Edge Detection Methods with Parallelization

EC526 Project

Mingdao Che, Pat Rick Ntwari, Fuyao Wang

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Boston University College of Engineering

BOSTON UNIVERSITY

Introduction

Edge Detection:

Mathematically identifying boundaries (edges) of objects within a digital image.

Canny edge detection:

An effective, multistage, and computational technique to reveal the edges of objects in an image. The technique sets itself apart in its reduction of the amount of processed data. Developed by Australian computer scientist John F. Canny. Candidate for parallelization due to constant pixel looping.

Applications:

- Object isolation in self-driving car algorithms
- Medical diagnoses such as tumor recognition
- License plate identification
- Fingerprint matching

Summary of the multistage algorithm

Input: Grayscale Image

I. Gaussian Filter
- Image smoothing
- Noise reduction

II. Intensity Gradient
- Derivatives and direction of neighbouring pixels
- Can be variable based on kernel

III. Non-maximum Suppression
- Find "the largest" edge
- Suppress all the gradient values except the local maxima

IV. Double Threshold
- Sort pixels by gradient values
- Establish strong, weak and “maybe” pixels

V. Hysteresis Tracking
- Evaluate the “maybe” pixels
- Eliminate non-edges

Output: Edge Image

Gaussian filter

Gaussian filter = Gaussian blurring = Gaussian smoothing

Reduce noise in image, and probability of false "positives"

Other possible filters: mean and median filters

Replace pixel with weighted average of neighbors

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

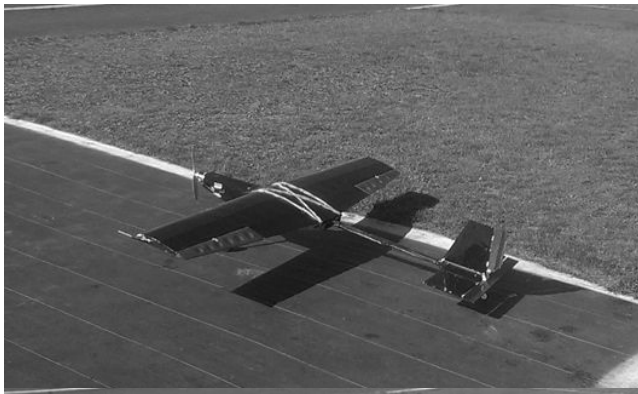
$\sigma \uparrow \; k \uparrow$

σ=1

$$\frac{1}{273}\begin{pmatrix} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{pmatrix}$$

k

Original



Blurred, σ=1

Find Intensity Gradient

- The edge generally is defined as an area where the intensity of the image changes rapidly in some local areas.
- The edge detection operator returns a value for the first derivative in the horizontal direction (Gx) and the vertical direction (Gy).

$$\mathbf{G} = \sqrt{\mathbf{G}_x{}^2 + \mathbf{G}_y{}^2}$$

- An edge in an image may point in a variety of directions, Canny algorithm assumed that direction angle is rounded to one of four angles representing vertical, horizontal and the two diagonals (0°, 45°, 90° and 135°).

$$\mathbf{\Theta} = \operatorname{atan2}(\mathbf{G}_y, \mathbf{G}_x),$$

Comparisons of Operators

Sobel:

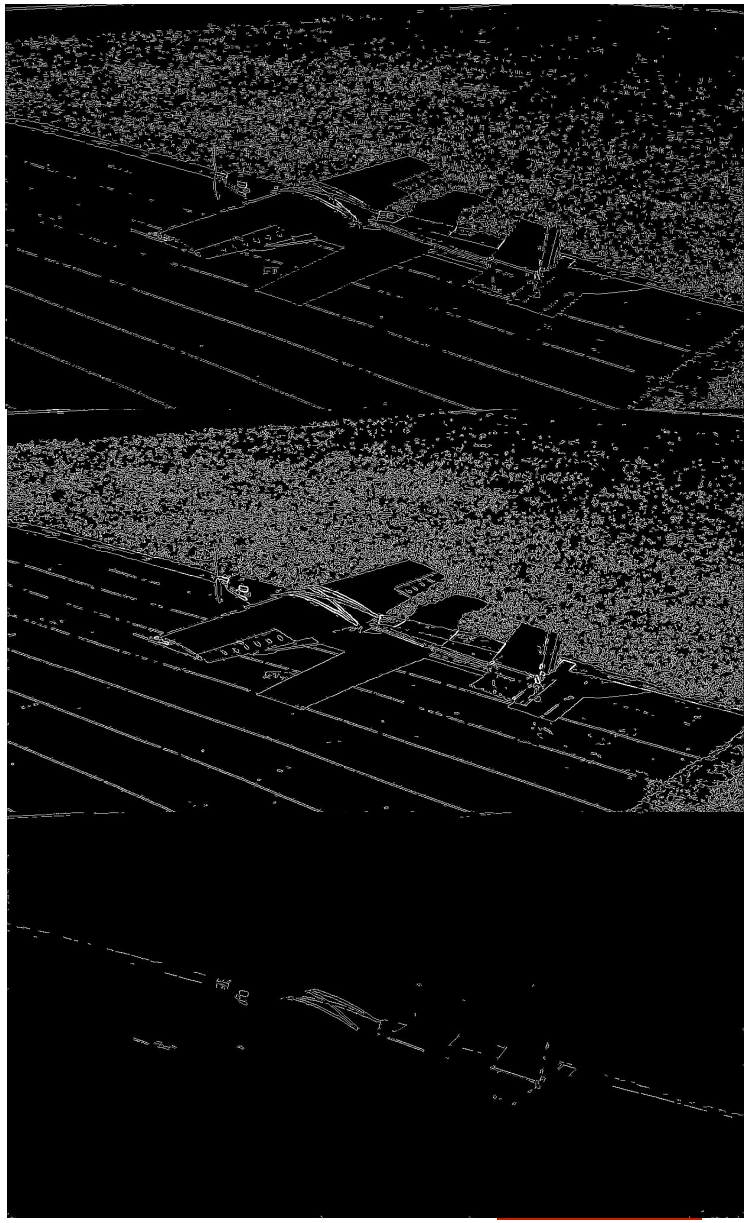
$$S_x = \begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{matrix} \qquad S_y = \begin{matrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{matrix}$$

