The Canny Edge Detector and the Hough Transform

CS 510

Lecture #12

February 27, 2019

Colorado State University

Before Canny - 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.

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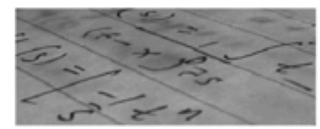
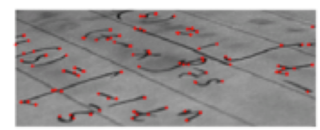
Feature detection





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)

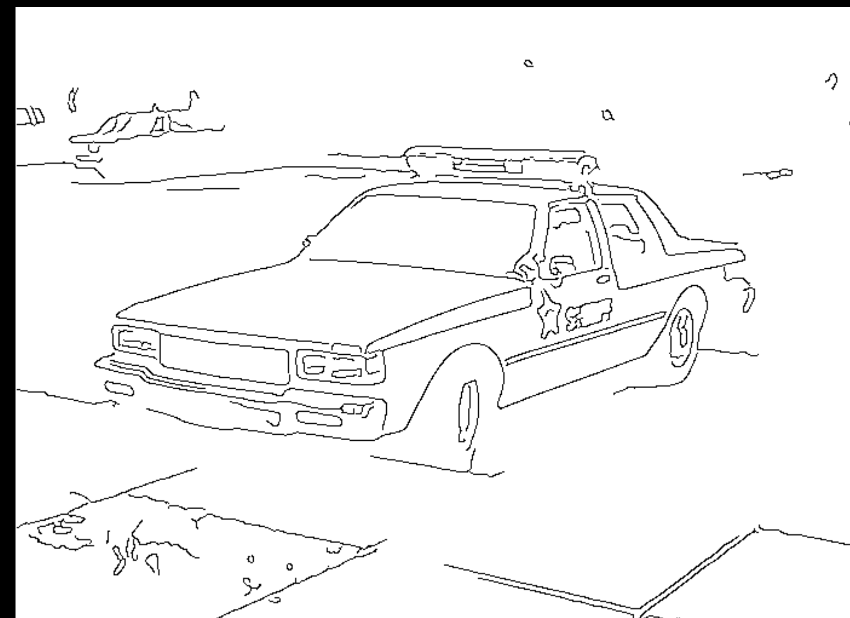
    2) Check neighbors in edge direction

       If either neighbor is “stronger”, set edge to zero.

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

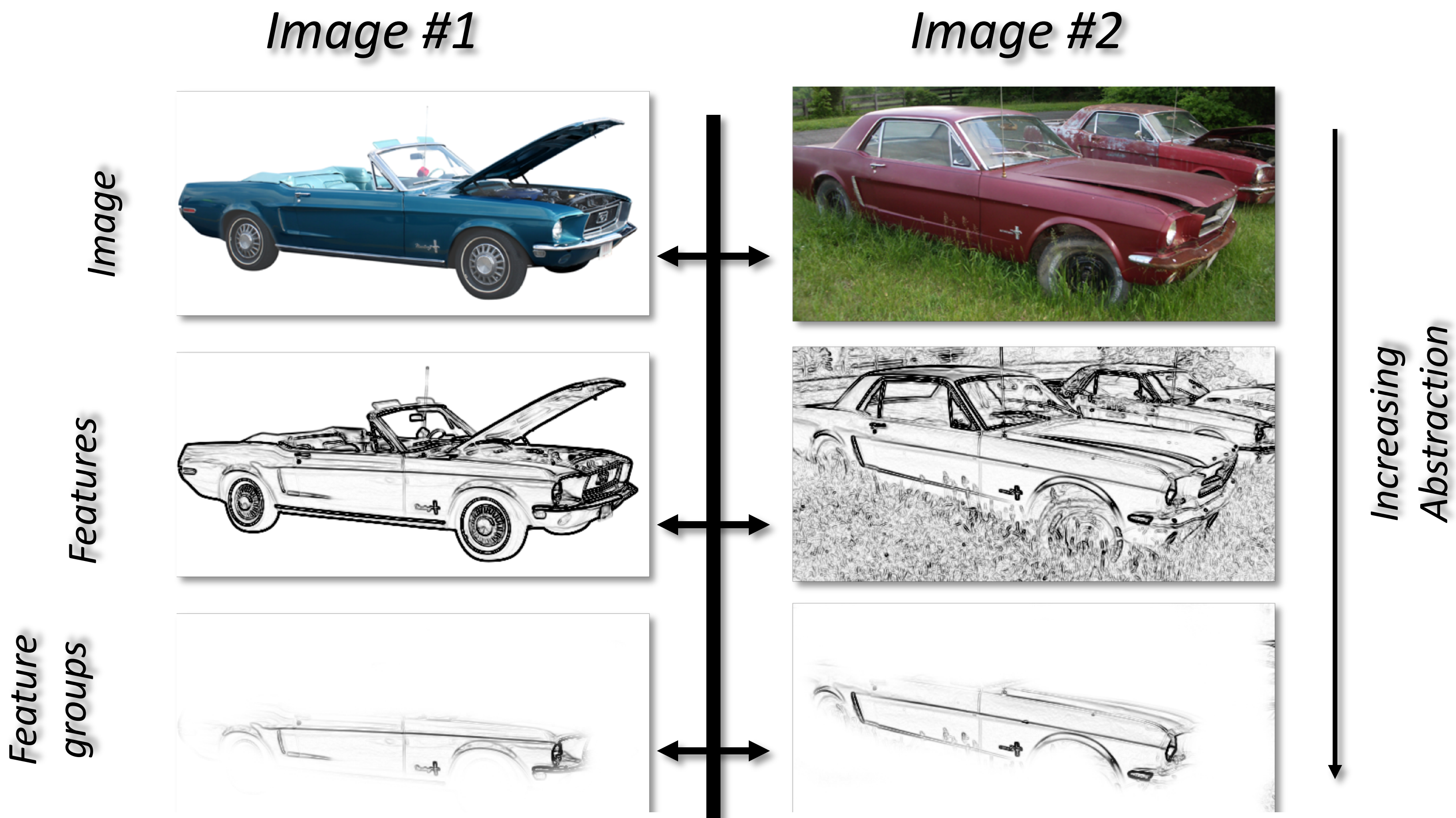
Sigma = 2.0
low = 0.4, high = 0.99

Canny Example (IV)

