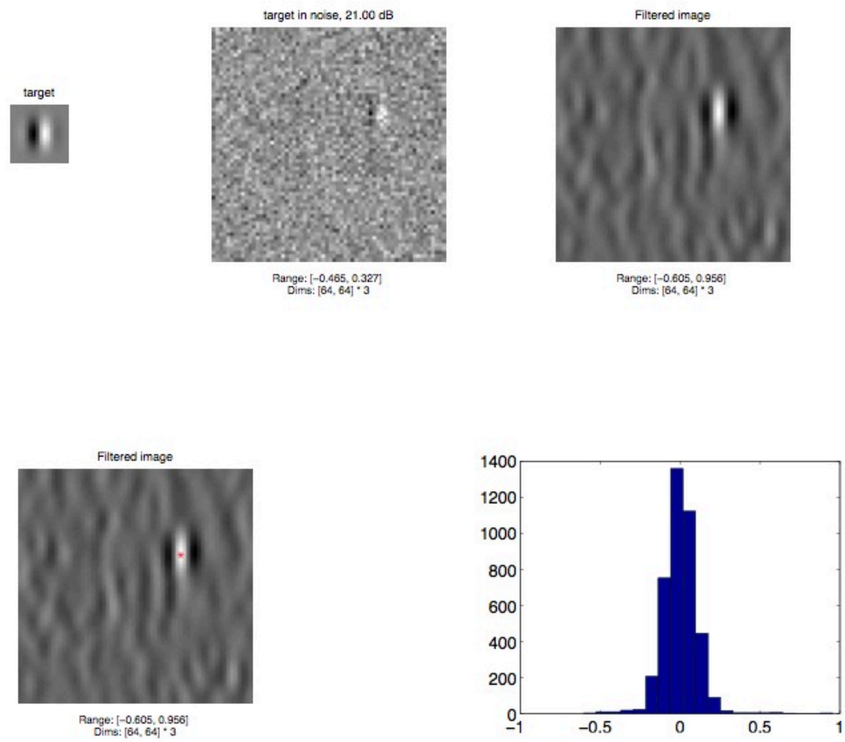
matched filter

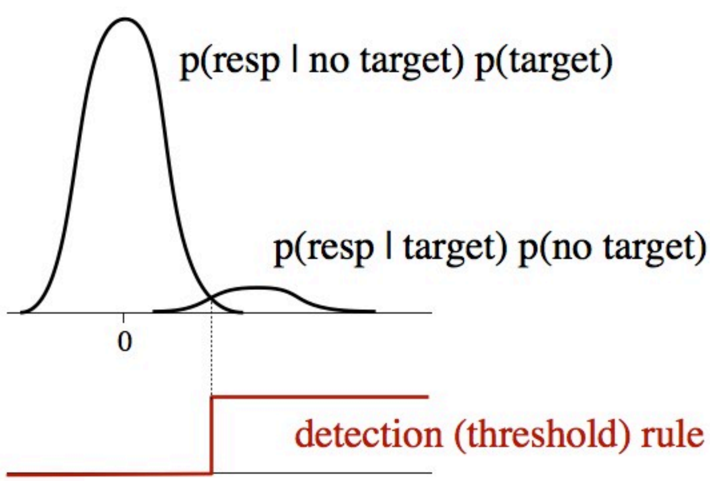
North, D. O. (1943). "An analysis of the factors which determine signal/noise discrimination in pulsed carrier systems". RCA Laboratories, Princeton, NJ, Technical Report PTR-6C.

- Known target
- Additive white Gaussian noise
- Linear + threshold detector

[on board]



Signal detection interpretation



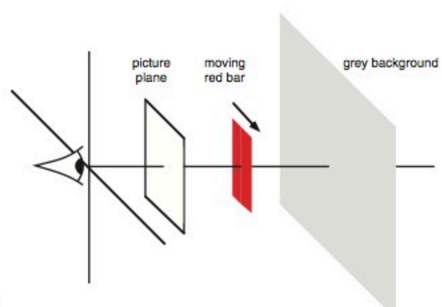
[on board]

