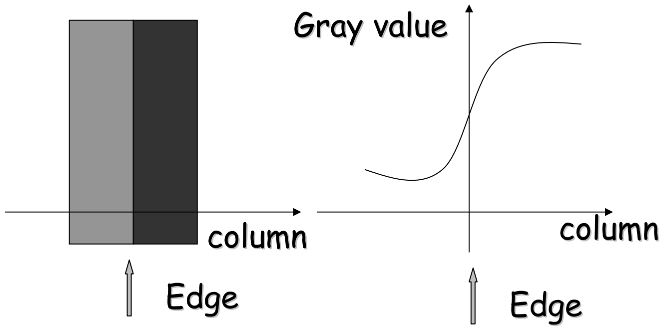
Image Features

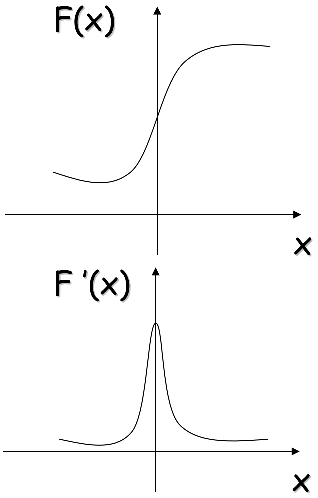
Local, meaningful, detectable parts of the image.
We will look at edges and corners

Edges

- They happen at places where the image values exhibit sharp variation



Edge detection (1D)



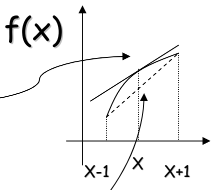
Edge= sharp variation

↓

Large first derivative

Digital Approximation of 1st derivatives

$$\frac{df(x)}{dx} = \lim_{\Delta x \to 0} \frac{f(x+\Delta x) - f(x)}{\Delta x}$$



$$\frac{df(x)}{dx} \cong \frac{f(x+1) - f(x-1)}{2}$$

⇒ Convolve with:

-1	0	1

Edge Detection (2D)

Vertical Edges:

Convolve with:

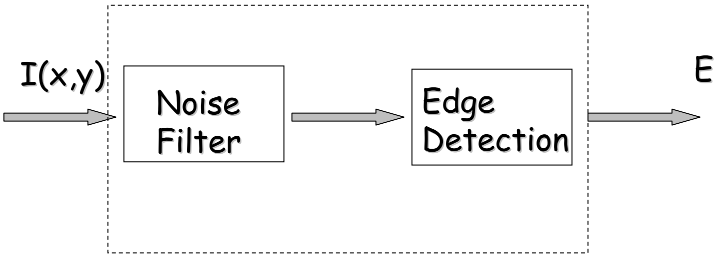
-1	0	1

Horizontal Edges:

Convolve with:

-1
0
1

Noise cleaning and Edge Detection



We need to also deal with noise
Combine Linear Filters

Noise Smoothing & Edge Detection

Convolve with:

-1	0	1
-1	0	1
-1	0	1

Noise Smoothing

Vertical Edge Detection

This mask is called the (vertical) Prewitt Edge Detector

Outer product of box filter $[1\ 1\ 1]^T$ and [-1 0 1]

Noise Smoothing & Edge Detection

Convolve with:

-1	-1	-1
0	0	0
1	1	1

Horizontal Edge Detection

Noise Smoothing

This mask is called the (horizontal) Prewitt Edge Detector

Sobel Edge Detector

Convolve with:

-1	0	1
-2	0	2
-1	0	1

and

-1	-2	-1
0	0	0
1	2	1

Gives more weight to the 4-neighbors

Example

0	0	0	0	0
0	0	0	0	0
0	0	50	50	50
0	0	50	50	50
0	0	50	50	50

$I_x =$

0	0	0	0	0
0	50	100	150	150
0	50	100	150	150
0	0	0	0	0
0	0	0	0	0

$I_y =$

0	0	0	0	0
0	50	50	0	0
0	100	100	0	0
0	150	150	0	0
0	150	150	0	0

-1	0	1
-1	0	1
-1	0	1

-1	-1	-1
0	0	0
1	1	1

Image Derivatives

We know better alternative to smoothing
Smooth using Gaussian filter
g(x) is a 1-D gaussian kernel, g(x,y) – 2-D gaussian kernel

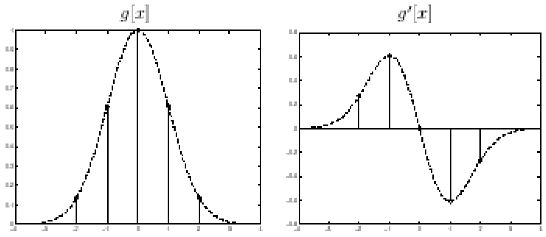
$$\tilde{I}[x,y] = I[x,y] * g[x,y] = \sum_{k=-\frac{w}{2}}^{\frac{w}{2}} \sum_{l=-\frac{w}{2}}^{\frac{w}{2}} I[k,l]g[x-k]g[y-l]$$

Taking a derivative – linear operation (take the derivative of the filter)