Prewitt:

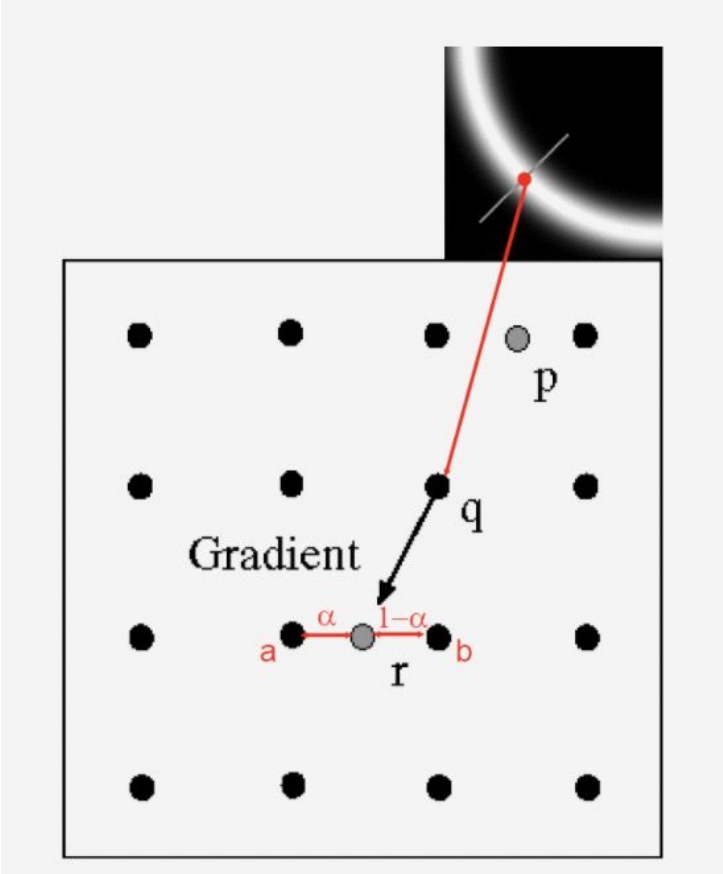
$$P_x = \begin{matrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{matrix} \qquad P_y = \begin{matrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{matrix}$$

Roberts:

$$R_x = \begin{matrix} 1 & 0 \\ 0 & -1 \end{matrix} \qquad R_y = \begin{matrix} 0 & 1 \\ -1 & 0 \end{matrix}$$



