The Canny Edge Detector and the Hough Transform

CS 510

Lecture #17

March 2, 2018

Colorado State University

Recall - Sobel Edges

Source Dx Image Dy Image

Sobel Edges: A Local Decision

- Magnitude = $(dx^2 + dy^2)^{1/2}$
- Orientation = $\tan^{-1} dy/dx$
- dy/dx responses are signed
- Edge Masks: sum of weights is zero
- Edges tend to be “thick”

Symbolic Edge Detection

- Although Sobel edges are optimal estimators for the slope of a planar facet, as symbols they:
  - Are continuous; edge yes/no based on threshold
  - May be “thick”; need to be localized
  - Are isolated; need to be grouped into longer lines
- If they correspond to scene structure (e.g. discontinuities), we want a model of how scene structures map to images.

Seminal Work – Canny Edges

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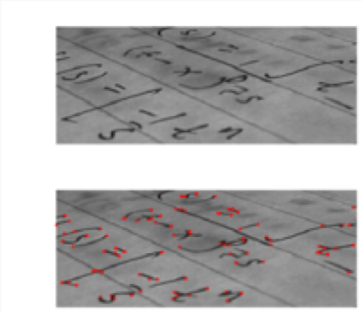
Canny edge detector

From Wikipedia, the free encyclopedia

The **Canny edge detector** is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. It was developed by John F. Canny in 1986. Canny also produced a *computational theory of edge detection* explaining why the technique works.

Contents [hide]

Feature detection



Output of a typical corner detection algorithm

Edge detection

Canny · Canny–Deriche · Differential · Sobel · Prewitt · Roberts cross

Canny Edge Detection (Step 1)

- In order to maximize the likelihood of finding step-edges,
  1. Smooth image with a Gaussian filter
     - Size is determined by noise model
  2. Compute image gradients over the same size mask

- The bigger the mask, the better detection is but the worse localization is...

Canny Edge Detection (step 2)

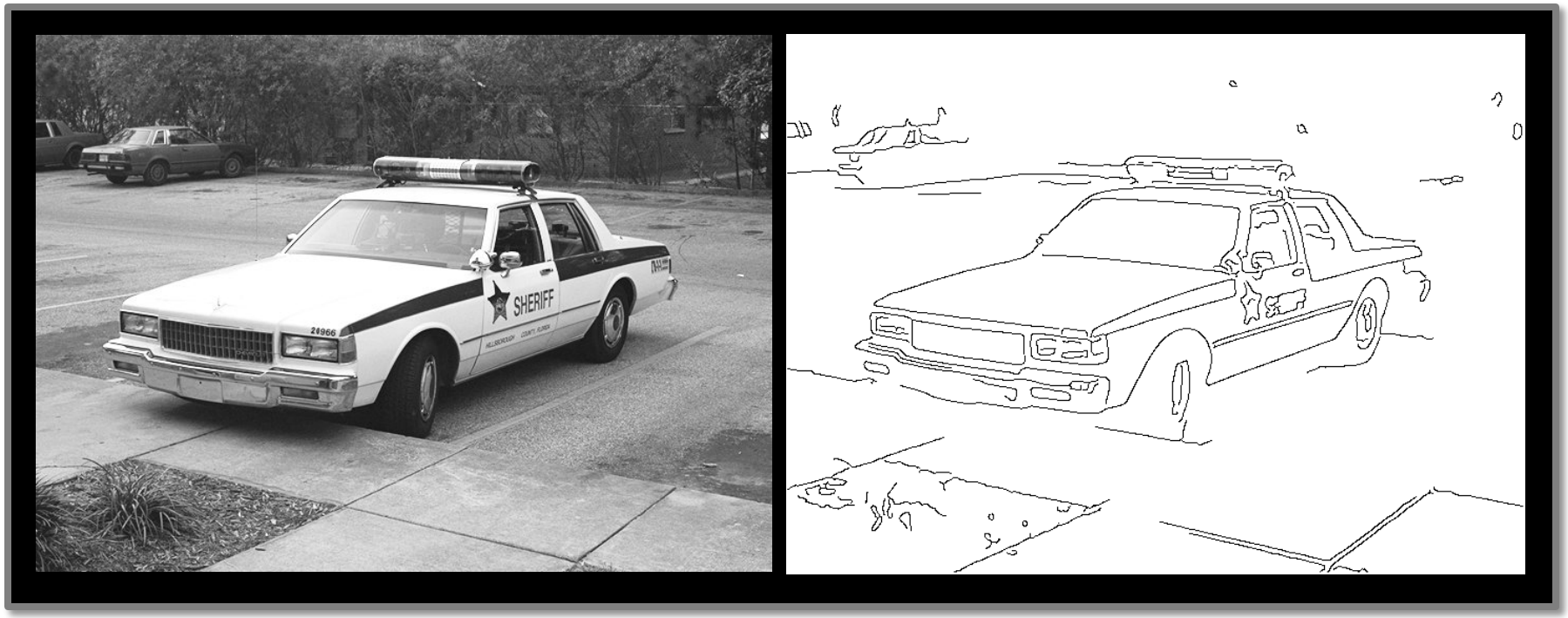
- Non-maximal suppression
  - So far, edges are still “thick”
  - For every edge pixel:
    - 1) Calculate direction of edge (gradient)
    - 2) Check neighbors in edge direction
    - If either neighbor is “stronger”, set edge to zero.

Drexel Tutorial –
http://dasl.mem.drexel.edu/alumni/bGreen/www.pages.drexel.edu/_weg22/can_tut.html

Canny Edge Detection (Step 3): Hysteresis Thresholding

- Continuous values still need thresholding
- Algorithm takes <u>two</u> thresholds: high & low
  - Any pixel with edge strength above the high threshold is an edge
  - Any pixel above the low threshold and next to an edge is an edge
- Iteratively label edges
  - they "grow out" from high points.
  - This is called hysteresis.