Sigma = 2.0
low = 0.2, high = 0.9

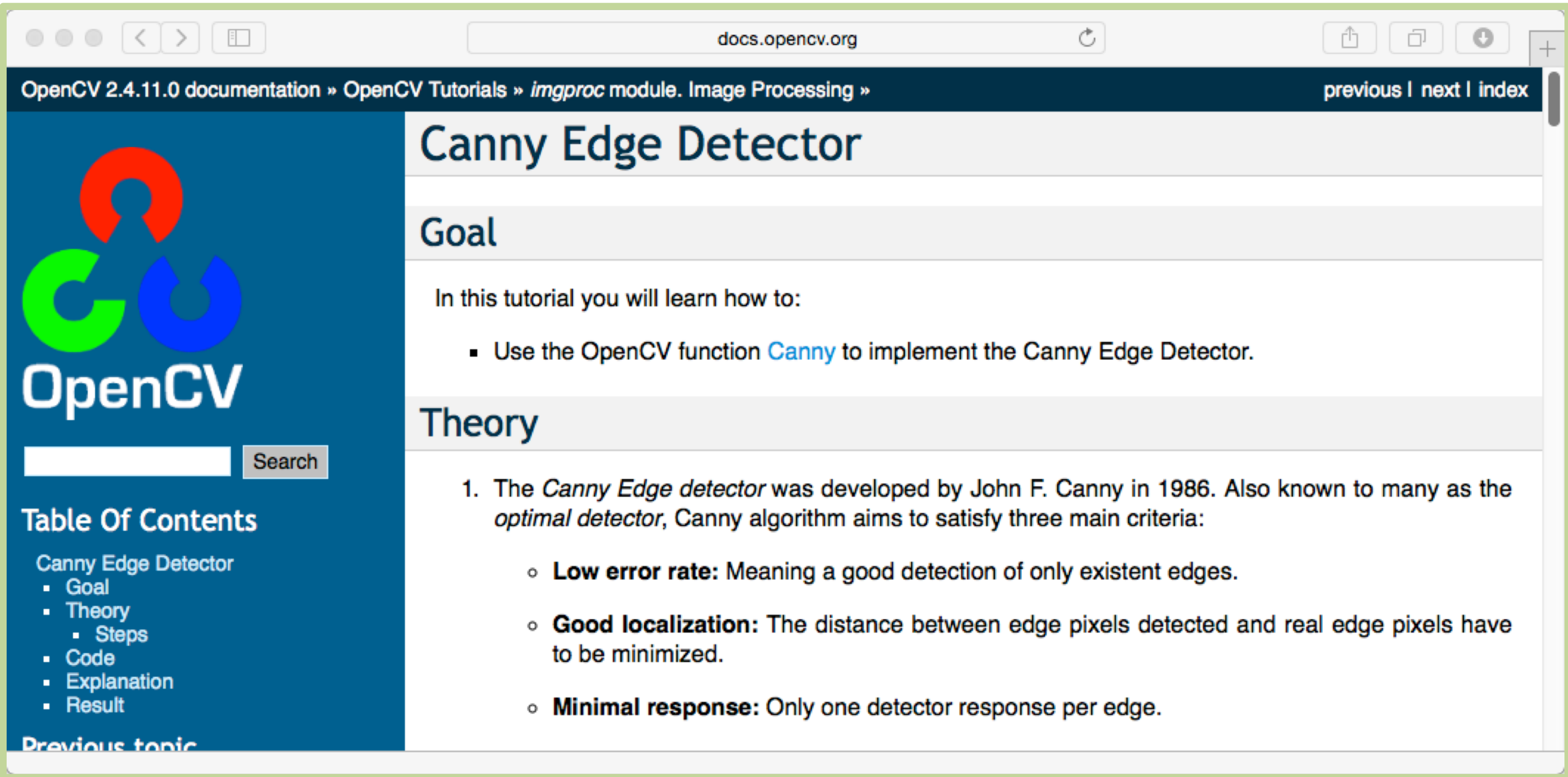
Sigma = 2.0
low = 0.6, high = 0.9

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 »

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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.