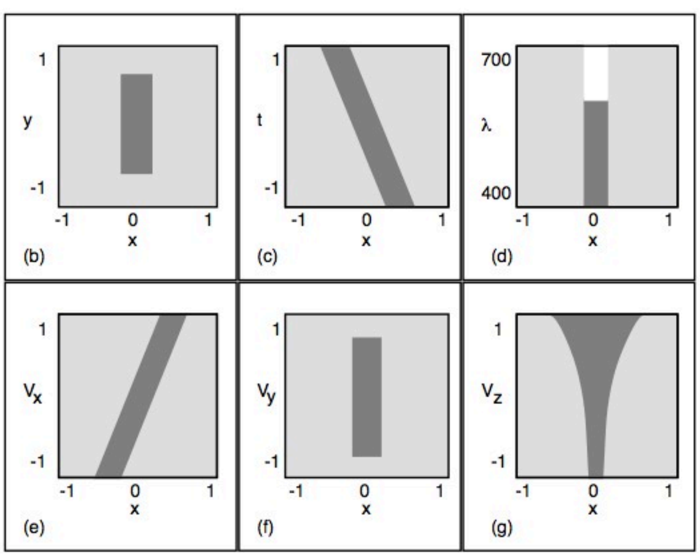
matched filter

- brute-force solution for finding known template at unknown location
- assumes white Gaussian noise (easily modified for correlated Gaussian noise)
- assumes a single copy of target (not a superposition)
- assumes known, fixed template (no distortions/ deformations)

Plenoptic slices

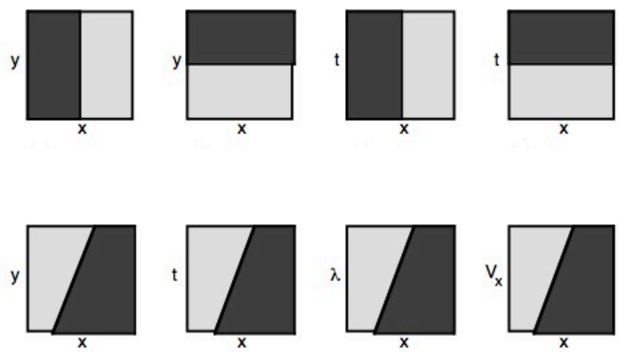
$$I(x, y, \lambda, t, V_x, V_y, V_z)$$





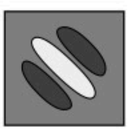
[Adelson & Bergen 91]

- Visual system is interested in relative quantities
- Machine vision systems often seek boundaries
- Where are the discontinuities, and at what orientation [space, time, etc]?



Derivatives are fundamental...

[Koenderink, 1984; Adelson & Bergen 1990]

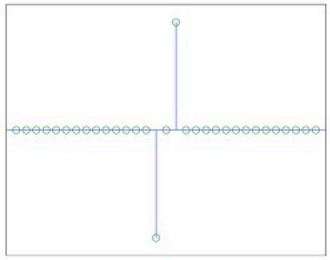


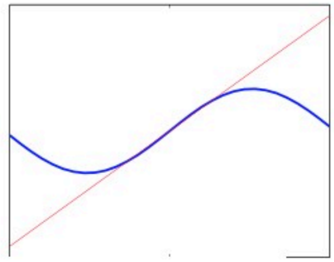
	x	y	t	λ	V_x
x	—				
y	**diag. "bar"** static achromatic no dispar	—			
t	**vert. "bar" leftward** achromatic no dispar	**hor. "bar" downward** achromatic no dispar	—		
λ	**vertical** static **hue-sweep** no dispar	**horiz.** static **hue-sweep** no dispar	full-field **sequential hue-sweep** no dispar	—	
V_x	**vert. "bar"** static achromatic **hor. dispar**	**hor. "bar"** static achromatic **vert. dispar**	full-field **sequential** achromatic **eye-order**	full-field static **hue-shift luster**	—

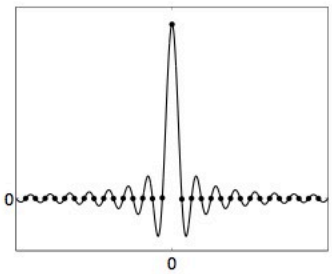
[Adelson & Bergen 91]

Discrete derivatives

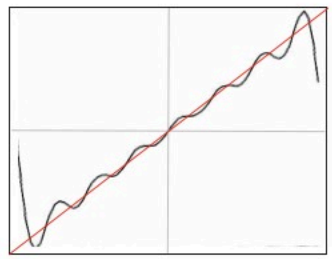
- calculus definition
- differences?
- sinc derivative?