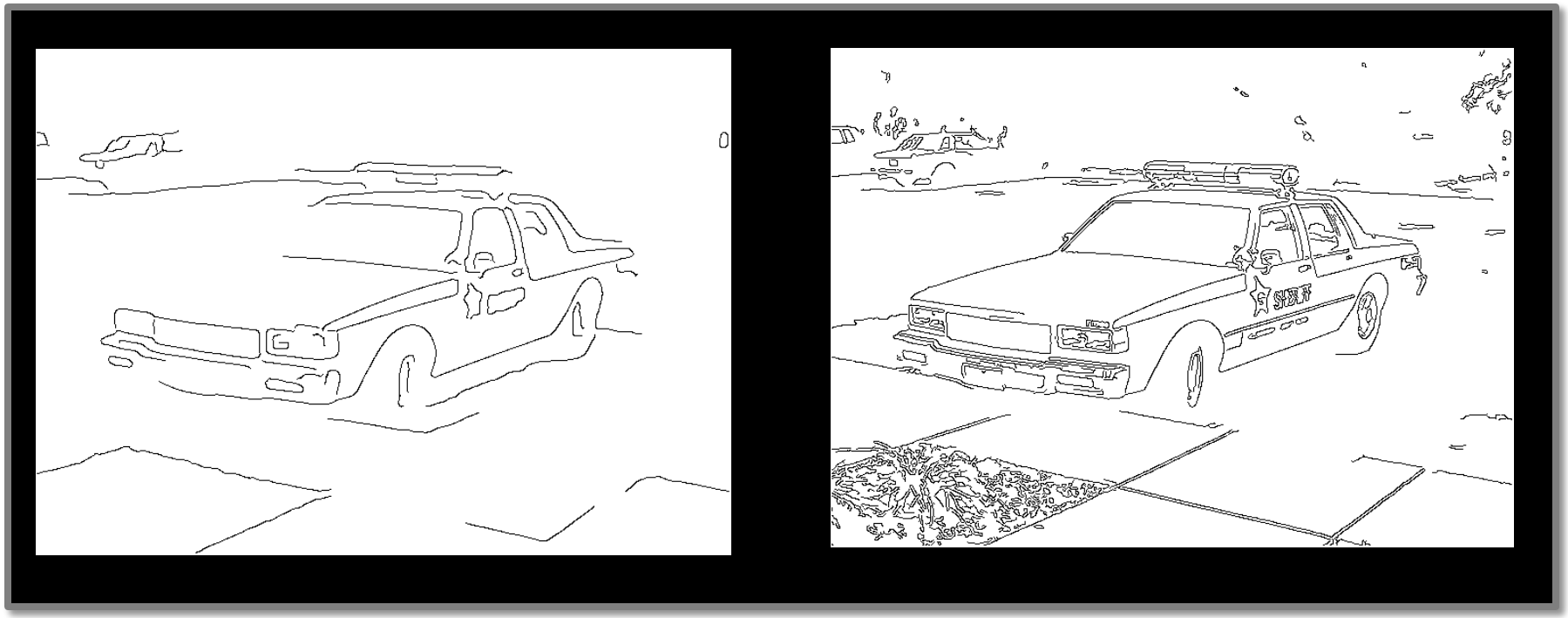
Canny Example



Source image

Canny: sigma = 2.0,
low = 0.40, high = 0.90

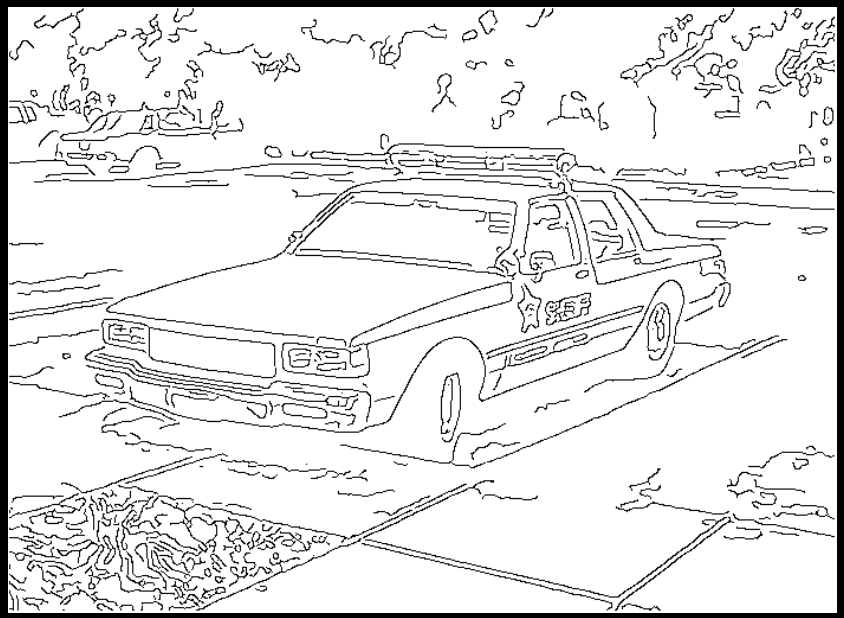
Canny Example (cont.)

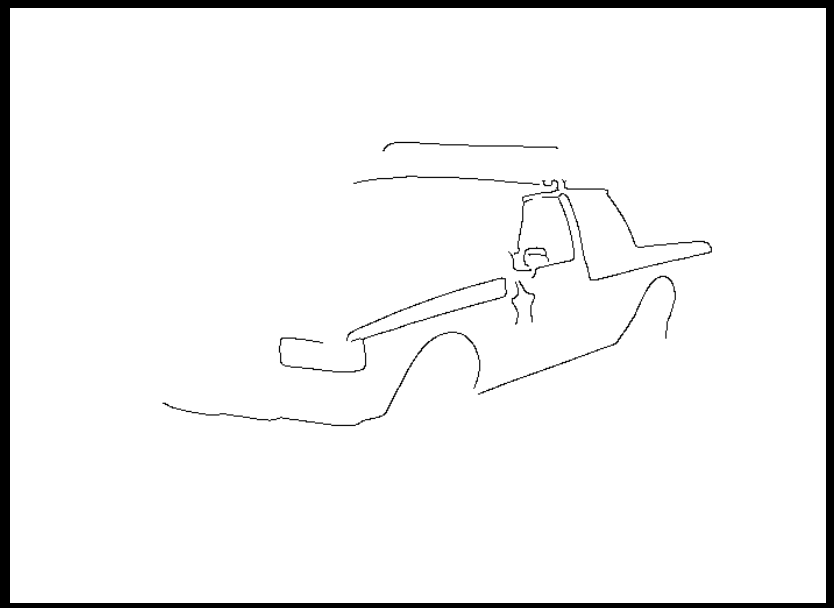


Sigma = 3.0
low = 0.4, high = 0.9

Sigma = 1.0
low = 0.4, high = 0.9

Canny Example (III)

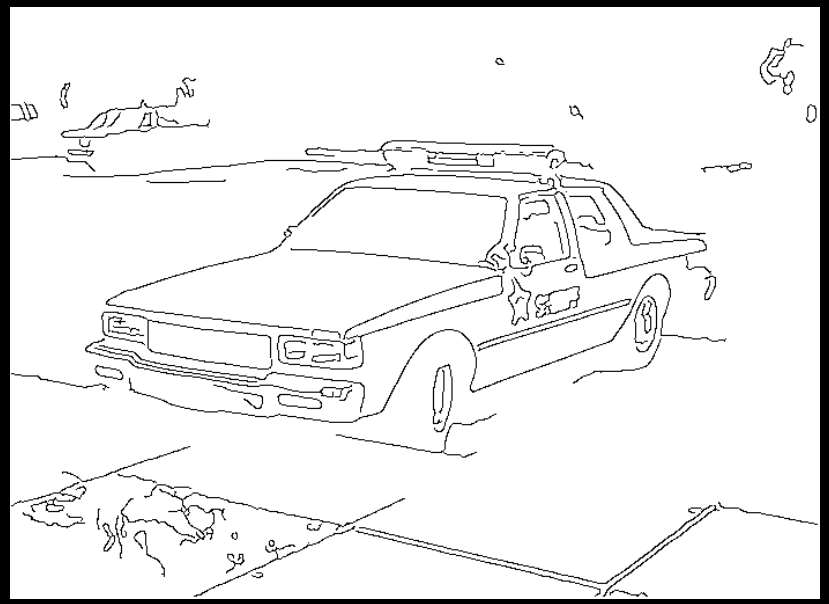




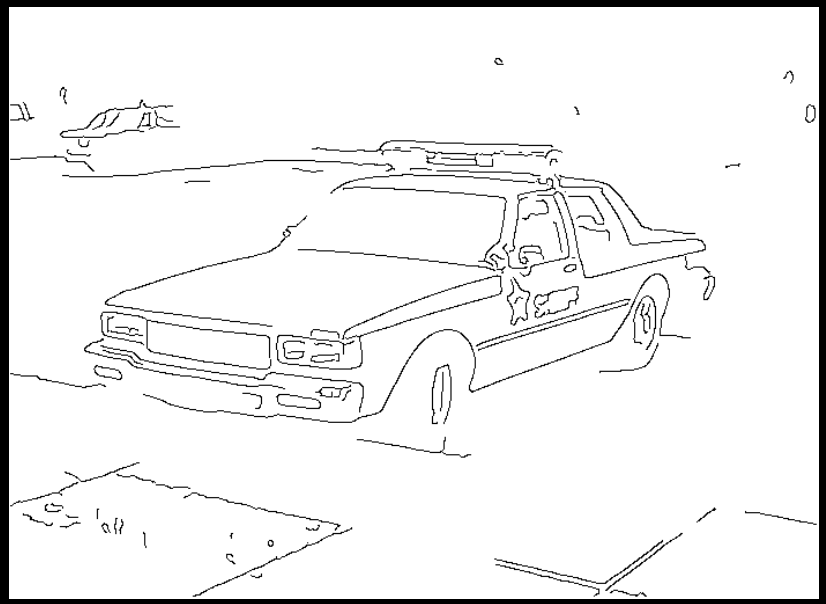
Sigma = 2.0
low = 0.4, high = 0.6

Sigma = 2.0
low = 0.4, high = 0.99

Canny Example (IV)