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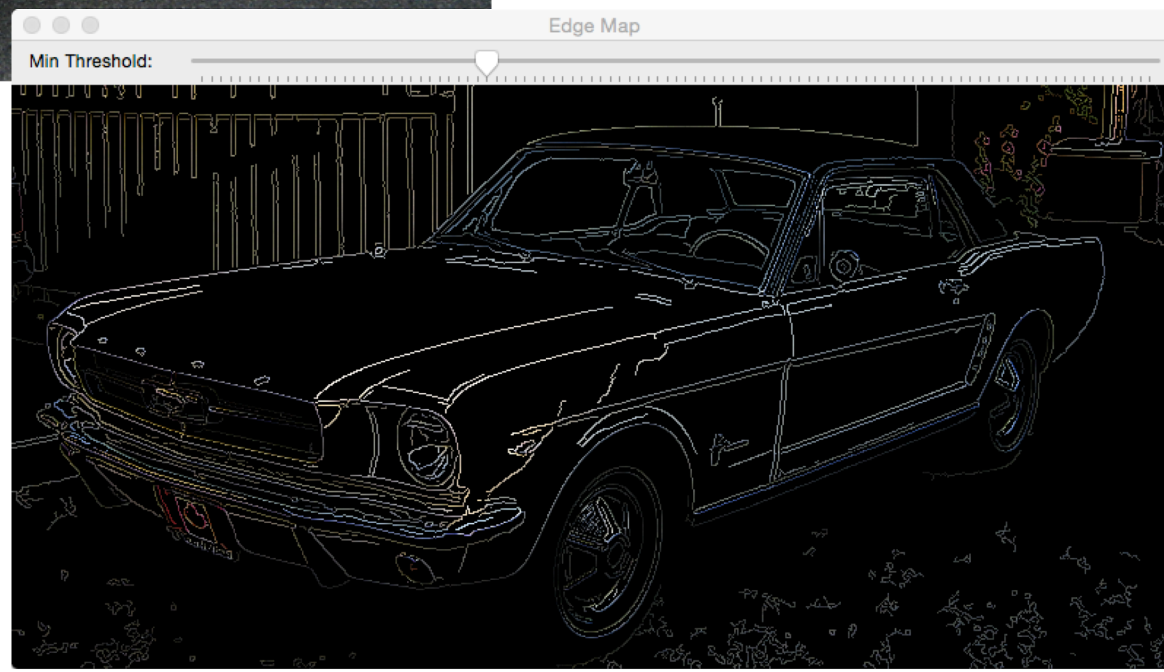
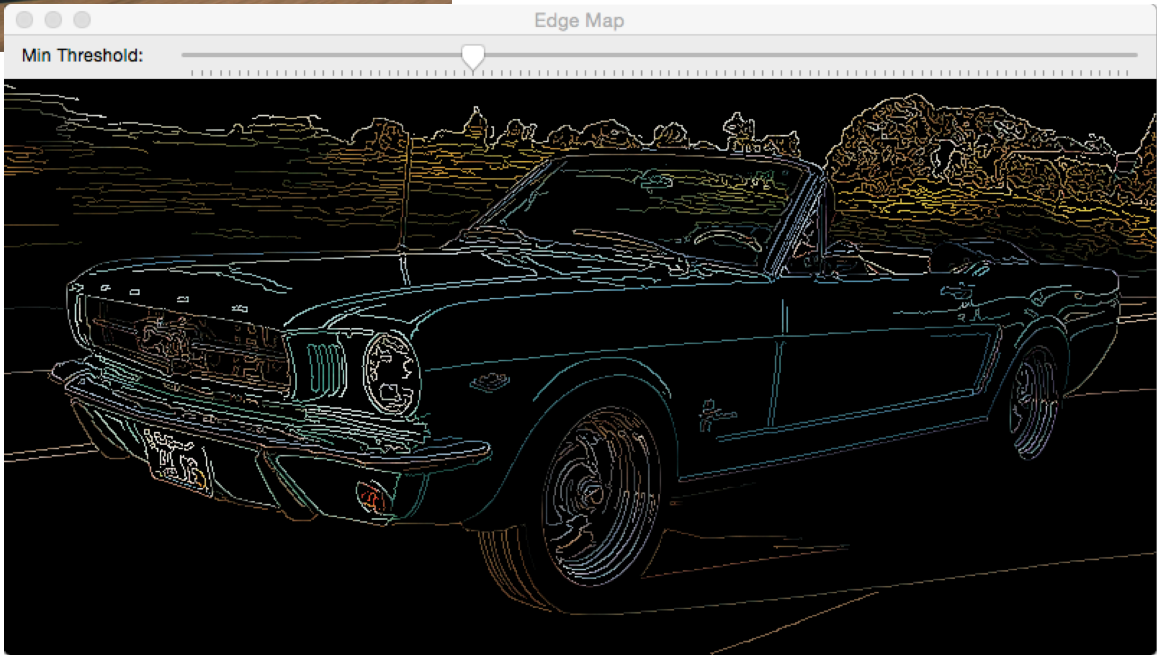
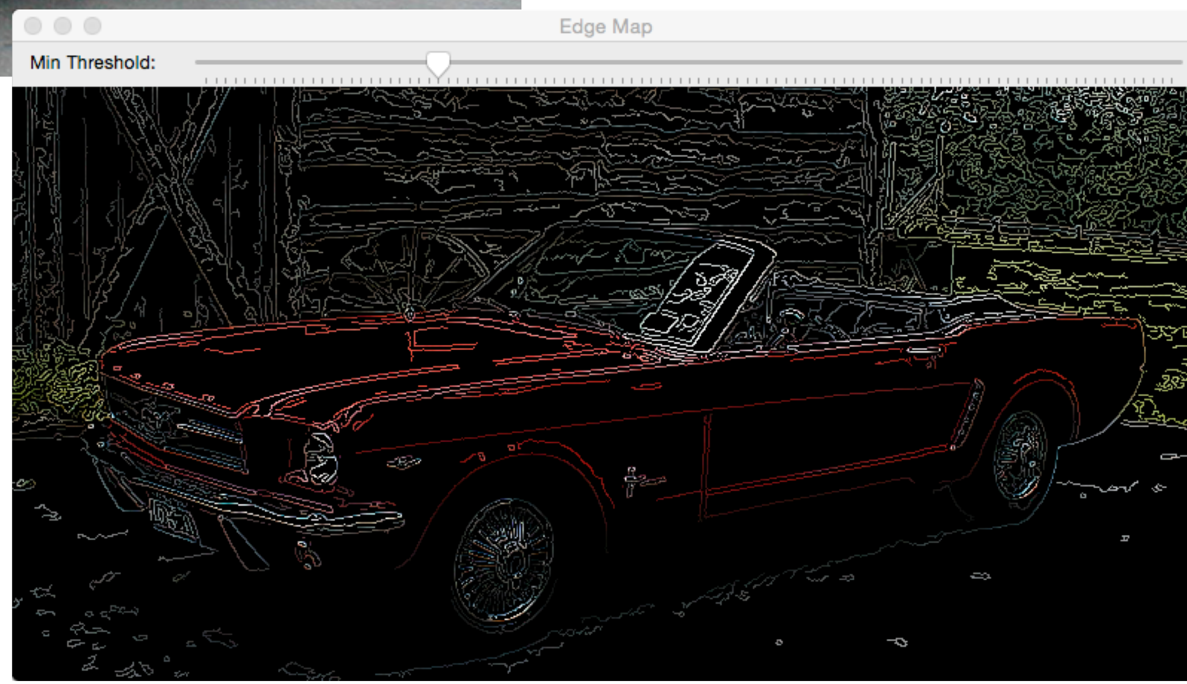

Edge Map
Min Threshold:


Edge Map
Min Threshold:

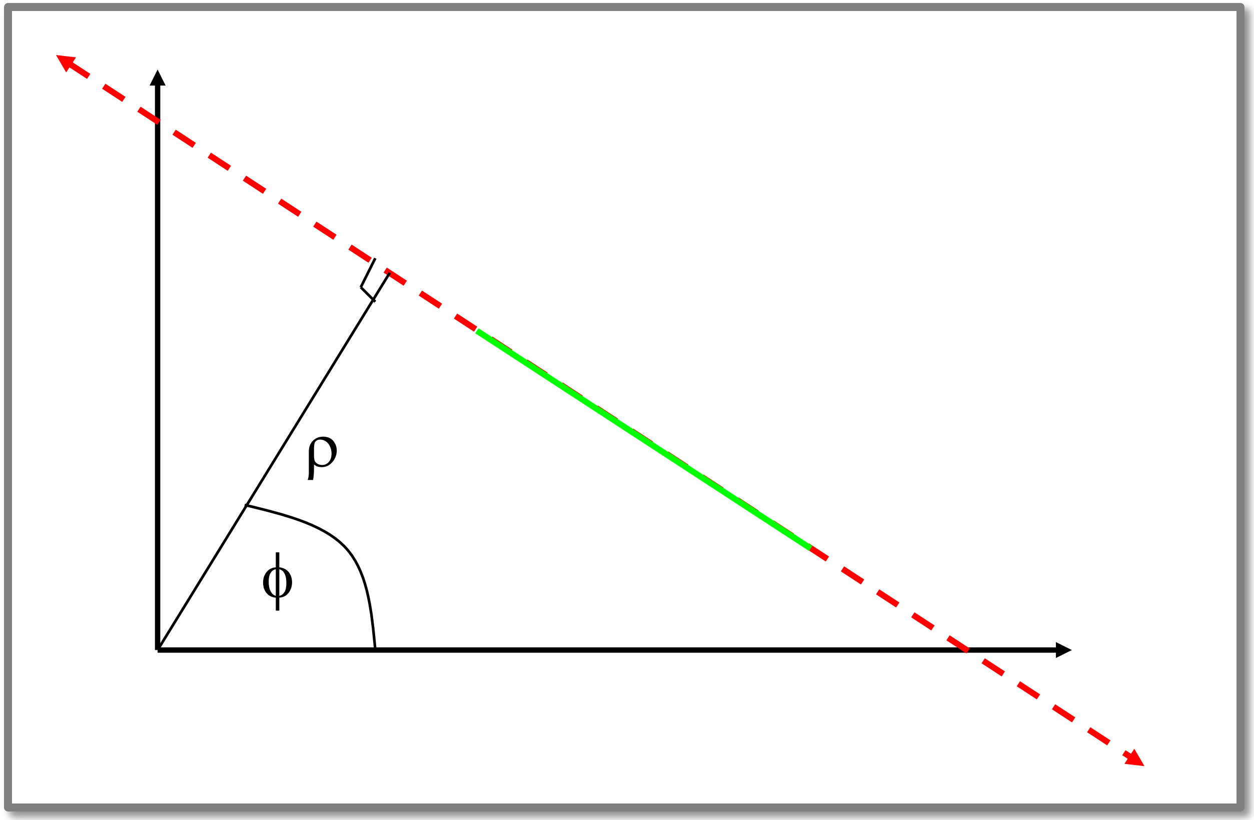

Edge Map
Min Threshold:

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 no 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):

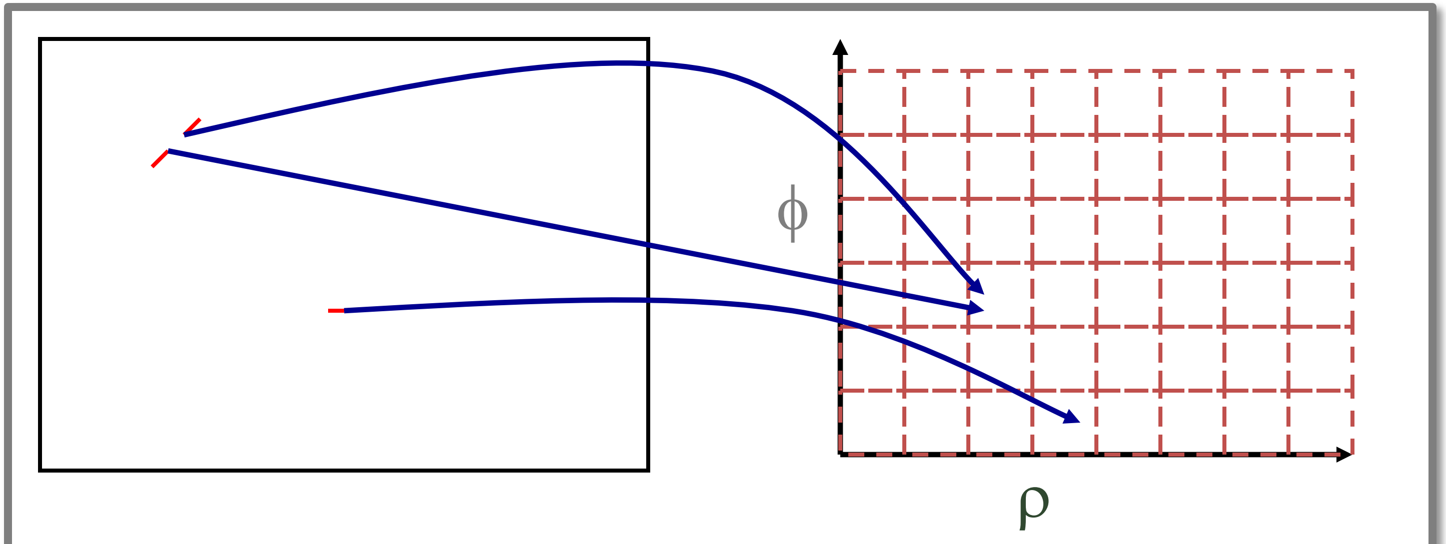


Hough Grouping (III)

- 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.