Non-maximum suppression



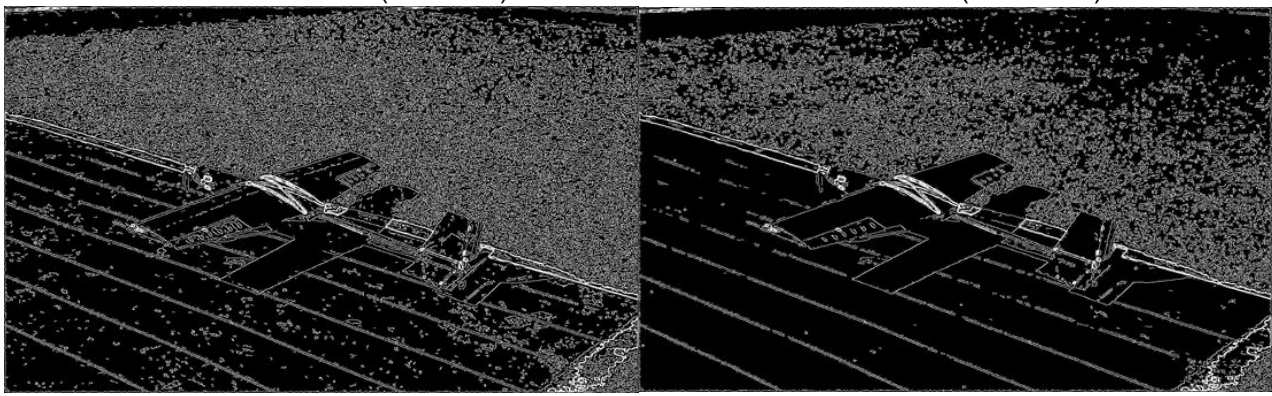
- There should only be one accurate response to the edge
- Find "the largest" edge

Double Threshold & Edge Tracking

- Establish min. and max. limit to pixel gradient (hence “double” threshold)
  - Keep pixels > max. threshold [strong edges]
  - Eliminate pixels < min. threshold [not edges]
  - Maybe’s (min < pixels < max) to be re-evaluated [weak edges]
- Track Edge
  - “Maybe” pixels assessed based of edge-ness of neighbors
  - Check for strong edges within a certain radius of “maybe” pixel

Final result depends on much user tuning based on situation

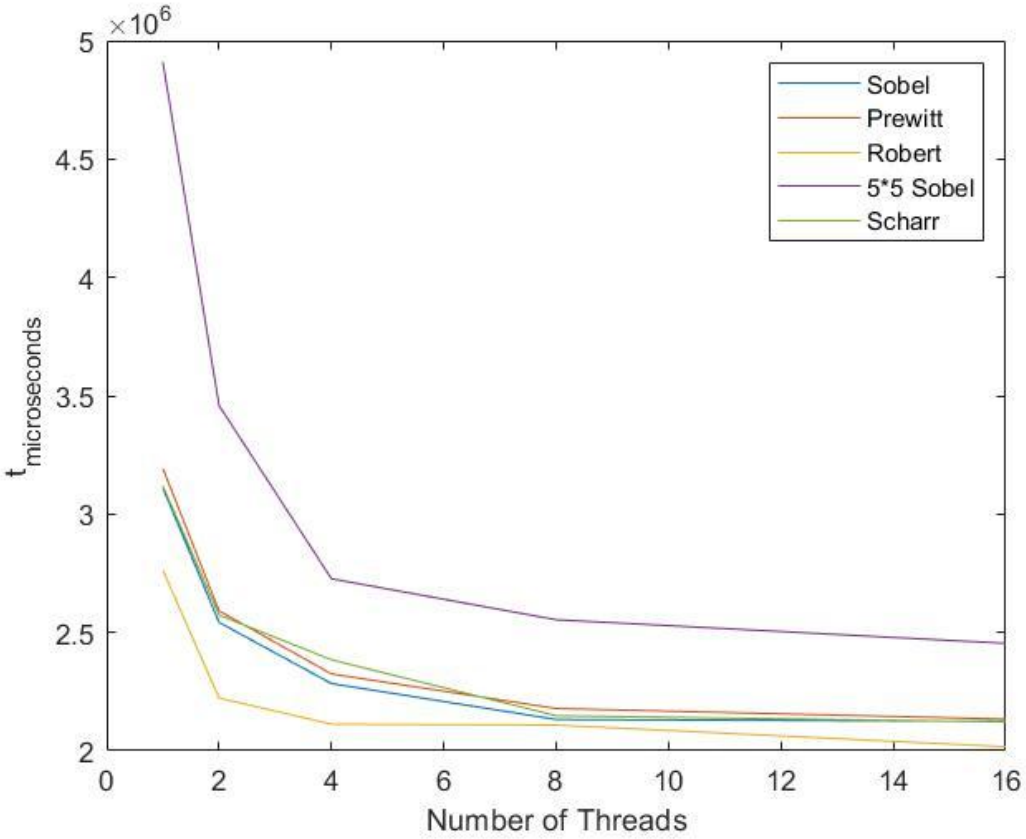
Min - Max/2 Max - Median (less strict) Min - 1Q Max - 3Q (more strict)



Final Result Comparison

Parallelization:

- We used openMP to parallelizing our code, including Gaussianblur, Image Gradients, Non-max-suppression and Double Threshold Hysteresis.