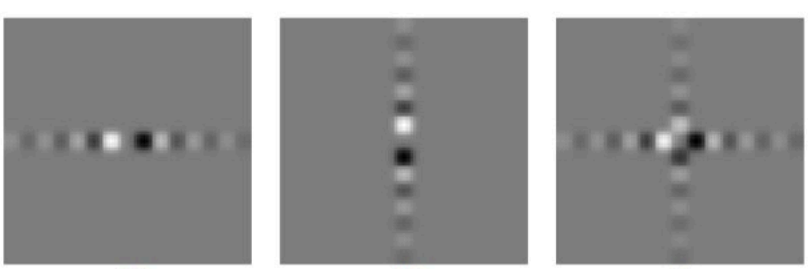
sinc



Fourier transform

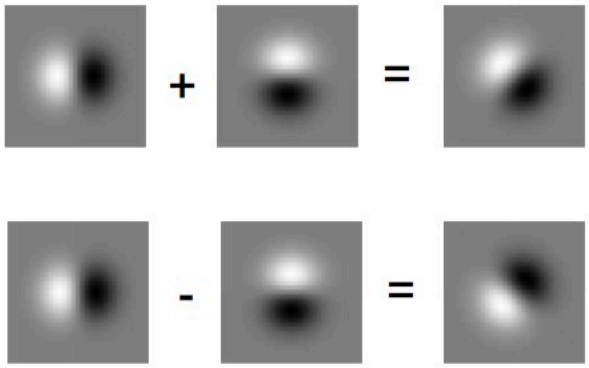
2D derivatives?

- vector calculus => need rotation invariance!
- differences, and sinc derivative, don’t work
- Compromise: incorporate prefiltering

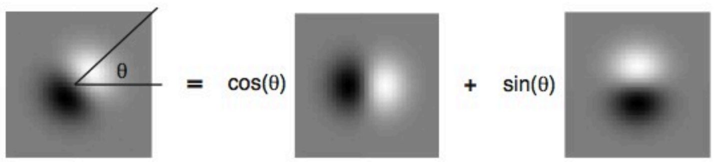


(a) (b) (c)

Rotation-invariance of gradient operators

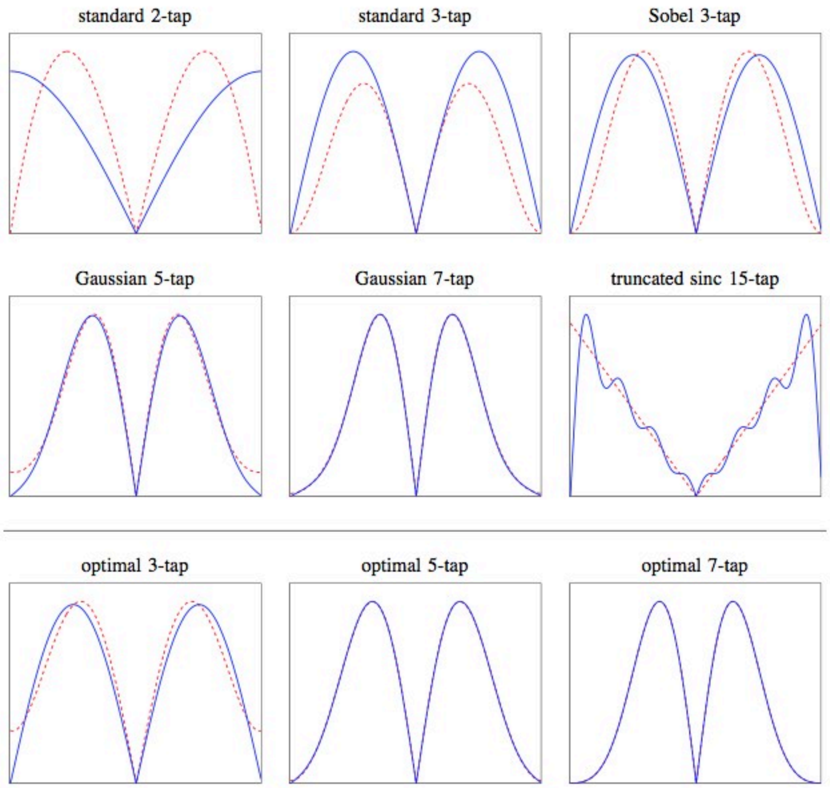


More generally:



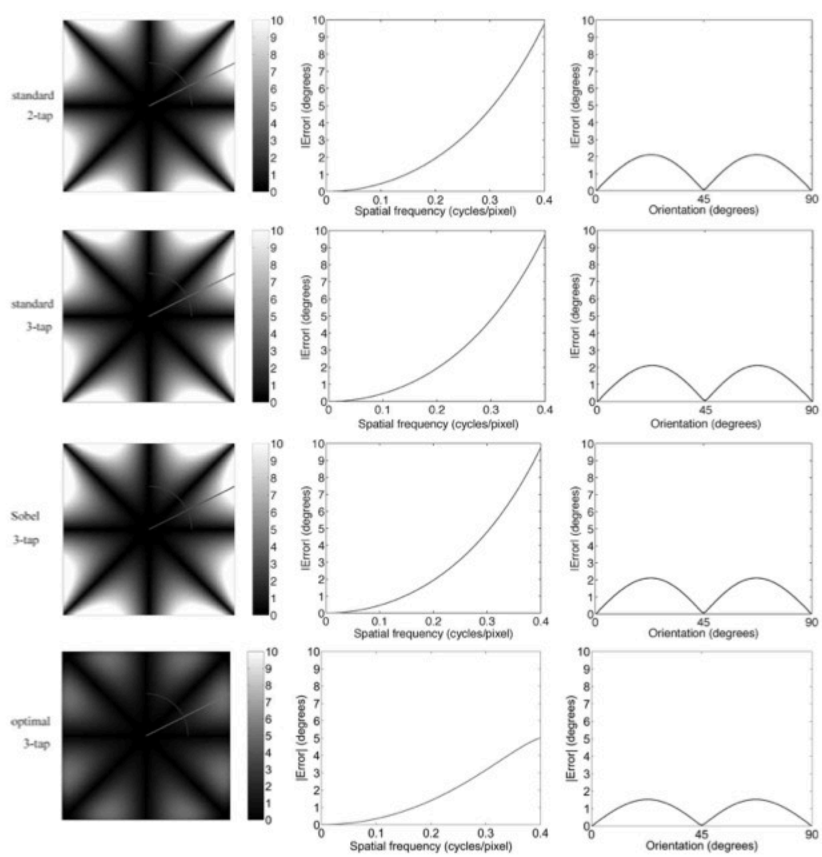
Multi-D differentiator criteria

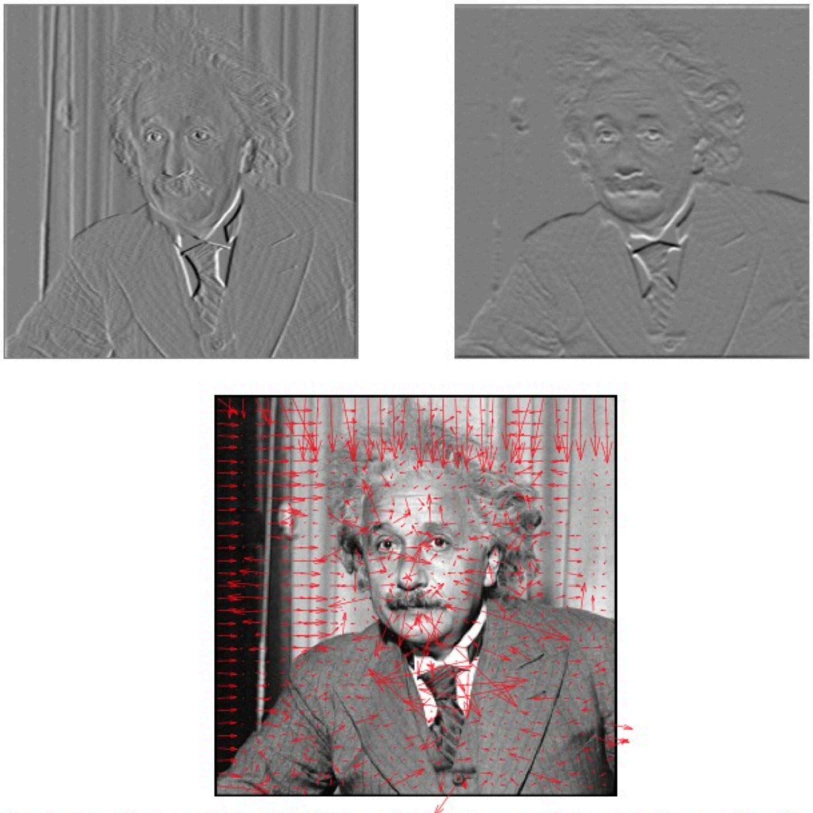
- *Two* 1D filters [interpolator, differentiator]
- Differentiator = interpolator .* ramp
- **Rotation-invariant gradient** !
- Localized



Fourier amplitudes, discrete differentiators (blue)
compared to ramp times interpolator (red dashed)

