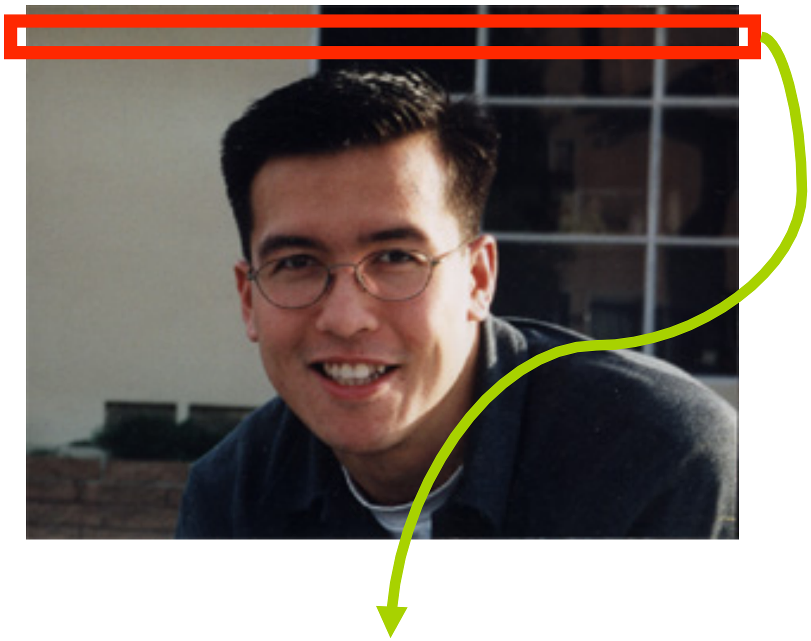
Edge Detection

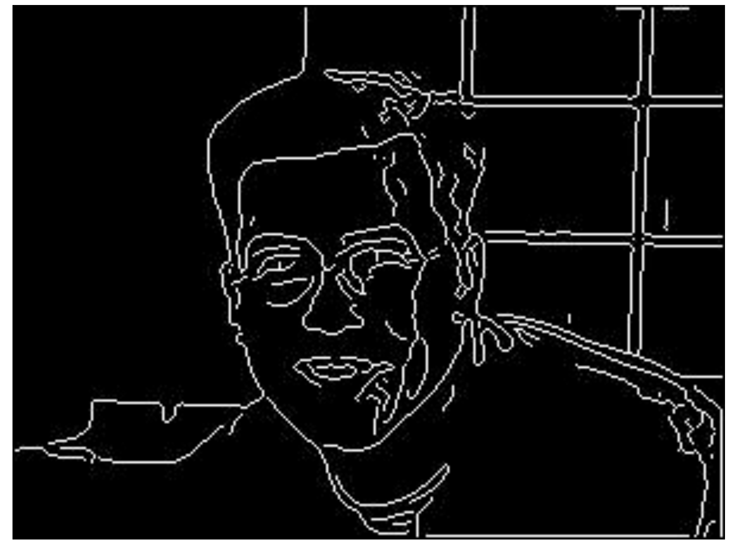
Ref: Forsyth+Ponce Ch. 7,8

Trucco+Verri Ch. 4

- Our goal is to extract a “line drawing” representation from an image
- Useful for recognition: edges contain shape information
  - **invariance**

Edge detection





$$\frac{df(x)}{dx} \approx \text{edges}$$

Derivatives

- Edges are locations with high image gradient or derivative*
- Estimate derivative using finite difference

$$\frac{\partial}{\partial x} I(x_0, y_0) \approx I(x_0 + 1, y_0) - I(x_0, y_0)$$

- Problem?

Smoothing

- Reduce image noise by smoothing with a Gaussian $J = G * I$

$$J(x,y) = \sum_{u,v} G(x-u, y-v) I(u,v)$$

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2}$$

Convolution is Associative

- We compute derivative of smoothed image:

$$J_x = \frac{\partial J}{\partial x} = K_{\partial/\partial x} * (G * I)$$

- Since convolution is associative:

$$\frac{\partial J}{\partial x} = \frac{\partial G}{\partial x} * I$$

Separable Convolution

- Note that G can be factored as

$$G(x,y) = \frac{1}{2\pi\sigma^2}\left(e^{-\frac{x^2}{2\sigma^2}}\right)\left(e^{-\frac{y^2}{2\sigma^2}}\right)$$