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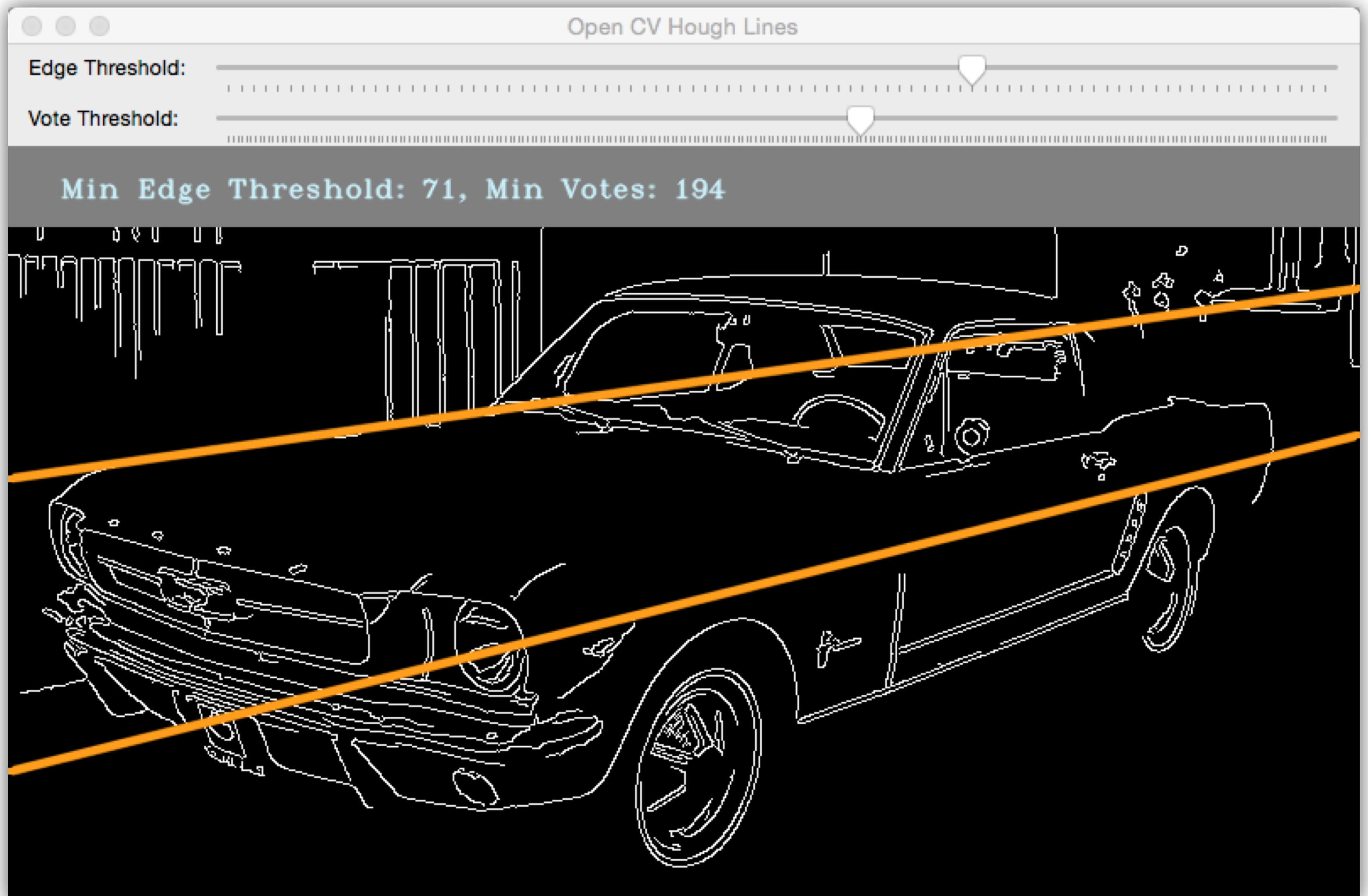
Basic Hough – Infinite Lines

- 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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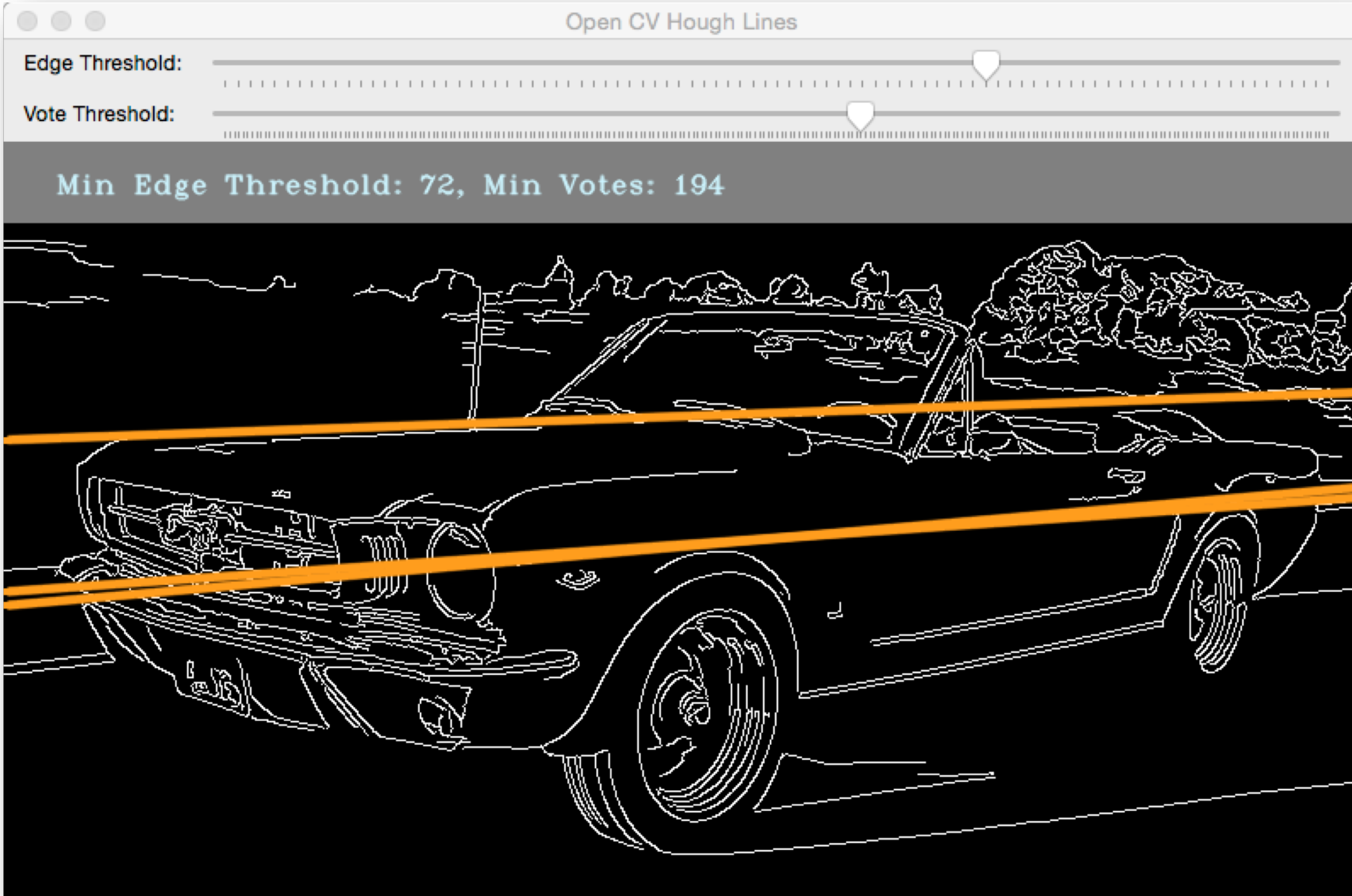
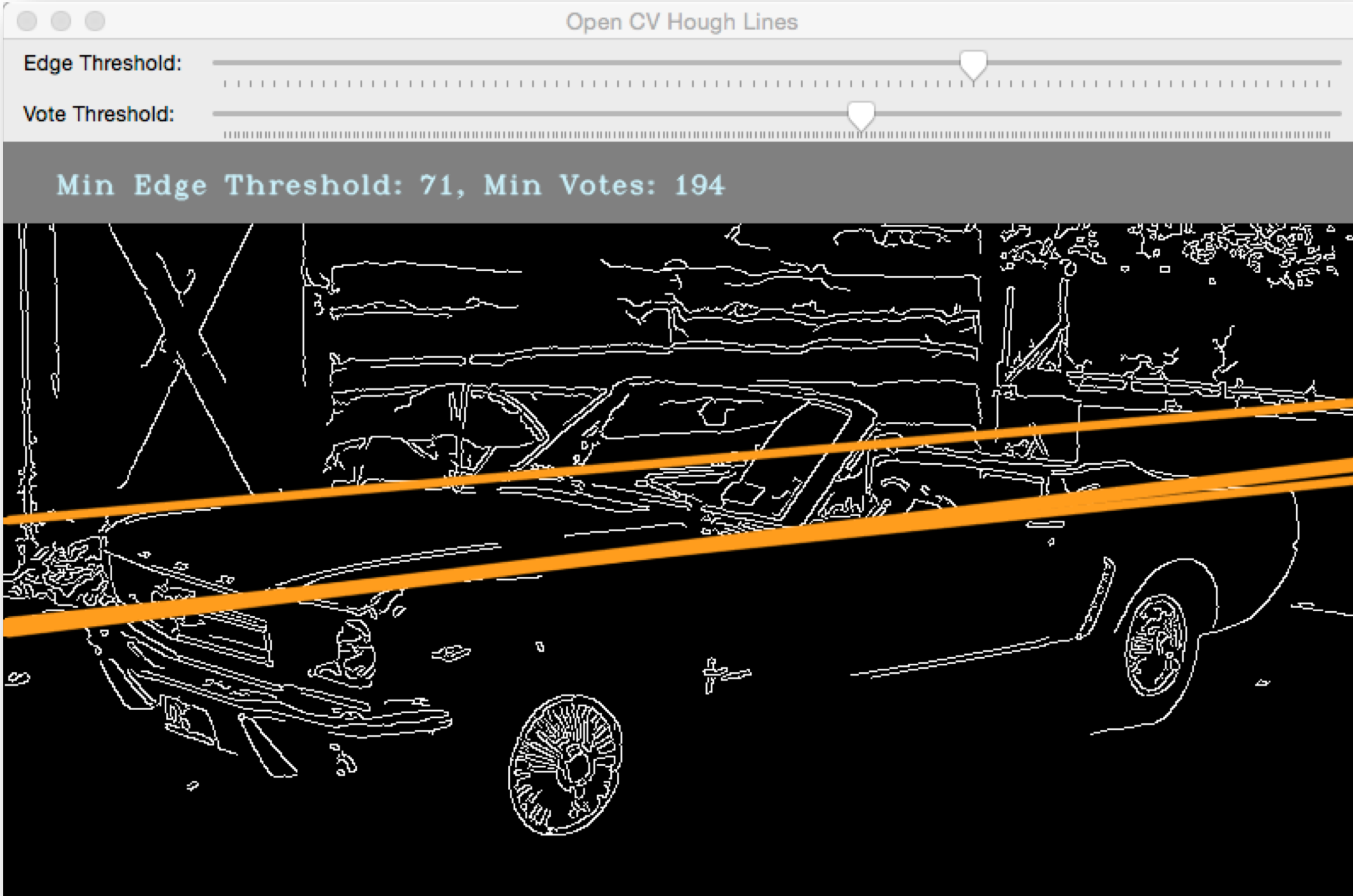

