Canny Edge Detection

Author: Muhammad Ahmad
Bscs23169

This document is a complete, step-by-step report for the 'Canny Edge Detection' assignment. It explains each step.

Contents

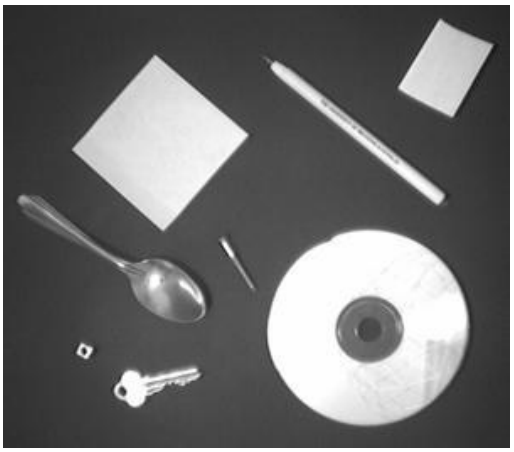
1. Abstract

This report is the working of the Canny Edge Detector. It takes input images and applies Gaussian derivative filtering, convolution, gradient calculation, non-maxima suppression, and hysteresis thresholding

2. Overview and Goals

The output marks significant object boundaries and rejects noise, leaving thin continuous edges intact. All steps of the implementation were written from scratch in NumPy and Pillow.

3. Step-by-step Methodology



Sample Image

Step 1 — Generate Mask

Generated Gaussian derivative masks Gx and Gy.

Implemented functions:

- `calculate_filter_size(sigma, T)`

$$sHalf = round(-\ ln(T) \cdot 2\sigma^2)$$

- `calculate_gradient(filter_size, sigma)`

$$Gx(x,y) = -\frac{x}{\sigma^2} \times e^{-\frac{x^2+y^2}{2\sigma^2}}, Gy(x,y) = -\frac{y}{\sigma^2} \times e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Masks were scaled by 255 and rounded to integers for convolution.

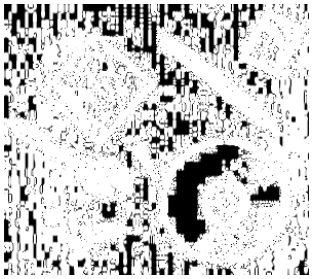
Step 2 — Convolution in X and Y

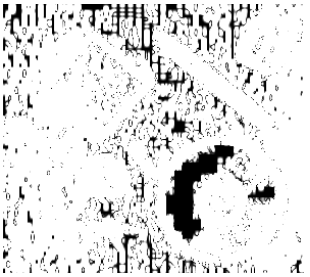
Convolved input images with Gx and Gy.

Results show vertical edge responses (`fx`) and horizontal edge responses (`fy`).

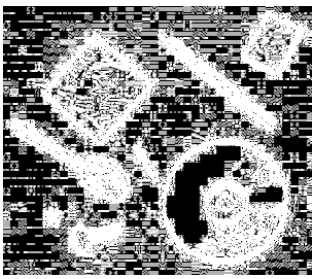
Fx :

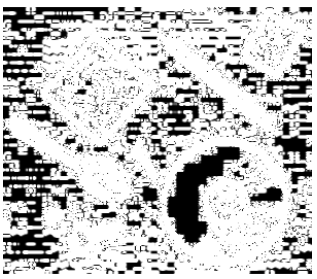

σ=0.5

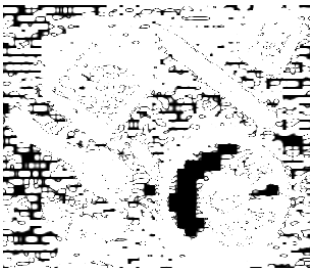

σ=1.0


σ=2.0

Fy :

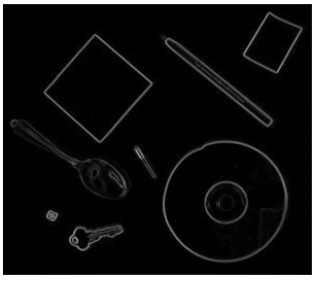

σ=0.5

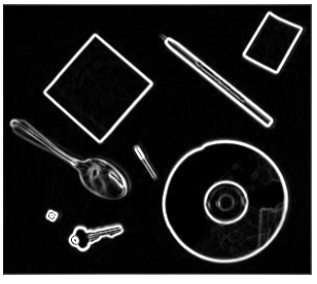

σ=1.0


σ=2.0

Step 3 — Gradient

- Computed gradient magnitude:
  - $M(x,y) = \sqrt{fx(x,y)^2 + fy(x,y)^2}$


σ=0.5


σ=1.0


σ=2.0

- Computed gradient direction using `atan2`:

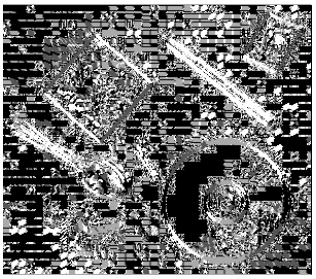
- $\theta(x, y) = arctan(\frac{fy(x,y)}{fx(x,y)})$

- Normalized magnitude to [0, 255].
- Direction converted to degrees in range [0–360].

