Lecture 4. Edge Detection

Canny edge detector

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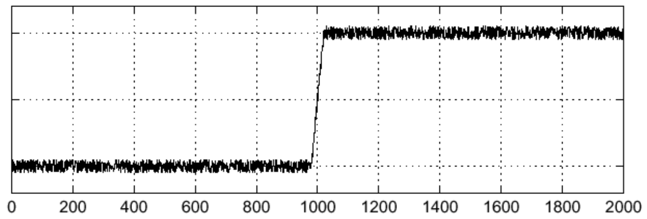
CS131 Computer Vision: Foundations and Applications

Canny edge detector

- This is probably the most widely used edge detector in computer vision
- Theoretical model: step-edges corrupted by additive Gaussian noise
- Canny has shown that the first derivative of the Gaussian closely approximates the operator that optimizes the product of *signal-to-noise ratio* and localization



J. Canny, ***A Computational Approach To Edge Detection***, IEEE Trans. Pattern Analysis and Machine Intelligence, 8:679-714, 1986.

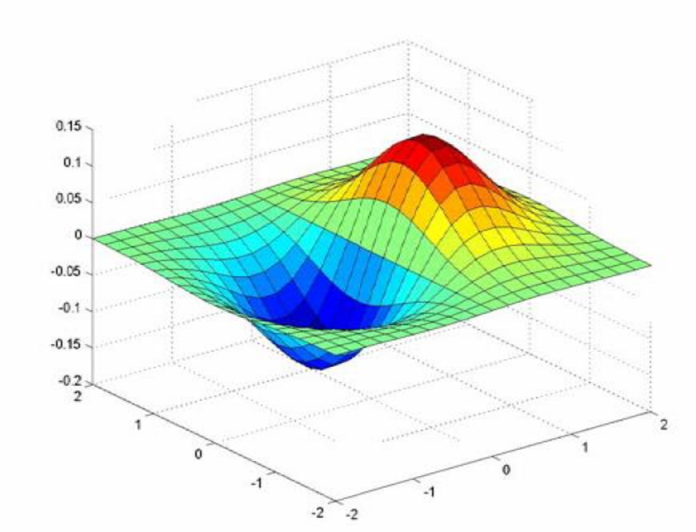
Canny edge detector

- Suppress Noise
- Compute gradient magnitude and direction
- Apply Non-Maximum Suppression
  - Assures minimal response
- Use hysteresis and connectivity analysis to detect edges