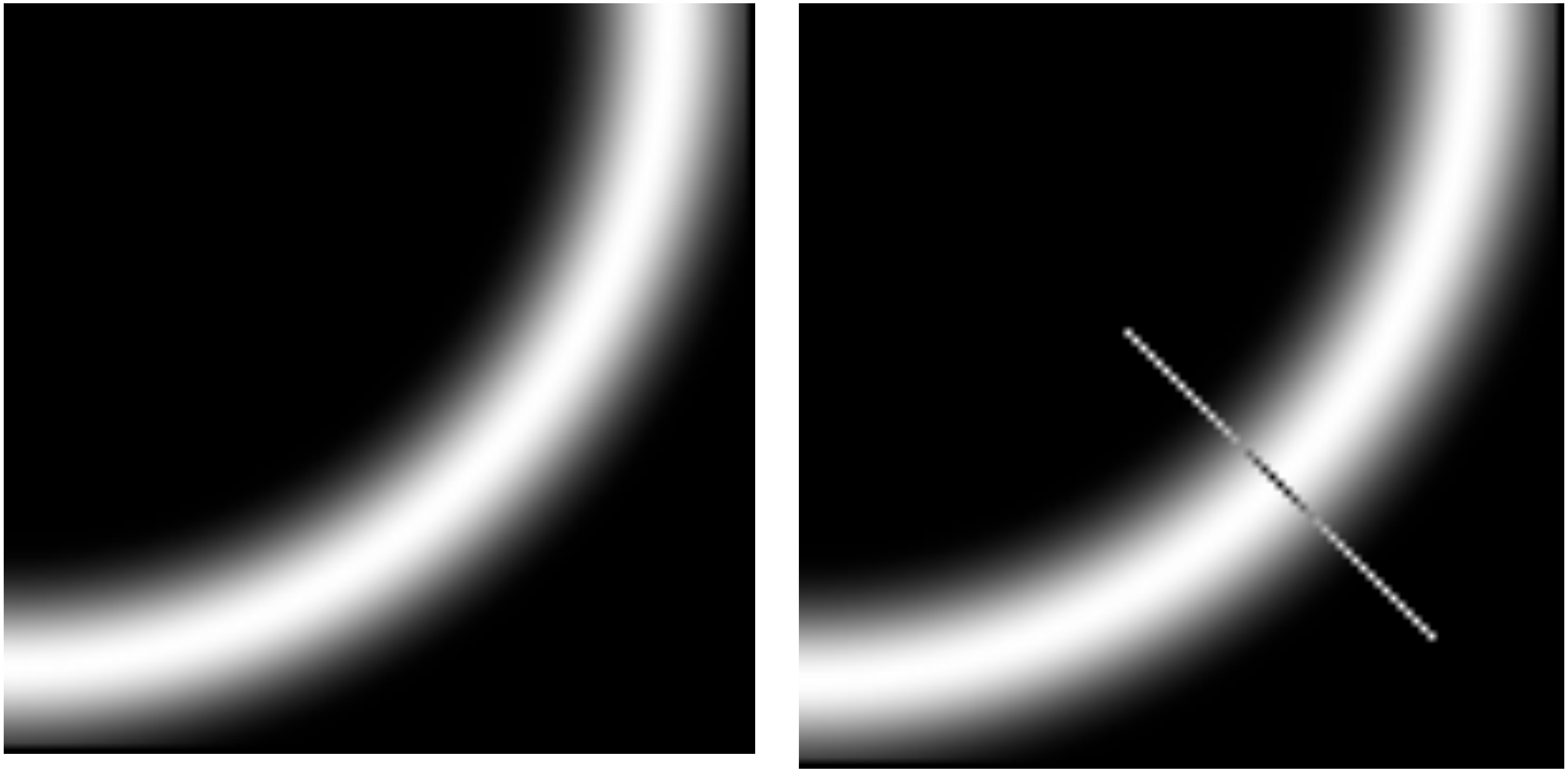
and computed as two 1-D convolutions

Edge orientation

- Would like gradients in all directions
- Approximate:
  - Compute smoothed derivatives in x,y directions
  - Edge strength $e_s(i,j) = \sqrt{J_x^2(i,j) + J_y^2(i,j)}$
  - Edge normal $e_o(i,j) = atan\frac{J_y}{J_x}$