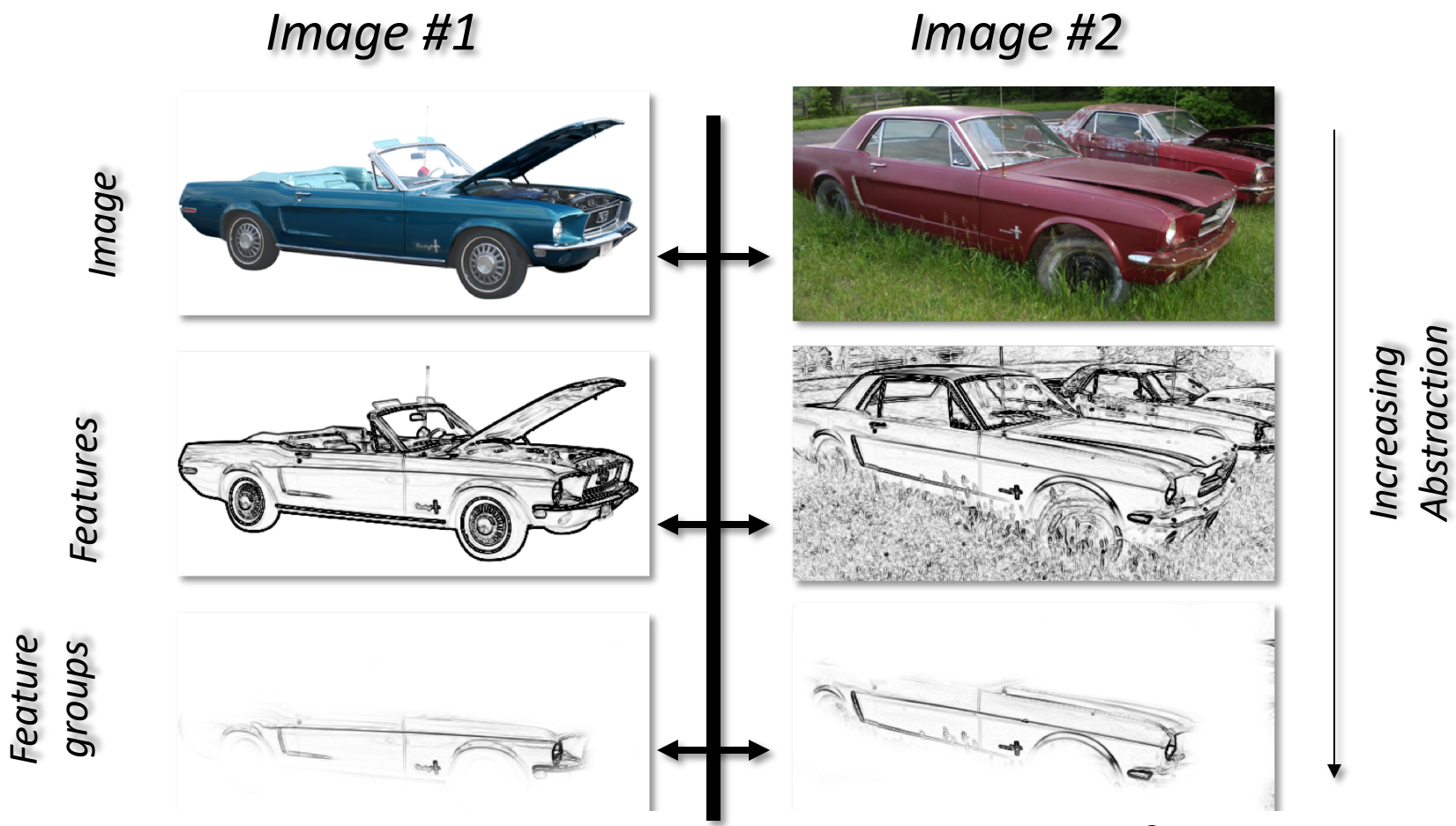


Sigma = 2.0
low = 0.2, high = 0.9



Sigma = 2.0
low = 0.6, high = 0.9

Motivation – Apprx. Invariance



Some PhotoShop liberties have been taken to illustrate the larger point here ☺

Canny in OpenCV

docs.opencv.org

OpenCV 2.4.11.0 documentation » OpenCV Tutorials » *imgproc* module. Image Processing » previous | next | index

OpenCV

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Canny Edge Detector

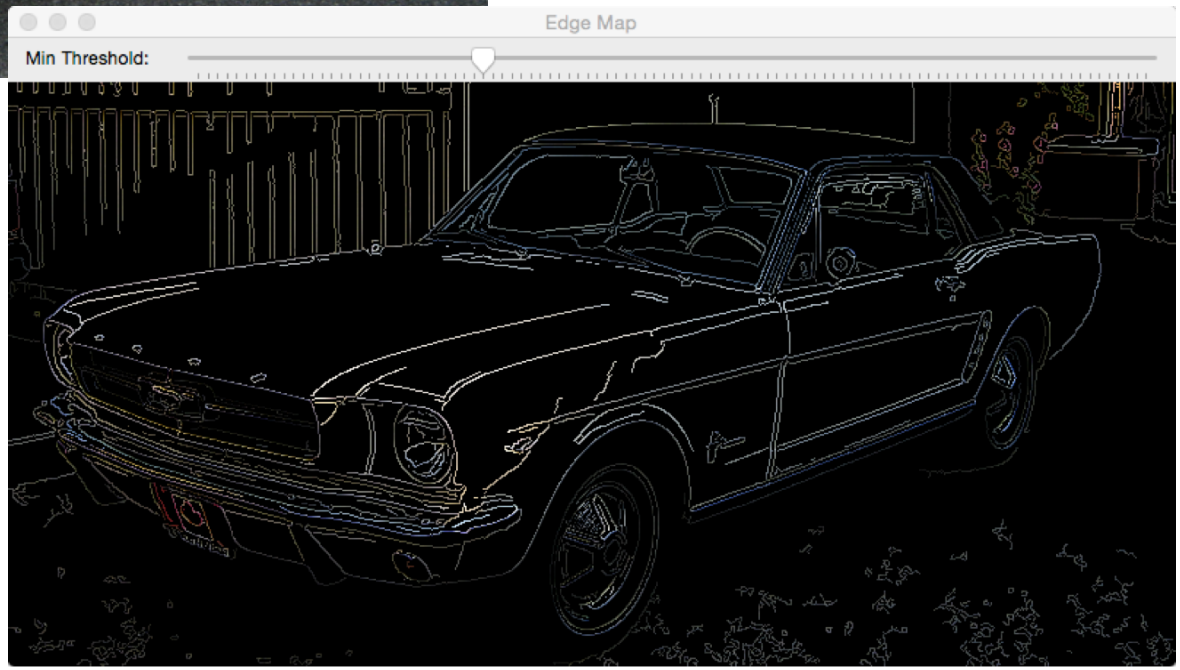
Goal

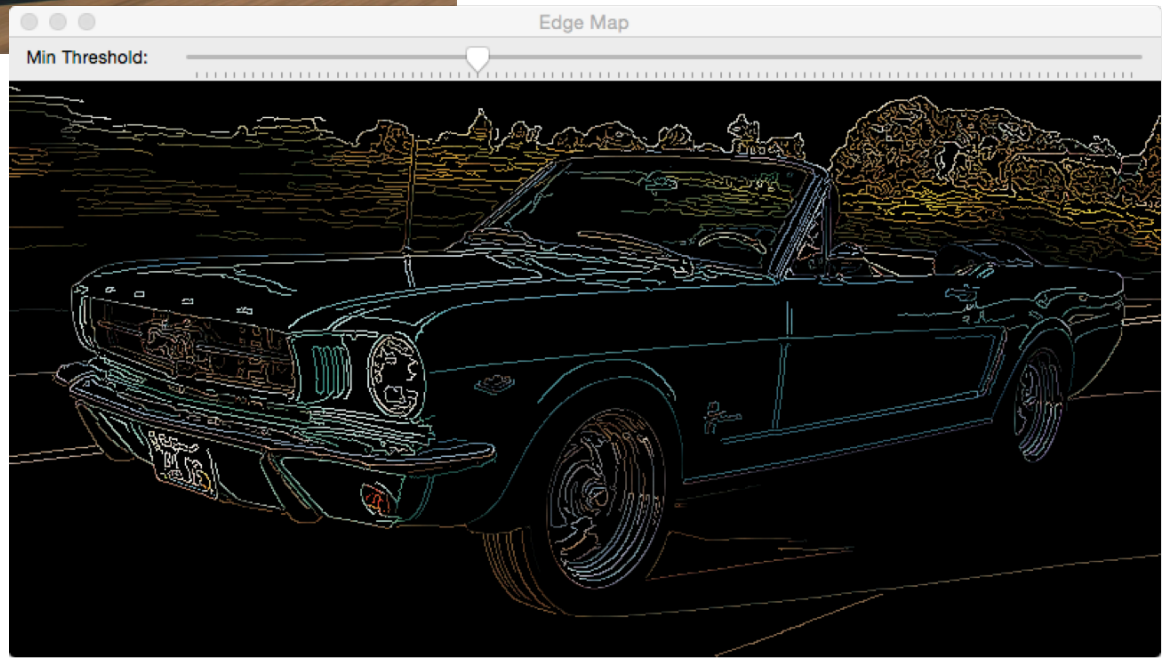
In this tutorial you will learn how to:

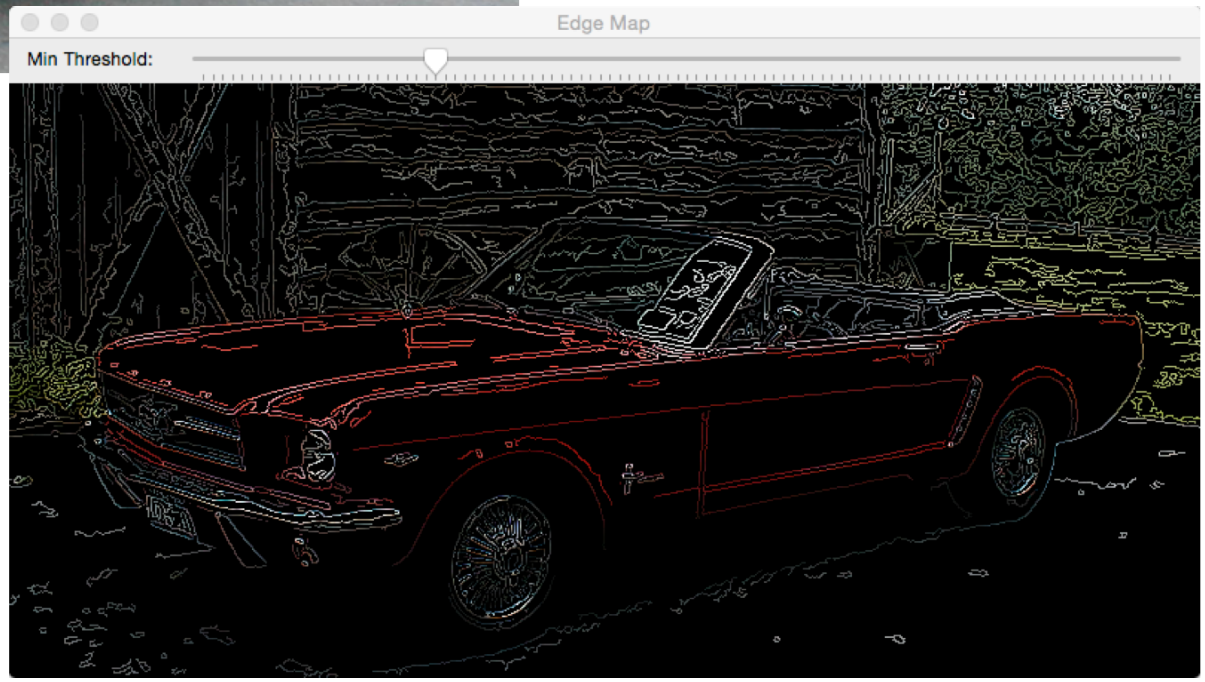
- Use the OpenCV function Canny to implement the Canny Edge Detector.

Theory

1. The *Canny Edge detector* was developed by John F. Canny in 1986. Also known to many as the *optimal detector*, Canny algorithm aims to satisfy three main criteria:
   - **Low error rate:** Meaning a good detection of only existent edges.
   - **Good localization:** The distance between edge pixels detected and real edge pixels have to be minimized.
   - **Minimal response:** Only one detector response per edge.


Edge Map
Min Threshold:


Edge Map
Min Threshold:

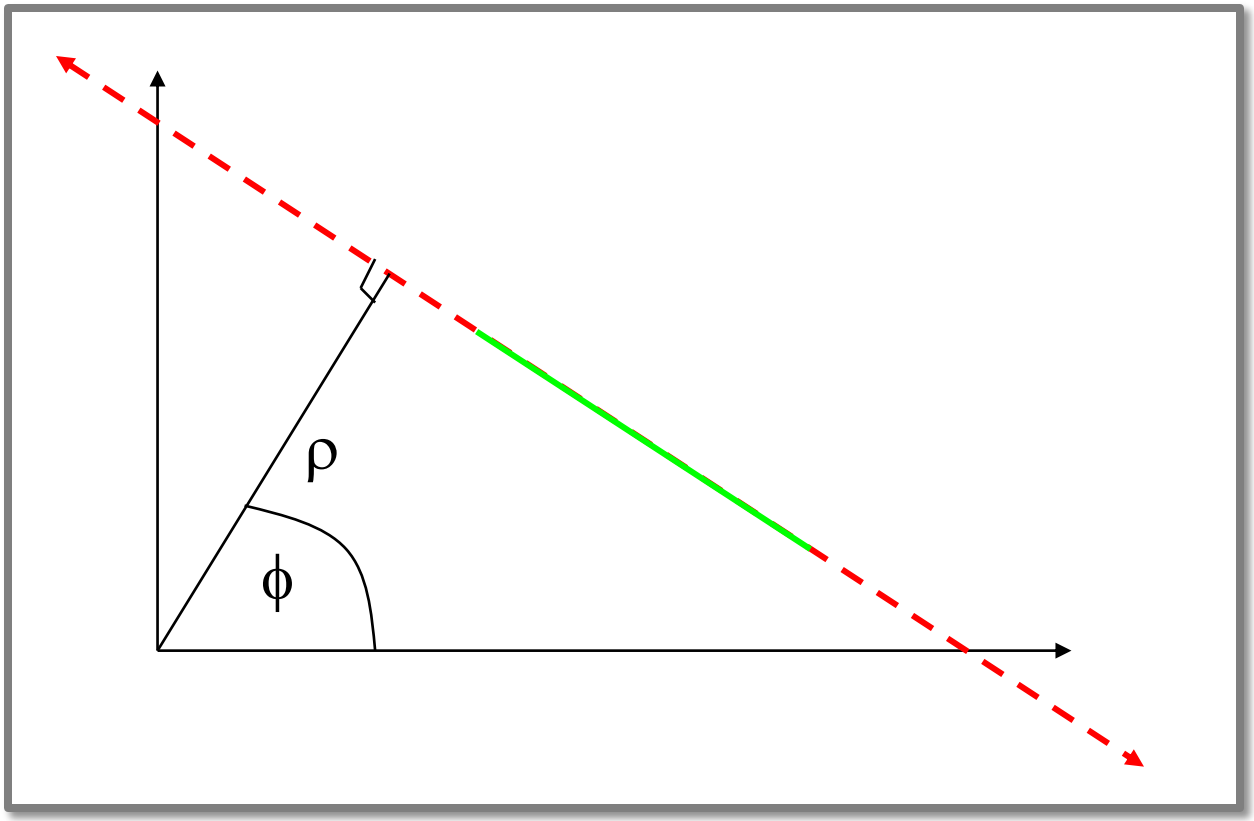

Edge Map
Min Threshold:

Hough Transform: Grouping

- The idea of the Hough transform is that a change in representation converts a point grouping problem into a peak detection problem.
- Standard line representations:
  - $y = mx + b$ -- *compact, but problems with vertical lines*
  - $(x_0, y_0) + t(x_1, y_1)$ -- *your raytracer used this form, but it is highly redundant (4 free parameters)*
  - $ax + by + c = 0$ -- *Bresenham's uses this form. Still redundant (3 free parameters)*
- How else might you represent a line?

Hough Grouping (cont.)