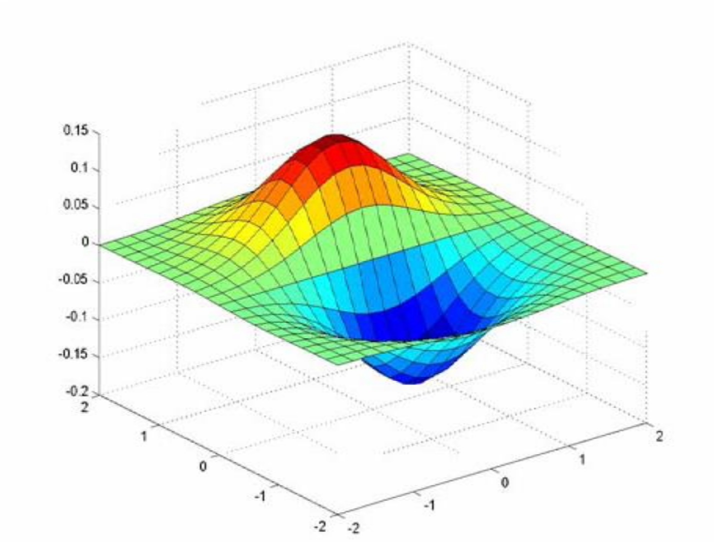
Example

original image

Derivative of Gaussian filter

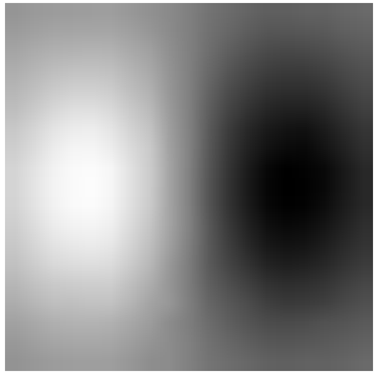


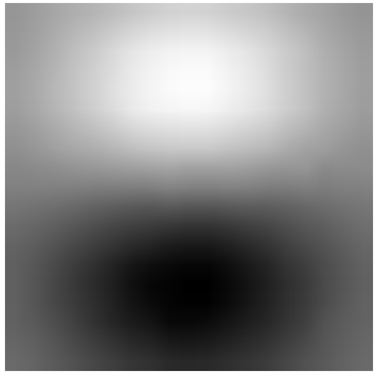
x-direction



y-direction

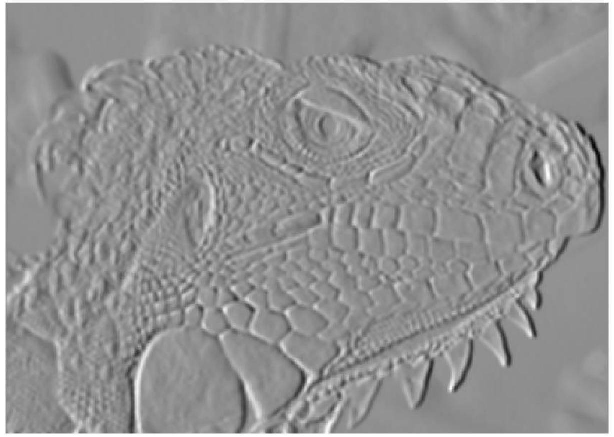
$$\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

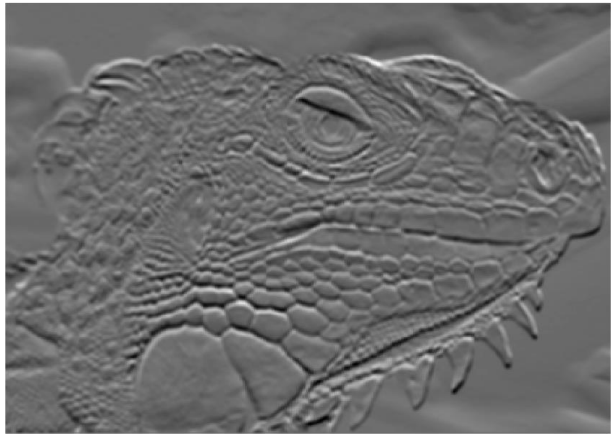




$$\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Computing gradients with the Derivative of Gaussian filter