[Farid & Simoncelli 03]





orientation undefined at local maxima/minima

Local orientation analysis

1) Find direction with largest summed projection:

$$\max_{\hat{u}} \sum_{\vec{x}_k \in \mathcal{N}} w_k \; \vec{\nabla} I(\vec{x}_k)^T \hat{u}$$

2) Find direction that captures most energy [better]:

$$\max_{\hat{u}} \sum_{\vec{x}_k \in \mathcal{N}} w_k \; ||\vec{\nabla} I(\vec{x}_k)^T \hat{u}||^2$$

[on board]

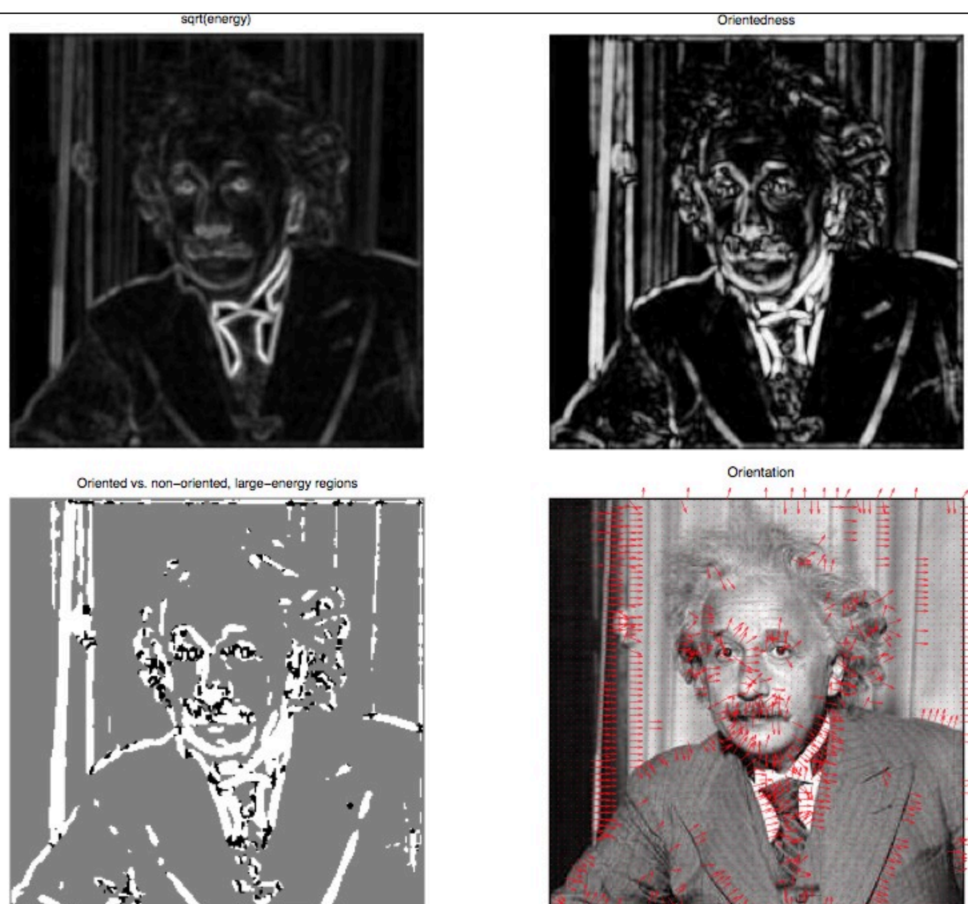
The structure tensor

$$M(\vec{x}) = \sum_{\vec{x}_k \in \mathcal{N}(\vec{x})} w_k \; \vec{\nabla} I(\vec{x}_k) \; \vec{\nabla} I(\vec{x}_k)^T$$

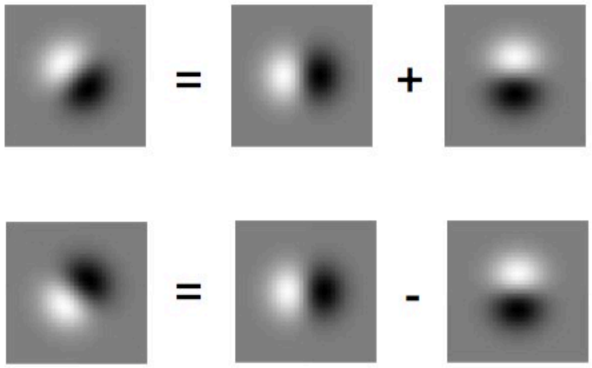
Let eigenvalues/eigenvectors be $\{\lambda_1, \lambda_2\}$ $\{\hat{e}_1, \hat{e}_2\}$