- Represent infinite lines as (ϕ,ρ):

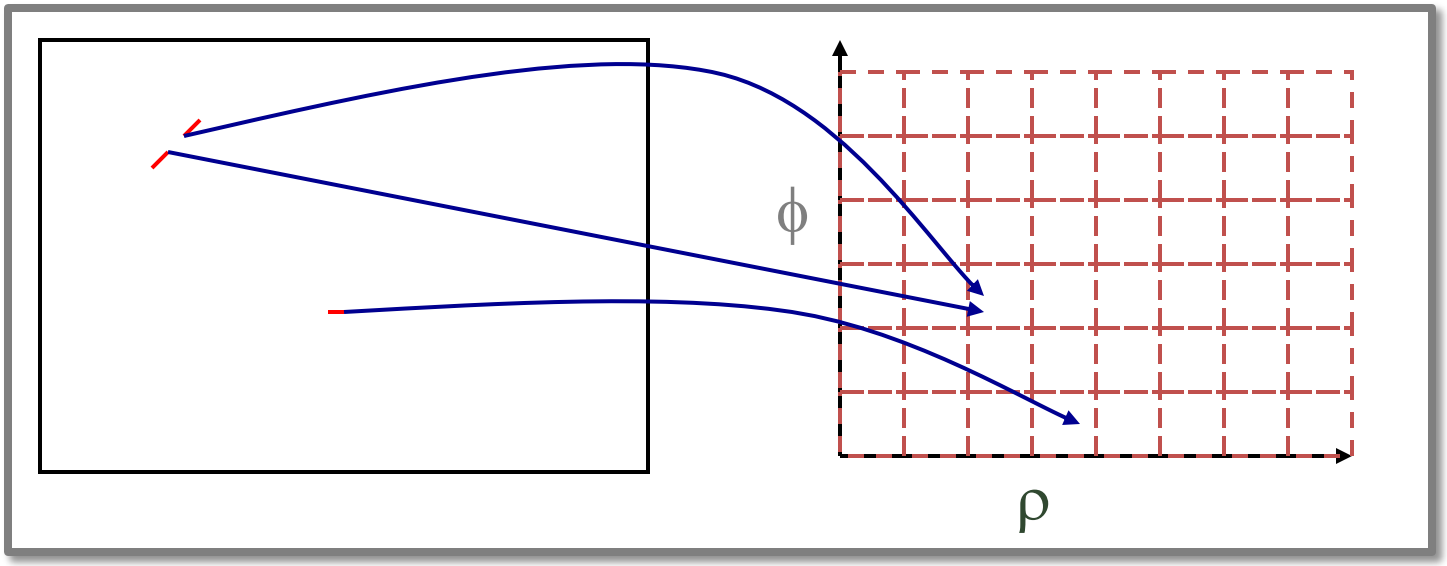


Hough Grouping (III)

- Why? This representation is:
  - Small: only two free parameters (like y=mx+b)
  - Finite in all parameters : $0 <= \rho < \sqrt{(row^2+col^2)}$, $0 <= \phi < 2\pi$
  - Unique: only one representation per line
- General Idea:
  - Hough space (ϕ,ρ) represents all possible lines
  - Next step - use discrete Hough space
  - Let every point "vote for" any line is might belong to.

Hough Grouping: Directed Edges

- Every edge has a location and position, so it can be part of only one (infinitely extended) line.



- Co-linear edges map to one bucket in Hough space.

Hough Grouping: Edges

- Reduces line grouping to peak detection
  - Each edge votes for a bucket (line)
  - # of votes equates to support
    - The # of participating edges.
  - Position of bucket provides the ϕ, ρ parameters
- Problem: if "true" line parameters are on the boundary of a bucket, supporting data may be split
- Solution: smooth the histogram (Hough image) before selecting peaks.

Basic Hough – Infinite Lines

- The Hough Transform in pure form …
- Does not return end-points
- Instead, it returns a rho and theta pairs.

```
    for (size_t i = 0; i < lines.size(); i++) {
        float rho = lines[i][0], theta = lines[i][1];
        Point pt1, pt2;
        double a = cos(theta), b = sin(theta);
        double x0 = a * rho, y0 = b * rho;
        pt1.x = cvRound(x0 + 1000 * (-b));
        pt1.y = cvRound(y0 + 1000 * (a));
        pt2.x = cvRound(x0 - 1000 * (-b));
        pt2.y = cvRound(y0 - 1000 * (a));
```