X-Derivative of Gaussian

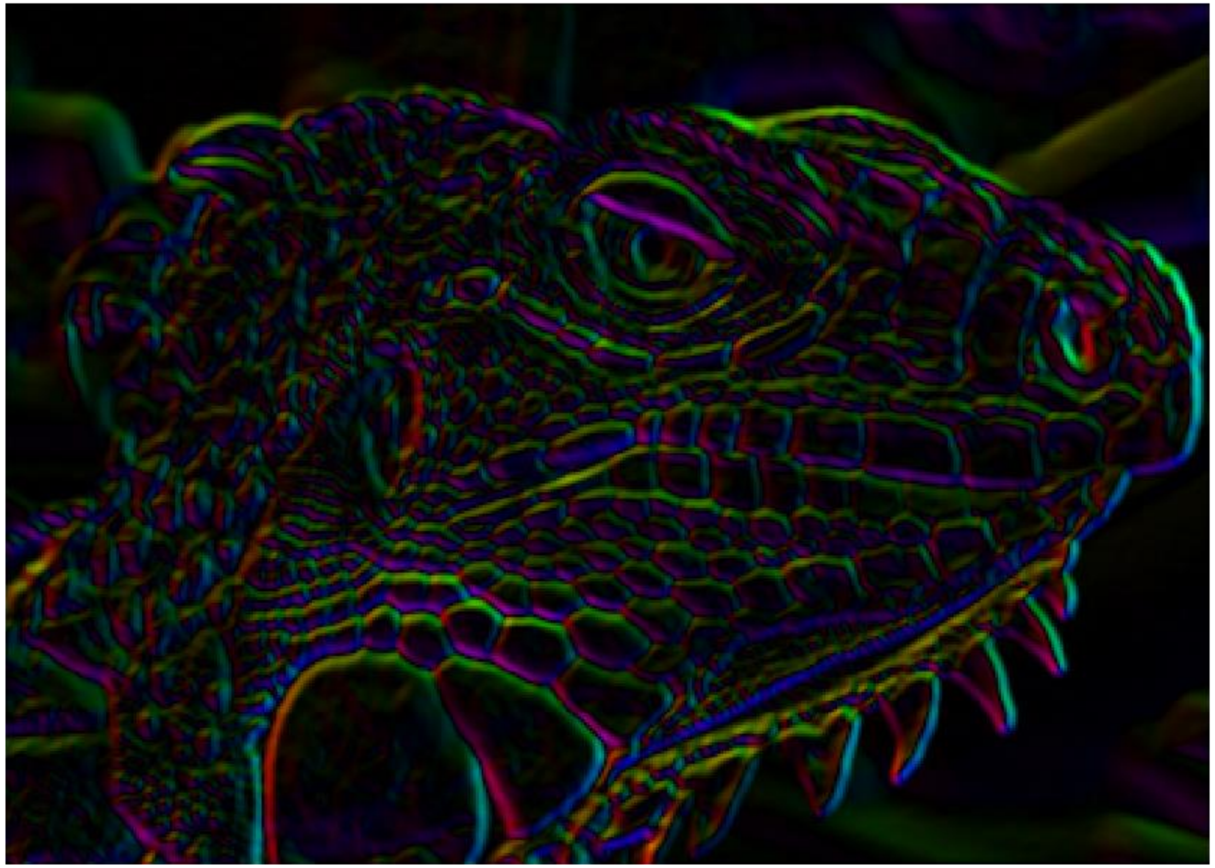

Y-Derivative of Gaussian


Gradient Magnitude

Source: J. Hayes

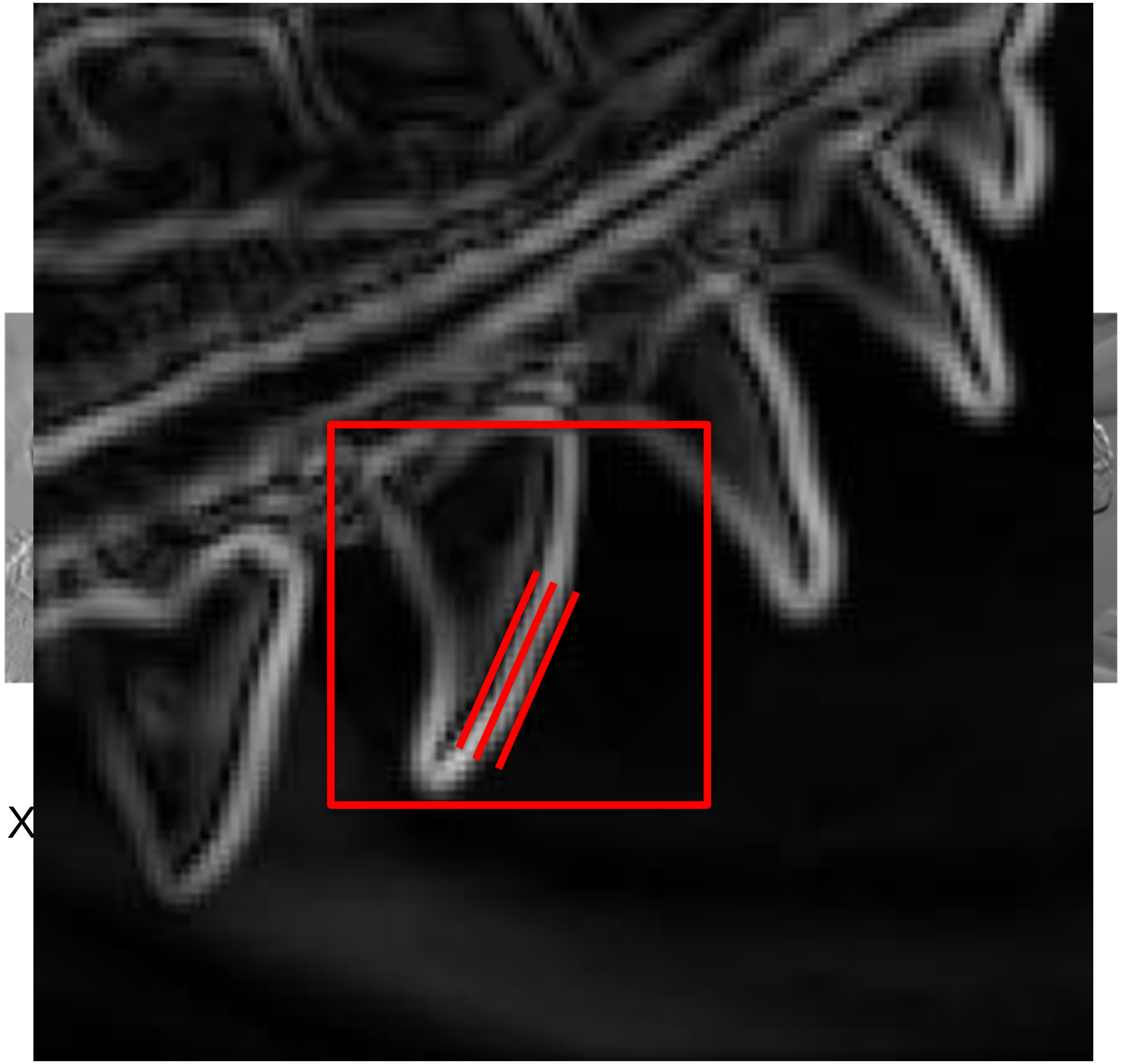
Get orientation at each pixel

$$\theta = \tan^{-1}\left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x}\right)$$



Source: J. Hayes

Compute gradients (DoG)



X

Gradient Magnitude

Canny edge detector

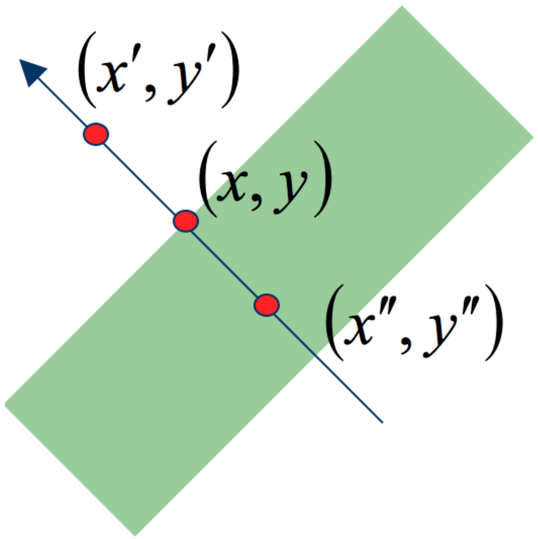
- Suppress Noise
- Compute gradient magnitude and direction
- Apply Non-Maximum Suppression
  - Assures minimal response

Non-maximum suppression

- Edge occurs where gradient reaches a maxima
- Suppress non-maxima gradient even if it passes threshold
- Compare current pixel vs neighbors along direction of gradient
  - Remove if not maximum

Remove spurious gradients

$|\nabla G|(x, y)$ is the gradient at pixel (x, y)