Open CV Hough Lines
Edge Threshold:
Vote Threshold:
Min Edge Threshold: 72, Min Votes: 194



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

Hough Fitting

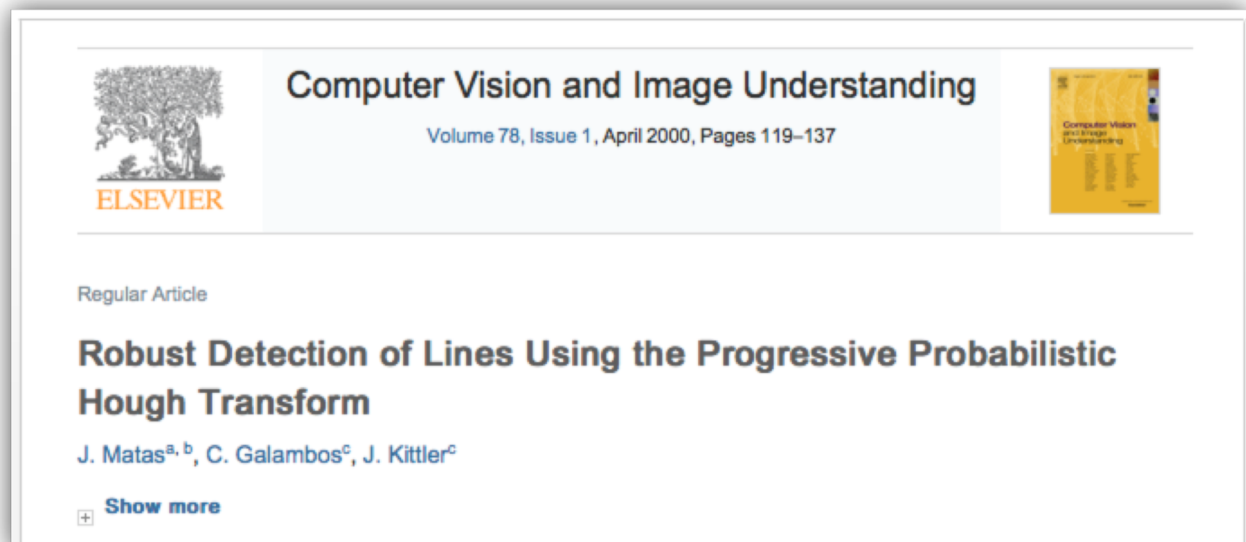
- After finding the peaks in the Hough Transform - still two potential problems:
  - Resolution limited by bucket size.
  - Infinite lines, not line segments
- Both of these problems can be fixed,
  - If you kept a linked list of edges (not just #)
  - Of course, this is more expensive...