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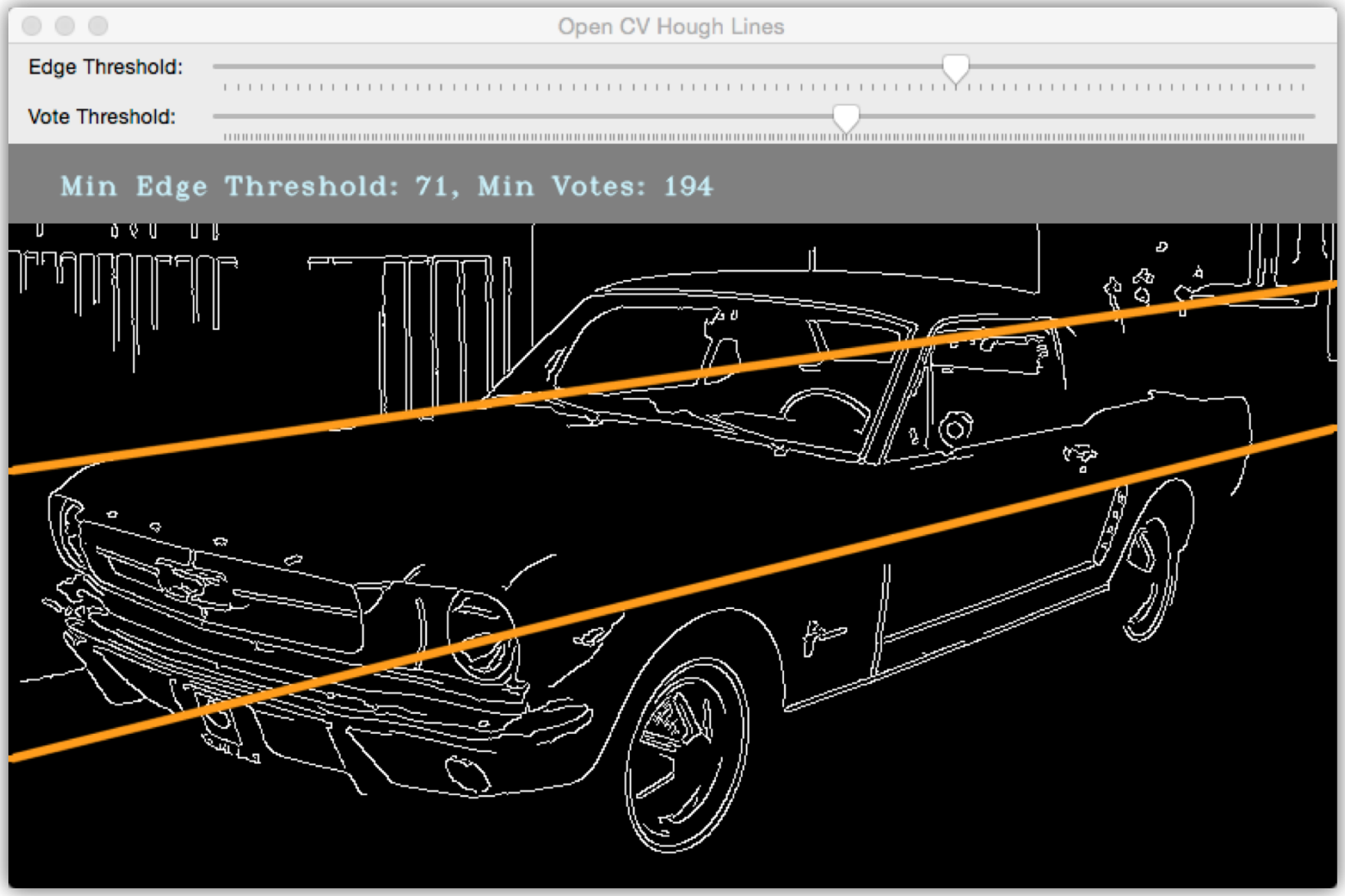
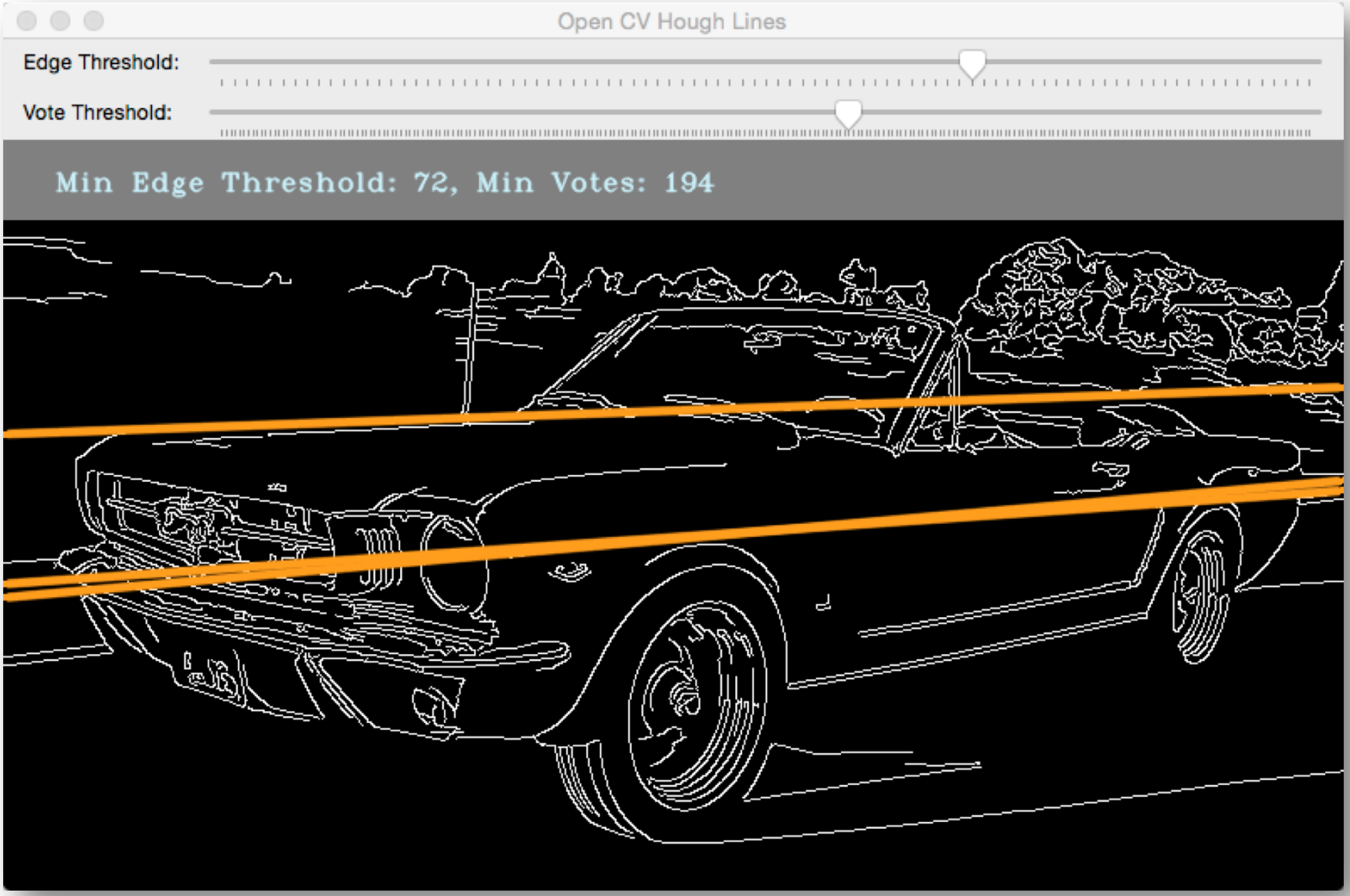
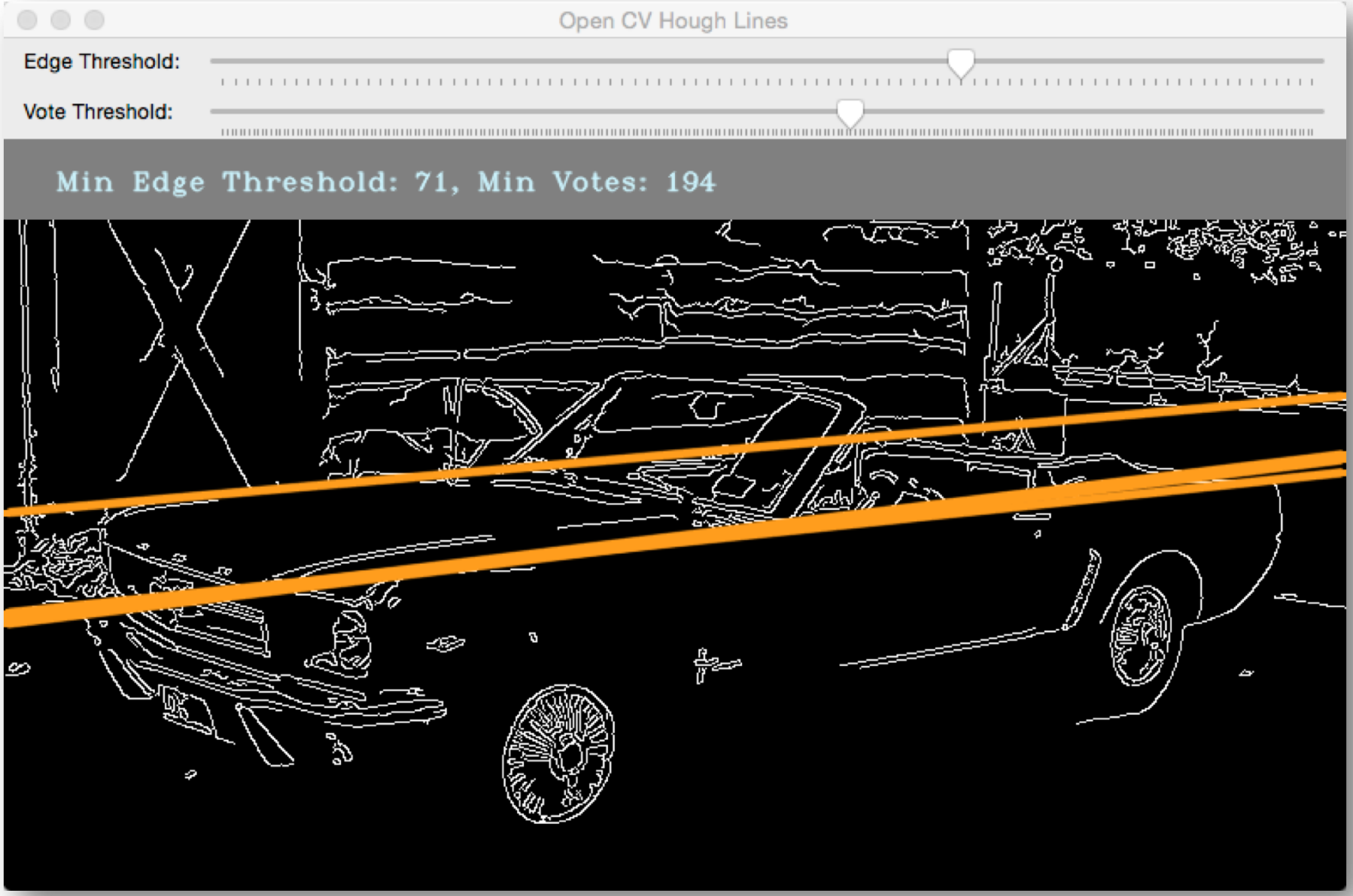

Open CV Hough Lines
Edge Threshold:
Vote Threshold:
Min Edge Threshold: 71, Min Votes: 194


Open CV Hough Lines
Edge Threshold:
Vote Threshold:
Min Edge Threshold: 72, Min Votes: 194


Open CV Hough Lines
Edge Threshold:
Vote Threshold:
Min Edge Threshold: 71, Min Votes: 194