Canny Edge Detection

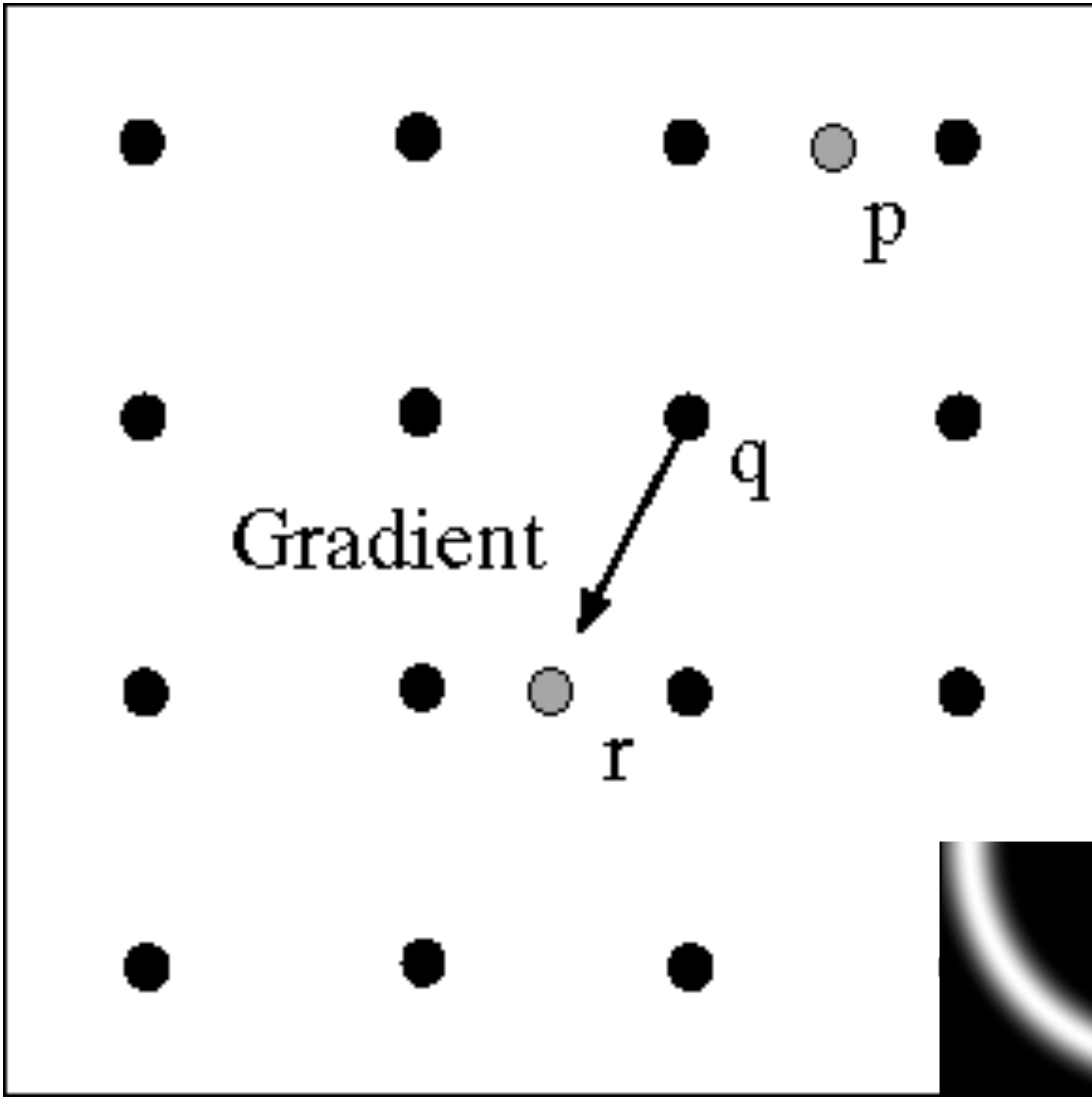
- Compute edge strength and orientation at all pixels
- "Non-max suppression"
  - Reduce thick edge strength responses around true edges
- Link and threshold using "hysteresis"
  - Simple method of "contour completion"



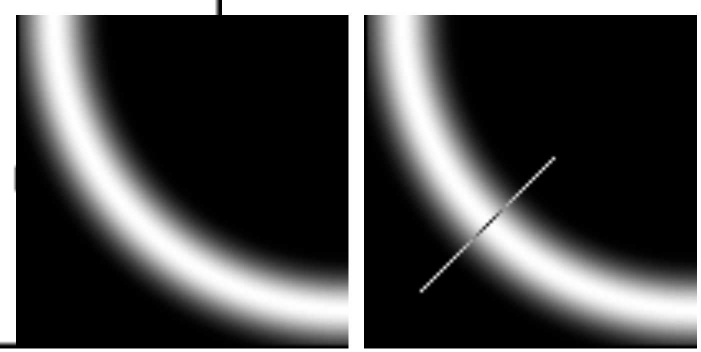
Non-maximum suppression:

Select the single maximum point across the width of an edge.