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



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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]

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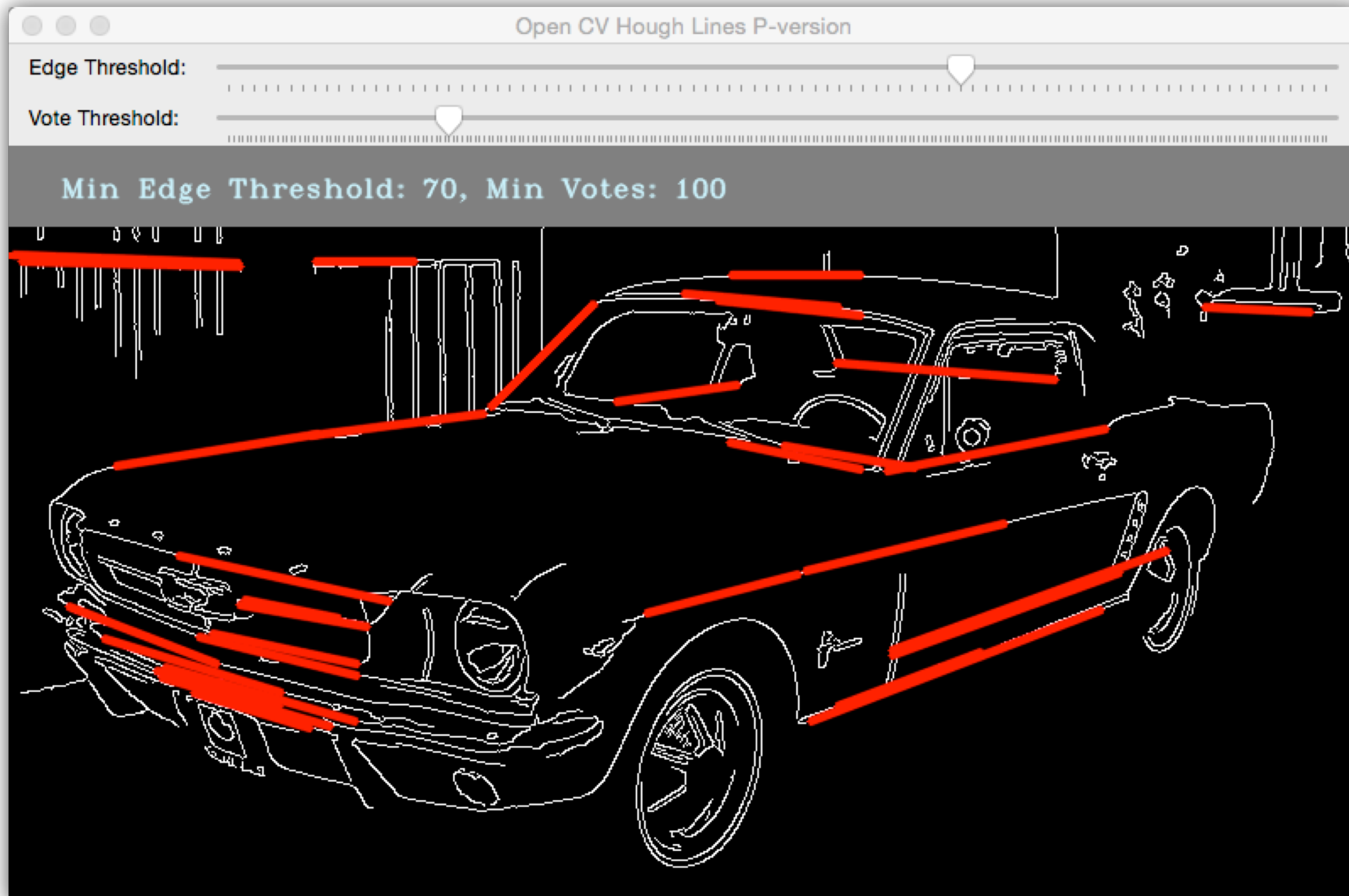
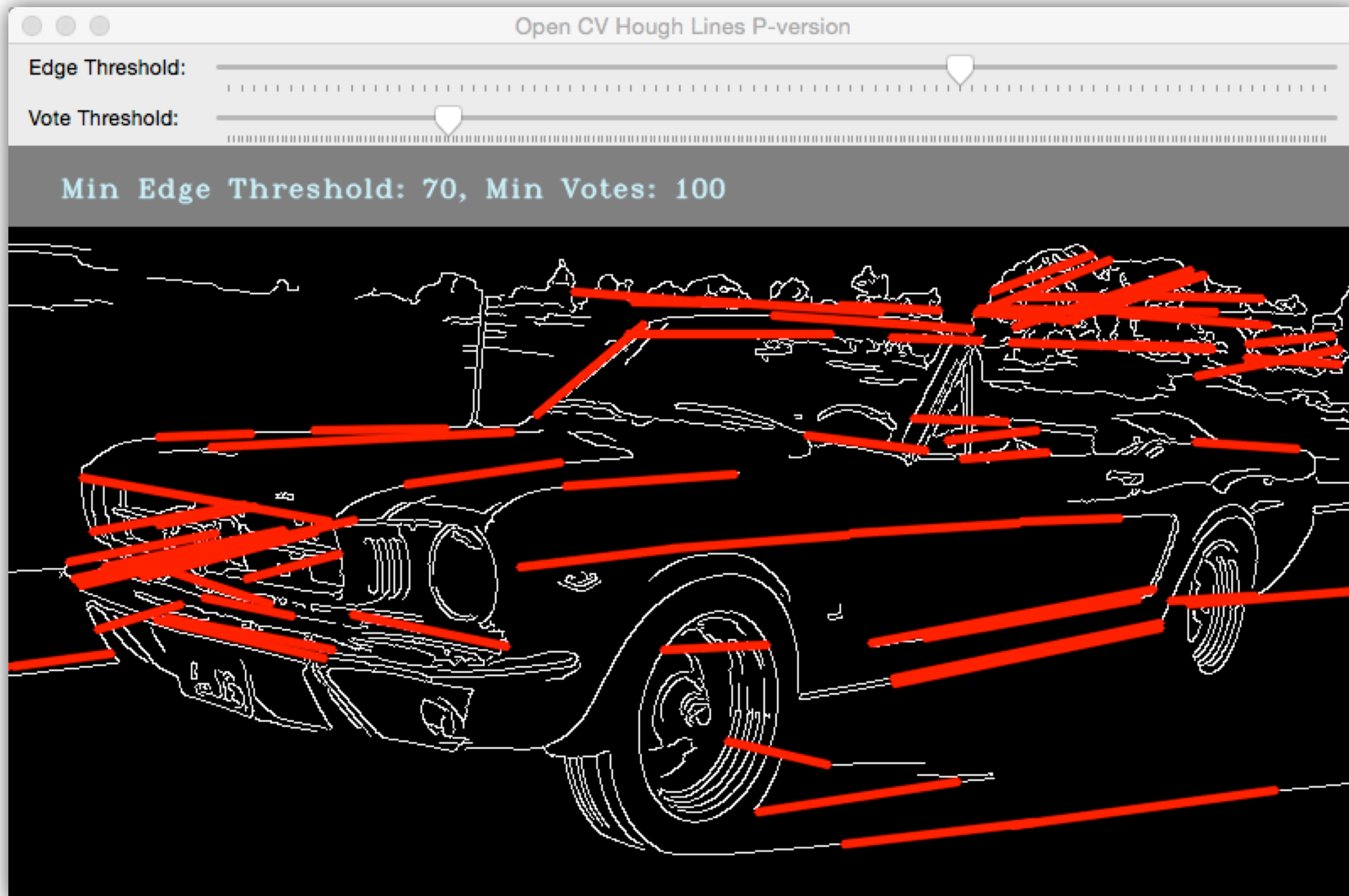