Hough Fitting

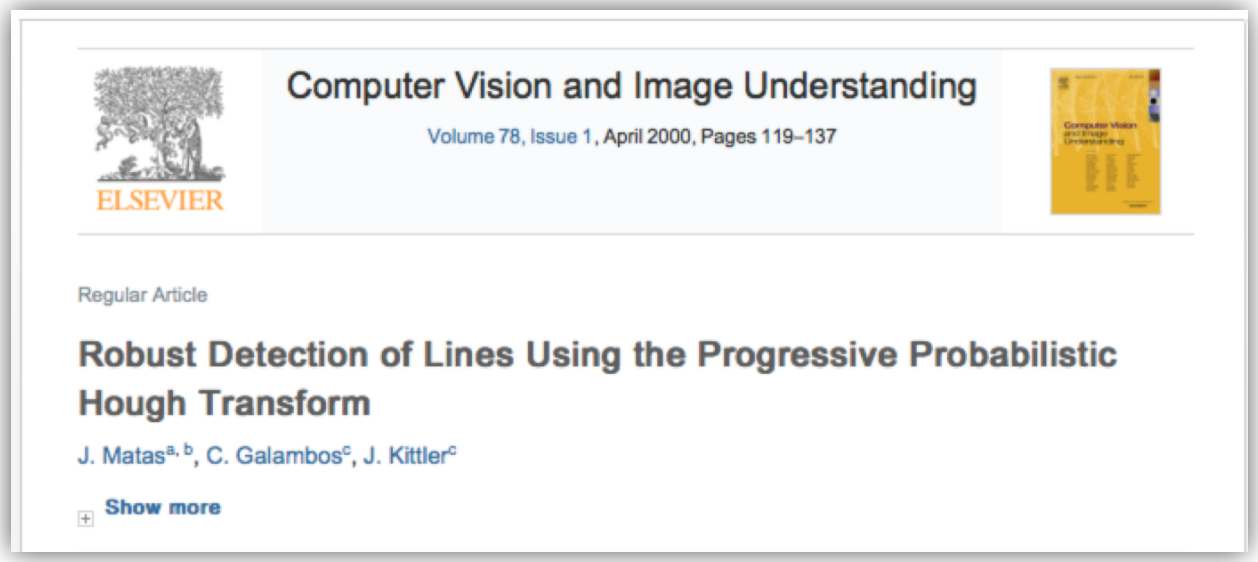
- After finding the peaks in the Hough Transform - still two potential problems:
  - Resolution limited by bucket size.
  - Infinite lines, not line segments
- Both of these problems can be fixed,
  - If you kept a linked list of edges (not just #)
  - Of course, this is more expensive...

Hough Fitting (II)

- Sort your edges
  - rotate edge points according to ρ
  - sort them by (rotated) x coordinate
- Look for gaps
  - have the user provide a “max gap” threshold
  - if two edges (in the sorted list) are more than max gap apart, break the line into segments
  - if there are enough edges in a given segment, fit a straight line to the points

Open CV Hough Version 2

- Second Hough algorithm in OpenCV
- Returns segments – based on work below



ELSEVIER

Computer Vision and Image Understanding

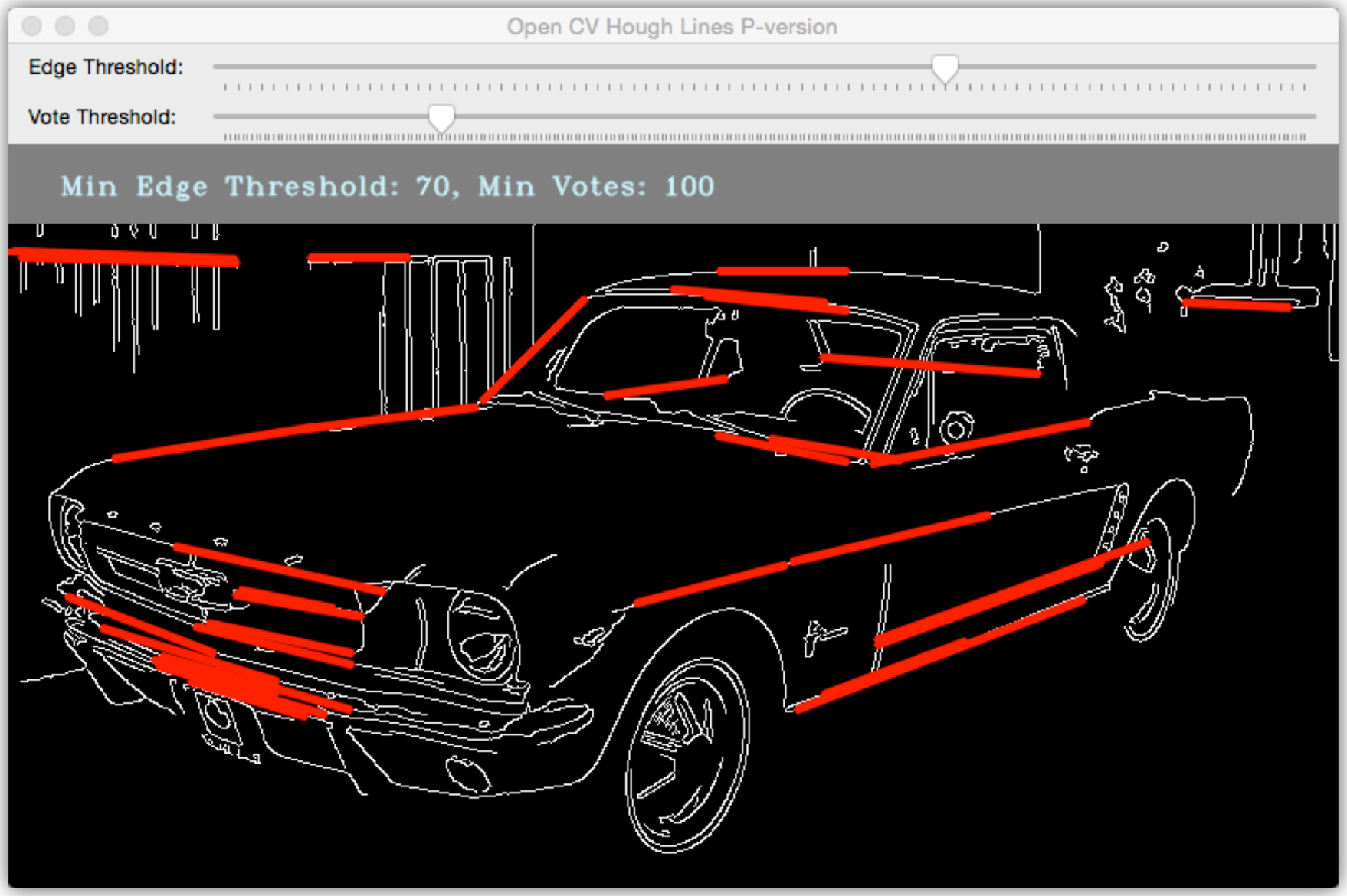
Volume 78, Issue 1, April 2000, Pages 119–137