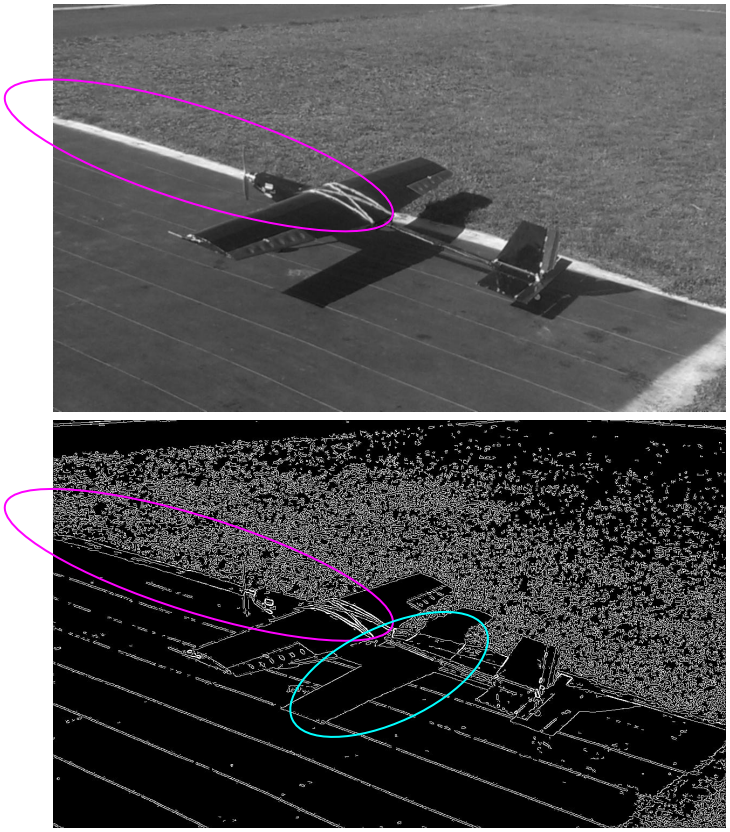


- The curve of running time decreases rapidly from 1(serial) to 4.
- But slows down after 4 threads.
- The Performance on larger matrix is better than smaller.

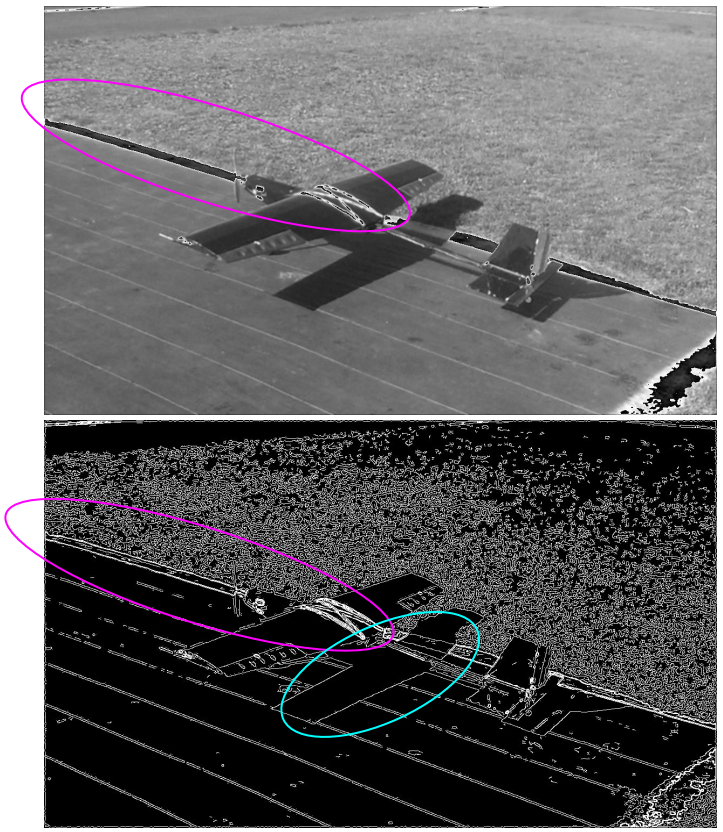
Kernel	Serial Time (microseconds)	4 Threads Time (microseconds)	% Change
Sobel	3,110,026	2,283,923	-27%
Prewitt	3,192,802	2,324,641	-27%
Robert	2,762,271	2,112,322	-24%
5x5 Sobel	4,910,604	2,726,721	-44%
Scharr	3,119,187	2,384,453	-24%

Other Observations (Gaussian Filter σ=1 & σ=1.4)

1



1.4



Reference:

[1] Canny edge detector: https://en.wikipedia.org/wiki/Canny_edge_detector

[2] Mehravar Rafati, Masoud Arabfard and Mehrdad Rafati-Rahimzadeh, “Comparison of Different Edge Detections and Noise Reduction on Ultrasound Images of Carotid and Brachial Arteries Using a Speckle Reducing Anisotropic Diffusion Filter”. In: Iran Red Crescent Med J. 2014 Sep.