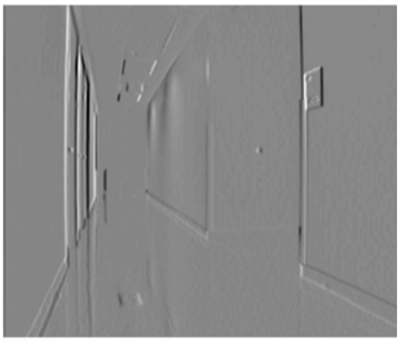
$$I_x[x,y] = I[x,y] * g'[x] * g[y] = \sum_{k=-\frac{w}{2}}^{\frac{w}{2}} \sum_{l=-\frac{w}{2}}^{\frac{w}{2}} I[k,l]g'[x-k]g[y-l],$$

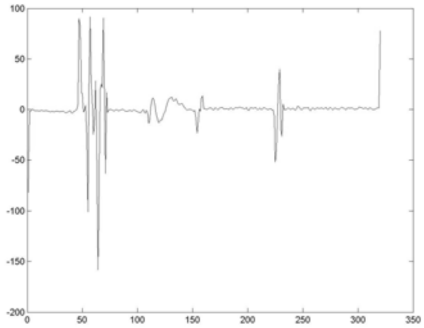
$$I_y[x,y] = I[x,y] * g[x] * g'[y] = \sum_{k=-\frac{w}{2}}^{\frac{w}{2}} \sum_{l=-\frac{w}{2}}^{\frac{w}{2}} I[k,l]g[x-k]g'[y-l].$$

Gaussian and its derivative



$$g(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{-x^2}{2\sigma^2}}, \quad g'(x) = -\frac{x}{\sigma^2\sqrt{2\pi}\sigma} e^{\frac{-x^2}{2\sigma^2}}.$$

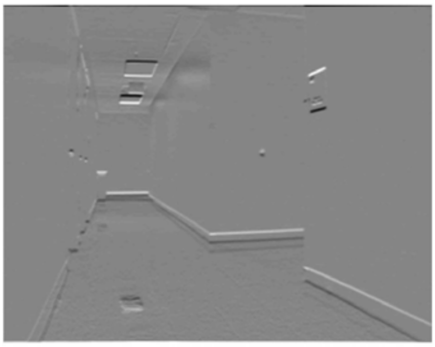


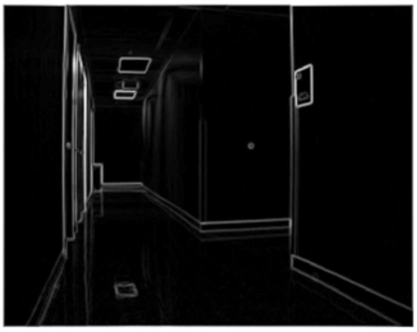


Vertical edges

First derivative

$$I_x(x,y) = \frac{\partial I}{\partial x}$$



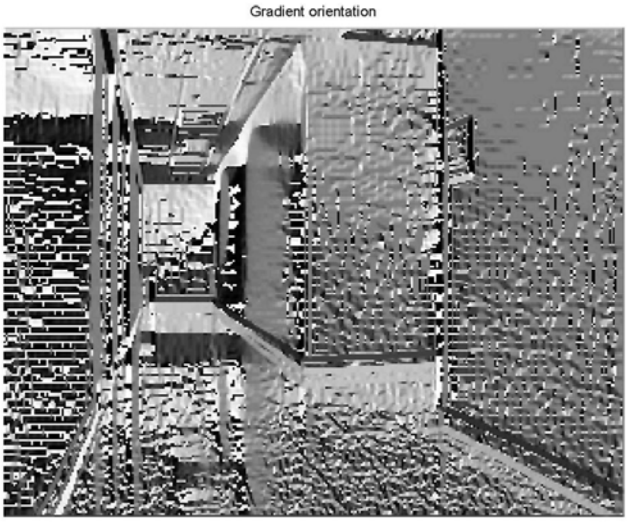


Horizontal edges $I_y(x,y) = \frac{\partial I}{\partial y}$

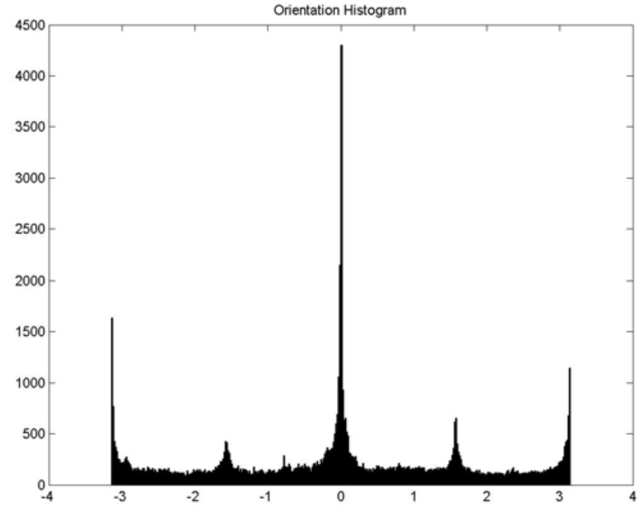
Gradient Magnitude

- Convolution along columns
- Image Gradient $\nabla I = [\frac{\partial I}{\partial x}, \frac{\partial I}{\partial y}]$

$$m = \sqrt{(\frac{\partial I}{\partial x})^2 + (\frac{\partial I}{\partial y})^2}$$



Gradient Orientation $\theta = \tan^{-1}(\frac{\partial I}{\partial x}, \frac{\partial I}{\partial y})$



Orientation histogram