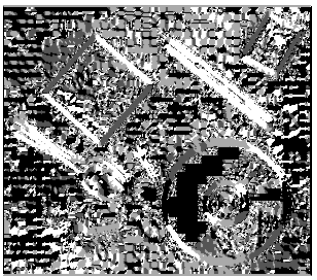
Step 4 — non maxima suppression

- Quantized directions into 4 bins (0°, 45°, 90°, 135°).

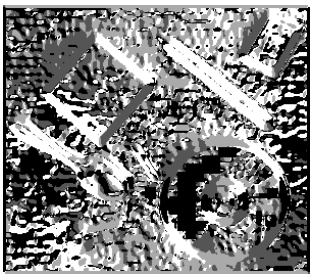
Quantize:



σ=0.5



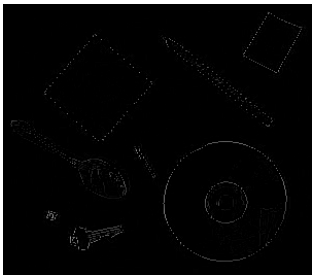
σ=1.0



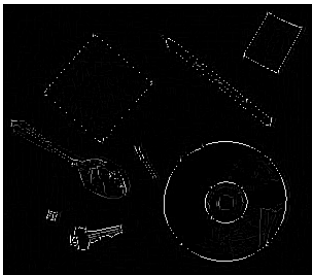
σ=2.0

- For each pixel, compared with two neighbors along the gradient direction.
- Kept the pixel only if it was the local maximum.
- Output: thin edges with reduced blurring.

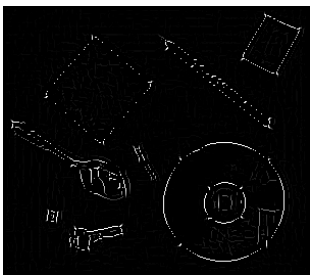
NMS:



σ=0.5



σ=1.0



σ=2.0

Step 5 — Hystherises

- Applied two thresholds:
    - **Pair 1:** Th = 0.2 × max, Tl = 0.1 × max
    - **Pair 2:** Th = 0.6 × max, Tl = 0.3 × max
- Strong edges (≥ Th) were retained.
- Weak edges (between Tl and Th) were kept only if connected to strong edges.
- Others suppressed to zero.

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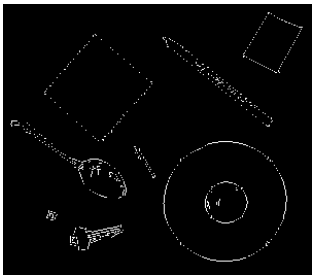
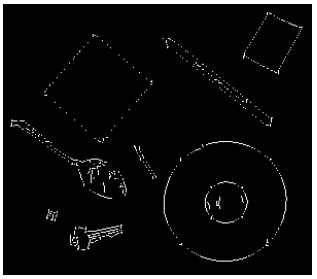
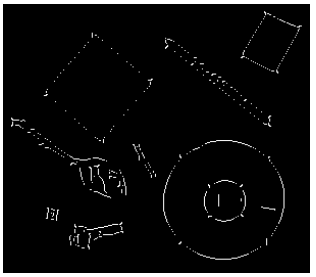
Threshold 0.2:



σ=0.5



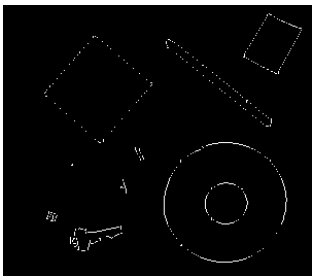
σ=1.0



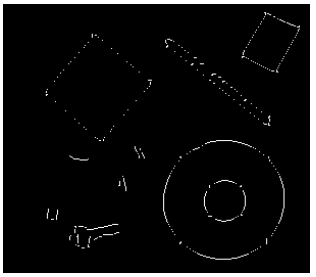
σ=2.0

Threshold 0.6:

σ=0.5



σ=1.0



σ=2.0