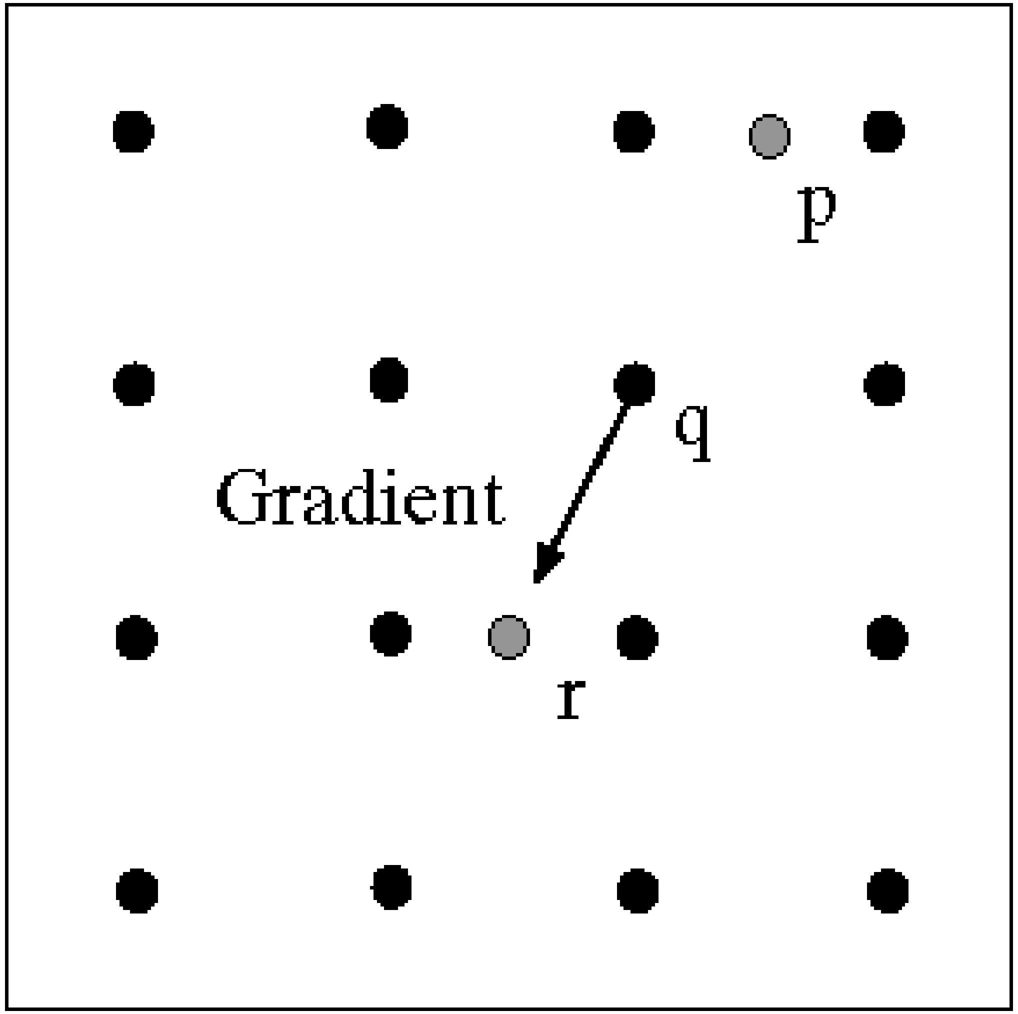


$$M(x,y) = \begin{cases} |\nabla G|(x,y) & \text{if } |\nabla G|(x,y) > |\nabla G|(x',y') \\ & \& |\nabla G|(x,y) > |\nabla G|(x'',y'') \\ 0 & \text{otherwise} \end{cases}$$

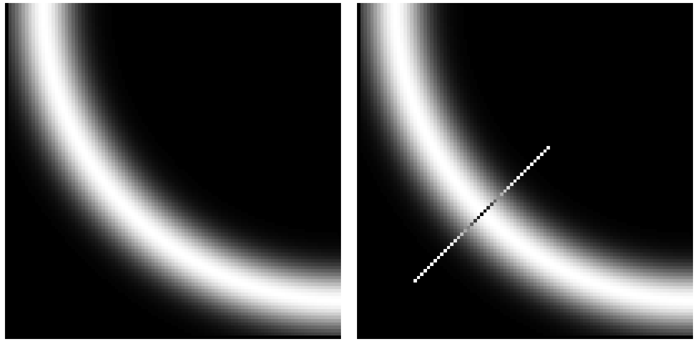
x' and **x**" are the neighbors of **x** along normal direction to an edge

Alper Yilmaz, Mubarak Shah Fall 2012, UCF

Non-maximum suppression



At q, we have a maximum if the value is larger than those at both p and at r. Interpolate to get these values.