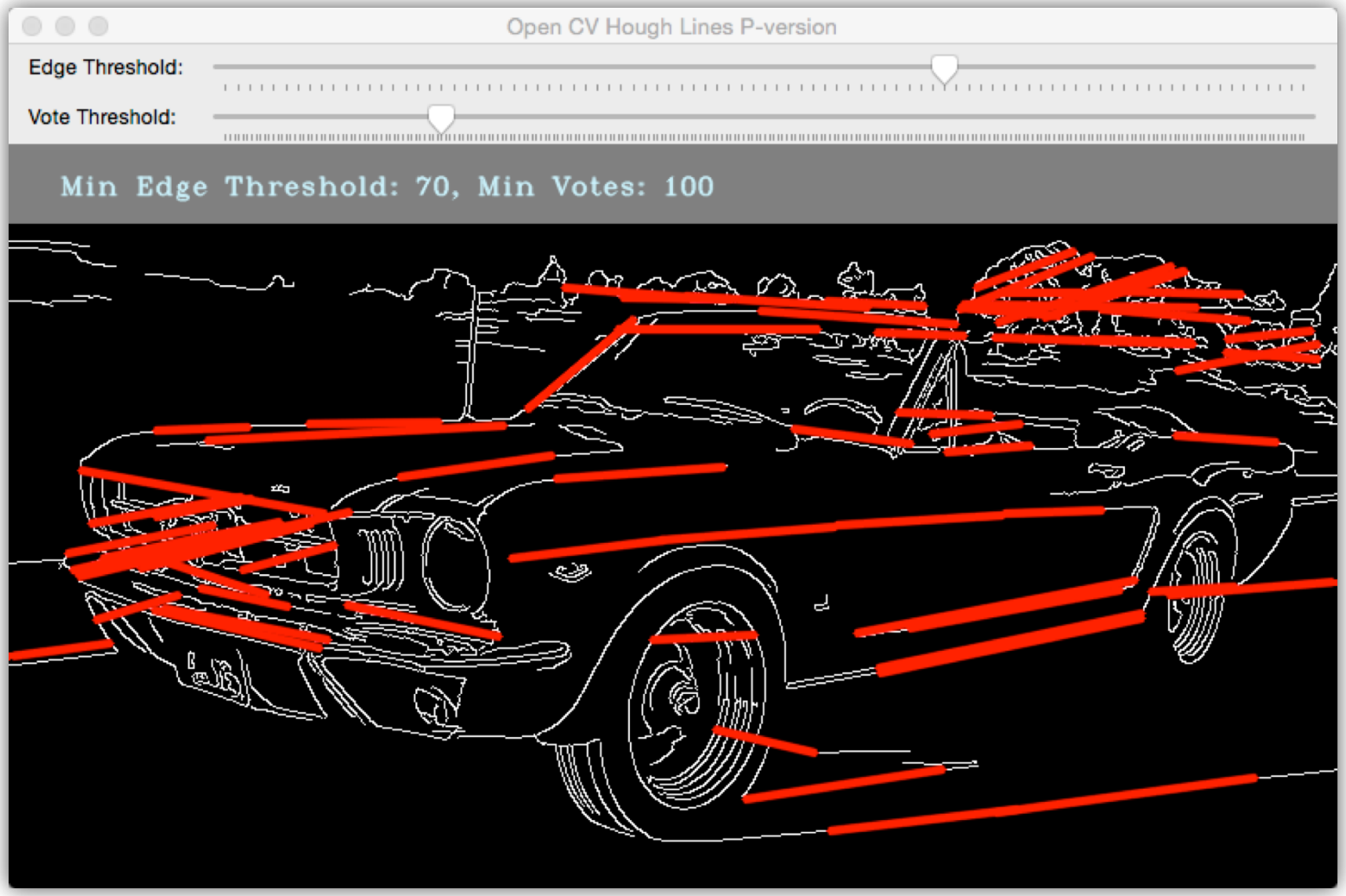
Regular Article

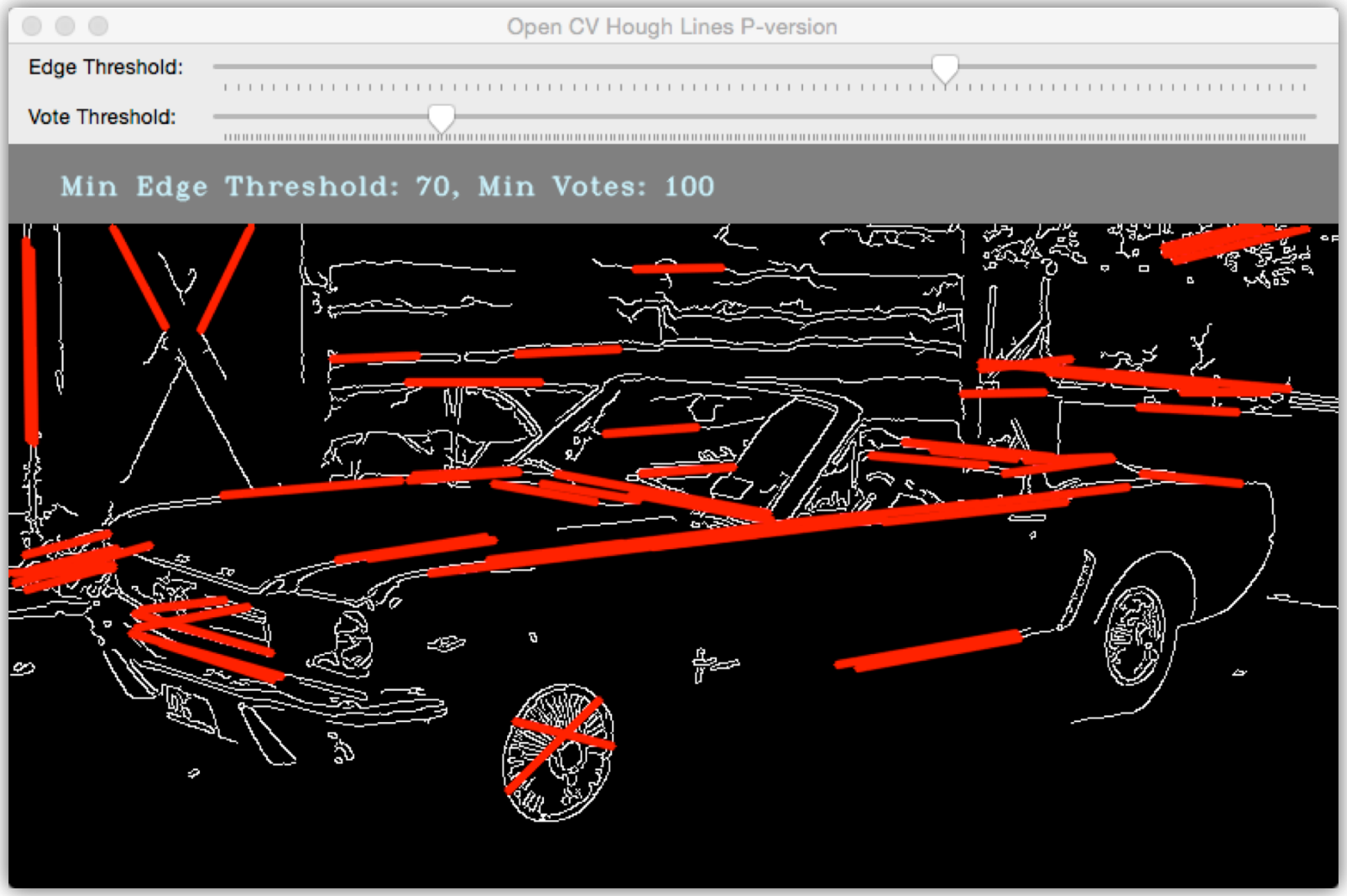
Robust Detection of Lines Using the Progressive Probabilistic Hough Transform

J. Matas[a, b], C. Galambos[c], J. Kittler[c]

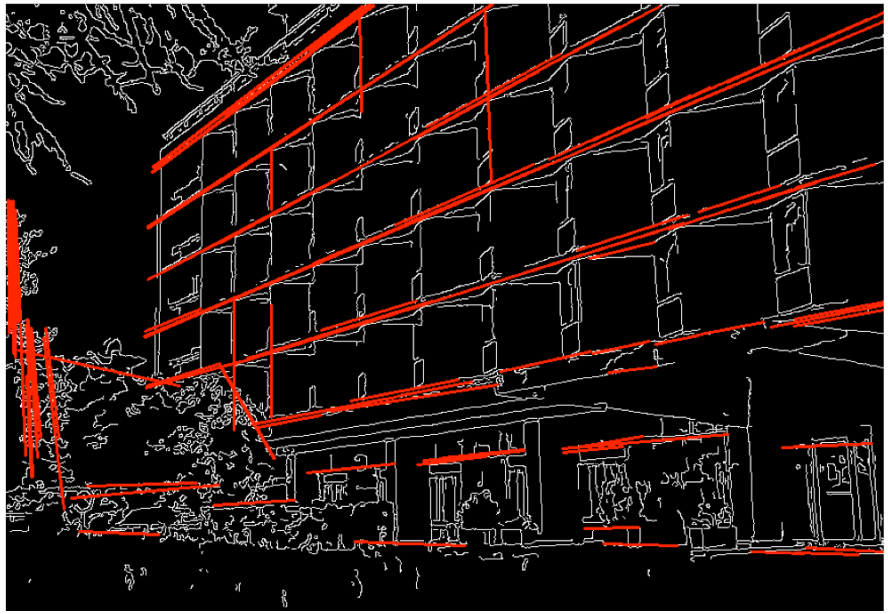
Show more


Open CV Hough Lines P-version
Edge Threshold:
Vote Threshold:
Min Edge Threshold: 70, Min Votes: 100


Open CV Hough Lines P-version
Edge Threshold:
Vote Threshold:
Min Edge Threshold: 70, Min Votes: 100


Open CV Hough Lines P-version
Edge Threshold:
Vote Threshold:
Min Edge Threshold: 70, Min Votes: 100

Building Example



http://docs.opencv.org/modules/imgproc/doc/feature_detection.html