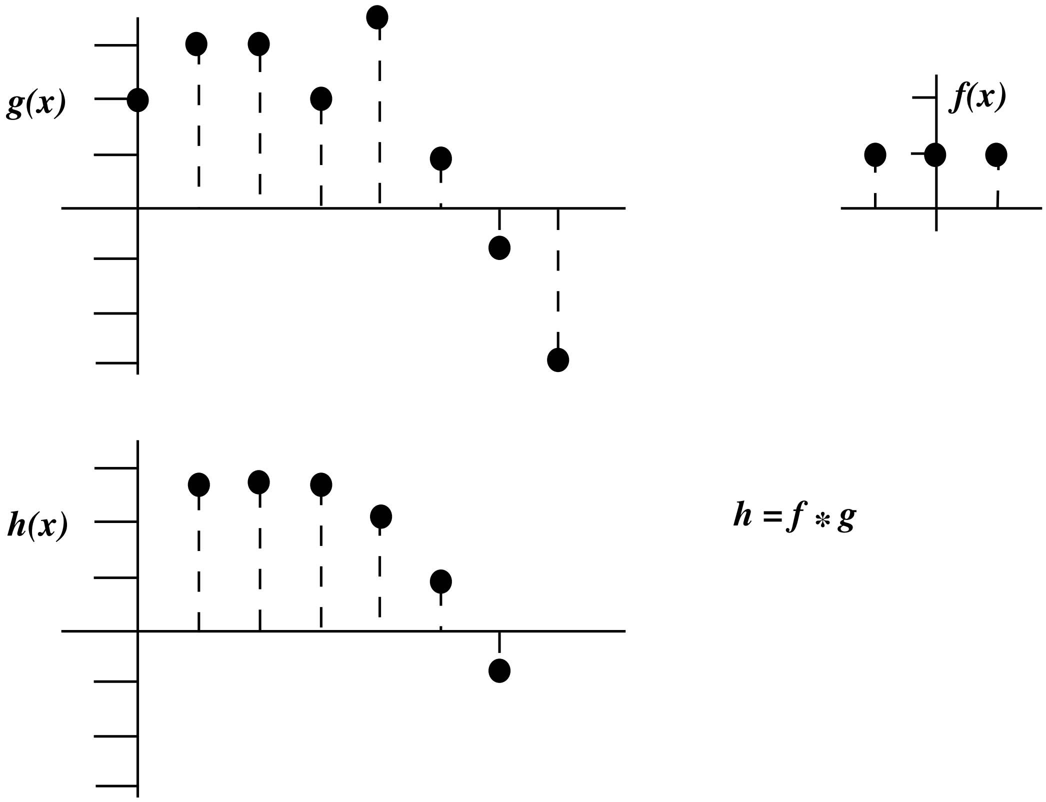
or

$$f(x,y) * g(x,y) = h(x,y) = \sum_{-\infty}^{\infty}\sum_{-\infty}^{\infty} f(u,v)g(x-u,y-v)$$



Early Processing - Smoothing

Low Pass Filter



Early Processing - Edges

Intensity Gradients

$$\nabla g = \frac{dg}{dx}\hat{x} + \frac{dg}{dy}\hat{y}$$

$$\begin{aligned}
\frac{dg(x,y)}{dx} &\approx \frac{g(x+1,y) - g(x-1,y)}{2} \\
&\Rightarrow f_x = \left[-\frac{1}{2},\ 0,\ \frac{1}{2}\right]_{1x3}
\end{aligned}$$

$$\begin{aligned}
\frac{dg(x,y)}{dy} &\approx \frac{g(x,y+1) - g(x,y-1)}{2} \\
&\Rightarrow f_y = \begin{bmatrix} -\frac{1}{2} \\ 0 \\ \frac{1}{2} \end{bmatrix}_{3x1}
\end{aligned}$$

$$\begin{aligned}
|\nabla g| &= \left[\left(\frac{dg}{dx}\right)^2 + \left(\frac{dg}{dy}\right)^2\right]^{\frac{1}{2}} \\
&= \\
\phi &= tan^{-1}\left(\frac{dg/dy}{dg/dx}\right)
\end{aligned}$$

Early Processing - Edge Sharpening

Laplacian

$$\nabla^2 g = \frac{d^2 g}{dx^2} + \frac{d^2 g}{dy^2} \Rightarrow f = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$