Source: D. Forsyth

Non-max Suppression

Before

After

Canny edge detector

- Suppress Noise
- Compute gradient magnitude and direction
- Apply Non-Maximum Suppression
  - Assures minimal response
- Use hysteresis and connectivity analysis to detect edges

Detecting edges with a single threshold

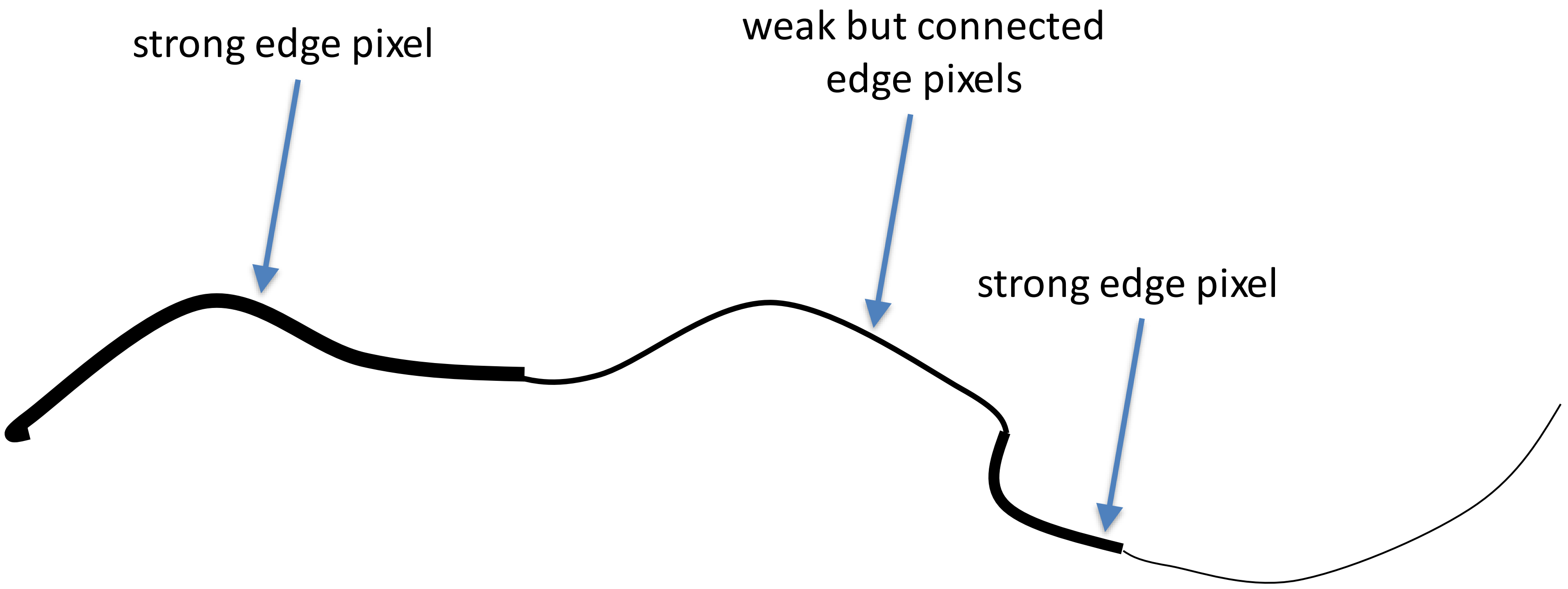
Threshold too high

Threshold too low

Hysteresis thresholding

- Avoid streaking near threshold value
- Define two thresholds: Low and High
- If less than Low, not an edge
- If greater than High, strong edge
- If between Low and High, weak edge
  - Consider its neighbors iteratively then declare it an "edge pixel" if it is connected to an 'strong edge pixel' directly or via pixels between Low and High

Hysteresis thresholding



Source: S. Seitz

Final Canny Edges

Canny edge detector

1. Filter image with x, y derivatives of Gaussian
2. Find magnitude and orientation of gradient
3. Non-maximum suppression:
   - Thin multi-pixel wide "ridges" down to single pixel width
4. Thresholding and linking (hysteresis):
   - Define two thresholds: low and high
   - Use the high threshold to start edge curves and the low threshold to continue them

Effect of σ (Gaussian kernel spread/size)

original

Canny with $\sigma = 1$

Canny with $\sigma = 2$

The choice of σ depends on desired behavior

- large σ detects large scale edges
- small σ detects fine features

Source: S. Seitz

Gradients
(e.g. Canny)