- Total energy: $\lambda_1 + \lambda_2$
- "Orientedness": $(\lambda_1 - \lambda_2)/(\lambda_1 + \lambda_2)$
- Dominant orientation: $\hat{e}_1$

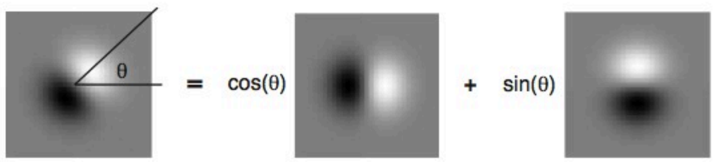
[Bigun & Granlund 87; Knutsson 89; many others]



Non-separable from separable

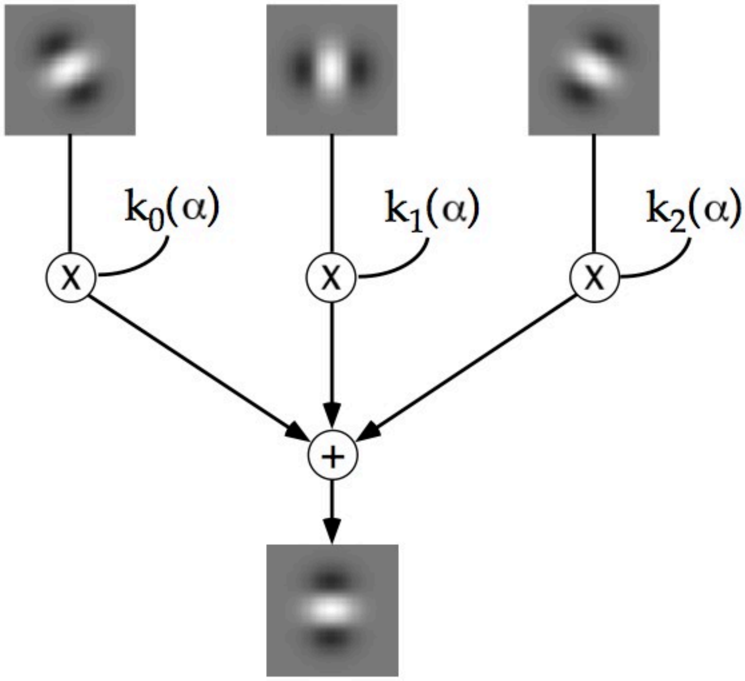


More generally:

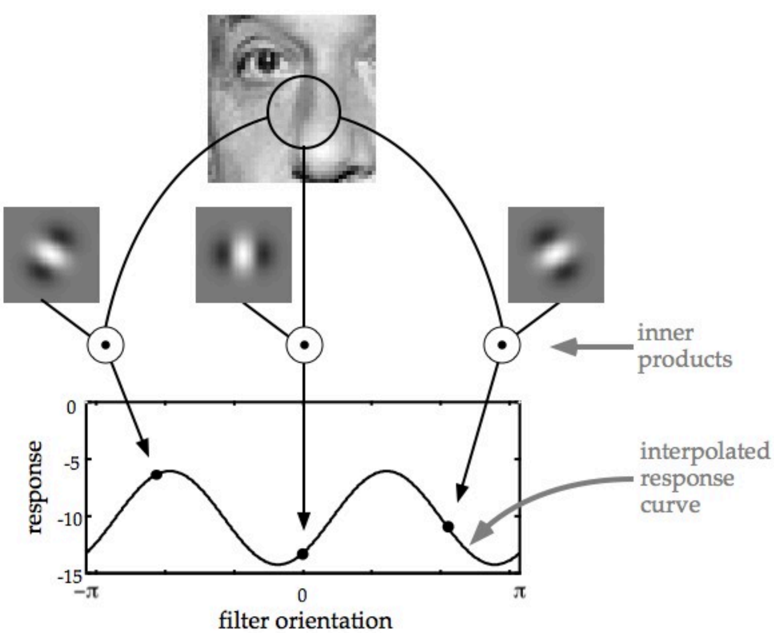


Generalizations [on board]

- Directional Nth-order derivatives [need N+1]
- Polar frequency interpretation
- Steerability: the angular Nyquist theorem
- Orientation estimation



Steerability



[Freeman&Adelson 91]