Edge Detection — Canny

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Edge Detection

- The edge detection process serves to *simplify* the analysis of images by drastically reducing the amount of data to be processed, while at the same time *preserving useful structural information* about object boundaries [1].
- **Common criteria** relevant to edge detector performance
  - Low error rate
  - The edge points be well localized
  - Only one response to a single edge
- There is an **uncertainty** principle relating *detection* and *localization* of noisy step edges
  - The *tradeoff* between detection and localization can be varied by changing *the spatial width of the detector*.

Assumption of Canny Algorithm

- The image consists of the edge and additive white Gaussian noise.
  - Not true of corners

Canny Edge Detector [1]

- To smooth the image to eliminate any noise.
- To find the image gradient to highlight regions with high spatial derivatives.
- To track along these regions and suppresses any pixel that is not at the maximum (non-maximum suppression).
- Hypothesis is used to track along the remaining pixels that have not been suppressed. Hypothesis uses **two thresholds**
  - If the magnitude is below the first threshold, it is set to zero (made a **nonedge**).
  - If the magnitude is above the high threshold, it is made an **edge**.
  - And if the magnitude is between the two thresholds, then it is set to zero unless there is a path from this pixel to a pixel with a gradient above T2.

Step1: Gaussian Filter

- To filter out any noise in the original image before trying to locate and detect any edges.

- **The larger the width of the Gaussian mask, the lower is the detector's sensitivity to noise**.

$$\frac{1}{115}$$

2	4	5	4	2
4	9	12	9	4
5	12	15	12	5
4	9	12	9	4
2	4	5	4	2

Figure 3 Discrete approximation to Gaussian function with σ=1.4

Step2: Sobel Operator

- The Sobel operator performs a 2-D spatial gradient measurement on an image.

- The approximate absolute gradient magnitude (edge strength) at each point can be found.

  $|G| = |G_x| + |G_y|$

- The edge direction

  $\theta = \arctan(G_y/G_x)$ ⟵

When the derivative in the *x* direction G_x is equal to zero, but the derivative in the *y* direction G_y is not zero, then the edge direction is equal to 90°.

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

Gx

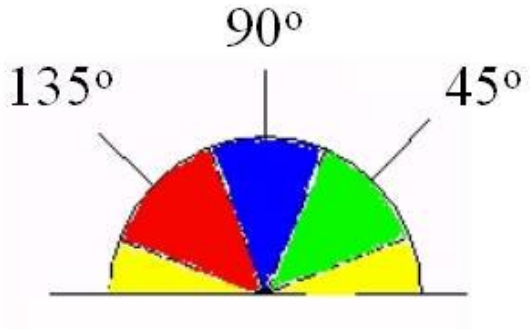
+1	+2	+1
0	0	0
-1	-2	-1

Gy

Step3: Edge Direction

- **0 degrees** (in the horizontal direction)
- **45 degrees** (along the positive diagonal)
- **90 degrees** (in the vertical direction)
- **135 degrees** (along the negative diagonal).

x x x x x
x x x x x
x x a x x
x x x x x
x x x x x



Step4: Non-maximum Suppression

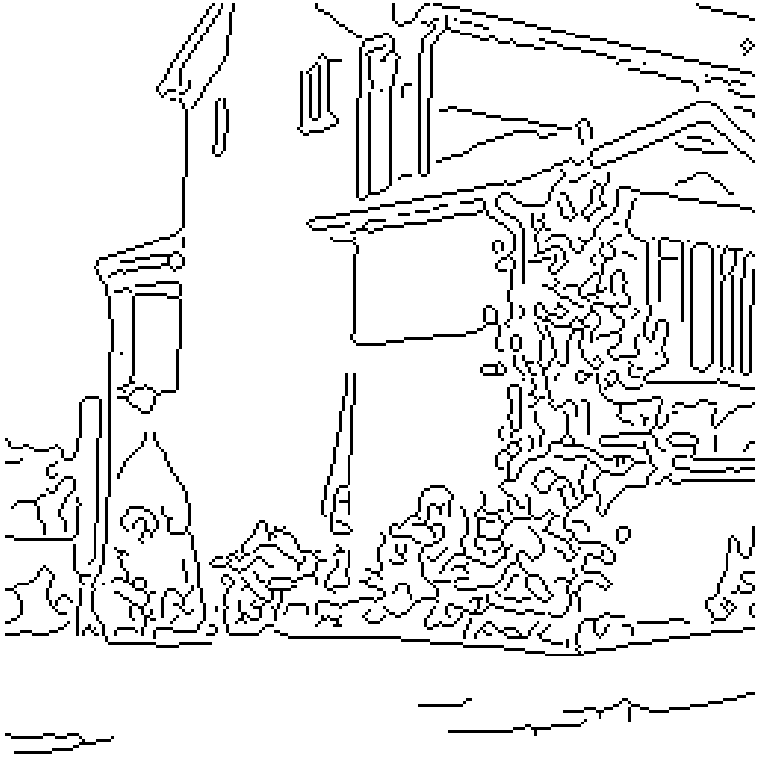
- Non-maximum suppression is used to trace along the edge in the edge direction and suppress any pixel value (sets it equal to 0) that is not considered to be an edge.

Step5: Hypothesis

- Hypothesis uses 2 thresholds, a high and a low.
- Any pixel in the image that has a value greater than T1 is presumed to be an edge pixel, and is marked as such immediately. Then, any pixels that are connected to this edge pixel and that have a value greater than T2 are also selected as edge pixels.
- If you think of following an edge, you need a gradient of T2 to start but you don't stop till you hit a gradient below T1.

Canny Edge Detector Result

Input Gray Image



Detected Edge Image

Multiresolution SEL [2]

- 1) Multiresolution image pyramid
- 2) Enhancement — a Gaussian weighted gradient operator
- 3) Edge information contained in lower resolution will guide the sequential search at higher resolution according to log-likelihood statistic.
  - Both the strength of an edge and the past path of the edge are used to determine the search direction.
    - The strength of an edge is measured by the likelihood ratio of the conditional probability that an edge pixel exists. (dominating when SNR is high)
    - The past path of an edge is modeled by a Markov random chain. (dominating when SNR is low)
  - **Inaccuracies** may result for highly curved segments.

MSEL Result

Input Gray Image

Detected Edge Image

MSEL for Noisy Images

Input Noisy Image

Detected Edge Image

Canny for Noisy Image

Input Noisy Image

Detected Edge Image

MSEL vs. Canny

Canny Edge Image

MSEL Edge Image

References

- [1] J. Canny, “A Computational Approach to Edge Detection,” IEEE Trans. Pattern Analysis and Machine Intelligence, 8(6), pp. 679-698, 1986.
- [2] J.W. Cook and E.J. Delp, “Multiresolution sequential edge linking,” in Proc. IEEE Intl. Conf. Image Processing, pp.41-44, 1995.

Thank You!

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