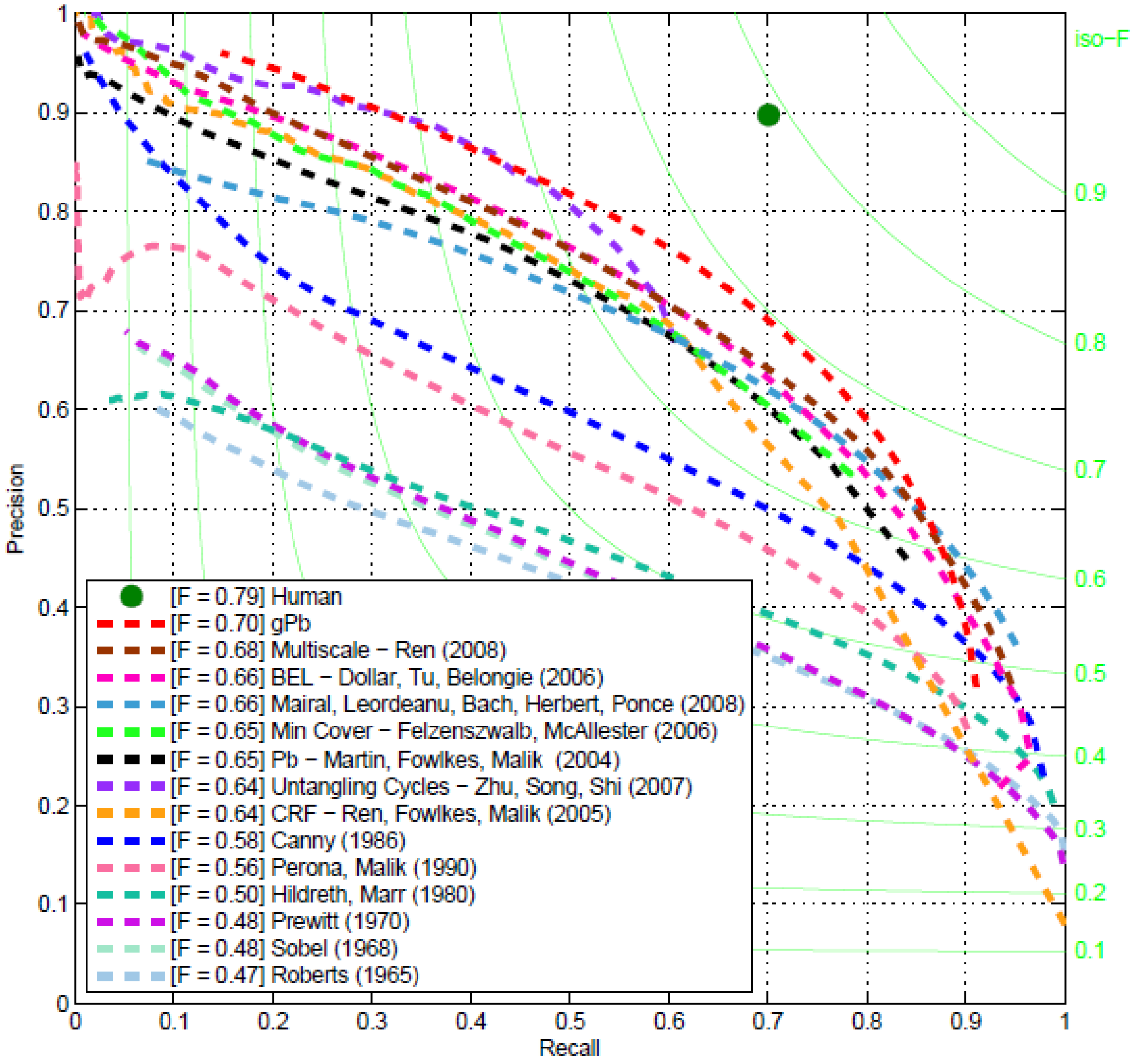
Color

Texture

Combined

Human

45 years of boundary detection



Source: Arbelaez, Maire, Fowlkes, and Malik. TPAMI 2011 (pdf)