Non-maximum suppression



At q, the value must be larger than values interpolated at p or r.



Examples: Non-Maximum Suppression

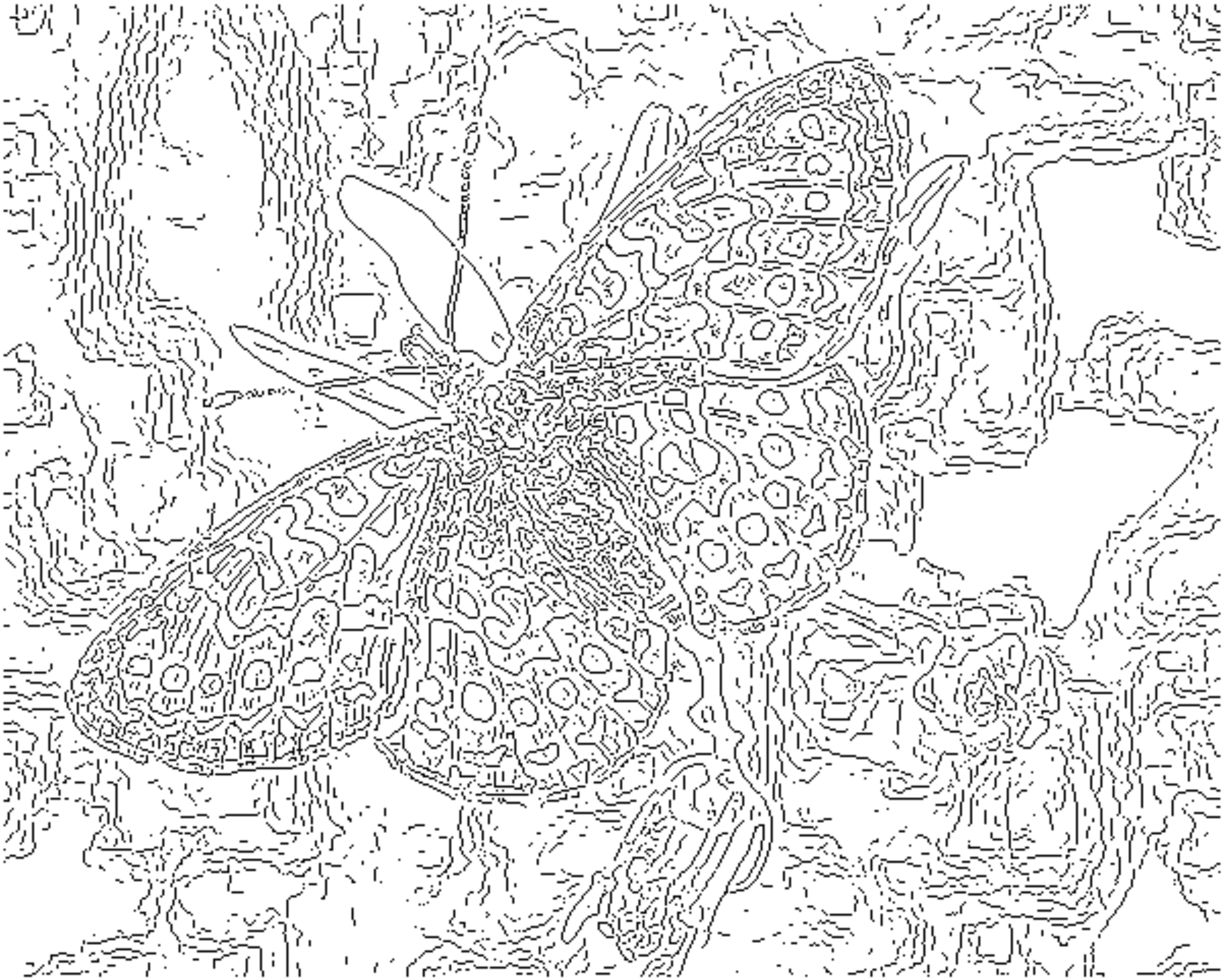
courtesy of G. Loy

Original image

Gradient magnitude

Non-maxima suppressed

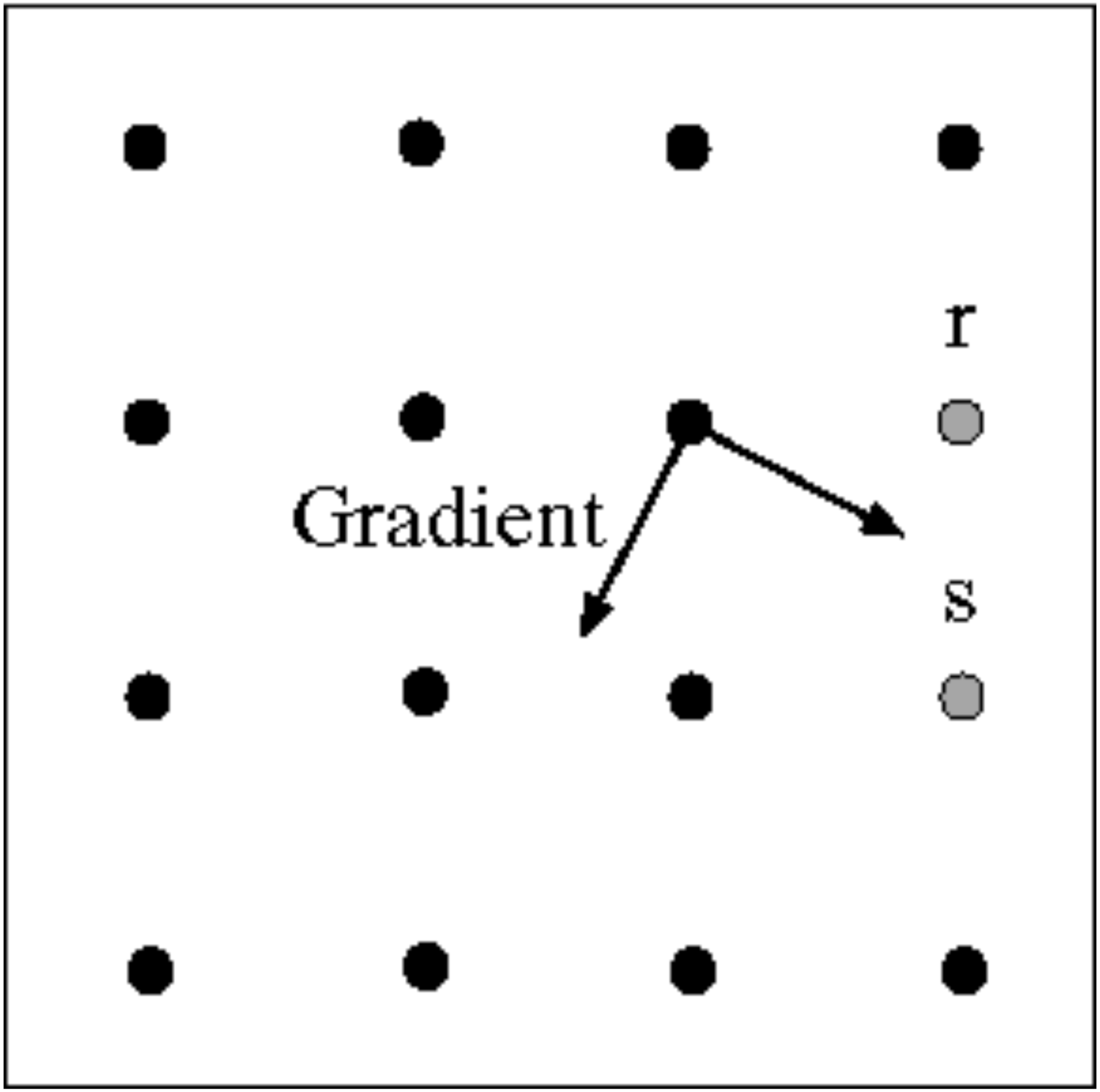
Slide credit: Christopher Rasmussen



fine scale
high
threshold

coarse
scale,
high
threshold

coarse
scale
low
threshold



Linking to the next edge point

Assume the marked point is an edge point.

Take the normal to the gradient at that point and use this to predict continuation points (either r or s).

Edge Hysteresis

- **Hysteresis**: A lag or momentum factor
- Idea: Maintain two thresholds k_{high} and k_{low}
  - Use k_{high} to find strong edges to start edge chain
  - Use k_{low} to find weak edges which continue edge chain
- Typical ratio of thresholds is roughly

$$k_{high} / k_{low} = 2$$

Example: Canny Edge Detection

gap is gone

Original image

Strong + connected weak edges

Strong edges only

Weak edges

courtesy of G. Loy

Problem?

- Texture
  - Canny edge detection responds all over textured regions