Open CV Hough Lines P-version
Edge Threshold:
Vote Threshold:
Min Edge Threshold: 70, Min Votes: 100



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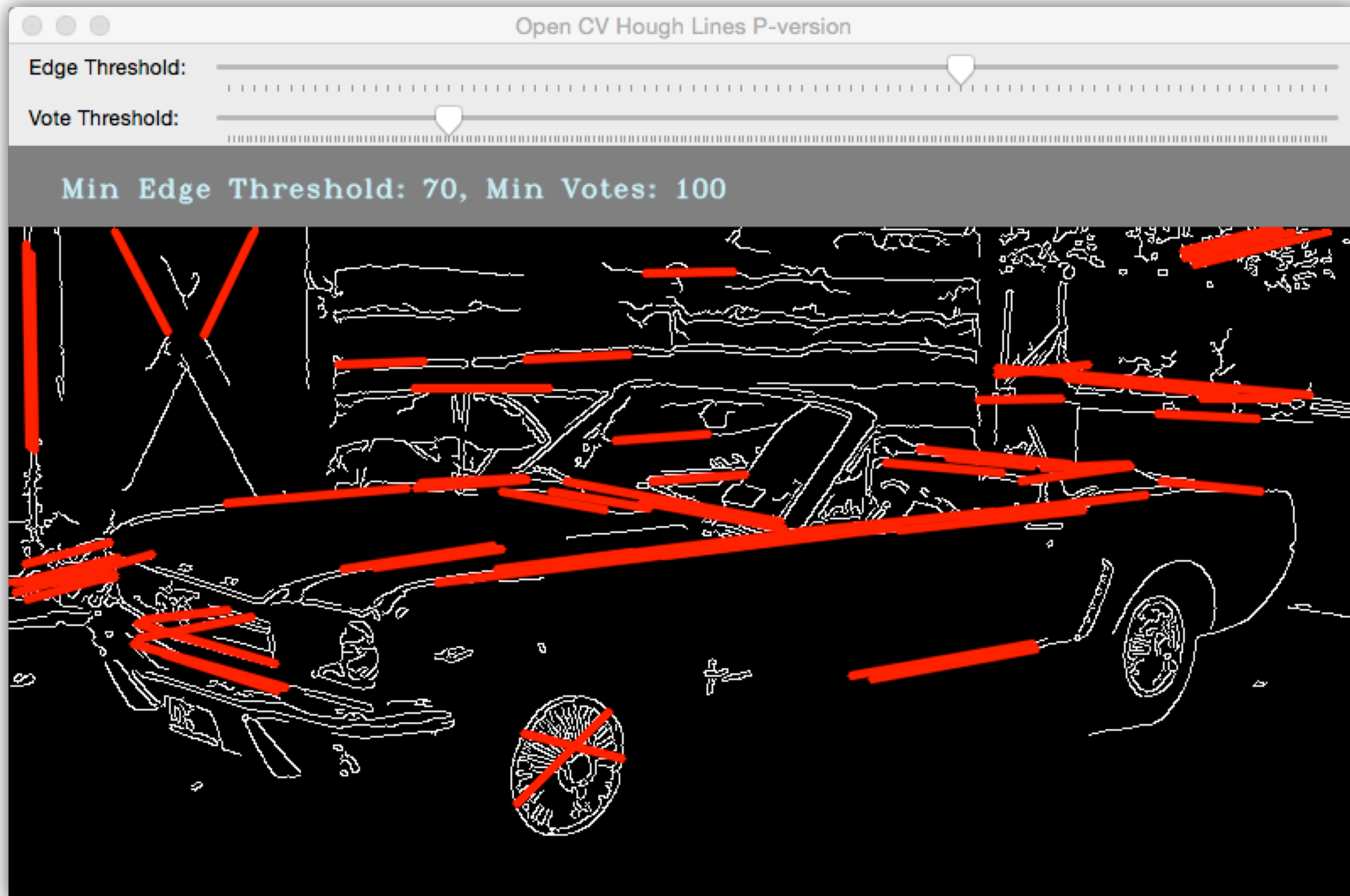

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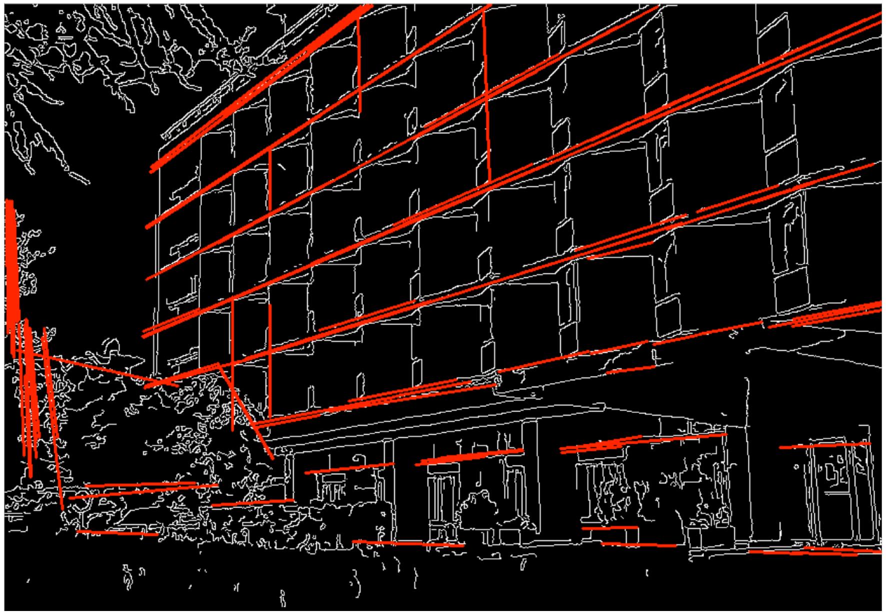
Building Example



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